Ketza River Holdings

August 15, 2011

ISSUED FOR USE
FILE: W23101051.104

Yukon Water Board
Suite 106, 419 Range Road
Whitehorse, YT Y1A 3V1

Attention: Joelle Janes, Licensing Officer
Kelly Boutilier, Licensing Officer

Subject: Water Use Application QZ10-026, Care and Maintenance of the Ketza River Mine Tailings Pond Information Request Response and Decision Document Requirements

1.0 INTRODUCTION

EBA, A Tetra Tech Company (EBA), was requested to prepare the Water Licence application for the existing Tailings Storage Facility (TSF) at the Ketza River Mine site by Ketza River Holdings (KRH), a 100% owned subsidiary of Yukon-Nevada Gold Corp. (YNG). Following the submission of the Water Licence application in March 2010, information requests were received from the Yukon Water Board (Water Board) on May 11, 2010. On February 28, 2011 a response was provided to the Water Board answering the majority of the questions contained within the May 11, 2010 information request. There were six outstanding items identified in the February 28, 2011 response which were to be addressed at a later date. These items included:

- An assessment of the rate of waste deposit, including water modelling for discharge scenarios;
- A review of the potential qualitative and quantitative effects that the deposit of a waste may have on groundwater;
- A hydrologic assessment, including review of dam classification and inundation study;
- An updated water balance;
- An assessment of amount of security adequacy; and
- Supplemental information related to the Action Items contained in the *Yukon Environmental and Socio-economic Assessment Act* (*YESAA*) Decision Document.

The supplemental information related to the Action Items contained in the *YESAA* Decision Document consists of 64 items, presented in Table 1.0-1. As discussed in meetings on January 11, 2011 and February 24, 2011 with Water Resources and the Water Board, the timeline to complete these items is dependent upon their complexity. Table 1.0-2 shows the plan for submission of the outstanding Water Licence requirements for the existing TSF, including the submission date and format of submission.

Table 1.0-1: Decision Document Requirements Ketza Existing Tailings

#	Actual Wording from Decision Document
1	Proponent shall, at a minimum, monitor Water Licence parameters as contained within the previous Water Licence QZ04-063.
2	In addition to the weekly compliance testing for arsenic proposed by the proponent, daily onsite testing for arsenic shall be adopted during periods of release using recognized methodology (e.g., APHA Standard Methods for the Examination of Water and Wastewater). The daily test method will provide an adequate level of detection (lower than water licence standard) and equipment will be calibrated regularly against appropriate reference materials.
3	Releases of tailings pond water to Cache Creek shall be ceased immediately if daily on-site testing indicates an exceedance of the arsenic effluent standard. Daily on-site testing shall be compared with weekly results from an accredited laboratory as soon as possible.
4	Daily on-site test results for arsenic and calibrations shall be reported to Yukon Water Board on a monthly basis.
5	Proponent shall conduct environmental monitoring of the receiving environment at all stations in Cache Creek and in the Ketza River on a weekly basis during periods of tailings pond release. Environmental monitoring will be in conjunction with weekly effluent compliance sampling. The samples from the receiving environment shall be taken within 24 hours of their respective effluent sample.
6	All exceedances of CCME guidelines for arsenic in Ketza River (station KR12) shall be highlighted in monthly reports.
7	Flow measurements shall be taken in conjunction with weekly water quality compliance sampling of the effluent and at environmental stations during release and include, at minimum, an upstream station (KR01), a near-field downstream station (KR08) and a far-field downstream station (KR12).
8a	Proponent shall provide the following information to the Yukon Water Board: A quality assurance and quality control (QA/QC) procedure for daily on-site and weekly compliance monitoring. The QA/QC procedure will include a record of training for site personnel (on-site and compliance testing).
8b	Proponent shall provide the following information to the Yukon Water Board: b. A water treatment operation and maintenance plan.
8c	Proponent shall provide the following information to the Yukon Water Board: c. Details about the water treatment plant including performance statistics, demonstrated results (i.e. influent vs. effluent), treatment capacity and history of use on site.
8d	Proponent shall provide the following information to the Yukon Water Board: d. Rationale for why the existing water treatment plant is capable of meeting the discharge standard for arsenic for all potential flow and volume situations that may be experienced in the tailings pond.
9	The water treatment plant shall be tested annually to ensure it is capable of implementation in a timely manner.
10	Proponent shall ensure staff are appropriately trained in the correct operation of the water treatment plant and that staff trained in the operation of the water treatment plant are on-site whenever water is released from the tailings pond.
11	Any exceedence of the recommended turnover times for compliance monitoring samples received by the laboratory shall be highlighted in monthly reports.
12	
13	Water releases from the tailings pond shall be limited by a maximum flow rate.
14	
15	Water releases from the tailings pond shall be limited to a single discharge line.
16	A lower limit for pond water elevation shall be established to reduce the unnecessary exposure of inundated tailings.

Table 1.0-1: Decision Document Requirements Ketza Existing Tailings

#	Actual Wording from Decision Document
17	The proponent will make best efforts to use water from other sources before using untreated tailings pond water for exploration.
18	Proponent shall, on a regular and consistent basis, inform the Ross River Dena Council of their environmental monitoring activities related to care and maintenance of the tailings pond and associated infrastructure.
19	Proponent shall provide an annual summary of environmental data gathered for this project to the Ross River Dena Council.
20	Proponent shall provide details and methodology, to the Yukon Water Board, about how the proposed water management approach (i.e. maintaining water levels in the tailings pond at or below proposed levels) affects arsenic mobilization from the tailings.
21	The proponent shall provide the Yukon Water Board a detailed geochemical model which demonstrates a clear understanding of: the chemical stratification within the pond; spatial variability of porewater concentrations within the tailings; attenuation mechanisms (e.g. groundwater dispersion, diffusion and sorption along the flowpath); dilution in surface water; geochemical conditions within soils; wet/dry cycling of exposed tailings; and runoff from tailings beaches. Proponent shall also discuss the implications of this model for monitoring at the site.
22	The proponent shall prepare necessary studies and a detailed site closure and decommissioning plan. This plan shall be submitted to the Yukon Water Board with a letter from Yukon government, Assessment and Abandoned Mines acknowledging their review and approval.
23	Proponent shall use routine environmental and effluent data of the Cache Creek and Ketza River basins along with any other pertinent information to refine, update and validate the site water balance model over the duration of the project. The revised model will incorporate sensitivity analysis and provide interpretation of the results and a discussion on the relevance to water management at the site.
24	This assessment and the recommended mitigations shall be in effect for a maximum three-year term after issuance of the Type A Water Licence. After this term, project activities, the environmental performances of the project and the site water balance model will require a new assessment.
25	A hydrogeological study for the tailings impoundment shall be completed by a qualified professional. This study will provide a better understanding of background groundwater quality, groundwater flowpaths, seasonal variability, soil physical parameters (e.g. hydraulic conductivities, etc.), hydraulic gradients, contaminant transport and attenuation mechanisms. This study will be provided to the Yukon Water Board.
26	Proponent shall ensure contaminated groundwater is not impacting the downstream receiving environment.
27	Proponent shall identify and quantify all water inputs to and outputs from the tailings pond in the site water balance model.
28	Proponent shall provide a summary of water quality and flow monitoring information that is available for mine portal water (i.e. portal 1430) and include an interpretation of the contribution of this input to the tailings pond water balance and chemistry. This information shall be submitted to the Yukon Water Board.
29	Proponent shall use site data to determine the fate of seepage water from the tailings pond.
30	Proponent shall evaluate the contribution of seepage from the tailings pond to seepage captured in the weirs below the North and South dams.
31	Proponent shall ensure that water diversion infrastructure (i.e. ditching and culverts) is maintained such that there are no blockages to water flow. Water diversion infrastructure shall ensure that surface runoff to the tailings pond is minimized.

Table 1.0-1: Decision Document Requirements Ketza Existing Tailings

#	Actual Wording from Decision Document
32a	Proponent shall prepare a dam failure analysis for the tailings pond. This analysis will be provided to Ross River Dena Council, the Yukon Water Board. The dam failure analysis shall provide the following information: a. An assessment of the potential physical damage and consequences resulting from a hypothetical dam failure.
32b	Proponent shall prepare a dam failure analysis for the tailings pond. This analysis will be provided to Ross River Dena Council, the Yukon Water Board. The dam failure analysis shall provide the following information: b. An updated model predicting short and long term arsenic release to the Ketza and Pelly Rivers.
32c	Proponent shall prepare a dam failure analysis for the tailings pond. This analysis will be provided to Ross River Dena Council, the Yukon Water Board. The dam failure analysis shall provide the following information: A current study detailing fish abundance, population size and sensitive habitats within the affected downstream environment.
32d	Proponent shall prepare a dam failure analysis for the tailings pond. This analysis will be provided to Ross River Dena Council, the Yukon Water Board. The dam failure analysis shall provide the following information: d. A current study detailing human use and presence within the affected downstream environment.
32e	Proponent shall prepare a dam failure analysis for the tailings pond. This analysis will be provided to Ross River Dena Council, the Yukon Water Board. The dam failure analysis shall provide the following information: e. Identification of appropriate mitigation for the potential effects of a dam failure.
32f	Proponent shall prepare a dam failure analysis for the tailings pond. This analysis will be provided to Ross River Dena Council, the Yukon Water Board. The dam failure analysis shall provide the following information: f. An implementation plan to conduct appropriate mitigation in a timely and effective manner.
33	Security for the Ketza Mine site shall be reviewed to ensure it is adequate to cover the costs per section 11 of the Waters Regulations, specifically, abandonment of the undertaking; restoration of the site of the undertaking; and any ongoing measures that may remain to be taken after abandonment of the undertaking.
34	Proponent shall provide a list of all recommendations for improvements and maintenance of the tailings pond issued as part of the geotechnical inspections during the previous water licence to the Yukon Water Board. This shall include: a. Details of the work completed to date; b. A detailed action plan for work that has not yet been completed; and, c. Annual updates of work done to address recommendations issued from annual geotechnical inspections.
35	Proponent shall perform the following tasks: a. Address any recommendations for improvements and maintenance of the tailings pond as part of the geotechnical inspections during the previous Water Licence; b. Review their dam classification in accordance with the recommendations in the CDA Dam Safety Guidelines 2007 and information provided by Environment Yukon. Proponent shall provide an explanation of their classification rating, supported by rationale; c. Identify the implications of the updated classification rating to associated dam plans and submit updated plans; and, d. Submit an operations and maintenance plan. This plan shall include a description of any upgrading or additional maintenance work to be done at the tailings dam or associated structures.
36	Proponent shall conduct regular monitoring of the tailing dams and drainage systems. Proponent shall implement appropriate mitigations if monitoring reveals any issues.
37	Proponent shall ensure the maximum water level of the pond is kept below 1309 m.
38	Proponent shall provide the as-built drawings for the toe berm constructed by Vista-Tek to the Yukon Water Board. This will include the specific locations of the piezometers.
39	Appropriate and effective sediment and erosion control structures shall be installed and will be inspected regularly during the course of work. Necessary repairs will be made if damage is discovered.
40	Proponent shall operate machinery in a manner that minimizes disturbance to the banks or bed of all waterbodies or watercourses.

Table 1.0-1: Decision Document Requirements Ketza Existing Tailings

#	Actual Wording from Decision Document
41	The proponent shall comply with the Department of Fisheries and Ocean's Pacific Region Operational Statement Culvert Maintenance.
42	Proponent shall evaluate the hydraulic capacity and erosion potential for the spillway (with repairs and potential upgrades) and: a. Repair flow measurement structures (weirs) downstream of the berm.
42a	Repair flow measurement structures (weirs) downstream of the berm.
42b	Construct an emergency spillway to the Cache Creek diversion.
42c	Cut saplings on upstream dam slopes.
42d	Survey dam crest and fill low areas.
42e	Repair riprap at the downstream segment of the Cache Creek diversion.
43	All machinery used should be in clean, good operating condition and inspected daily for small leaks.
44	All equipment will be checked for leaking hydraulics and no refuelling is to take place within 30 metres of the water.
45	Fuel storage cache setback 100m from creek.
46	The proponent shall not in any circumstances deposit or allow the deposit of any deleterious substance, including but not limited to, fuels, lubricants, and coolants, of any type into any waters or in any place under any conditions where the deleterious substances may enter any waters.
47	The proponent shall prevent contaminants from entering receiving water bodies.
48	Any full or partially full fuel drums left on site be secured in a lined area and protected from rain and snow accumulation on top of each drum. Fuel drums should be placed on pallets to prevent contact with water that may have collected on the liner.
49	During machine repair activities, a service area must be established to manage the special wastes generated. The service area for machine repair activities shall be bermed and lined with a synthetic or natural liner. A synthetic liner shall be 60 mil (or two 30 mil), hydrocarbon resistant and UV resistant. If not UV resistant, the synthetic liner must be covered. The natural liner shall be 1m thick with a maximum permeability of 1 x 10-6 cm/s.
50	The proponent shall at all times have on site sufficient spill clean-up equipment and material in readiness to immediately clean up any spill of petroleum products.
51	The proponent is required to report all spills to the 24-hour Yukon Spill Report Centre at 867-667-7244.
52	All spills must be assessed and remediated in accordance with the Contaminated Sites Regulations and its protocols and standards, including proper delineation of the affected area and confirmatory sampling after remediation is complete to demonstrate that the remediation program has been effective.
53	All employees shall receive adequate training before being allowed to work on site.
54	Proponent shall prepare and implement: A comprehensive safety program with ongoing updates; Monitoring and maintenance programs to ensure facility and worker safety and equipment integrity; Emergency plan with ongoing updates; Back up plan for rescue assistance; Contractor Safety Management Plan; and Return to Work Program for injured workers.
55	Proponent shall install appropriate signage along the access road to the extent that it is relevant (e.g. 'Entering flood risk zone').
56	Deleted.
57	Proponent shall monitor and record evidence of wildlife and bird presence at the tailings pond and adjacent downward riparian area. A record of wildlife and bird observations shall be provided to the Regional Biologist or Conservation Officer in a timely and consistent manner.
58	Proponent shall make best efforts to deter wildlife and birds from using water in the tailings pond and adjacent downward riparian area.

Table 1.0-1: Decision Document Requirements Ketza Existing Tailings

#	Actual Wording from Decision Document
59	The proponent shall notify the Regional Biologist or Conservation Officer for advice on additional mitigations should any dead animals be found in the area.
60	If new clearing or earthwork is proposed during the breeding period (May 1 – July 31), preworking surveys shall be conducted for nesting birds.
61	If any SARA or COSEWIC listed species are found to be present, evidenced by active nests (including tree cavities), a 10 meter buffer zone shall be maintained around nests.
62	The proponent shall not destroy or damage animal dens, lodges or burrows located during the project. A Yukon Government inspector shall determine setbacks from these wildlife features if discovered on-site.
63	The proponent shall refer to the "*Guidelines for Industrial Activity in Bear Country*" booklet for best practices to reduce impacts on bears.
64	The proponent shall notify the Regional Biologist or Conservation Officer for advice on further mitigations if any bears are frequenting project site.
65	All attractants, including water treatment plant products and waste, shall be stored in a manner that prevents access by bears and other wildlife, until properly disposed of.
66	Deleted

Table 1.0-2: Plans for Submission Outstanding Water Licence Requirements Ketza Existing Tailings

Task	Proposed Submission Date	Format
Outstanding DD items, including security	15-Jun-11	Complete
DD items 1-15, 17 Tailings Water Quality Management Plan, including discharge	15-Jun-11	Complete
DD item 22 Detailed site (tailings closure and decommissioning plan (plan for plan 1 June)	15-Jun-11	Plan
DD items 23 and 27 Sensitivity analysis for water balance (and updated water balance tailings)	15-Jun-11	Complete
DD items 25, 29, 30 Hydrogeological assessment, including installation of two additional monitoring wells (plan for plan 1 June)	15-Jun-11	Information available and plan
DD item 26 Pump-back or treat strategy if discharging groundwater exceeds water quality standards	15-Jun-11	Complete
DD item 32c Consequences to fish in the event of a dam failure	15-Jun-11	Complete
DD item 32d Consequences to human environment in the event of a dam failure	15-Jun-11	Complete
DD items 31, 34, 36, and geotechnical components of 42 and 42 a-e. Operations Maintenance, and Surveillance (OMS) Manual	15-Jun-11	Complete
DD item 35 Dam safety review and hydrotechnical design work, including hydrological assessment	15-Jun-11	Information available and plan
DD items 57 and 58 Protocols for wildlife monitoring and recording on-site formalized with YNG	15-Jun-11	Complete

The information contained in this addendum supersedes the information contained in the Water Licence application. For clarity, each response follows the text of each of the Water Board's information requests, and each of the Decision Document requirements. The original information requests and requirements have been highlighted in bold to clearly separate them from the responses. The numbering of the responses matches that of the letter from the Water Board dated May 11, 2010 and in the Decision Document issued November 4, 2010.

Two survey coordinate systems and datums are presented throughout this report, GSD95 Geoid (GSD95), and Canadian mean sea level (msl). Please note that the elevations used in previous regulatory correspondence (and used in the *Yukon Environmental and Socio-economic Assessment Act* (*YESAA*) Decision Document) refer to GSD95, while the operating system at Ketza River Mine uses msl. Both systems are represented in order to alleviate any confusion in reporting. The Addenda to this report refer to elevations in msl unless otherwise noted:

- The GSD95 system was generated from a YES survey completed in August 2005 using the UTM coordinate system, NAD83 horizontal datum, and GSD95 elevation;
- The msl system is based on current project surveying methods implemented in 2006 by Challenger at the Ketza River Mine using the UTM coordinate system and NAD27 Canada horizontal datum, and mean sea level elevation.

2.0 INFORMATION REQUEST OUTSTANDING ITEMS

The following section addresses only those items still outstanding from the information request letter of the Water Board, dated May 11, 2010. The section is structured by first listing the item number from the information request letter, followed by the identification of the outstanding item, and a description of the proposed measures to address the outstanding item. Please refer to the February 28, 2011 Information Request Response that was addressed to the Water Board for the complete response to each question.

2.1 Item 12: Deposit of a Solid or Liquid Waste

Question 38 pertains to the deposit of a solid or liquid waste. As previously indicated, this application must be stand alone. If the answer to question 38 lies in another report, please provide a copy of that report and specify the section in which the response is located. Alternatively, summarize the contents of the report in the response to questions a) through i).

a) **the type and quantity of waste proposed to be deposited and the reason for the deposit; b) in the case of a liquid waste, the chemical characterization and concentration of the waste proposed to be deposited; c) in the case of a solid waste, the geochemical characteristics of the waste; d) the location, rate, timing, frequency and duration of the deposit; e) the baseline surface and groundwater quality at the location of the proposed discharge; f) the potential qualitative and quantitative effects that the deposit may have on any watercourse and/or surface water and/or groundwater; g) the proposed methods for collecting, storing, treating and discharging the waste, and the volumes of any waste storage systems; h) a description of the construction methods, schedule, quality assurance/quality control measures, and inspection and maintenance procedures and schedule proposed to be used for any waste treatment/storage/**

discharge facilities; i) a description and justification of the standards proposed to be applied to any discharges of waste to the receiving environment.

Issues a) and e) as identified above remain outstanding for Item 12 and are discussed in more detail below.

2.1.1 First Outstanding Issue: Item 12a

a) The type of waste proposed to be deposited is the same as that outlined in Water License QZ04-063 (provided as Addendum F of the information request response document dated February 28, 2011), and is essentially water currently contained in the existing tailings pond. The quantity of waste proposed to be deposited would be on an as needed basis to maintain safe water elevations within the pond. Typically the rate of deposit is 10 litres per second (L/s) although this is being assessed, and further details will be provided to the Water Board when complete.

Additional Information to Address Item 12a

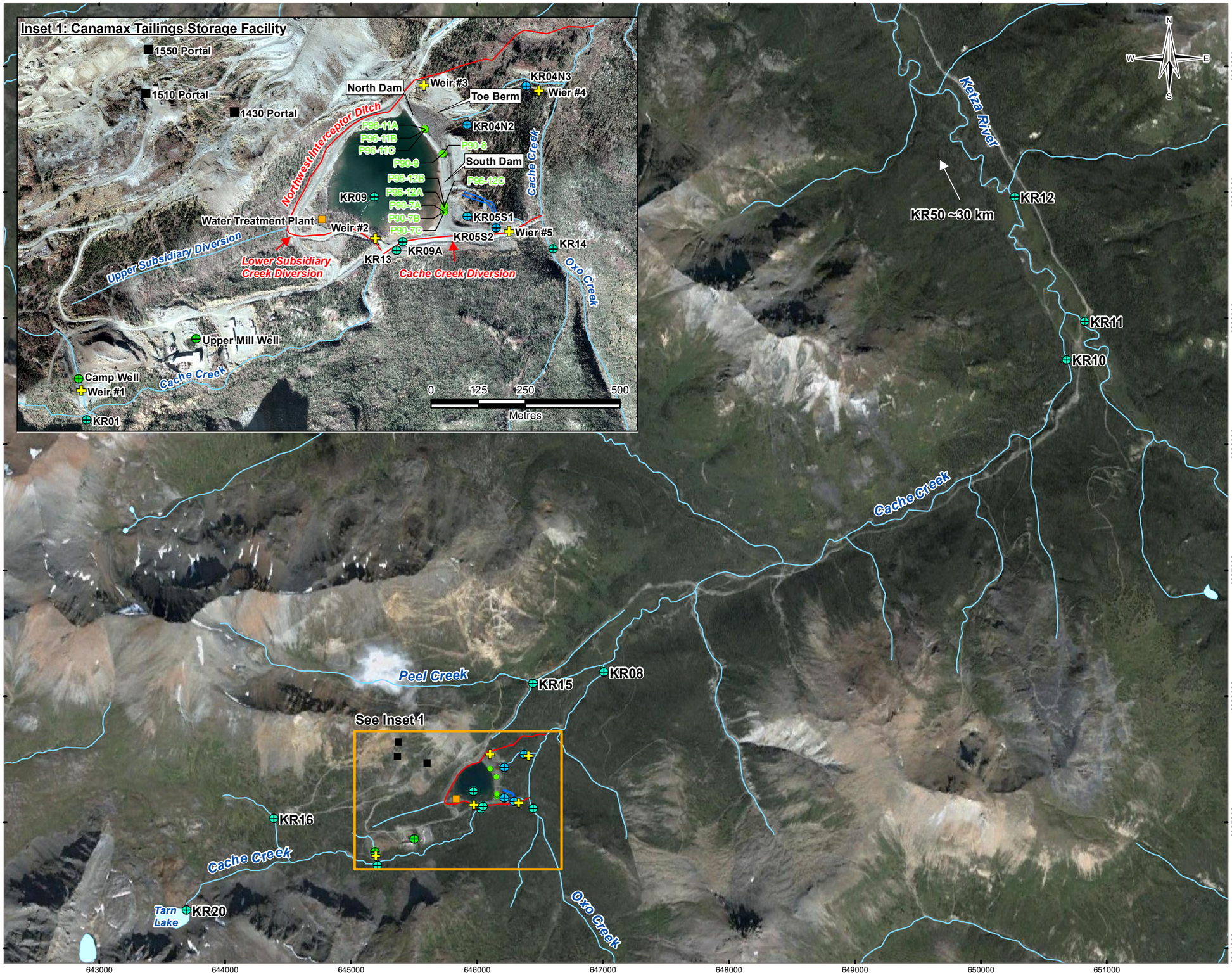
The maximum proposed rate of deposit is 20 L/s. In an average year it would require 30 days of pumping at 10 L/sec 24 hours per day to maintain 1309 m (GSD 95; 1,306 m msl). In a wet year, it would require 40 days of pumping at 10 L/sec 24 hours per day to maintain 1309 m (GSD 95). Water modelling for discharge scenarios is included in the water balance for the project below.

2.1.1.1 Water Balance

A water balance is required to quantify the total amount of tailings pond water that can be discharged to the Cache Creek and Ketza River watersheds without exceeding the CCME guidelines for the protection of aquatic life at the confluence of these two basins. The confluence for this study is assumed to be at KR12 on the Ketza River (Figure 2.1.1-1). The objective of pumping is to establish a water elevation behind the dam that maintains dam stability and minimizes the risk of overtopping. The *YESAA* Decision Document for the Project has required that the tailings pond be maintained below 1,309 m (GSD 95; 1,306 m msl).

Both the quantity of water that is required to be pumped and the amount that can be safely pumped are dependent upon precipitation. A higher amount of precipitation will generate greater local runoff, increase the water level in the pond, and allow greater pumped discharges for control measures. Estimates of allowable pumping rates used the 1:10 year dry runoff year, the 1:10 wet runoff year, and the average runoff year to gain an understanding of the sensitivity of runoff estimates. The 1:10 dry and 1:10 wet runoff years refer to the likely driest and wettest years in a ten year period. For example a 10-year wet precipitation event would have a 1/10 or 10% chance of being exceeded in one year where as a 25-year wet precipitation would have a 4% chance of being exceeded. Conservatively, the 95% percentile of the average arsenic concentrations were used to calculate total arsenic loadings.

Arsenic was chosen as the contaminant of concern as it was found to occasionally exceed CCME guidelines (0.005 mg/L) in the fish-bearing Ketza River. The water balance was based on local flows and arsenic loading where a maximum discharge from the pond was back calculated from the Ketza River to ensure concentrations were below 0.005 mg/L (YESAB 2010).



LEGEND

- Surface Water Quality Monitoring Site
- Water Quality Seepage Site
- Well
- Water Treatment Plant
- Portal
- Weir
- Groundwater Monitoring Well
- Emergency Spillway
- Diversion
- Drainage
- Waterbody

NOTES

Base data source: Imagery from Google Earth Pro (August 10, 2005)

STATUS

ISSUED FOR USE

WATER BOARD SUBMISSION
KETZA RIVER MINE, YUKON

Sampling Locations and Site Features

PROJECTION UTM Zone 8		**DATUM** NAD27			**CLIENT** Ketza River Holdings
Scale: 1:30,000 (500 250 0 500 Metres)					
FILE NO. W23101051_104_Figure2_1_1-1.mxd					eba A TETRA TECH COMPANY
PROJECT NO. W23101051.104	**DWN** SL	**CKD** TP	**APVD** TP	**REV** 0	**Figure 2.1.1-1**
OFFICE EBA-VANC	**DATE** August 15, 2011				

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Water Inputs and Outputs from Tailings Pond

The surface area of the tailings pond, estimated at 8 ha in size, is isolated from overland flows by a large embankment dyke and diversion ditches. Inputs into the tailings pond consist of only direct precipitation. Outflows considered in the water balance consist of direct evaporation, seepage, and pumped discharges. Table 2.1.1-1 summarizes the total inputs and outputs estimated for the average, the 1:10 wet and the 1:10 dry years.

Table 2.1.1-1: Water Inputs and Outputs from the Existing Tailings Pond

Scenario	Average year	10 year wet	10 year dry
Yearly Precipitation (m^3)	56,480	64,640	48,160
Yearly Evaporation (m^3)	-22,720	-22,720	-22,720
Yearly Seepage (m^3)	-7,670	-7,670	-7,670
Total net water added to the Tailings Pond (m^3)	**26,090**	**34,250**	**17,770**
Available Pumping without treatment (m^3)	34,450	54,639	16,700
Annual Change In Water Level Without Pumping (m)	0.33	0.43	0.22
Annual Change In Water Level With Pumping (m)	-0.10	-0.25	0.01

Yearly Precipitation

Precipitation was obtained from the Ketza River Mine weather station which was considered to be the most representative of the climatic conditions in the vicinity of the existing tailings pond. For the estimation of the wet, dry, and average year precipitation, values and distributions were derived from the data gathered at the Ketza River Mine climate stations between 1985-1986 and 2006-2010. Precipitation estimations for wet dry and average year conditions are shown in Table 2.1.1-2 below.

Table 2.1.1-2: Mean and Extreme Annual Precipitation at Regional Sites and Ketza Mine Site

Meteorological Service of Canada Station	Elevation (m)	Average Precipitation (mm)	10-Year Wet Precipitation (mm)	10-Year Dry Precipitation (mm)
Ketza River Mine gauge	1,380	706	808	602

Evaporation

Pan evaporation data is not available for the Ketza River Mine site and estimates of evaporation were derived from other secondary sources. The available information included the Hydrological Atlas of Canada and detailed onsite meteorological data. A bulk aerodynamic calculation based on the Dalton evaporation equation was used to interpolate the onsite meteorological data to derive the temporal variation of evaporation for the ice free months of May through September. The annual evaporation at the Ketza Site using the bulk aerodynamic method was evaluated to be 284 mm. The Hydrological Atlas of Canada evaporation estimates were used check the accuracy of the bulk aerodynamic method. The Hydrological Atlas of Canada indicated a mean annual lake evaporation of approximately 285 mm.

Seepage

Seepage is where groundwater either flows into the dam or out of the dam. Where the water elevation within the tailings pond does not change much, the groundwater will equilibrate with the water within the lake and the net flow will be relatively small. After periods of rapid pumping for instance groundwater will quickly flow in as a result of the increased difference in water level between the dam and the surrounding groundwater. At this time, while flow into the dam is likely present, it is likely the overwhelming majority of seepage would be seeping out of the north and south dams. These flows are measured at two weirs at the toe of the south and north dams, KR05S2 and KRO4N3 respectively (Figure 2.1.1-1). Flow at these weirs is relatively consistent over the course of a year and averages at approximately 2 L/s or 171 m^3/day. At this rate, the dam would be constantly emptying, however, anecdotal evidence shows that, on average, the pond levels rise slowly.

Based on the assessment of water quality data, it is assumed that the water measured at the toe of the dam is mixed with other groundwater. This assumption is supported by the concentrations of arsenic measured at the toe of the dam which are significantly lower than those measured in the tailings pond. Table 2.1.1-3 below details the relative concentrations of arsenic, flows, and estimated yearly seepage from the tailings pond used in the mass balance.

Table 2.1.1-3: Seepage Estimates from the Existing Tailings Pond

	North Dam	South Dam
Base Tailings Pond Concentration (mg/L)	0.552	0.001
Seep Concentration (mg/L)	0.036	0.102
Proportion Of Seepage From Tailings Pond	6%	19%
Average Flow measured at weirs (m^3/day)	90	82
Estimated Seepage From Pond (m^3/day)	6	15
Estimated Seepage From Pond (m^3/year)	2,114	5,555

Pumping

Pumping is required from the existing tailings pond to maintain the maximum water elevation at or below a safe operational elevation of 1,309 m (GSD 95; 1,306 m msl). The rate of pumping from the dam is limited by the quantity of arsenic. Arsenic was found to be the pollutant most likely to exceed the CCME guidelines for the protection of aquatic life in the tailings pond water. It is also present in the background concentrations in the Cache Creek and Ketza River basins. A mass balance for the Cache Creek and Ketza River was used to assess the total volume that could be pumped from the tailings pond at a concentration of 500 ug/L (this concentration assumes no treatment) without exceeding the guidelines for arsenic at the confluence of the Ketza River and Cache Creek (location KR12). A summary of monthly discharge rates and volumes for the average, 1:10 wet and the 1:10 dry years are shown in Table 2.1.1-4.

Table 2.1.1-4: Discharge Rates and Volumes

	10 Year Dry Runoff Year		Average Runoff Year		10 Year Wet Runoff Year	
	Monthly Discharge (m^3)	Average Discharge Rate (L/s)	Monthly Discharge (m^3)	Average Discharge Rate (L/s)	Monthly Discharge (m^3)	Average Discharge Rate (L/s)
January	-	-	-	-	-	-
February	-	-	-	-	-	-
March	-	-	-	-	-	-
April	-	-	-	-	-	-
May	2,903	1.1	6,606	2.5	10,525	3.9
June	8,888	3.4	16,160	6.2	24,219	9.3
July	2,558	1.0	6,140	2.3	10,388	3.9
August	1,020	0.4	1,941	0.7	3,201	1.2
September	898	0.3	1,827	0.7	2,868	1.1
October	433	0.2	1,777	0.7	3,438	1.3
November	-	-	-	-	-	-
December	-	-	-	-	-	-
Annual	**16,700**		**34,450**		**54,639**	

The mass balance used to assess the quantity of water pumped from the tailings pond is discussed below.

The alternative scenario is pumping from the pond with treatment. If the water was treated to remove arsenic, then arsenic concentrations would not be limited to the quantity that could be pumped.

Mass Balance

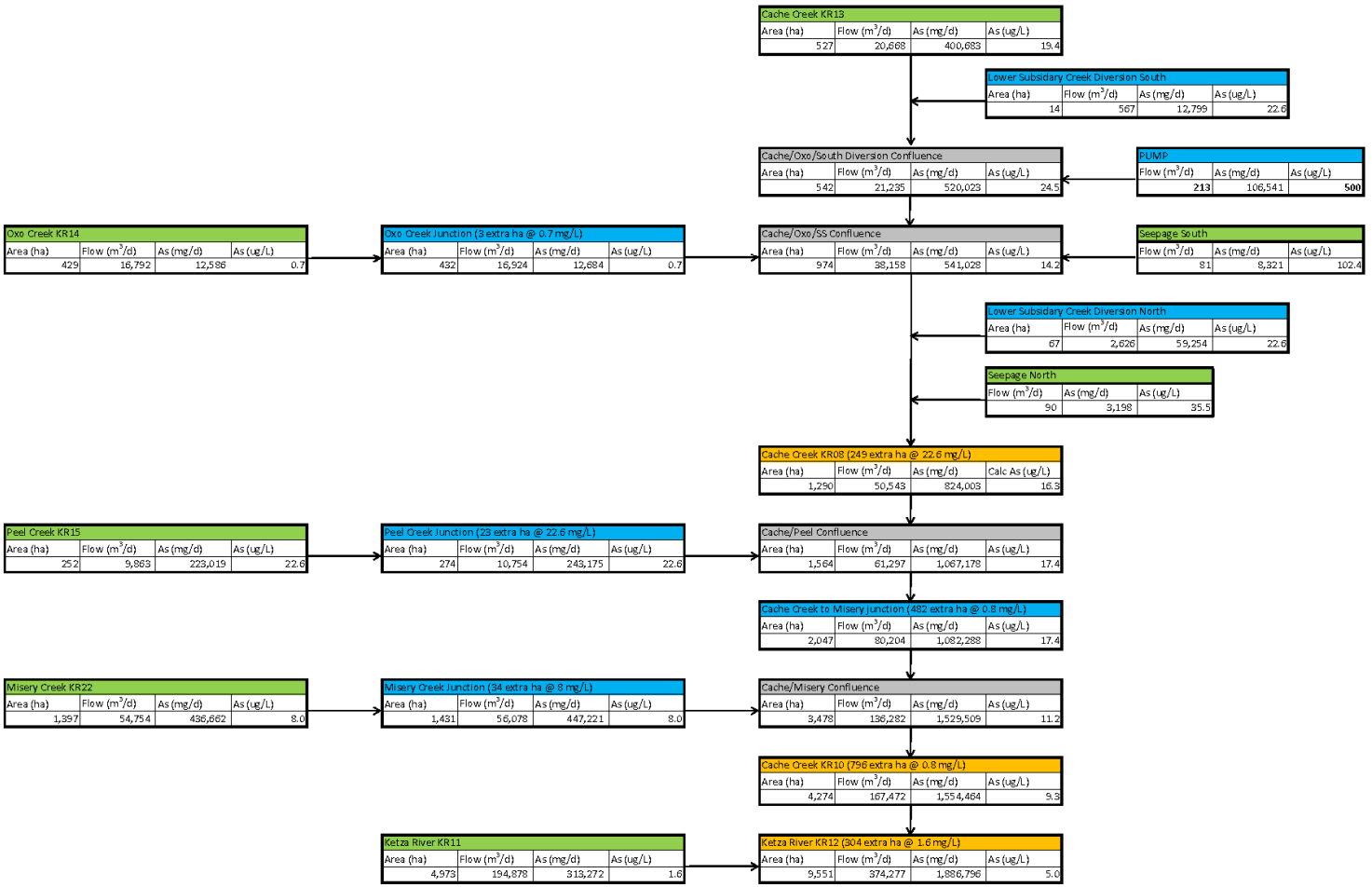
Historical flows and environmental and discharge data of the Cache Creek and Ketza River basins along with any other pertinent information where used to refine, update and validate the site water balance model. Assumptions for catchment hydrology, area and arsenic loading were developed for the site and used to populate the model. The water balances were constructed for each month for the average, 1:10 wet and 1:10 dry years for pumping and no pumping scenarios. The no pumping conditions were validated against historical water quality and flow measurements. The summary of maximum pumping values is summarized above in Table 2.1.1-4. Examples of the monthly water balances (average water balances for May, July and September, and wet and dry water balances for July) are shown in Figures 2.1.1-2 to 2.1.1-6.

Mass Balance Assumptions

The Ketza River Mine catchment area for this hydrologic baseline update was defined by the boundary of the catchment area upstream of the Cache Creek and Ketza River confluence. Within this catchment there are three other notable tributaries: Peel Creek; Oxo Creek; and Misery Creek. Several locations within the Cache Creek watershed were used for the collection of water quality samples and occasional instantaneous flow gauging. Catchment areas for the relevant gauging and water quality locations were derived from available contour information and reviewed, where possible, with a site visit. The creeks, catchments and local gauging stations are shown in Figure 2.1.1-1. A summary of the inputs and the assumptions for the mass balance are shown in Table 2.1.1-5.

WATER BALANCE:

Month: May
Condition: Average



LEGEND

NOTES

STATUS
ISSUED FOR USE

CLIENT
Ketza River Holdings

A TETRA TECH COMPANY

WATER BOARD SUBMISSION
KETZA RIVER MINE, YUKON
WATER BALANCE - AVERAGE MAY

PROJECT NO.	DWN	CKD	APVD	REV
W23101051.104	WW			0

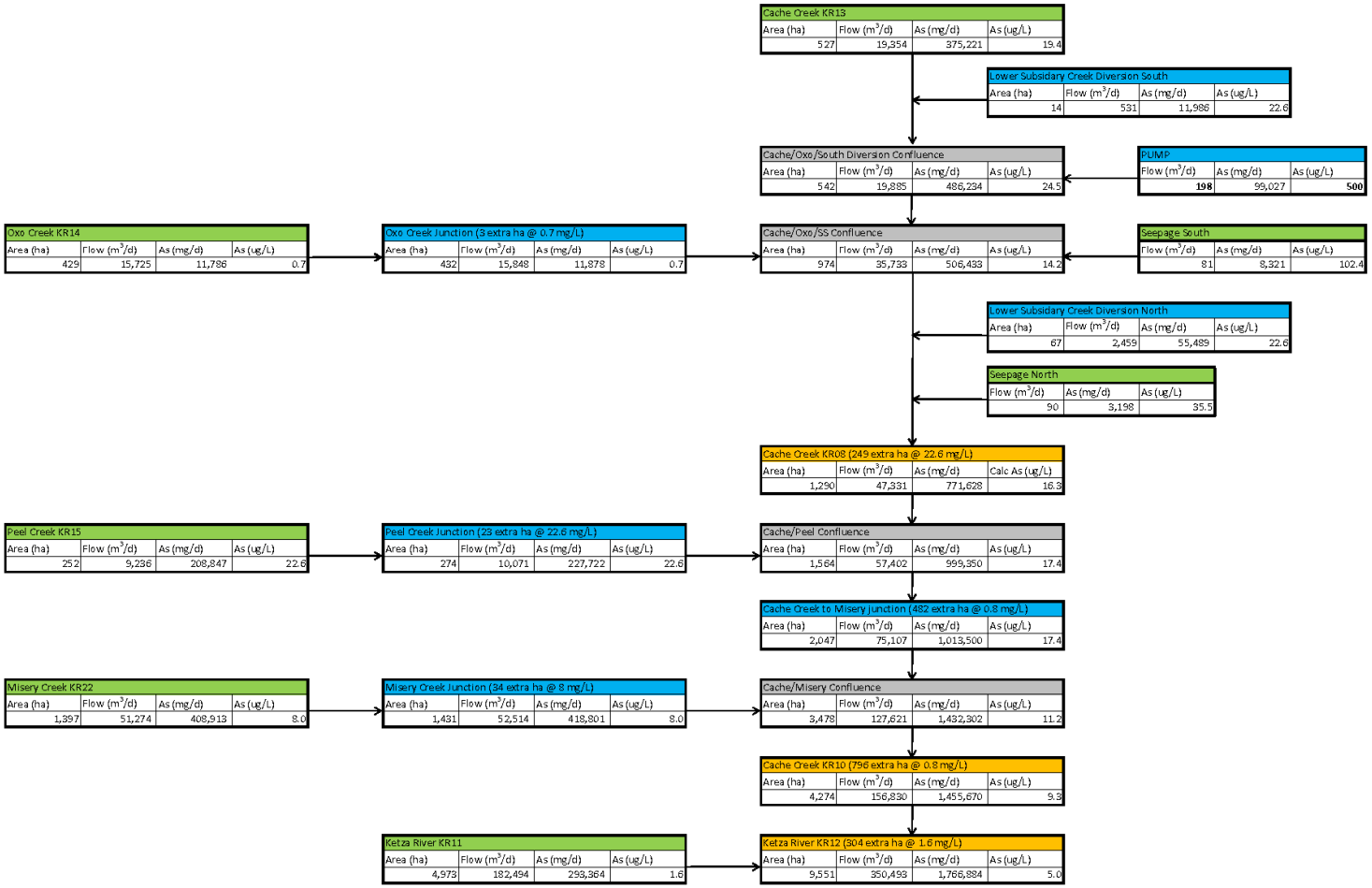
OFFICE	DATE
EBA-VANC	August 15, 2011

Figure 2.1.1-2

Q:\Vancouver\Engineering\V132\Projects\W23101051.104.009 - Ketza DSR\Working\WW\WL_Application_IFU\Figure 2.1.1-2-Avg May-W23101051.104-Ketza Water Balance.doc

WATER BALANCE:

Month: July
Condition: Average



LEGEND

NOTES

STATUS
ISSUED FOR USE

CLIENT
Ketza River Holdings

WATER BOARD SUBMISSION
KETZA RIVER MINE, YUKON
WATER BALANCE - AVERAGE JULY

A TETRA TECH COMPANY

PROJECT NO.	DWN	CKD	APVD	REV
W23101051.104	WW			0

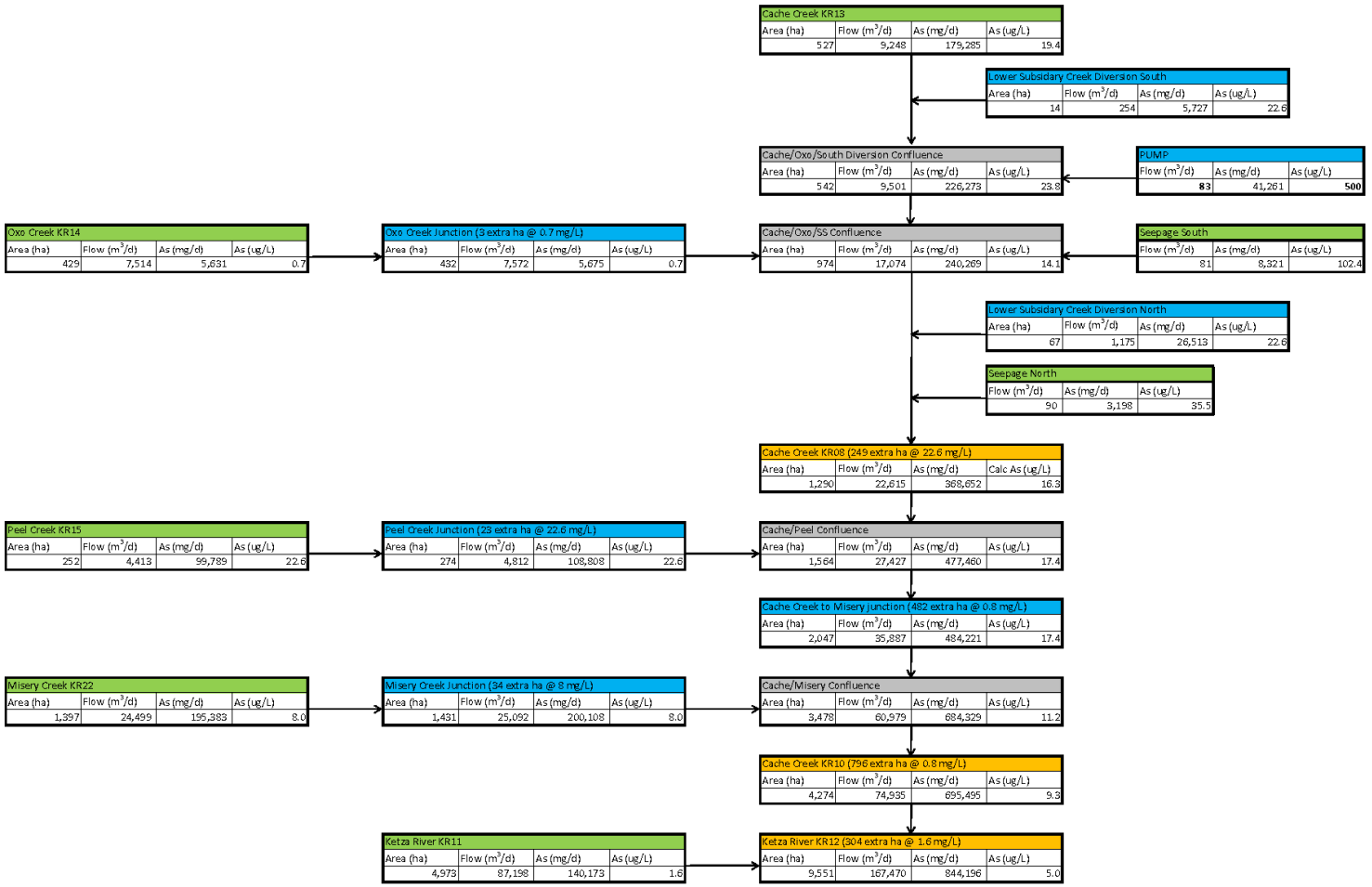
OFFICE	DATE
EBA-VANC	August 15, 2011

Figure 2.1.1-3

Q:\Vancouver\Engineering\V132\Projects\W23101051.104.009 - Ketza DSR\Working\WW\WL_Application_IFU\Figure 2.1.1-3-Avg July-W23101051.104-Ketza Water Balance.doc

WATER BALANCE:

Month: July
Condition: Dry



LEGEND

NOTES

STATUS
ISSUED FOR USE

CLIENT
Ketza River Holdings

A TETRA TECH COMPANY

WATER BOARD SUBMISSION
KETZA RIVER MINE, YUKON
WATER BALANCE - DRY
JULY

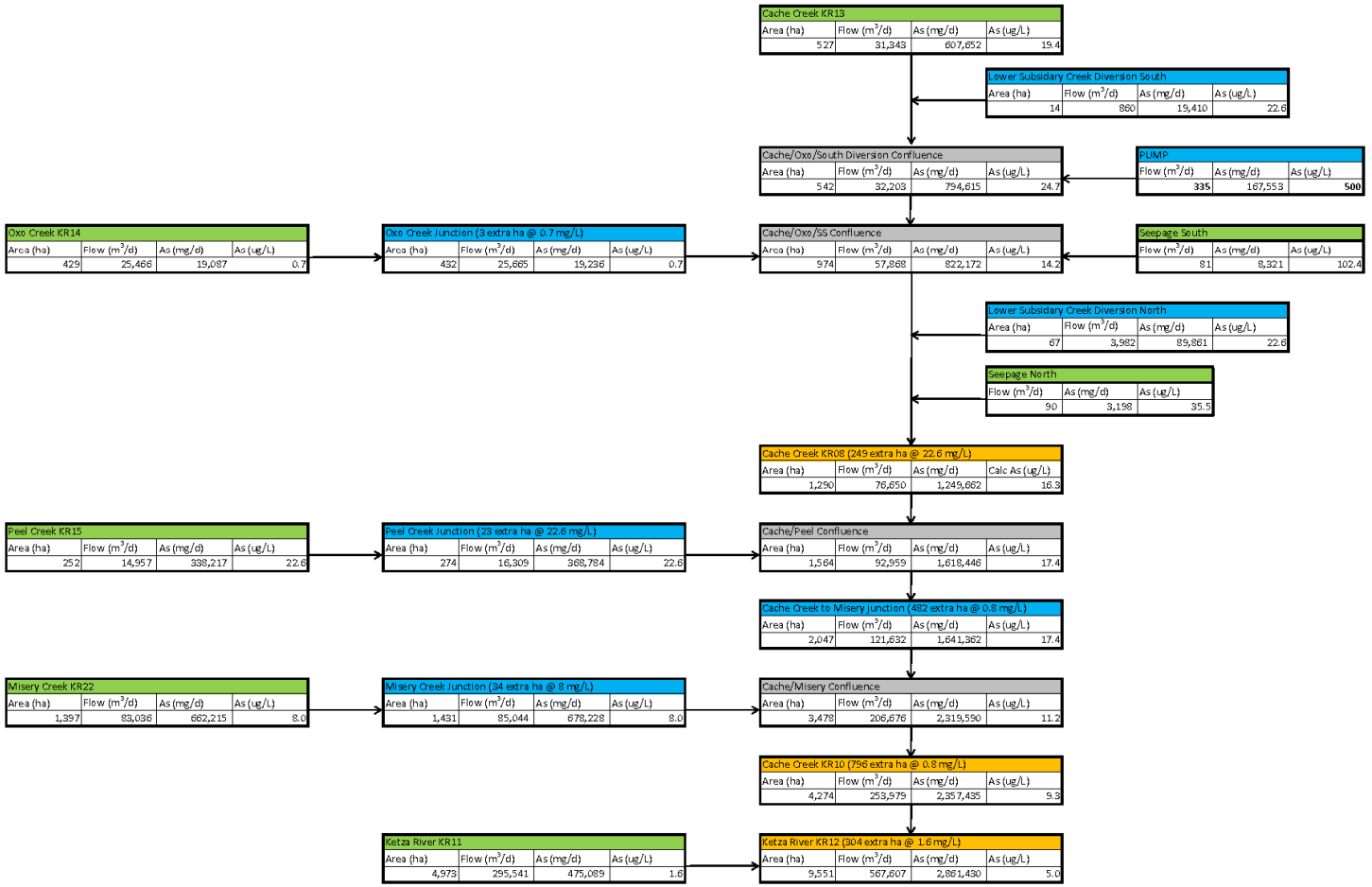
PROJECT NO.	DWN	CKD	APVD	REV
W23101051.104	WW			0

OFFICE	DATE
EBA-VANC	August 15, 2011

Figure 2.1.1-4

WATER BALANCE:

Month: July
Condition: Wet



LEGEND

NOTES

STATUS
ISSUED FOR USE

CLIENT
Ketza River Holdings

A TETRA TECH COMPANY

WATER BOARD SUBMISSION
KETZA RIVER MINE, YUKON
WATER BALANCE - WET
JULY

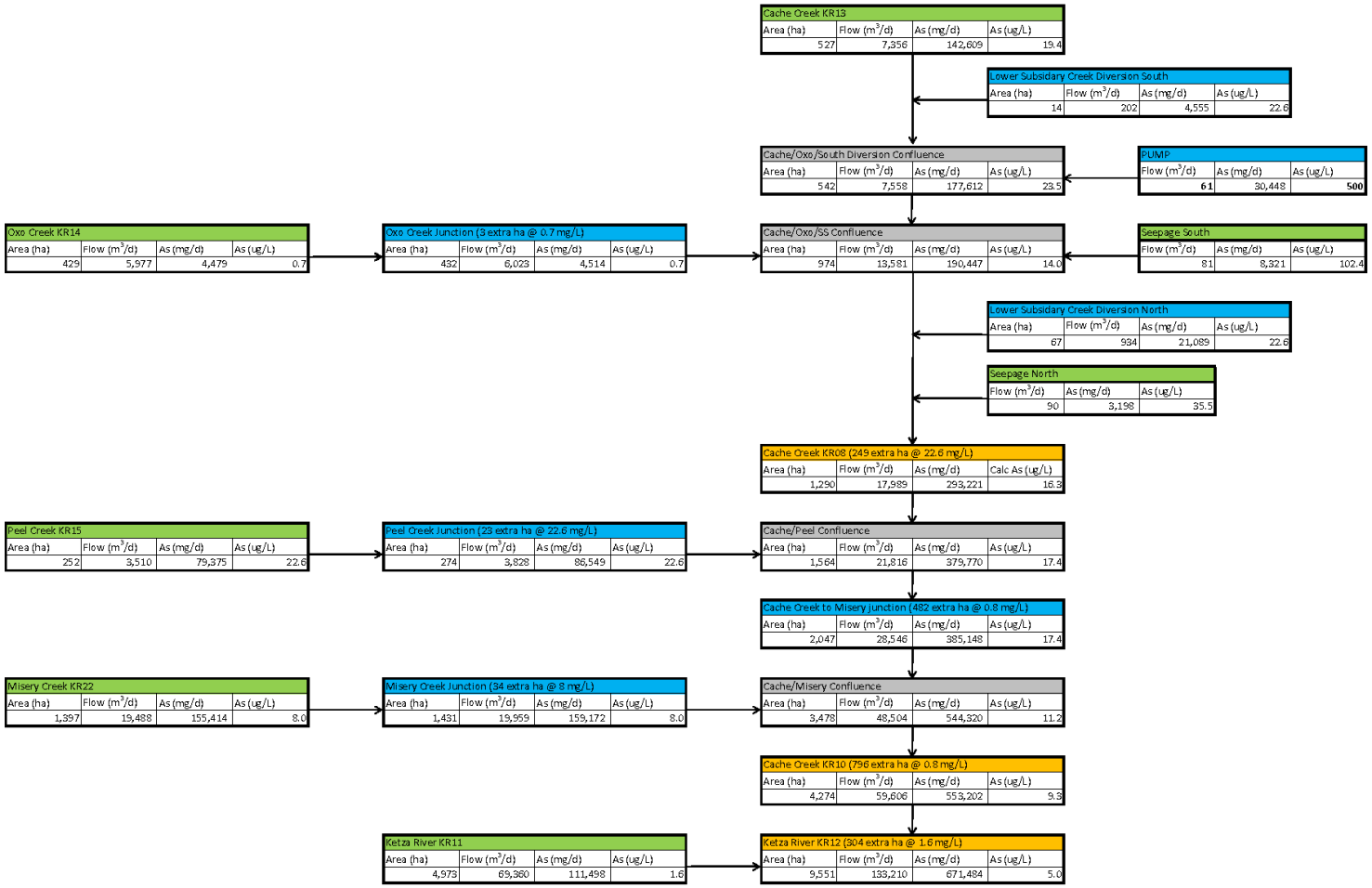
PROJECT NO.	DWN	CKD	APVD	REV
W23101051.104	WW			0

OFFICE	DATE
EBA-VANC	August 15, 2011

Figure 2.1.1-5

WATER BALANCE:

Month: September
Condition: Average



LEGEND

NOTES

STATUS
ISSUED FOR USE

CLIENT
Ketza River Holdings

WATER BOARD SUBMISSION
KETZA RIVER MINE, YUKON
WATER BALANCE - AVERAGE SEPTEMBER

A TETRA TECH COMPANY

PROJECT NO.	DWN	CKD	APVD	REV
W23101051.104	WW			0

OFFICE	DATE
EBA-VANC	August 15, 2011

Figure 2.1.1-6

Q:\Vancouver\Engineering\V132\Projects\W23101051.104.009 - Ketza DSR\Working\WW\WL_Application_IFU\Figure 2.1.1-6-Avg September-W23101051.104-Ketza Water Balance.doc

Table 2.1.1-5: Summary of Inputs and Assumption for the Water Balance

Input Name	Area (ha)	Arsenic Concentration (µg/L)	Notes
Cache Creek KR13	527	19.39	Arsenic Concentrations are the 95% percentile of the mean measured total Arsenic values
Lower Subsidiary Creek Diversion South	20	22.57	Average of 20% of 100 hectares diverted south, Arsenic concentrations calculated based on KR08
Tailings Pond Pump	n/a	500.00	Arsenic concentrations are maximum value allowed for discharge
Oxo Creek KR14	429	0.75	Arsenic concentrations are the 95% percentile of the mean measured Total Arsenic Values
Oxo Creek Junction	3	0.75	Arsenic concentrations assumed similar to upstream station KR14
Tailings Pond Seepage from South Dam	n/a	102.43	Estimated flows and arsenic loading are assumed to be consistent throughout the year. Arsenic concentrations are the 95% percentile of the mean measured total Arsenic values
Lower Subsidiary Creek Diversion North	80	22.57	Catchment area average of 80% of 100 hectares diverted north, Arsenic concentrations calculated based on KR08
Tailings Pond Seepage from North Dam	n/a	35.52	Estimated flows and Arsenic loading are assumed to be consistent throughout the year. Arsenic concentrations are the 95% percentile of the mean measured total Arsenic values
Cache Creek KR08	216	22.57	Arsenic concentrations calculated based on average measured values
Peel Creek KR15	252	22.61	Total Arsenic concentrations are 1.6 times the 95% confidence of measured total dissolved Arsenic values at KR15
Peel Creek Junction	23	22.61	Total Arsenic concentrations are assumed to be consistent with upstream measured concentrations
Cache Creek to Misery Creek Junction	482	17.4	Total Arsenic concentrations are assumed to be consistent with upstream calculated concentrations
Misery Creek KR22	1397	7.98	Total Arsenic concentrations are 1.6 times the 95% confidence of measured total dissolved Arsenic values at KR22
Misery Creek Junction	34	7.98	Total Arsenic concentrations are assumed to be consistent with upstream measured concentrations
Cache Creek KR10	796	0.75	Total Arsenic concentrations calculated loads were below 0 µg/L, assumed background values for Oxo Creek KR14 were substituted
Ketza River KR11	4974	1.61	Arsenic concentrations are the 95% percentile of the mean measured total Arsenic values
Ketza River KR12	303	1.61	Total Arsenic concentrations were assumed to be equivalent to KR 11 since local values incorporate the effects of effluent discharge from the Tailings Pond

Monthly Runoff

There is no continuous, long-term, streamflow data available within the study area watershed. Instantaneous field measurements of flows have been gauged by field staff since 1985. In total, 142 flow measurements from 10 locations have been collected across the Ketza River Mine site. Each catchment was assumed to generate the equivalent amount of runoff per unit area. Average monthly runoff rates in l/s/ha were calculated from these field measurements and combined to approximate the average yearly runoff unit hydrograph. The King Creek at km 20.9 Nahanni Range Road hydrometric station (Water Survey of Canada 10AB003) was chosen to estimate the sensitivity of flows, as it is the most representative of the Cache Creek basin based on catchment size, mean basin elevation, and land use. Using the King Creek hydrometric station, monthly estimates for the average, 1:10 wet and 1:10 dry runoffs were calculated. See Table 2.1.1-6 for the evaluated runoff used in the mass balance.

Table 2.1.1-6: Average Monthly Runoff Rates Per Hectare

Month	Average Runoff (L/s/ha)	10-Yr Wet Runoff (L/s/ha)	10-Yr Dry Runoff (L/s/ha)
January	3.1	5.5	1.1
February	5.7	11.8	1.5
March	2.3	4.1	0.7
April	1.9	2.9	1.0
May	39.2	60.2	19.4
June	93.2	137.8	53.0
July	36.7	59.4	17.5
August	14.2	21.0	9.3
September	13.9	19.7	8.8
October	13.4	22.2	6.2
November	5.0	7.8	2.5
December	4.0	5.8	2.1

2.1.2 Second Outstanding Issue: Item 12e

e) The potential qualitative and quantitative effects that the deposit may have on groundwater are being compiled, and will be provided to the Water Board when complete.

Additional Information to Address Item 12e

e) The potential effects of tailings pond seepage on groundwater quality downgradient of the tailings pond have been assessed using groundwater quality data collected from 2007 to 2010 from the monitoring wells presented in Table 2.1.2-1. It was usually not possible to collect water samples from wells P90-7A, P96-11A, and P96-11B because the wells were either blocked, contained insufficient water, or were dry. Data collected from the tailings pond have been compared to data from monitoring wells located downgradient of the tailings pond. Monitoring station locations are shown in Figure 2.1.1-1. A total of 208 samples were used for this assessment, 76 samples from the tailings pond (KR09) and 132 groundwater samples collected from the monitoring wells (Table 2.1.2-1; Figure 2.1.1-1).

Table 2.1.2-1: Monitoring Wells Downgradient of Tailings Pond Used in Assessment

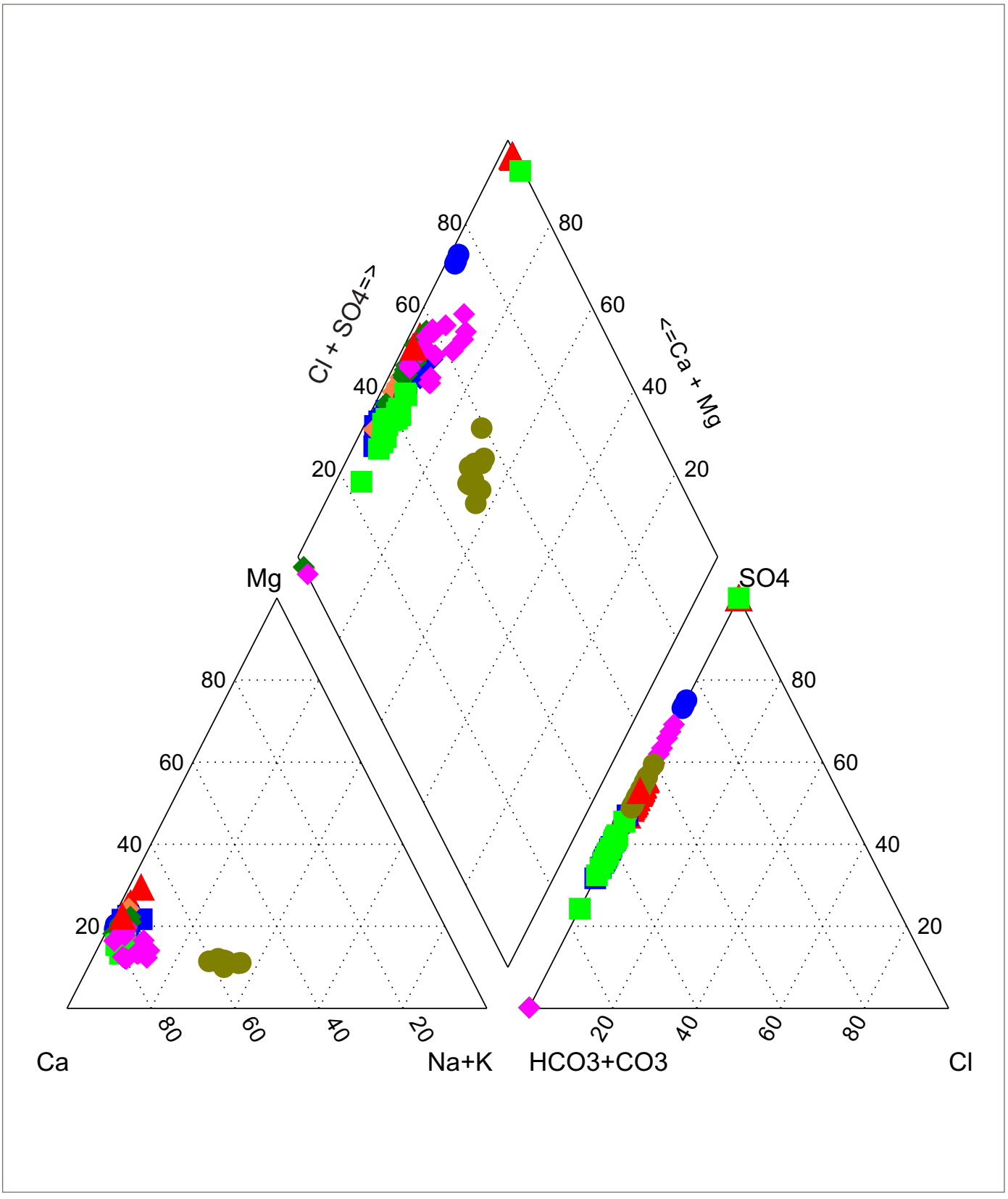
Monitoring Well ID	Completion Details	Comments
P90-7A	Completed in dam	Insufficient water or dry
P90-7B	Completed in bedrock	Water quality data available
P90-7C	Completed in overburden	Water quality data available
P90-8	Completed in overburden	Water quality data available
P90-9	Completed in overburden	Water quality data available
P96-11A	Completed in bedrock	Blocked
P96-11B	Completed in overburden	Blocked
P96-11C	Completed in dam	Water quality data available
P96-12A	Completed in bedrock	Water quality data available
P96-12B	Completed in overburden	Water quality data available
P96-12C	Completed in dam	Water quality data available

The general groundwater flow follows the local topography in a northeasterly direction. Currently, estimates of the local flow direction in the area of the tailings pond cannot be determined as the existing monitoring wells are located approximately along a line. As such, triangulating groundwater elevations measured in these monitoring wells to infer the hydraulic gradient and flow direction is not possible. A better estimate of the local groundwater flow direction is currently underway as part of the hydrogeological assessment for the tailings pond area.

However, based on the general groundwater flow direction inferred from topography close to the tailings pond and hydrogeological data for the greater Ketza River Mine area, all existing monitoring wells are most likely located downgradient of the tailings pond.

Figure 2.1.2-1 shows a Piper Plot illustrating the major ion composition of the groundwater and tailings pond samples. The cation composition (calcium, magnesium, sodium, and potassium) is similar for all samples analyzed, except for the samples collected from monitoring well P96-12C which is completed within the tailings dam and shows higher sodium concentrations compared to the other samples. The cation composition of the tailings pond water (monitoring station KR09) is very similar to most groundwater samples. The anion composition of the groundwater samples is more variable with varying concentrations of bicarbonate and sulfate. In general, samples from wells completed in bedrock appear to be dominated by bicarbonate and those collected from wells completed within the dam and overburden sediments tend to be dominated by sulfate; however, there is considerable variability within the individual data sets and the trend described above is not very pronounced.

The Piper Plot shows that the major ion composition is very similar for samples collected from the tailings pond and downstream monitoring wells, with a more variable anion composition of the groundwater samples. Without groundwater quality data immediately upgradient of the tailings facility, it is, however, not possible to infer any potential effect from tailings pond water on the downstream groundwater quality. The similar chemical composition of the tailings pond water and groundwater may indicate an effect from tailings pond seepage; however, it may also indicate that daylighting groundwater is a major source of water stored in the tailings impoundment.



LEGEND

- P9007A
- P9007B
- P9007C
- P9008
- P9009
- P9611C
- P9612A
- P9612B
- P9612C
- KR09

STATUS
ISSUED FOR USE

CLIENT
Ketza River Holdings

A TETRA TECH COMPANY

GROUNDWATER QUALITY
KETZA RIVER MINE, YUKON

Piper Plot

PROJECT NO.	DWN	CKD	APVD	REV
W23101051.101	SK			0

OFFICE	DATE
EBA-WHSE	June 2, 2011

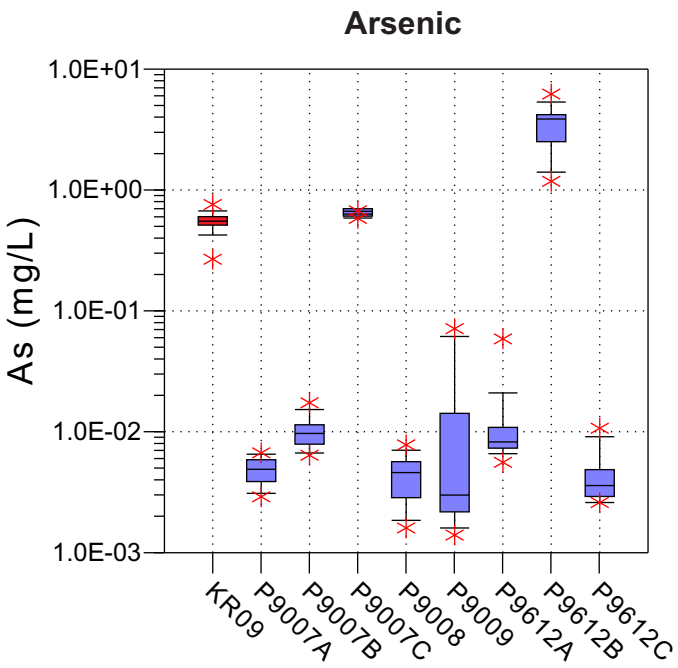
Figure 2.1.2-1

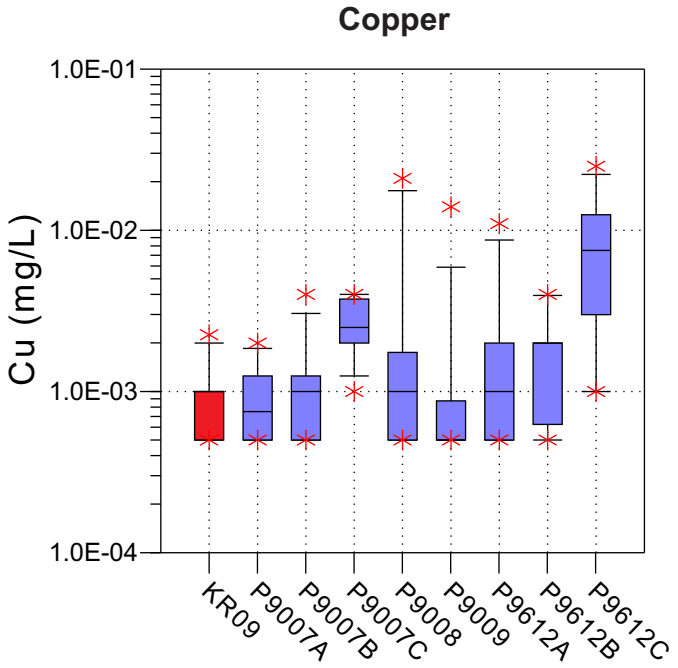
Figures 2.1.2-2 and 2.1.2-3 show the concentrations of regulated parameters (arsenic, copper, cyanide, lead, nickel, zinc, ammonia, and pH) with maximum allowable concentrations at effluent stations as defined in the expired Water Licence QZ04-063. In contrast to surface water, it is common practice to use dissolved rather than total concentrations when assessing groundwater quality. This is because total concentrations measured in unfiltered samples obtained from a monitoring well are usually not representative for local groundwater but mainly affected by the well construction, well development, and sampling method. Dissolved concentrations were therefore used for the above mentioned parameters for this assessment.

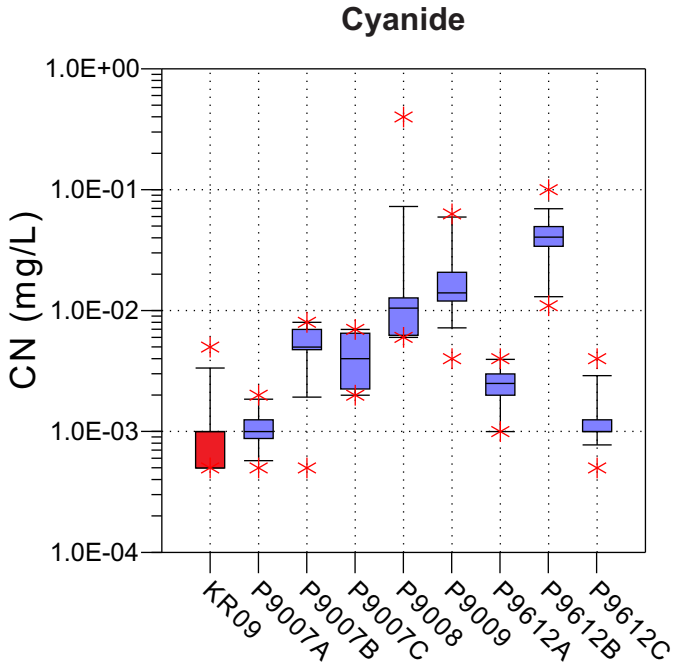
The water quality data are presented in Figures 2.1.2-2 and 2.1.2-3 as minimum, maximum, median, and 5th, 25th, 75th, and 95th percentiles to provide a suitable representation of variability in the data. Note that all concentrations, except for pH, are plotted on a logarithmic scale.

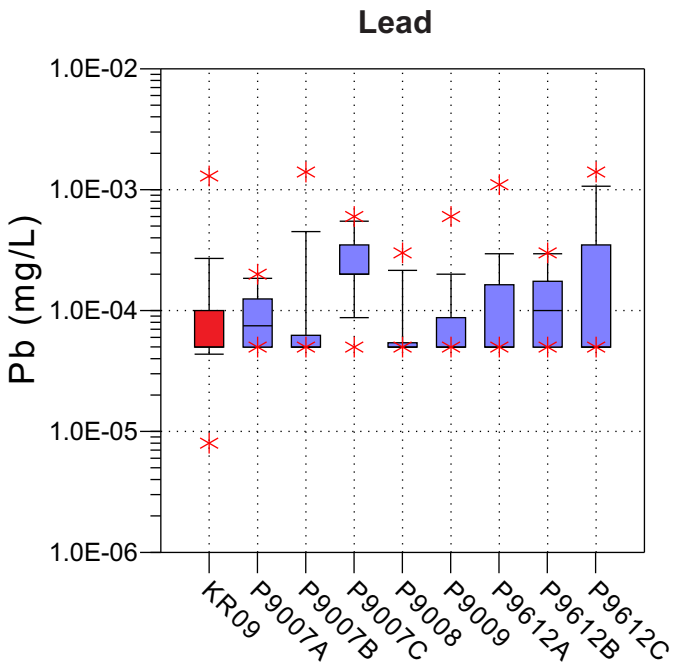
Similar to the major ion composition, none of the parameters in Figures 2.1.2-2 and 2.1.2-3 show a significant difference between the tailings pond water (KR09) and the groundwater samples. The observed concentrations in the tailings pond are mostly very similar to those in the downgradient groundwater wells. The arsenic concentration in the tailings pond is significantly higher than that observed in most monitoring wells, except for wells P90-07B, where the arsenic concentration is very similar to the tailings pond, and P96-12B, where the arsenic concentration is higher than in the tailings pond (cf. Figure 2.1.2-2). Similarly, the nickel and ammonia concentrations in monitoring wells P90-07A, P96-12A, and P90-07A, P90-07C, P96-12A, and P96-12C, respectively, exceed the concentrations in the tailings pond (cf. Figure 2.1.2-3). This may either indicate that the tailings pond is not the primary source of the arsenic, nickel, and ammonia in these samples, i.e., that the natural background concentrations in groundwater from certain areas or aquifers are higher than in the tailings pond. The other possible explanation is that these metals and ammonia are mobilized from the tailings when the water passes through the deposits, resulting in higher concentrations in the seepage than in the supernatant water of the impoundment.

In conclusion, to qualitatively and quantitatively assess a potential effect of the tailings deposits on downstream groundwater quality, a better understanding of baseline groundwater quality upgradient of the tailings pond is required. Additional monitoring wells located upgradient of the tailings pond are necessary to determine the baseline groundwater quality and further assess potential effects from the deposit on the downstream groundwater quality. The installation of these additional monitoring wells is planned as part of the hydrogeological assessment for the area of the tailings pond. A work plan for the proposed hydrogeological assessment is provided in Section 4.5.









LEGEND

- Max.
- 95th Percentile
- 75th Percentile
- Median
- 25th Percentile
- 5th Percentile
- Min.

STATUS
ISSUED FOR USE

CLIENT
Ketza River Holdings

GROUNDWATER QUALITY
KETZA RIVER MINE, YUKON

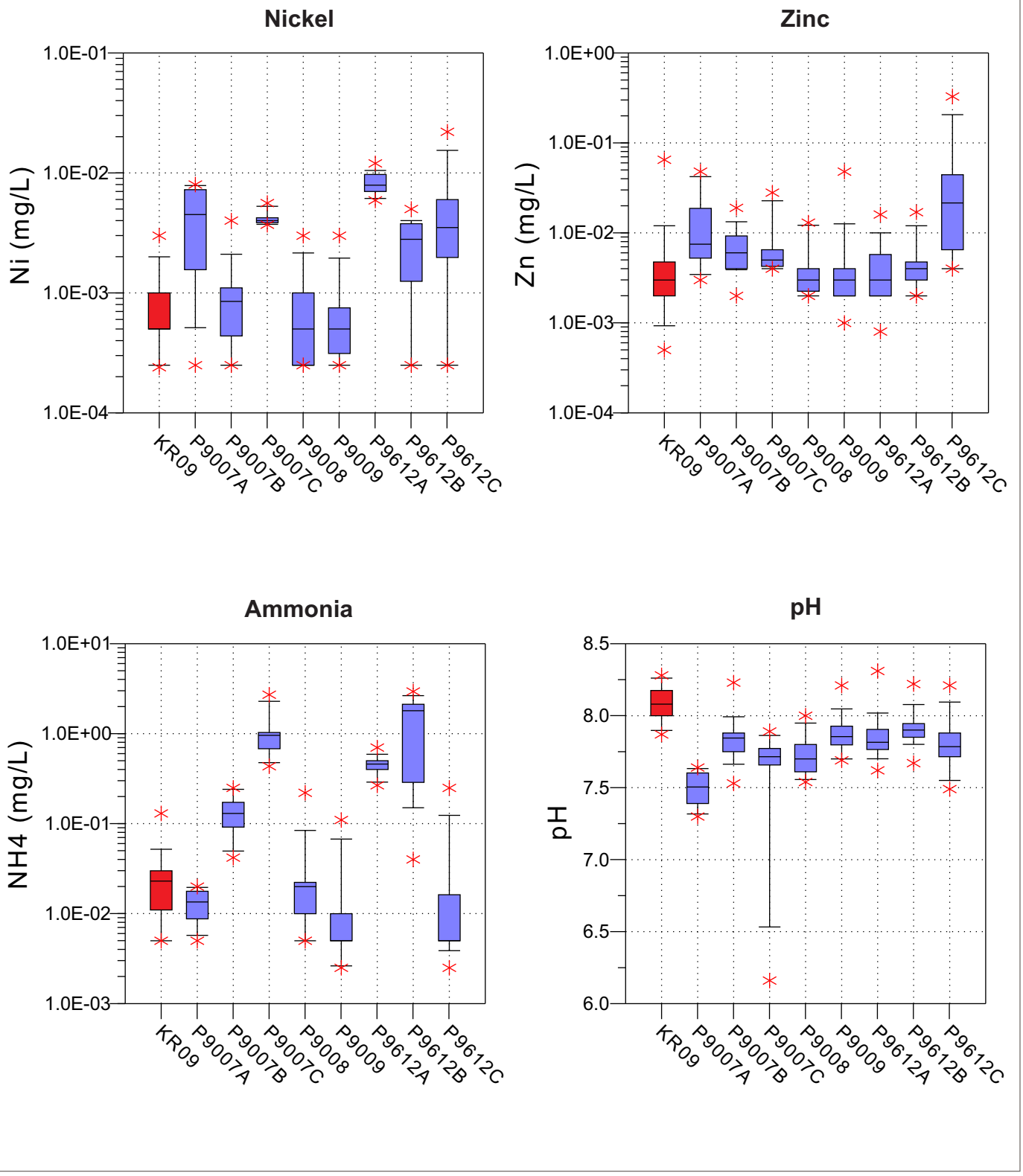
Groundwater Chemistry in the Tailings Pond Area

eba
A TETRA TECH COMPANY

PROJECT NO.	DWN	CKD	APVD	REV
W23101051.101	SK			0

OFFICE	DATE
EBA-WHSE	June 2, 2011

Figure 2.1.2-2



LEGEND

- Max.
- 95th Percentile
- 75th Percentile
- Median
- 25th Percentile
- 5th Percentile
- Min.

STATUS
ISSUED FOR USE

CLIENT
Ketza River Holdings

GROUNDWATER QUALITY
KETZA RIVER MINE, YUKON

Groundwater Chemistry in the Tailings Pond Area

A TETRA TECH COMPANY

PROJECT NO.	DWN	CKD	APVD	REV
W23101051.101	SK			0

OFFICE	DATE
EBA-WHSE	June 2, 2011

Figure 2.1.2-3

2.2 Item 14: Emergency Response Plan

Question 40 pertains to an emergency response plan. Please provide scenarios for failure and/or emergencies, mechanisms of detection, and the process for addressing such failures. It is indicated that a standby water treatment plant is available. Please provide details of the plant, including the type of technology used re-agents that may be added to the discharging water, the capacity of the plant, target effluent discharge standards, etc. Will the treatment system result in the production of treatment solids (sludge) and if so, what are the plans for the management of that waste? It is indicated that the plant will only treat arsenic. How do you propose to meet the other water quality parameters proposed in this application? Does the ability exist to store the treated water in a temporary enclosure to confirm the results in an accredited lab prior to discharge? Please explain and provide a drawing if appropriate. Please provide a detailed water balance of all water inputs and output for the tailings as requested in question 40.

2.2.1 First Outstanding Issue for Item 14

A hydrologic assessment is being completed, including a review of the dam classification and an inundation study. When this study is complete it will be submitted to the Water Board.

Additional Information to Address Item 14

A hydrologic study *Ketza River Mine Hydrotechnical Assessment* was completed for the site and is included as Appendix A.

2.2.2 Second Outstanding Issue for Item 14

The water balance for the project is being updated and will be provided to the Water Board when complete.

Additional Information to Address Item for Item 14

The water balance has been updated and is discussed in Section 2.1.1.1.

2.2.3 Item 21: Security

Please provide an update of the amount of security currently being held for the project and the basis for that security. Please provide a rationale as to why or why not the security being held is adequate.

2.2.4 Outstanding Issue for Item 21

The amount of security currently being held for the project is $3,087,600. The adequacy of the security being held is being assessed and will be provided to the Water Board when available.

Additional Information to Address Item 21

The adequacy of the security has been assessed against the *Decommissioning Liability Cost Estimate for Water-Related Issues at the Ketza River Mine Site* (SteveJan 2010). The security estimate is based upon the proposed works outlined in the *Final Reclamation and Decommissioning Plan, Class A Water Licence QZ04-063, Ketza River Mine Site, Yukon*, dated December 2009 (EBA File: W23101051.101). The current security assessment is based upon the 2009 and 2007 security estimates, with revisions made based on inflation and changes made since the 2007 security estimate was prepared. The security assessment is presented in Table 2.2-1.

2.3 Item 24: Operating Regime for the Tailings Pond

Please provide the operating regime of the tailings pond. This should include, but not necessarily be limited to:

- **The range of the discharge flow rates required to maintain the desired level of the tailings pond;**
- **The current frequency of discharge (continuous, daily, etc.);**
- **The mechanism by which the water is actively discharged (pump, gates and gravity fed ditches, etc.);**
- **How the target level was determined;**
- **The design level rationale of the 2.5 m freeboard.**

2.3.1 Outstanding Issue for Item 24

Water modelling for discharge scenarios was included in the original Type A Water Licence application (*Response to YESAB's Adequacy Review Report for the Proposed 2010 Ketza River Mine Type B Water Licence Application (YESAB Project Number 2010-0080) June 15, 2010*). This model is being updated, and will be provided to the Water Board when complete.

Additional Information to Address Item 24

The water modelling for discharge scenarios is presented in Section 2.1.1.1.

Table 2.2-1: Ketza River Project - Review of Security Cost Estimates 2011

Area & Item	Preparations Phase	Ketza Rationale	YTG Security Estimate - Interim C&M	Ketza Security Estimate - Interim C&M	Ketza Rationale for Revised Estimate	Permanent Closure	YTG Security Estimate - Permanent Closure	Ketza Security Estimate - Permanent Closure	Ketza Rationale for Revised Estimate
Table 3.1									
1430 Portal (Generates water and has been routed to tailings facility)	Ensure short term portal integrity and security ($4K). - On-going mntce. of plastic line is covered in Table 3.7.2	1. Lowered by 10K, as the cost for removal of cables, etc is not related to this water licence. 2. Lowered by 40K due to a contractor estimate (30Kx2)	4,000	4,000		Remove electric cables, air & water lines. Water lines alone are considered to be 1/2 of total cost of $10K ($5K); - Install hydraulic bulkhead, or alternate ($100k)	105,000	55,000	1. Lowered by 10K, as the cost for removal of cables, etc is not related to this water licence 2. Lowered by 40K due to a contractor estimate
Table 3.3									
Follow-up to Toe Berm Construction Report	Contract Engineer of Record to confirm that depth of fill placed meets the intent of the design		2,000	2,000			-	-	
Install additional monitoring instrumentation	Install new replacement flow weirs, calibrated sections in ditches,-Install 1-2 new piezos in toe berm, movement and settlement monuments on tailings dams & toe berm crest and downstream slopes, etc.- Repair existing piezos as included in 2009 Water Licence Report, by EBA; Confirm adequacy of installed monitoring instrumentation. - Survey, calibrate and confirm status of all installed instrumentation		75,000	25,000	Weirs are in place; toe berm piezos installed; equipment is monitored and calibrated	Confirmation of operational status of devices with provision for minor maintenance, estimated at 4 campaigns over the 10 year period at $6K/campaign	24,000	24,000	
Tailings Facility Upgrade/Upkeep	Survey dam crest ($5K) and fill in low areas ($10K), assuming minimal fill requirements		15,000	-	Dam crest survey and fill completed 2010		-	-	
Tailings facility overflow spillway	Survey entire spillway route($5K);Assess hydraulic capacity and erosion potential and remediate, if required for short-term ($5K)		10,000	5,000	Hydraulic capacity study and spillway design completed; survey of entire spillway route to be done (2011)	Breach north dam and construct a new spillway ($50K)and armored channel (~250m) to Cache Creek ($125K) with as-built survey	175,000	175,000	

Table 2.2-1: Ketza River Project - Review of Security Cost Estimates 2011

Area & Item	Preparations Phase	Ketza Rationale	YTG Security Estimate - Interim C&M	Ketza Security Estimate - Interim C&M	Ketza Rationale for Revised Estimate	Permanent Closure	YTG Security Estimate - Permanent Closure	Ketza Security Estimate - Permanent Closure	Ketza Rationale for Revised Estimate
Relocate Tailings	Not applicable	Previous reviewers did not have bathymetric map prepared in 2005. Tailings should be located in a different location that the estimate, and this requires less heavy equipment work	-	-		Relocate 80,000 m^3 to north side of basin (as proposed by Brodie 1998 and GL 2002) in winter with as-built survey	400,000	400,000	
Tailings Cover	Not applicable	The area to be covered is estimated at 70,000 square metres.With 0.5 metre of cover at $5/cubic metre, the cost to KRH would be ~ $175,000. It is estimated that the cost to government would be twice that amount.	-	-		1m thick simple soil cover (as per GL 2002), over entire tailings surface (8 ha.) with as-built survey	800,000	350,000	The area to be covered is estimated at 70,000 square metres. With 0.5 metre of cover at $5/cubic metre, the cost to KRH would be ~ $175,000. It is estimated that the cost to government would be twice that amount
Revegetation of tailings facility surfaces	Not applicable		-	-		Establishment of vegetation on tailings (8 ha), dams & cleared areas (3 ha), for stability and erosion control at $2,250/ha for app. Rates of 50kg/ha seed mix & 250 kg/ha for fertilizer	25,000	25,000	
Pump down pond water level in tailings basin to <1309.0 m and maintain that level-capital cost. (considered to be in place with on-going drawdown programs)	System is already in place		-	-		N/A	-	-	
Northwest Runoff Interceptor Ditch	Upgrade to meet long-term requirements (costs for study covered in T. 3.6)		15,000	-	This work was completed	Long-term maintenance (see T. 3.7)	-	-	

Table 2.2-1: Ketza River Project - Review of Security Cost Estimates 2011

Area & Item	Preparations Phase	Ketza Rationale	YTG Security Estimate - Interim C&M	Ketza Security Estimate - Interim C&M	Ketza Rationale for Revised Estimate	Permanent Closure	YTG Security Estimate - Permanent Closure	Ketza Security Estimate - Permanent Closure	Ketza Rationale for Revised Estimate
Lower Subsidiary Creek Diversion - Upgrade	Increase capacity by replacing existing 24" culvert with 36"($5K). Upgrade channel to meet long¬term requirements ($10K), as req'd. (costs for study are found in T. 3.6)		15,000	10,000	Culvert replacement was completed, and channel upgrades are partially complete - included in annual geotechnical inspections of the earthworks	Long-term maintenance (see T. 3.7)	-	-	
Construct Water Treatment Plant (including wells, pumps, pump-back pumps, sludge handling system & piping)	Replace or upgrade existing plant, as required. Estimate provided is for an upgraded plant with additional throughput capacity		200,000	50,000	Water treatment plant is in placewith specifications demonstrating that the plant is capable of treating water to standards as set in the previous water license - $50k for pipe replacement & pump maintenance	WTP will already be in place	-	10,000	Cost to decommission WTP pump & pipe
Tailings Water Treatment (including dam seepage, pond drawdown pumping/ siphoning costs) includes ops & mntce costs	Treatment campaigns every 2 years at 30,000 m^3 (0.5m depth) per campaign & $2.00/$m^3$ (Yrs 1&3)	YTG's estimate is calculated for 20-year period; this should be a 10-year period as other closure estimates	120,000	80,000	Calculated for a 2 year licence term prior to decommissioning rather than 3	As in Prep Phase but spanning next 7 years, every 2 years, in Yrs 1-(just prior to tailings relocation), & 2 more times during remainder of phase	180,000	180,000	
North Dam Seepages (KR-4) (2 ponds with pumps)	Operate pump back system (costed above)		-	-		Operate and maintain collection and pumping system, as required (costed above)	-	-	
South Dam Seepages (KR-5) (2 ponds with pumps)	Operate pump back system (costed above)		-	-		Operate and maintain collection and pumping system, as required (costed above)	-	-	
Cache Creek Diversion: -Narrowing of channel along several sections; -Includes one major slump of bank material	Interim repairs of riprap on right bank of lower section. Maintenance is covered under Monitoring and Maintenance in T. 3.7	Estimate is too high, remaining work estimated at 30K	15,000	10,000	Cost to repair riprap overestimated	Re-configure lower section so as to pass design flow (from GL 2002 and SRK 1996) incl flow from tailings facility	200,000	200,000	
Maintenance of site diversions & ditches	Covered under Monitoring and Maintenance in T. 3.7		-	-		Covered in Monitoring & Maintenance, in T. 3.7	-	-	

Table 2.2-1: Ketza River Project - Review of Security Cost Estimates 2011

Area & Item	Preparations Phase	Ketza Rationale	YTG Security Estimate - Interim C&M	Ketza Security Estimate - Interim C&M	Ketza Rationale for Revised Estimate	Permanent Closure	YTG Security Estimate - Permanent Closure	Ketza Security Estimate - Permanent Closure	Ketza Rationale for Revised Estimate
Table 3.5									
GS&A	3 years at $50K/yr		150,000	100,000	Calculated for a 2 year licence term prior to decommissioning rather than 3	2 years at $90K/yr, 8 years at $15K/yr	300,000	300,000	
Contractor Overheads	3 years at $25K/yr		75,000	50,000	Calculated for a 2 year licence term prior to decommissioning rather than 3	2 years at $50K/yr, 8 years at $4K/yr	132,000	132,000	
Table 3.6									
Development of an Emergency Response Plan (ERP) for the site	Develop an ERP for interim period	Estimate too high; only nominal amount required to update existing plan	5,000	3,000	ERP development costs overestimated	Update the ERP for the period of final site decommission-ing & long-term periods, once final plan is known	2,000	5,000	Update for closure conditions estimated to cost more than $2k
Ecological and Human Health Risk Assessment	Required		10,000	10,000		Incorporate results of assessment into permanent closure plan	5,000	5,000	
Contaminants Pathways Analysis modeling program to determine downstream loadings of selected contaminants of concern including arsenic	Required. Consider use of GoldSim or similar modeling program		20,000	20,000		Incorporate results of assessment, likely being continued water pumping and treatment, but changes may be required (cost included in T. 3.3)	-	-	
Updated Site Water Balance and area hydrologic assessment	Follow-up to Aug06 EBA report and built onto the above Contaminants Pathways Analysis ($10K); -Incorporate final results into water quality management plan ($5K). -Implement priority action items (costed individually, elsewhere)		15,000	-	Complete	Incorporate results into comprehensive site decommissioning plan (new plan is costed below)	-	-	
Tailings Facility Dams - Dam Safety Review including Inundation Study	To be undertaken, as specified in CDA Dam Safety Guidelines. -Results to be incorporated in facility upgrade, as shown in T. 3.3		20,000	-	Complete	Incorporate results of safety review and facility upgrade into long-term management plans (excludes physical improvements included in Sec. 3.3)	10,000	10,000	

Table 2.2-1: Ketza River Project - Review of Security Cost Estimates 2011

Area & Item	Preparations Phase	Ketza Rationale	YTG Security Estimate - Interim C&M	Ketza Security Estimate - Interim C&M	Ketza Rationale for Revised Estimate	Permanent Closure	YTG Security Estimate - Permanent Closure	Ketza Security Estimate - Permanent Closure	Ketza Rationale for Revised Estimate
Tailings Pond Treatability Study and Design of a new Water Treatment Plant	Required prior to site decommission-ing. Estimated to take 2 years to complete		40,000	-	The water treatment plant is in place with specifications demonstrating that the plant is capable of treating water to standards as set in the previous water license	Not applicable	-	-	
Two studies: Liquification potential for dry tailings under a dry cover; and determination of need for de-water or bonding agents for tailings and evaluation of alternatives	Studies proposed in Final R&C Plan by EBA (2009)		30,000	30,000		Not applicable	-	-	
Comprehensive Decommission-ing Plan with implementation schedule, additional supporting studies, interim measures, AMPs and cost estimates	Prepare a Plan for regulatory review and approval. Estimate water-related tasks comprise 33% of complete plan prep cost of $50K		17,000	17,000		Update Plan based on status of mine. Re-submit for regulatory approval, Water-related issues estimated at 33% of overall update cost of $25K	8,000	8,000	
Table 3.7.2									
Water Quality Monitoring - consider to be the same as WL QZ04-063 for surface and groundwater	Estimate of 332 samples per yr for analysis at $300/full suite of req'd parameters per sample (average unit cost for surface and groundwater analysis)		299,000	199,000.00	Calculated for a 2 year licence term prior to decommissioning rather than 3	Consider requirements to remain as for Preparations Phase for 4 years and then drop by 50% for last 6 years (i.e., 161 WQ samples/yr)	697,000	348,600	During decommissioning sampling every two months would be sufficient
Biological Monitoring consider to be the same as WL QZ04-063 (1 campaign at 5 sites); and MMER EEM requirements (3 sites: 1 upstream reference site & 2 downstream affected sites)	1 campaign as per current WL ($10K) for 5 sites; and EEM at $20K per site		70,000	70,000		Consider requirements to be equal to those during Preparations Phase, due to changes to water management system at the site	70,000	70,000	
Monitoring-supplies' cost	Required for duration of permit, assumed to be 3 years at $2K per year		6,000	4,000	Calculated for a 2 year licence term prior to decommissioning rather than 3	Required for 10 years, cost estimate of $2K per year during active decom work, then $1K /yr for next 8 years	12,000	12,000	

Table 2.2-1: Ketza River Project - Review of Security Cost Estimates 2011

Area & Item	Preparations Phase	Ketza Rationale	YTG Security Estimate - Interim C&M	Ketza Security Estimate - Interim C&M	Ketza Rationale for Revised Estimate	Permanent Closure	YTG Security Estimate - Permanent Closure	Ketza Security Estimate - Permanent Closure	Ketza Rationale for Revised Estimate
Monitoring – labor cost (for collecting samples, checking levels and flows)	Estimated an average of 1/2 time for summer and 1/8 time during winter. Say, 1/4 man overall for 3 years at $80k/man-year		60,000	40,000	Calculated for a 2 year licence term prior to decommissioning rather than 3	During first 2 years: estimate 1/4 time person at $80K/yr; For next 8 years: estimate 1/8 man annualized, at $80k/man-year for 8 years	120,000	120,000	
Annual geo-technical & reclamation inspections	For 3 years, estimated at a total cost of $10K/yr	Already covered in Table 3.6	30,000	20,000	Calculated for a 2 year licence term prior to decommissioning rather than 3	For 10 years, estimated cost of $10K/yr for 2 yrs and then $8K/yr for next 8 years	84,000	84,000	
Reporting	For 3 years, includes compilation of bi-monthly monitoring reports, and annual comprehensive reports. Estimated cost of $5K/yr	Estimate is too high	15,000	10,000	Calculated for a 2 year licence term prior to decommissioning rather than 3	For 10 years, includes compilation of bi-monthly monitoring reports, & annual comprehensive reports. Estimated cost of $5K/yr	50,000	50,000	
Maintenance - Supplies & Services	Required for duration of permit, assumed to be 3 years at $10K/yr		30,000	20,000	Calculated for a 2 year licence term prior to decommissioning rather than 3	Required for minimum of 10 years: first 5 yrs at $10K/yr & next 5 yrs at $5K/yr	75,000	75,000	
Maintenance - Labour	Contracted service. Costs for 3 years of 1/4 man (annualized basis) at $80K/yr		60,000	40,000	Calculated for a 2 year licence term prior to decommissioning rather than 3	Contracted service. First 2 years at 1/4 time for 1 man; Next 8 yrs at 1/8 time for 1 man at $80K/yr	120,000	120,000	
Contingency (20%)			284,600	179,760	20% of recalculated total		718,800	551,720	20% of recalculated total
Total			**1,707,600**	**1,078,560**			**4,312,800**	**3,310,320**	
Grand Total YTG		**Grand Total YTG**	**6,020,400**						
Grand Total KRH		**Grand Total KRH**	**4,388,880**						

3.0 DECISION DOCUMENT REQUIREMENTS

The following section lists the outstanding requirements that were identified in the Decision Document along with the information provided to address these requirements (Table 3.0-1). The outstanding requirements from the Decision Document are referenced by number in this section for brevity. The full Decision Document wording is presented in Table 1.0-1 above.

Table 3.0-1: Proposed Actions to Address Outstanding Decision Document Requirements

Decision Document Number (see Table 1.0-1 above)	Description/Additional Information Provided to Address Outstanding Requirements	Location of Additional Information
1-15, 17	Tailings Water Quality Management Plan, Including Discharge	Section 4.2
16, 18-19	Lower limit for tailings pond water	Section 4.1
20, 21	Detailed geochemical model, including details and methodology about how maintaining levels in tailings pond affects arsenic mobilization from the tailings	To be Provided by KRH during the Life of the Water Licence
22	Detailed site (TSF) closure and decommissioning plan	Section 4.3
23, 27	Sensitivity analysis for water balance	Section 2.2
25, 26, 29, 30	Detailed hydrogeology studies	Section 4.4
28	Summary of water quality and flow monitoring information for mine portal water	Section 4.5
31, 34, 36,42b, and 42e	Operation, Maintenance, and Surveillance (OMS) Manual	Appendix B
32a	Potential physical damage and consequences from hypothetical dam failure	To be Provided by KRH during the Life of the Water Licence
32b	Model of short and long term arsenic release to the Ketza and Pelly Rivers	To be Provided by KRH during the Life of the Water Licence
32c	Consequences to fish in the event of a dam failure	Section 4.6
32d	Consequences to human environment in the event of a dam failure	Section 4.7
32e and 32f	Appropriate mitigation for potential effects of dam failure and implementation plan	To be Provided by KRH during the Life of the Water Licence
33	Security assessment	Section 2.2-3
35	Dam safety review and hydrotechnical design work, including hydrological assessment	Appendix C
37	Ensure tailings pond below 1,309 m	Section 4.1
38	As-built drawings for the toe berm constructed by Vista-Tek	*Water Use Application QZ10-026, Care and Maintenance of the Ketza River Mine Tailings Pond Information Request,* Addendum P
39-41	Sediment control, machinery operation, culverts	Section 4.1
43-55	Fuel management	Section 4.1
42a, c, d	Repair weirs, cut saplings, survey dam crest	Section 4.8
57 and 58	Protocols for wildlife monitoring and recording onsite formalized with YNG	Section 4.9
59-65	Wildlife management	Section 4.1

4.0 PROPOSED WATER LICENCE CONDITIONS

4.1 General Conditions

DD #s 16, 18-19, 37, 39-41, 43-55, 59-65

- The lower limit of the tailings pond would be 1,298 m (msl);
- The proponent would on a regular and consistent basis, inform the Ross River Dena Council of their environmental monitoring activities related to care and maintenance of the tailings pond and associated infrastructure;
- The proponent would provide an annual summary of environmental data gathered for this project to the Ross River Dena Council;
- The proponent would ensure that the maximum water level of the tailings pond is kept below 1,309 m (GSD 95; 1,306 m msl);
- Appropriate sediment and erosion control structures would be installed and would be inspected regularly during the course of work. Necessary repairs would be made if damage is discovered;
- The proponent would operate machinery in a manner that minimizes disturbance to the banks or bed of all waterbodies or watercourses;
- The proponent would comply with the Department of Fisheries and Ocean's Pacific Region Operational Statement Culvert Maintenance;
- All machinery used would be in clean, good operating condition and inspected regularly for small leaks;
- All equipment would be checked for leaking hydraulics and no refuelling is to take place within 30 m of a waterbody or watercourse;
- Any fuel storage cache for the existing TSF would be set back 100 m from Cache Creek;
- The proponent would not under any circumstances deposit or allow the deposit of any deleterious substance, including but not limited to, fuels, lubricants, and coolants, of any type into any waters or in any place under any conditions where the deleterious substances may enter any waters;
- The proponent would prevent contaminants from entering receiving water bodies;
- Any full or partially full fuel drums left onsite be secured in a lined area and protected from rain and snow accumulation on top of each drum. Fuel drums would be placed on pallets to prevent contact with water that may have collected on the liner;
- During machine repair activities, a service area would be established to manage the special wastes generated. The service area for machine repair activities would be bermed and lined with a synthetic or natural liner. A synthetic liner would be 60 mil (or two 30 mil), hydrocarbon resistant and UV resistant. If not UV resistant, the synthetic liner would be covered. The natural liner would be 1m thick with a maximum permeability of 1 x 10-6 cm/s;

- The proponent would at all times have on site sufficient spill clean-up equipment and material in readiness to immediately clean up any spill of petroleum products;
- The proponent is required to report all spills to the 24-hour Yukon Spill Report Centre at 867.667.7244;
- All spills would be assessed and remediated in accordance with the Contaminated Sites Regulations and its protocols and standards, including proper delineation of the affected area and confirmatory sampling after remediation is complete to demonstrate that the remediation program has been effective;
- All employees would receive adequate training before being allowed to work on site;
- The proponent would prepare and implement a comprehensive safety program with ongoing updates, monitoring and maintenance programs to ensure facility and worker safety and equipment integrity, an emergency plan with ongoing updates, a back-up plan for rescue assistance, a contractor safety management plan, and a return to work program for injured workers;
- The proponent would install appropriate signage along the access road to the extent that it is relevant (e.g., 'entering flood risk zone');
- The proponent would notify the Regional Biologist or Conservation Officer for advice on additional mitigations should any dead animals be found in the area of the TSF;
- If new clearing or earthworks are proposed during the breeding period for nesting birds (i.e., May 1 – July 31), pre-work surveys would be conducted;
- If any SARA or COSEWIC listed species are found to be present, evidenced by active nests (including tree cavities), a 10 meter buffer zone would be maintained around nests;
- The proponent would not destroy or damage animal dens, lodges or burrows located during the project. A Yukon Government inspector would determine setbacks from these wildlife features if discovered on-site;
- The proponent would refer to the "Guidelines for Industrial Activity in Bear Country" booklet for best practices to reduce effects on bears;
- The proponent would notify the Regional Biologist or Conservation Officer for advice on further mitigations if any bears are frequenting project site;
- All attractants, including water treatment plant products and waste, would be stored in a manner that prevents access by bears and other wildlife, until properly disposed of.

4.2 Tailings Water Quality Management Plan, Including Discharge

DD #1 Water Licence Monitoring

Parameters shall be monitored as per the schedule set out in the previous Water Licence (QZ04-63), Schedule A, Section III.

DD #2 Compliance Testing for Arsenic

On-site analysis for arsenic would be undertaken daily during discharge at the discharge point (KR09A) using a MTI Diagnostics PDV 6000 portable heavy metals analyzer. Analysis of data would be undertaken using compatible voltametric analytical software. During on-site testing with the PDV 6000 the standard comparison method would be used, as per the PDV 6000 operation manual. The standard comparison method uses a three curve analysis: blank, standard, and sample. Standards and blanks would be replaced weekly, or as necessary, whichever is more frequent. Daily on site arsenic concentration results would be compared to accredited laboratory results on a weekly basis. If on-site daily arsenic levels differ within a statistical confidence limit of 5% or greater from laboratory results discharge would be ceased. In the event the daily and laboratory results differ by more than 5%, field techniques would be reviewed and adjusted until satisfactory comparative results with the laboratory are achieved.

DD # 3 Ceasing Releases

In the event daily or weekly laboratory arsenic results exceed the arsenic standard, discharge would be ceased immediately and the output from the water treatment plant would be adjusted to achieve favourable results prior to discharge recommencing.

DD #4 Reporting On-site Test Results

Daily on-site test results would be compiled, tabulated and delivered by the proponent to the Water Board at the close of each calendar month in that month's Water Licence report. Due to necessary delays caused by data compilation and reporting, there would be a one month delay between sampling and deliverable dates.

DD #5 Environmental Monitoring Receiving Environment

Receiving environment stations to be sampled on a weekly basis during periods of tailings pond release in conjunction with weekly compliance sampling include: KR8, KR10, KR11, and KR12. Upstream stations KR01 and KR13 would also be sampled during this event to monitor parameter background levels. These samples would be analyzed with the weekly discharge laboratory concentration check.

DD # 6 Monthly Reports

All arsenic concentration results from the Ketza River (station KR12) would be compared to the CCME Protection of Aquatic Life Guidelines, and any exceedance would be highlighted in monthly results.

DD # 7 Flow Measurements

Flow measurements would be taken in conjunction with weekly water quality compliance sampling and at environmental stations during release and include an upstream station (KR01), a near-field downstream station (KR08) and a far-field downstream station (KR12).

During times of accessible open water flow readings would be taken via swoffer meter. During times of ice cover flow readings would be taken via salt slug method.

DD #8a Quality Assurance and Quality Control

KRH would provide a quality assurance and quality control (QA/QC) procedure for daily on-site and weekly compliance monitoring. The QA/QC procedure would include a record of training for site personnel (on-site and compliance testing).

QA/QC on site would be carried out via regular calibration of equipment as described in the PDV 6000 heavy metals analyser operation manual, section 3.2. On-site results would be cross referenced with those results obtained at a certified analytical laboratory. Equipment calibration records would be kept in a log book on site, as well as scanned and saved digitally and delivered in the monthly water quality report. Any repair to field equipment would be carried out by a certified supplier. Analytical laboratory QA/QC methods and controls are listed with results. Laboratory QA/QC results would be included with submission of analytical results to the Water Board.

A record of training would be kept on site, as well as scanned and saved digitally. The record of training would include: trainer, trainee, date of training, equipment trained, expiration date (if any) of training. All relevant equipment manuals would be available to trained staff.

DD #8b Water Treatment Operation and Maintenance Plan

The water treatment operation and maintenance plan is as follows:

Water treatment would be undertaken using the on-site Orca Kemloop 1000 system. The ORCA Kemloop 1000 system functions using a combination of filtration and chemical treatment. Chemical treatment is undertaken with chlorine bleach (as an oxidant for Arsenic III and V) and iron (as a precipitate coagulant). The ORCA Kemloop system comprises many individual components, all with different expected lifespans. A list of these components can be found in the operations and maintenance manual. Any component integral to the functioning of the plant would have all necessary replacement parts available on site. Any time discharge is scheduled to take place, staff trained in maintenance and repair would be on site. All staff involved with operations of the Orca would receive training from a Yukon Nevada Gold Corp. representative (see the inspection and maintenance schedule and procedures for the water treatment facility (*February 28, 2011 Information Request Response question 12 g*).

DD #8c Water Treatment Plant Details

Once regular treatment commences, the proponent would supply all requested on-site data as it becomes available, including: on-site performance statistics, demonstrated results, treatment capacity and history of use. The above information would be supplied once a a Yukon Nevada Gold Corp. representative has been contacted, the equipment has been inspected for competency and initial trial treatments have been conducted. Demonstrated results and history of use on site cannot be supplied at this time as the water treatment equipment has not been operational at the site.

In September 2005 NSF International, in cooperation with the U.S. Environmental Protection Agency, issued an Environmental Technology Verification Report (NSF 05/20/EPADWCTR) on the ORCA Kemloop 1000 system as it related to arsenic removal in drinking water. The report states that the ORCA system is capable of reducing arsenic concentrations from an average of 22 µg/L to 3 µg/L at an average discharge flow rate of 9.9 gallons/minute over a period of 336 consecutive hours.

DD #8d Water Treatment Plant Rationale

KRH would provide a rationale for why the existing water treatment plant is capable of meeting the discharge standard for arsenic for all potential flow and volume situations that may be experienced in the tailings pond within three months of Water Licence issuance, once a trained YNG representative has inspected the equipment, and a model for water inputs to and outputs from the tailings pond in a site water balance has been generated and compared with the ORCA system's on-site discharge flow rate capabilities.

DD #9 Annual Testing Water Treatment Plant

Once a trained Yukon Nevada Gold Corp. representative has inspected the equipment, and trained on-site personnel in the operations of said equipment, KRH staff would test the function of the plant annually to ensure it is capable of timely implementation. The implementation test should be performed from start-up, following the ORCA operations guide pre-operation checklist, to release of treated effluent.

DD #10 Staff Training in Water Treatment Plant

Prior to the initial operation of the ORCA system, a trained YNG representative would be brought to site to train additional staff in the use of the ORCA plant. At least 1 trained staff member would be on-site during any discharge event. The proponent would have up to 3 employees trained in the operation of the ORCA plant employed simultaneously. In the event no trained staff are available on site, no discharge would be undertaken. In the event a trained employee is no longer available, a replacement employee would be trained.

DD #11 Laboratory Time Exceedance

In the event that a recommended sample expiration time is missed, the on-site sampling and shipping practices would be re-examined. Sampling should be conducted and samples shipped in such a way as to minimize the amount of time between sampling and analysis. Samples would be shipped in the most expedient manner possible. Any exceedance of the recommended turnover times for compliance monitoring samples received by the laboratory would be highlighted in monthly reports.

DD #13 Maximum Flow Rate

Water releases from the tailings pond would be limited by a maximum flow rate. The maximum flow rate is proposed to be 20 L/sec. This is discussed in more detail in Section 2.2.

Controlled releases from the pond are through a treatment system (described above) and a pump prior to discharge into Cache Creek immediately downstream of KR13 at location KR09A (see Figure 2.1.1-1). The maximum flow rate has been defined in this study such that the water quality at the junction of Ketza River and Cache Creek meet the CCME guidelines for the Protection of Aquatic Life for arsenic (0.005 mg/L). As a result, the maximum pond release rate varies with the flow in the Cache Creek and upper Ketza River catchments. Based on the current understanding of the hydrology and hydraulics of the Cache Creek and upper Ketza River catchment, anticipated maximum pond release flow rates for the average, 1:10 year wet and 1:10 year dry years have been developed (Table 4.2-1). The derivation of these results is discussed in further detail in Section 2.2.

Table 4.2-1: Monthly Discharge Rates and Volumes

	10 year Dry Discharge Rate (L/s)	Average Year Discharge Rate (L/s)	10 year Wet Monthly Discharge (m^3)
January-June	-	-	-
May	1.1	2.5	3.9
June	3.4	6.2	9.3
July	1.0	2.3	3.9
August	0.4	0.7	1.2
September	0.3	0.7	1.1
October	0.2	0.7	1.3
November -December	-	-	-

The maximum discharges were calculated based on flows and baseline concentrations at KR12. The assessment indicates that for every 1.6 m^3/s greater than 0.4m^3/s at KR12, 1 L/s of flow can be discharged from the dam. The assumption in this calculation is that the baseline water quality at KR12 is equal to 7 µg/L of arsenic.

DD #15 Single Discharge Line

If at any time, for any reason, discharge originates from more than one source, all discharge would be ceased immediately. Any additional discharge points, and their receiving environments, would be sampled after the cessation of discharge.

DD # 17 Exploration Water Sources

KRH would make best efforts to use water from other sources before using untreated tailings pond water for exploration.

4.3 Tailings Closure and Decommissioning Plan

DD # 22 Detailed Site Plan (Tailings Closure and Decommissioning Plan)

EBA previously prepared and submitted a report entitled *Final Reclamation and Decommissioning Plan, Class A Water Licence QZ04-063, Ketza River Mine Site, Yukon*, dated December 2009 (EBA File: W23101051.101). This plan was developed to address the requirements for a Final Reclamation and Decommissioning Plan in Part F of the Type A Licence QZ04-063 issued to Ketza River Holdings Ltd. for ongoing Care and Maintenance activities associated with the tailings ponds and associated structures.

The current plan outlines options that could be undertaken to reclaim the tailings pond and associated facilities. Two alternatives (wet versus dry) were considered for the final decommissioning of the existing Canamax tailings pond and associated infrastructure. They have since been modified to the following:

- Leaving the existing pond as a water retaining structure with upgrades to the spillway and diversions. Locally recontour and cap exposed tailings (wet scenario) or

- Draining the tailings pond, recontouring the tailings (as required), and capping the tailings (dry scenario).

The dry decommissioning scenario offers the best potential for reducing arsenic loadings to the receiving environment through the isolation and capping of much of the tailings solids. Lowering the water level would also allow for drainage of the existing tailings.

The dry scenario still requires some additional investigation and analyses which includes:

- Determining the liquefaction potential of capped tailings under the dry scenario;
- Potential requirement for a de-watering or bonding agent for the tailings.

The current decommissioning plan also includes:

Tailings Pond

- The tailings pond water level would be lowered to expose as much of the tailings solids as is considered possible;
- The lowering of the pond would be accomplished through pumping with water treatment conducted as required to maintain the discharge arsenic concentration below licence standards;
- Exposed tailings that require recontouring would be allowed to drain in-situ and freeze in order to facilitate handling by equipment;
- A temporary dry tailings stockpile would be located along the southern portion of the existing facility;
- The final exposed face of the recontoured tailings would be temporarily covered with a non-woven geotextile to allow for retention of fine grained particulate while still allowing for drainage of water from the materials. The non-woven geotextile would also prevent any erosion of the exposed tailings from rainfall or run-off;
- The north and south dams would be maintained during the lowering of the pond water level and the recontouring of the tailings;
- It is anticipated that revegetation of the tailings cap would take approximately four to five years;
- The north dam would be breached and a coarse armoured channel constructed through the footprint of that structure;
- The south dam would remain in place following decommissioning but would be covered with a thin veneer of soil and revegetated.

Diversions

- The diversion ditches would be left in place.

Water Treatment

- Water treatment is expected to be required for several years under the dry decommissioning scenario; a more precise time estimate and treatment options would be determined during detailed decommissioning design.

Revegetation

- Natural regeneration of local species would be encouraged by providing an initial cover by seeding disturbed areas with a custom seed mixture;
- Seed selection would be based in part on rapid emergence for erosion control, low nutrient tolerance, tolerance to alkaline soils, extensive seed production, and drought tolerance.

Monitoring

- Monitoring of water quality would be conducted at selected locations during and after the decommissioning of the tailings pond to evaluate whether water quality objectives established for the site are being achieved;
- It is expected that site monitoring would be conducted for a minimum period of five (5) years following decommissioning of the tailings pond, depending on the results of the water quality monitoring program;
- Geotechnical performance monitoring would be conducted for the existing tailings pond and associated infrastructure while the north and south dams remain in place to provide containment of sediment and water draining from the tailings.

A final detailed site closure and decommissioning plan will be prepared in the future, which would build on these proposed concepts. The plan would be submitted to the Yukon Government, Energy Mines and Resources Assessment and Abandoned Mines Department to obtain a letter acknowledging their review and approval, and to the Yukon Water Board. The final site closure and decommissioning plan would be submitted to the Yukon Water Board within two years of Water Licence issuance.

4.4 Hydrogeology

DD # 25, 29, 30 Hydrogeological Study of TSF to Provide a Better Understanding of Background Groundwater Quality, Groundwater Flowpaths, Seasonal Variability, Soil Physical Parameters, Hydraulic Gradients, Contaminant Transport and Attenuation Mechanisms; Determine the Fate of Seepage Water from the TSF; Evaluate the Contribution of Seepage from the TSF to the Weirs Below North and South Dams

A hydrogeological assessment in the area of the existing tailings pond is required to characterize the local groundwater regime. The hydrogeological assessment would use data from the existing monitoring wells downgradient of the tailings pond as well as data from two monitoring wells that are proposed for installation upgradient of the tailings pond. These additional monitoring wells serve to characterize current groundwater quality upgradient of the tailings pond and would provide a better understanding of the overall groundwater quality in relation to the tailings pond.

The field data would be used to characterize the groundwater regime in the area of the tailings pond including:

- Groundwater flow direction;
- Hydraulic gradient;
- Aquifer hydraulic conductivity;
- Groundwater flow velocity;
- Groundwater quality;
- Identification of natural exceedances of water quality guidelines;
- Seasonal variability of both groundwater flow and water quality;
- Estimate of seepage rate from tailings pond;
- Assessment of potential effects from the tailings pond on downgradient groundwater quality.

Seasonal data collection over the course of at least one year would be necessary to properly assess groundwater conditions upgradient of the tailings pond. The hydrogeological assessment would therefore be completed and submitted to the Yukon Water Board one year after installation of the additional monitoring wells which is currently planned for the summer 2011 but depends on the availability of a drill.

DD # 26 Ensure Contaminated Groundwater Not Impacting Downstream Receiving Environment

Groundwater is discharging downgradient of the tailings pond in the area of monitoring stations KR04N2, KR04N3, KR05S1, and KR05S2 before it enters Cache Creek. The monitoring stations KR04N3 and KR05S2 are located shortly before the water is released into Cache Creek through Weirs #4 and #5, respectively. If water quality guidelines set in the Water Licence are exceeded at these locations, the water would be captured at Weirs #4 and #5 and pumped back into the tailings pond.

The hydrogeological assessment would yield additional information on the fate of seepage from the tailings pond and potential effects from the tailings pond on downgradient groundwater quality. The proposed strategy to verify that contaminated groundwater is not affecting the downstream receiving environment will be re-visited when additional information from the hydrogeological assessment becomes available.

4.5 Portal Water Quality and Contribution to Water Balance

DD # 28 Summary of Portal Water Quality Info and Contribution to the Water Balance and Chemistry

Historical portals 1430 and 1510 are inspected annually during the geotechnical inspection, and are discussed in the annual Geotechnical Investigation Reports, submitted to the Water Board.

The *2008 Geotechnical Inspection Report Ketza River Mine, Yukon* (EBA 2011, Addendum K, Appendix B) stated that the 1430 and 1510 portals had an estimated volume of less than one litre per second of water seepage, and 1550 portal had no seepage observed. The 2008 report also stated that portals 1430 and 1510 were plugged by massive ice and that the seepage observed could be from ice melt. The report

recommended that monthly inspections of the portals be carried out and that if seepage continues, water quality samples should be collected and tested.

The *2010 Geotechnical Inspection Ketza River Mine, Yukon* (EBA 2011, Addendum E) stated that the 1430 portal had no seepage. It estimated that seepage observed from the 1510 portal was less than five litres per second and recommended that that if seepage from the 1510 portal continued, water quality samples should be collected and tested.

Given the small volumes of water seeping from the portals, it is likely that portal seepage chemistry has little influence on the overall tailings pond chemistry. Seepage from portal 1430 is captured in an existing pipe for transport to the tailings pond. Seepage from portal 1510 infiltrates into the ground.

Sampling portal seepage on a routine basis is challenging due primarily to the safety issues surrounding the stability of the terrain around the portals. Furthermore, portal seepage volumes are very small, making error-free sampling difficult.

4.6 Consequences to Fish in the Event of a Dam Failure

DD # 32c Consequences to Fish in the Event of a Dam Failure

A detailed summary of fish presence and distribution along with the identification of sensitive habitats in the receiving waters will be provided no later than August 31, 2011. A summary of the consequences to fish in the event of a dam failure will also be completed and submitted to the Water Board six months after the completion of the assessment of potential physical damage and consequences resulting from a hypothetical dam failure (DD #32a).

4.7 Consequences to Human Use and Presence in the Event of a Dam Failure

DD # 32d Consequences to Human Use and Presence within the Affected Downstream Environment in the Event of a Dam Failure

This section completes an assessment of the possible socio-economic effects if a failure of the existing tailings dam occurred. The goal of this assessment is to:

- Outline human presence and use in the area downstream of the tailings impoundment and identify those with an interest in that area;
- Assess the possible socio-economic effects of a total failure of the tailings dam.

The assessment is based on a worst case scenario, which involves a total dam failure resulting from and exacerbated by a one-in-two-hundred-year flood event.

This assessment is based in part on the February 2011 *Ketza River Mine Hydrotechnical Assessment* (EBA 2011; Appendix A). The report provides the likely water volumes, flow rates, and areas of inundation from the tailings dam downstream on Cache Creek and the Ketza River as far as its confluence with the Pelly River.

The study area for this assessment includes the area along the watercourses that are expected to be flooded by a combination of a one-in-two-hundred-year flood and a total release of the tailings.

4.7.1 Human Presence and Use

Ross River Dena: Traditional Land Stewards

The Ross River Dena have been present and using the area for thousands of years. They continue to hunt, trap and to act as stewards of the land using traditional Kaska approaches to manage hunting and trapping.

Martin S. Weinstein (1992) sums up the difficulties in defining the Kaska land use system precisely:

> *"The Kaska… system of land and harvesting access is difficult to define because of its inherent flexibility. To outsiders, the flexibility often gives it an appearance of being open and without rules… The basic principles of the Kaska system rest on the notion of sharing and ensuring, primarily, that the needs of the community are met and, secondarily, that the needs of other people who want to harvest in the area are taken care of if there is a harvestable surplus beyond the requirements for conservation… The rules for access and land use were based on social affiliation; again with only informally defined limits… Part of the Indian system of resource management was an assessment of the animal abundance to determine if family lands could support more people. In those cases other families were invited. Consequently, resource management was both economic and social."*

On one level the system of Kaska land use allowed anyone to use any of the First Nation's land and resources as they needed. But in practice: "…the combination of ecology, culture and history result in particular individuals and family groups having recognized authority over different regions of the band's territory. These are the traditional land stewards of a particular region within the Kaska traditional territory.

There is no published data on hunting or trapping use by the Ross River Dena in the study area.

Built Infrastructure

There are no permanent residents living within the study area and there are no known cabins or other permanent structures. However there is built infrastructure including the bridge along the Robert Campbell Highway that crosses the Ketza River and large sections of the existing access road to the Ketza River site itself.

The Yukon Government Department of Highways and Public Works is responsible for maintaining the Robert Campbell Highway and the bridge over the Ketza River. However, although the Ketza access road is classified as a public road and is used by the general public, it is not maintained by government. There is no data available on traffic or usage of the Ketza road.

The Yukon government does collect vehicle count data for the Robert Campbell Highway; however, estimating the actual level of highway use around the Ketza River is problematic due to the location of the counters. The nearest counter is located near the intersection of the South Canol Road at Km 355.2, approximately 15 km north of the Ketza bridge. The counter is in place only seasonally (May through October) and captures traffic from and to both the South Canol Road (which intersects the Campbell at Km 354.7) and the Robert Campbell Highway further south. Data from the counter shows an average daily traffic volume of 76 vehicles per day during the summers from 2004 through 2008.

Users of the Ketza road include:

- Employees and contractors of KRH;
- Other mining exploration companies and prospectors;
- Ross River Dena hunters and trappers as discussed above;
- Non-RRDC hunters;
- Yukon Stone Outfitters Ltd.

Yukon Stone Outfitters has indicated that they make use of the road some years (though not all) to haul a number of horses into one area of their outfit at the beginning of the season and then haul them out at season's end.

To summarize, those with an identified interest in the area that would be affected by a dam failure include:

- The Ross River Dena, and in particular;
  - The traditional land stewards of the area;
  - The trappers who use that portion of the large group trap line managed by the First Nation;
- Non-RRDC hunters who use the mine road to access hunting areas;
- Yukon Stone Outfitters Ltd.;
- Mining claim holders and prospectors who use the Ketza River road to access their claims;
- Yukon Government Department of Highways and Public Works;
- Users of the Robert Campbell Highway bridge over the Ketza River.

4.7.2 Socio-economic Effects of Tailings Dam Failure

A catastrophic tailings dam failure caused by a one-in-two-hundred-year natural flood would create a number of negative socio-economic effects both on built infrastructure and on human use of the area.

Effects on Built Infrastructure

The February 2011 *Ketza River Mine Hydrotechnical Assessment* (EBA 2011; Appendix A) shows that a scenario combining a total failure of the tailings dam with a one-in-two-hundred-year flood would certainly result in the inundation of large sections of the Ketza access road. Given the high volumes of water expected (1,615 m^3/second at the junction of Cache Creek and the Ketza River and 1,159 m^3/second 10 km further downstream) it appears safe to assume that the scenario would see extensive damage to the road, and possible closure until repairs could be made.

In the event of serious damage to sections of the Ketza access road, the major socio-economic effects would be:

- The cost to KRH for making the necessary repairs to re-open the road;
- The costs of any necessary evacuation of people working at the mine site;

- Any financial losses caused by disruption of the exploration or mine development schedules of either KRH or other mining operations in the area and;
- The loss of access to the area for the Ross River Dena and other users, including Yukon Stone Outfitters Ltd. for the duration of the road closure.

Most of those costs would be borne by KRH. However, the road repairs and evacuation would result in increased work for local contractors undertaking the road repairs and assisting with the evacuation as well as increased associated employment.

The *Ketza River Mine Hydrotechnical Assessment* (EBA 2011; Appendix A) does not specify the likelihood of damage to the Robert Campbell Highway or the Ketza River bridge. From the assessment it is clear that some sections of the highway would be inundated, but the maximum water depth at the bridge would be 0.6 metres. Whether the expected inundation would result in sufficient damage to the road or bridge that would result in a protracted road closure is unknown. If the Robert Campbell Highway is damaged and closed for an extended period, the major socio-economic effects would be:

- The cost to the Yukon government of making the necessary repairs to re-open the highway;
- The risks inherent in having what is an alternate road route connecting the Yukon to the south not available in the event that the Alaska Highway was closed at any point between Watson Lake and Jake's Corner (of course, this is in itself a highly unlikely event).

Effects on Human Use

Beyond the reduction in access caused by damage to the road, a complete failure of the dam and release of all the tailings and the water into the environment could have long term effects on human use of the area, particularly by the Ross River Dena. People would have very strong concerns about the environmental and health effects caused by the release of toxic material.

A detailed assessment of possible human health effects through using the water or the consumption of country foods following a failure is not possible until further work is carried out to assess the chemical composition of the tailings and to model how and where any substances may enter the food chain. However, even if environmental effects are found to be minimal and/or very short lived, the perception that the entire area has been poisoned would remain.

During the development and operation of the Faro mine, fears of contaminated drinking water helped push the Ross River Dena people away from their traditional use of the region even when experts would assure them that the water was safe. Weinstein (1992) writes:

> *"The importance of perceptions in land use decisions have a tendency for making continued use in the face of industrial development relatively fragile. Belief in the relevance of drinking water standards to human health are based on trust of professional authority. This works fairly well for urban populations with common cultural experience. The Indian experience has a less comfortable history. The experience of some elders and other band members… results in a broad mistrust of the ability of technical professionals to identify problems."*

One means of partially mitigating the long held mistrust of professional assurances on water quality in the event of a tailings dam failure is to have plans in place to involve the Ross River Dena fully from the very beginning in testing the tailings. At best this would include asking the First Nation to select trusted experts to monitor and review the work as well as having Ross River Dena citizens participate in the testing itself.

4.7.3 Next Steps in Determining Socio-economic Effects of Dam Failure

Within six months of completing the assessment of potential physical and chemical damage and consequences from a hypothetical dam failure (DD # 32a), a summary of potential effects to human use in the event of a dam failure would be completed and submitted to the Water Board. The potential effects to human use would be considered in the completion of DD items 32 e and f: Appropriate mitigation for potential effects of dam failure and the implementation plan will be submitted by KRH as a separate document.

4.8 Repairs and Surveying

DD 42 a, c, d Repair Weirs, Cut Saplings, Survey Dam Crest

The weirs downstream of the berm were repaired in 2010. The saplings on the dam slopes were cut in 2010. The dam crest was surveyed and repaired in 2010 and reported in Appendix B of the *2010 Geotechnical Site Inspection Ketza River Gold Mine, Yukon* (EBA 2011, Addendum E).

4.9 Wildlife Monitoring and Recording Protocols

DD # 57 Monitoring Wildlife and Bird Use / Presence at Tailings Pond and Adjacent Downstream Riparian Area

Rationale: Recommendations are based on history of no wildlife (including birds) use or presence at the Ketza tailings pond or downstream riparian area during mine operations/activities.

Proposed Water Licence Conditions:

- Continue KRH Employee Incidental Wildlife Reporting program, asking employees to specifically monitor the tailings pond and riparian area as opportunities arise. The type of information recorded on the Incidental Wildlife Reporting form is provided below.

Date	Observer	Species	Number	Location	Comments

- The camp environmental technician would include a daily visit to the tailings pond and riparian area, at random times, to monitor and record any wildlife presence/use.
- A copy of the Incidental Wildlife Reporting form would be electronically transmitted (via email) monthly to the Regional Biologist or Conservation Officer.

DD #58 Deterring Use of Water from Tailings Pond and Riparian Area

Rationale: Recommendations are based on no observations or records of wildlife or birds drinking/feeding in the tailings pond or downstream riparian area; and no fish are present.

Proposed Water Licence Conditions:

- Implement an adaptive management approach should it be determined that wildlife and/or birds are using the water in the tailings pond. Management options may include:
  - Using visual and audible nonlethal deterrents;
  - Using automatic propane powered sound scare cannons.

5.0 LIMITATIONS OF REPORT

This information request response has been prepared for the exclusive use of Ketza River Holdings for the purpose of supporting the Water Licence application. This report and its contents are intended for the sole use of Ketza River Holdings and their agents. EBA does not accept any responsibility for the accuracy of any of the data, the analysis or the recommendations contained or referenced in the report when the report is used or relied upon by any Party other than Ketza River Holdings, or for any Project other than the proposed development at the subject site. Any such unauthorized use of this report is at the sole risk of the user. Use of this report is subject to the terms and conditions stated in EBA's Services Agreement. A copy of EBA's General Conditions is provided in Appendix D of this report.

With respect to regulatory compliance issues, please note that regulatory statutes and the interpretation of regulatory statutes are subject to change over time. Moreover, this report is not meant to represent a legal opinion regarding compliance with applicable laws.

6.0 CLOSURE

We trust this letter meets your present requirements. Should you have any questions or comments, please contact the undersigned at your convenience.

Sincerely,
EBA, A Tetra Tech Company, on behalf of Ketza River Holdings Ltd.

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7.0 REFERENCES

SteveJan Consultants Inc. (SteveJan). 2010. Decommissioning Liability Cost Estimate for Water Related Issues at the Ketza River Mine Site. November 22, 2010.

Weinstein, Martin S. 1992. Just Like a People Get Lost: A retrospective assessment of the impacts of the Faro mining development on the land use of the Ross River Indian people.

Yukon Environmental and Socio-economic Assessment Board (YESAB). 2010. Designated Office Evaluation Report – Ketza Type A Water Licence Project Assessment. YESAA File Number 2010-0080.

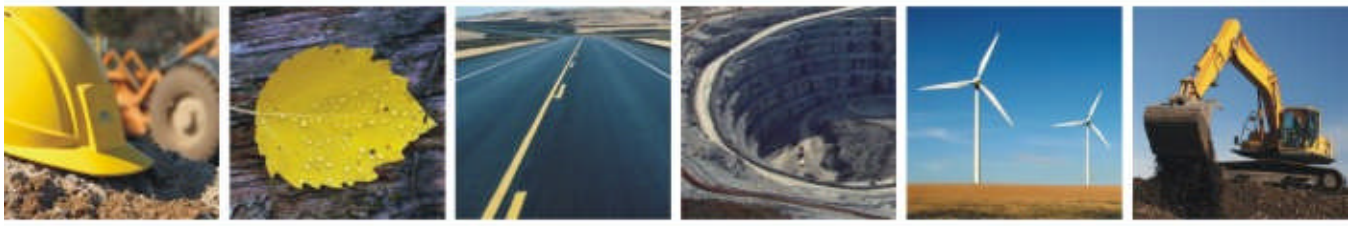
APPENDIX A

APPENDIX A KETZA RIVER MINE HYDROTECHNICAL ASSESSMENT

Ketza River Holdings

YUKON-NEVADA GOLD CORPORATION

KETZA RIVER MINE
HYDROTECHNICAL ASSESSMENT



REPORT

AUGUST 2011
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EXECUTIVE SUMMARY

Located in the Pelly Mountains, the Ketza River mine is situated in the headwaters of Cache Creek, an easterly flowing tributary of the upper Ketza River. The existing tailings facilities at the mine site include a tailings pond impounded by the north and south tailings dams, an emergency spillway, and diversion ditches. In support of the current water licence application for the existing tailings pond at the Ketza mine site, EBA, a Tetra Tech Company, has been retained by Yukon-Nevada Gold Corporation (YNGC) since October 2010 to provide the required hydrotechnical services. The purpose of this water licence application is to allow for the continued storage of water in and discharge from the existing tailings pond. The current hydrotechnical assessment involved a hydrologic assessment to determine the Inflow Design Flood (IDF), a flood routing and hydraulic analysis to assess the capacity of the dam to pass the IDF. In addition, the erosion protection requirements for the emergency spillway were also determined.

A site visit was not completed for the current study due to weather conditions. In the absence of a site visit, EBA obtained site specific information from both staff of YNGC and EBA, who are familiar with the mine site. This was followed by a hydrologic analysis to determine the characteristics of the study watershed, to compile regional climatic and hydrometric data, and to derive the appropriate IDF. Based on previous studies and the current dam break analysis, it was determined that the tailings dams are classified as High Consequence dams. Accordingly, the IDF for the tailings dams was considered to be 1/3 between the flood with an annual exceedance probability of 1 in 1000 and the Probable Maximum Flood (PMF). As recommended by the 2007 Canadian Dam Association Dam Safety Guidelines, IDFs for both the summer-autumn season and for the spring season were determined.

Flood routing analyses were performed to assess the capacity of the spillway to pass the IDFs. A wind and wave analysis was also performed during the freeboard determination. Results indicate that there will be no overtopping by 95% of waves either caused by the most critical wind with a frequency of 1/1000 year when the reservoir is at its maximum normal elevation or caused by the most critical wind when the reservoir is at its maximum extreme level during the passage of the IDF. Therefore, the amount of freeboard available would be adequate, assuming that all local low areas along the dam crest will be raised to an elevation of 1310.5 m.

The erosion protection requirements for the spillway, chute and its outlet were determined. The current median rock size along the spillway as reported by others is 75 mm, which is not adequate to handle the design flow during the IDFs. It is recommended that the spillway and the spillway chute be lined using a 700 mm thick riprap layer with a median rock size of 410 mm underlain by a 200 mm thick granular filter layer with a median rock size of 40 mm.

It should be noted that no detailed site information has been obtained for the outlet of the spillway chute at the time of the study. In general, it is recommended that the chute sides be extended up to a minimum of 1.7 m on the opposite bank of the receiving stream. To further minimize the potential of toe erosion, larger size rocks should also be placed along the eastern portion of the outlet area.

The conditions of the diversion/interceptor channels around the tailings pond were also assessed. It was determined that these channels are Significant Consequence Classification structures, and the 200-year flood was selected as the IDF. Results of the analysis indicate that the channels are sufficient to handle the inflow design flood, and there is no erosion concern along the Northwest Runoff Interceptor ditch upstream of the pond and along the Lower Subsidiary Creek diversion channel.

The existing culvert crossings around the tailings pond were evaluated, and results show that the existing twin 600 mm diameter culvert near the upstream end of the Lower Subsidiary Creek diversion and the existing 900 mm diameter culvert located further downstream are inadequate for the design flow condition. In view of the frequent blockage issues at these crossings, it is recommended that a new 750 mm diameter culvert and a new 600 mm diameter culvert be added to the twin culvert crossing and the 900 mm diameter culvert crossing, respectively. Also, it is recommended that regular monitoring and maintenance be conducted for the culvert crossings around the pond to minimize blockage issues.

The erosion protection requirements for the NWRI ditch downstream of the mine access road and the Cache Creek diversion were determined; however, more site information such as the existing riprap material size along both channels, the actual alignment and slope of this sub-reach of the NWRI ditch is required to confirm the need for erosion protection. For the unstable areas along the Cache Creek diversion as identified from previous geotechnical inspections, it is recommended that remediation be implemented. The rest of the Cache Creek diversion should also be protected by the suggested riprap materials where necessary.

It is recommended that a site visit be conducted to get a better understanding of the spillway chute and outlet condition and to refine the erosion protection requirements prior to any proposed works at the spillway.

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APPENDICES

Appendix A EBA's General Conditions

1.0 INTRODUCTION

The Ketza River Gold Mine is located in central Yukon, approximately 70 km south of the town of Ross River. The existing tailings facilities at the mine site include a tailings pond impounded by the north and south tailings dams, an emergency spillway, and diversion ditches.

Yukon-Nevada Gold Corporation (YNGC) c/o Ketza River Holdings Ltd. (KRH) is currently applying for a Type A Water Licence for the Ketza mine site. The purpose of this water licence application is to allow for the continued storage of water in and discharge from the existing tailings pond. In support of the current water licence application for the existing tailings pond at the Ketza mine site, EBA, a Tetra Tech Company, has been retained by YNGC since October 2010 to provide the required hydrotechnical services. This report summarizes the methodology and results of the current assessment.

2.0 SCOPE OF WORK

The scope of work for the current study is outlined as follows:

- Review of background information relevant to the current assessment;
- Review of dam classification based on a dam break analysis and previous studies;
- Hydrologic analysis to determine the appropriate Inflow Design Flood (IDF) corresponding to the dam classification of the tailings dams;
- Hydraulic analysis to determine the capacity and erosion potential of the emergency spillway; and
- Hydrotechnical assessment of other applicable hydraulic structures around the tailings pond.

It should be noted that a site visit was planned at the early stage of the project. An attempt to visit the dam site by helicopter with EBA's environmental team was made in October 2010, but due to the weather conditions at the time of the visit, it was considered unsafe to travel to the site. Another site visit was not considered at the later stage of the project because snow accumulated after October would likely impede the site work. A site visit is therefore recommended to refine the current assessment and prior to any proposed works related to the emergency spillway. In the absence of a site visit, EBA obtained site information from both staff of YNGC and EBA, who are familiar with the mine site.

As a federal standard for dams, the 2007 Canadian Dam Association (CDA) Guidelines were followed throughout the study.

A water balance model for the mine site is currently being updated by EBA based on the flow/concentration information collected since 2006. Details regarding this updated model will be included in a separate report.

3.0 PROJECT SITE DESCRIPTION

The Ketza River Mine can be accessed from Ross River by travelling 40 km south along the Campbell Highway and then 40 km along the Ketza River Mine access road. Located in the Pelly Mountains, the mine is situated in the headwaters of Cache Creek, an easterly flowing tributary of the upper Ketza River. The Ketza River, in turn, flows into the Pelly River approximately 12 km south of Ross River. A location map of the mine site is provided in Figure 3.1.

The tailings impoundment is located to the east and downstream of the mill site facilities in a natural depression at the confluence of Cache Creek and Subsidiary Creek. Bypass channels, or diversion ditches, have been constructed to divert these flows around the tailings impoundment area. The tailings pond is retained by two separate embankments: the North Tailings Dam and the South Tailings Dam. The two dams are separated by a ridge of native material. An emergency spillway has been excavated into the ridge, and it is fully contained within native material. The area covered by the tailings pond at the spillway crest elevation (1309 m) is approximately 8 ha.

The North Tailings Dam has a length of approximately 210 m and is about 20 m high. The South Tailings Dam has a length of approximately 110 m and is about 10 m high. The dam crest elevation for both the North and South tailings dams ranges from a minimum of 1309.7 m to a maximum of 1310.5 m (YNGC, 2011). The tailings dams were designed by Golder Associates in 1986. The construction of the dams was completed in 1987, and tailings discharge to the impoundment commenced in 1988 (SRK, 1994). A free-draining berm was constructed in 2009 at the toe of the North Tailings Dam as recommended in previous dam inspection reports (EBA, 2010). The berm was designed by EBA, however, the construction was monitored by others and a completion report was prepared by AECOM in December 2009. As part of the toe berm construction, a small draw was in-filled below the toe berm.

The emergency spillway separates the south dam from the north dam. It is assumed that the native material underlying this area is predominantly morainal sand and gravel (EBA, 2010). As outlined in previous reports, the emergency spillway channel is lined with rip-rap with a median diameter of approximately 75 mm. Based on available contour information, the average slope of the spillway chute was determined to be approximately 6%. The outlet of the spillway currently ties into a seepage channel prior to joining with the Cache Creek diversion channel.

Runoff from the catchment upstream of the tailings pond is diverted around the southern perimeter of the impoundment by the Lower Subsidiary Creek diversion ditch and the Cache Creek diversion ditch and around the northwestern perimeter of the impoundment by the Northwest Runoff Interceptor ditch. The Northwest Runoff Interceptor ditch directs the flow partly to the west where it joins with Lower Subsidiary Creek before draining to the Lower Subsidiary Creek diversion ditch and partly to the east where it discharges through a 600 mm diameter CSP culvert and into Cache Creek downstream of the tailings dams. The combined flow from part of the Northwest Runoff Interceptor ditch and Lower Subsidiary Creek passes through two 600 mm diameter CSP culverts. The flow continues along the Lower Subsidiary Creek diversion ditch and discharges through a 900 mm diameter CSP culvert with integral steel headwall before entering the Cache Creek diversion ditch. The Cache Creek diversion channel receives flows from the natural Cache Creek upstream and from the Lower Subsidiary Creek diversion ditch. The lower reach of the Cache Creek diversion joins with a seepage channel before joining up with Oxo Creek, prior to re-joining the original Cache Creek channel.

A general arrangement plan of the Ketza River Mine site is shown in Figure 3.2. More details of the tailings impoundment can be found on Figure 3.3. As preferred by YNGC, unless noted otherwise, all elevations used in the current analysis are based on the UTM NAD27 Ht2 MSL coordinate and elevation system.

4.0 REVIEW OF BACKGROUND INFORMATION

The following documentation, either obtained from EBA's previous work for the mine site or provided by YNGC, was reviewed to obtain relevant project background information:

- AECOM, "Report to Government of Yukon Water Resources Branch on Ketza Mine North Tailings Dam Toe Berm Assessment", December 2009
- EBA Engineering Consultants Ltd., "Report to Yukon-Nevada Gold Corporation on 2007 Geotechnical Site Inspection Ketza River Gold Mine", Yukon, October 2007
- EBA Engineering Ltd., "Letter Report to Ketza River Holdings Ltd. on Response to Comments Regarding the North Dam Toe Berm Ketza River Mine", Yukon, April 2008
- EBA Engineering Consultants Ltd., Report to Yukon-Nevada Gold Corporation on 2008 Geotechnical Site Inspection Ketza River Gold Mine, Yukon, February 2010
- EBA Engineering Consultants Ltd., "Report to Ketza River Holdings Ltd. on 2009 Annual Water Licence Report Ketza River Mine, Yukon", February 2010
- EBA Engineering Consultants Ltd., "Report to Yukon-Nevada Gold Corporation on 2010 Geotechnical Site Inspection Ketza River Gold Mine", Yukon, November 2010
- Fish and Wildlife Branch, Yukon Environment, "Memo on Classification of Ketza River Mine Tailings Dams by Nathan Miller", 2008
- Fish and Wildlife Branch, Yukon Environment, "Memo on Ketza Tailings Dam Hypothetical Failure and Downstream Water Quality by Bob Truelson", 2008
- Golder Associates, "Report to Canamax Resources Inc. on Geotechnical Design of Tailings Disposal Facilities, Camp Site and Mill Site, Ketza River Project, Yukon", December 1986
- Golder Associates Ltd., "Report to Canamax Resources Inc. on Ketza Mines Tailings Pond Operation Yukon Territories", September 1989
- Steffen Robertson & Kirsten (B.C.) Inc., "Memorandum to Canamax Resources Inc. on Ketza River Tailings Impoundment, Revised Spillway Details and Issues Relating to the Stability of Dams for Decommissioning", August 29, 1990
- Steffen Robertson & Kirsten Consulting Engineers, "Report to Wheaton River Minerals Limited on Ketza River Mine Abandonment Plan", February 1994
- Steffen, Robertson & Kirsten Consulting Engineers, "Report to YGC Resources Limited on Ketza River Mine Assessment of Risks Associated with Tailings Dams", December 1994

- Steffen Robertson & Kirsten Consulting Engineers, "Report to YGC Resources Ltd. on Addendum to the 1994 Decommissioning Plan, Ketza River Mine, Tailings Management Facility, Yukon Territory", May 1996
- SRK Consulting Engineers and Scientists, "Report to Government of Yukon, Department of Environment on Geotechnical Inspection Waste & Water Management Facilities, Ketza River Mine, Yukon Territory", September 2005
- UMA Engineering Ltd., "Report to Government of Yukon Water Resources Branch on Ketza River Mine 2007 Geotechnical Inspections", February 2008
- Water Resources Branch, Yukon Environment, "Ketza River Inspection Report", August 9, 2010
- Water Resources Branch, Yukon Environment, "Ketza Type A Water License Application Review Comments 2010-0080", August 26, 2010
- Yukon Environment and Socio-economic Assessment Board, "Designated Office Evaluation Report, Ketza Type A Water License Project Assessment 2010-0090", September 16, 2010
- Yukon-Nevada Gold Corporation, "Letter on Survey Dam Crest and Identify and Fill Areas below Design Elevation", September 2010
- Personal communications/2010 Spillway photos from Mr. Todd Johnson and Mr. Ian Walkley of YNG
- Yukon-Nevada Gold Corporation, Inter-Office Memo on Ketza River Project Coordinate System and Elevation Issue from Mr. Ian Walkley, January 16, 2011.

5.0 REVIEW OF DAM CLASSIFICATION

A review of dam classification for the North and South tailings dams was conducted based on findings from previous studies and a hypothetical dam break analysis resulting in the determination of a flood wave in the event of a dam breach, and inundation mapping. The following sections highlight the important findings of the previous studies, summarize the current dam break analysis, and establish the updated dam consequence classification for the tailings dams.

5.1 Previous Studies

A number of previous studies have discussed the consequence classification of the tailings dams. This section provides a summary of these previous assessments in chronological order.

Addendum to the 1994 Decommissioning Plan Ketza River Mine, Tailings Management Facility, Yukon Territory by SRK, 1996

The consequence classification of failure of the tailings impoundment was considered to be "high" in this previous study as part of the reconsideration of the design flow for the proposed spillway when the tailings facilities are decommissioned. The consequence classification was selected, in accordance with the 1995 CDA dam safety guidelines, on the basis that there would be "substantial increase in social, economic and/or environmental losses" as a result of failure, as compared to the consequences of the same event without dam failure. Consideration of potential loss of life leads to a "low" consequence category while the economic, social and environmental considerations lead to a higher consequence category, and hence, the "high" designation was selected.

Ketza River Mine 2007 Geotechnical Inspections by UMA, February 2008

In this study, the tailings dams were classified using the 2007 CDA dam safety guidelines in terms of the reasonably foreseeable consequences of failure. The classifications were based solely on a cursory inspection and review of available background information with respect to the dams. Both North and South tailings dams were considered to be "High" consequence classification dams in view of the significant environmental impact that would occur with uncontrolled release of tailings pond water and tailings into the Cache Creek valley during a dam breach.

Ketza Type A Water License Application Review Comments by Water Resources Branch of Environment Yukon, August 2010

The Water Resources Branch (the Branch) of Environment Yukon provided review comments with regard to the water licence application of the tailings pond. The Branch, with assistance from Environment Yukon's Fish and Wildlife Branch, provided information on fisheries values downstream of the tailings dams and an assessment report of downstream water quality. Based on other previous environmental studies, the presence of three species of freshwater fish in Cache Creek and the Ketza River had been confirmed. A model of fish habitat suitability was also developed for the new Yukon Placer regime, identifying the Pelly River as a Chinook salmon production zone. Furthermore, the lower reaches of the Ketza River were classified as moderate-high habitat for Chinook salmon production. Along the upper reaches of the river, the habitat was classified as moderate-moderate, and most of the Ketza River was classified as moderate-low habitat for Chinook production. Most of Cache Creek was defined as "Freshwater Fisheries Production Zone". Discussion of tailings release with reference made to the 1994 SRK study was included in this review document. It was concluded that the consequence classification of the tailings dams should be "High" due to the "immediate destruction of all fish populations in the entire Ketza River drainage downstream of the dam and the long-term destruction of habitat through high levels of arsenic contamination for a long period in both the Ketza River and Cache Creek".

5.2 Dam Break Analysis

In accordance with the 2007 CDA Guidelines, a dam break analysis, including characterization of a hypothetical dam breach, flood wave routing, and inundation mapping, was carried out.

A flood-induced dam failure scenario either at the south or the north tailings dam was considered in the analysis. Flood wave routing was carried out using SMPDBK. Input data requirements for the dam break scenario include parameters defining the geometry of the dam, reservoir and downstream valley, and timing of the breach. The dam breach parameters were determined from typical equations for earth embankments based on the conditions of the pond when either of the dams is overtopped. A summary of the overall dam breach parameters is provided in Table 5.1.

Table 5.1: Summary of Dam Breach Input

Parameter	Value (Note)
Type of Dam	Earth Embankment
Dam Breach Elevation (DBE)	1310.5 m (at dam crest, overtopping failure)
Final Breach Elevation	1297.4 m (at pond bottom from 2005 survey)
Volume of Reservoir at DBE	771,800 m^3 (including volume of tailings)
Surface Area of Reservoir at DBE	77,900 m^2 (at dam crest)
Final Breach Width	39 m
Non-Breach Flow	23.6 m^3/s (flow through spillway)
Breach Development Time	4.3 minutes

A total reach length of approximately 76 km was modelled extending from just downstream of the dam to the confluence of the Ketza River and the Pelly River. Detailed topographic information was used in extracting cross sections for the upper reaches of Cache Creek, while 1:50,000 scale NTS maps (in UTM NAD83 MSL datum) were used in extracting cross sections for the reaches downstream. A total of eight cross sections were extracted, and the downstream channel roughness coefficient was determined based on a reasonable Manning's n value. As a conservative approach, the volume of reservoir specified at the dam breach elevation was based on the as-built storage curve prior to tailings discharge (Golder, 1989). This takes into account both the volume of tailings and the volume of free water between the existing pond bottom elevation (1297.4 m) and the dam crest elevation (1310.5 m). The volume of tailings was determined to be approximately 243,000 m^3, which is about 93% of the reported volume (260,000 m^3 based on 340,000 tonnes of known production with an in-situ bulk density of 1.3 tonnes/m^3). The slight difference in the volumes might be due to datum discrepancies.

The parameters were input to the SMPDBK model to determine the preliminary flood levels and timing in the receiving channel. The peak outflow from the dam breach and the time to reach the peak elevation at each channel cross section were calculated.

It should be noted that the maximum water elevations calculated in SMPDBK did not consider natural floods along downstream reaches. Natural floods with a return period of 200-year were assumed to occur during the dam breach event as a conservative approach. The natural flood estimate at each cross section was obtained from the regional analysis as part of the hydrologic analysis (see details in Section 6.0). The peak outflow from the dam breach was added to the natural flood at each cross section, and the final water surface elevation was calculated using FlowMaster, a hydraulic program for steady flow calculations. Overall results of the dam break analysis are presented in Table 5.2. The drainage area boundaries at the study cross section locations are shown on Figure 5.1.

Table 5.2: Results of Dam Break Analysis

Cross Section	Distance from Dam (km)	Max Breach Flow (m^3/s)	200-year Flow (m^3/s)	Total Flow (m^3/s)	Approx. Channel Invert Elev. (m)	Max Water Elev. (m)	Max Water Depth (m)	Time to Reach Max Water Elev. (hrs)
XS 1	0.00	2207	6	2213	1283.0	1288.7	5.7	0.07
XS 2	0.18	2171	6	2177	1272.0	1276.7	4.7	0.08
XS 3	0.72	1882	9	1891	1251.0	1256.3	5.3	0.08
XS 4	6.9	1592	23	1615	1097.3	1098.2	0.9	0.37
XS 5	17	1096	63	1159	1036.3	1038.3	2.0	1.2
XS 6	33	783	132	915	975.4	976.2	0.8	3.2
XS 7	62	775	172	946	853.4	854.0	0.6	7.9
XS 8	76	767	208	975	731.5	732.3	0.7	9.6

It should be noted that the peak flow as a result of the dam breach, taking into account natural floods, varies from 2213 m^3/s at the dam to 975 m^3/s at the confluence of the Ketza River and the Pelly River. There is an attenuation of about 56% within this 76 km long study reach. In addition, the times to reach the peak water elevation at the confluence of Cache Creek and the Ketza River and at the confluence of the Ketza River and the Pelly River are less than 1hour and 9.6 hours, respectively.

Based on available topographic information, an inundation map was prepared for the modelled dam breach scenario (Figure 5.2 to Figure 5.4). Flood levels were interpolated from the resulting flood profile and used to draw flood level isograms at 25 m intervals. It should be noted that approximately 5 km upstream of XS 7, a relatively large area was determined to be inundated due to its flat topography. Downstream of XS 7, the area near the Robert Campbell Highway bridge crossing would be inundated in the event of a dam breach combined with the 200-year flood. However, no further information is available to confirm the deck elevation of the bridge crossing, and therefore it is difficult to assess if the bridge would be overtopped. The time required to reach the peak flood depth at this downstream location would be about 8 hours after the dam breach.

An assessment of risks associated with tailings dams for the Ketza River Mine was conducted by SRK in 1994 to provide supplementary information of the 1994 Ketza River Mine Abandonment Plan. A breach at either the North or South tailings dam caused by seismic activity, a landslide into the impoundment, or piping was first modelled. This was followed by modelling of a breach at the proposed spillway to be built in a way that such a breach would not threaten the integrity of the South tailings dam. Due to the different dam breach assumptions considered in this previous analysis and those for the current analysis, the results of both studies are not comparable. However, it should be noted that the breach parameters used in the current analysis are more conservative than those in the 1994 SRK study, and hence, the resulting peak flows are greater and the times to reach the peak water level are shorter than those values estimated in the previous study.

The current dam break analysis has modelled the tailings as free water with a total volume of 243,000 m^3. This was considered conservative in generating the inundation maps. A detailed tailings transport analysis is not part of the current work scope, and a different dam breach scenario such as during a dry weather condition would be required to determine the greatest impact of the tailings release on downstream reaches. It is our understanding that YNGC may look into this issue in a separate study to determine the short-term and long-term impacts of the tailings release.

5.3 Summary of Consequence Classification

The 2007 CDA dam safety guidelines were reviewed to update the consequence classification of the tailings dams. In order to classify the consequence of a dam failure, the most likely path of the flood wave was analyzed. During a dam breach, the breach outflow would travel along Cache Creek down to its confluence with the Ketza River in less than 1 hour and would continue along the Ketza River down to its confluence with the Pelly River in less than 10 hours. The area in the vicinity of the Robert Campbell Highway crossing would be inundated with a temporary potential population at risk. Therefore, the incremental loss related to loss of life is unspecified. The consequence classification using this criterion would be "Significant". However, in terms of the infrastructure and economic incremental losses, it was considered that the dams would be classified as "High". In view of the significant amount of tailings likely to be released during a dam breach, the short travel time of the flood wave from the dam site to the Pelly River, and the environmental values of the downstream reaches, the incremental losses to the environmental and cultural values were considered to be significant. The consequence classification of the tailings dams using this criterion would be "High".

Based on a review of the previous studies and results of the current dam break analysis, the consequence classification for the tailings dams was established to be "High" in accordance with the 2007 CDA guidelines. For a dam with a High consequence classification, the Inflow Design Flood (IDF) is to be determined as 1/3 between the 1000-year event and the Probable Maximum Flood (PMF).

6.0 HYDROLOGIC ANALYSIS

The following sections provide a brief description of the study watershed, a review of available climatic and hydrometric data, and a summary of the development of the Inflow Design Flood (IDF).

6.1 Watershed Characteristics

The total drainage area of the tailings pond is approximately 7 km^2, of which 0.08 km^2 is the pond itself. This drainage area was derived by assuming that the bypass flows collected by the Northwest interceptor ditch, Subsidiary Creek diversion ditch and the Cache Creek diversion ditch would be overtopped during the Inflow Design Flood (IDF). The immediate drainage area just upstream of the tailings pond is approximately 1.3 km^2, and the drainage area of the Cache Creek diversion just upstream of the tailings pond is approximately 5.5 km^2. The average slopes of the direct drainage area of the tailings pond and the Cache Creek diversion area upstream of the tailings ponds are 27% and 15%, respectively. The median basin elevation of the total drainage area of the tailings pond is about 1630 m. The boundaries of the study watershed are shown in Figure 6.1.

6.2 Climatic and Snow Course Data

A number of climate stations operated by the Meteorological Service of Canada (MSC) are located within the study region. In view of their close proximity to the project site, elevation, and relatively long period of record, the following stations were considered to have climatic data that are useful in determining the climate conditions at the project site (Table 6.1).

Table 6.1: Regional Climate Stations

Station Name	Station No.	Elevation (m)	Period of Record	Distance to Site (km)
Ketza River Mine	2100FPP	1380	1985 - 95, 2006 - 10	2
Whitehorse A	2101300	706.2	1953 - 2009	177
Teslin A	2101100	705	1953 - 2009	154
Carmacks	2100300	524.9	1963 - 2008	222
Mayo A	2100700	503.8	1924 - 2009	297
Anvil	2100120	1158	1967 - 1991	110
Faro A	2100517	716.6	1977 - 2008	95
Ross River A	2100940	705.3	1961 - 1994	49
Ross River YTG	2100941	698	1993 - 2008	51

The climate data obtained from the Ketza River Mine station (1380 m) is the most representative of the climate conditions at the project site. However, this station was operated by MSC only from 1985 to 1995, with intermittent data gaps. This station was re-activated in 2006, and its data has been collected by the mine staff on an hourly basis. This more recent climate data was provided by YNGC to EBA. In addition, the Ross River A and Ross River YTG stations are very close to each other and the climate data at these two stations were combined to represent the climate conditions at Ross River.

Rainfall intensity frequency data is available at the Whitehorse A, Teslin A, Carmacks and Mayo A stations. Table 6.2 shows the rainfall intensity frequency data at these stations for various return periods. The 1000-year 24-hour rainfall totals were obtained by extrapolation of this data.

Table 6.2: 24-hour Rainfall Totals (mm) at Regional Climate Stations

Return Period (Yrs)	Whitehorse A	Teslin A	Carmacks	Mayo A
2	18.6	19.5	15.4	18.0
5	26.6	24.6	19.8	22.6
10	31.9	28.0	22.7	25.6
25	38.6	32.3	26.5	29.4
50	43.6	35.4	29.2	32.2
100	48.5	38.6	32.0	35.0

Environment Yukon's Water Resources Branch has a number of snow course sites within the study region. Regional snow course data was used in determining the snowmelt component during the development of the Inflow Design Flood (IDF) for the tailings dams. The snow course site located closest to the study area is the Hoole River snow course site (at elevation of 1036 m). Other useful snow course sites include the Burns Lake, Jordan Lake and Tintina Airstrip. Table 6.3 presents the general information for these snow course sites. Average snow depth and water equivalent for the period of record at each of the regional snow course sites are summarized in Table 6.4.

Table 6.3: Regional Snow Course Sites

Station Name	Station No.	Elevation (m)	Period of Record	Distance to Site (km)
Hoole River	09BA	1036	1977	36
Burns Lake	09BA	1112	1986	148
Jordan Lake	09AD	930	1987	79
Tintina Airstrip	10AA	1067	1977	74

Table 6.4: Average Snowpack Data

Month	Snowpack Depth (cm)				Snow Water Equivalent (mm)			
	Hoole R.	Burns L.	Jordan L.	Tintina A.	Hoole R.	Burns L.	Jordan L.	Tintina A.
Feb-1	41	N/A	N/A	61	71	N/A	N/A	107
Mar-1	59	88	61	80	117	192	122	178
Apr-1	63	94	64	87	136	221	140	205
May-1	31	67	33	62	86	212	88	180
May-15	7	26	4	30	20	96	13	98

The data shows that in general the average maximum snowpack depth (ranges from 63 cm to 94 cm) in the region occurs in April, and the average maximum snow water equivalent (ranges from 136 mm to 221 mm) also occurs in April.

6.3 Hydrometric Data

There is no long-term streamflow data available within the study watershed. Historical hydrometric data was obtained from the Water Survey of Canada and from Environment Yukon's Water Resources Branch to characterize the hydrology of the study area. The regional hydrometric stations used in this study are listed in Table 6.5.

Table 6.5: Regional Hydrometric Data

Station ID	Station Name	Drainage Area (km^2)	Period of Record	Years of Peak Flow Data	Status
09AD001	Nisutlin River above Wolf River	8030	1979 - 1994	17 Daily, 16 Instant.	Inactive
09AD002	Sidney Creek at km 46 South Canol Road	372	1982 - 1994	13 Daily, 13 Instant.	Inactive
09AG001	Big Salmon River near Carmacks	6760	1951 - 1998	38 Daily, 36 Instant.	Inactive
09AG003	South Big Salmon River below Livingstone Creek	515	1982 - 1998	14 Daily, 13 Instant.	Inactive
09BA001	Ross River at Ross River	7250	1958 - 2010	47 Daily, 40 Instant.	Active
09BB001	South MacMillan River at km 407 Canol Road	997	1974 - 1998	22 Daily, 19 Instant.	Inactive
09BB002	MacMillan River near the Mouth	13800	1984 - 1998	12 Daily, 13 Instant.	Inactive
09BC001	Pelly River at Pelly Crossing	49000	1951 - 2010	56 Daily, 46 Instant.	Active

Table 6.5: Regional Hydrometric Data

Station ID	Station Name	Drainage Area (km^2)	Period of Record	Years of Peak Flow Data	Status
09BC002	Pelly River at Ross River	18400	1951 - 1977	19 Daily, 14 Instant.	Inactive
09BC004	Pelly River below Vangorda Creek	22100	1970 - 2010	37 Daily, 34 Instant.	Active
10AB003	King Creek at Km 20.9 Nahanni Range Road	13.7	1975 - 1988	12 Daily, 12 Instant.	Inactive
29BA002	180 Mile Creek at Km 296 North Canol Highway	83.1	1975 - 1982, 1983 - 93	11 Daily, 11 Instant.	Inactive
29BC003	Vangorda Creek at Faro Townsite Road	91.2	1977 - 1985, 1989 - 2008	27 Daily, 24 Instant.	Active
29BC004	Blind Creek near Faro	618	1992 - 2008	13 Daily, 11 Instant.	Active

Of the above selected hydrometric stations, the Pelly River at Pelly Crossing station has the largest drainage area and the longest period of record. The King Creek at km 20.9 Nahanni Range Road station has the smallest drainage area (13.7 km^2), which is the most comparable with the study watershed (7 km^2). By analyzing available peak flow data at the selected stations, it was determined that peak flows in the region occur in the late spring months (May to June). In general, peak flows in the region are dominated either by snowmelt events or by a combination of heavy rainfall with snowmelt (rain-on-snow events). However, for small catchments such as the study watershed, peak flows can also be governed by heavy rainstorms during the summer-autumn period.

6.4 Determination of Inflow Design Flood

Based on the review of dam consequence classification as part of the current assessment, the North and South tailings dams are classified as a High consequence dam in accordance with the 2007 Canadian Dam Association (CDA) Dam Safety Guidelines. The usual standard for Inflow Design Floods (IDFs) for High Consequence dams is 1/3 between a flood with an annual exceedance probability of 1 in 1000 and the Probable Maximum Flood (PMF). In general, the PMF is defined as the most severe flood that may reasonably be expected to occur at a particular location. Two PMFs were considered in the current study: summer-autumn PMF and spring PMF. The summer-autumn PMF is generated by the summer-autumn Probable Maximum Precipitation (PMP). The spring PMF is defined as the greater of:

- the PMF computed with the spring PMP and the 100-year snow accumulation; and
- the PMF computed with the Probable Maximum Snow Accumulation (PMSA) and a 100-year rainstorm.

The reason for computing two separate PMFs for the spring season is that it would not be reasonable to assume that snow accumulation and a spring rainstorm, which are two independent phenomena, are simultaneously extreme. The following sections summarize the methodology and results of the determination of the summer-autumn and the spring IDFs.

6.4.1 Summer-Autumn IDF

The summer-autumn IDF was determined to be 1/3 between the flood resulting from a 1000-year 24-hour rainstorm during the summer-autumn season and one resulting from a 24-hour summer-autumn PMP. A hydrologic model was used in modelling such rainfall-runoff processes.

The rainfall intensity frequency data from Whitehorse A, Teslin A, Carmacks and Mayo A climate stations were used as the basis for determining the 1000-year 24-hour rainfall depth at the site. Since the climate stations with rainfall intensity frequency data are at elevations (from about 500 to 700 m) much lower than the median basin elevation of the study watershed (1630 m), daily rainfall data from stations at higher elevations were analyzed. The two stations situated at higher elevations are the Ketza River Mine (1380 m) and the Anvil (1158 m) climate stations, both with relatively short periods of record. The average maximum daily rainfall totals during the summer-autumn season were calculated from available data in the region, and a relationship between average maximum daily rainfall during the summer-autumn season and elevation was developed (Figure 6.2). The summer-autumn average maximum daily rainfall extrapolated to the site elevation is approximately 20.8 mm. Based on this, a ratio of the summer-autumn average maximum daily rainfall at site to that at each station was determined. This ratio was then applied to the 1000-year 24-hour rainfall total at each of the climate stations with rainfall intensity frequency data. The average of the resulting 1000-year 24-hour rainfall totals was determined to be 62 mm, which was used as the 1000-year 24-hour rainfall depth at site.

The 24-hour summer-autumn Probable Maximum Precipitation (PMP) was estimated using the Hershfield method described in the Rainfall Frequency Atlas for Canada (Hogg and Carr, 1985). The Hershfield empirical relationship is as follows:

$$K_{M24} = 19 \times 10^{-0.000965 X_{24}}$$

$$X_{PMP} = X_{24} + K_{M24} \times S$$

where

K_{M24} = frequency factor for a 24-hour duration rainfall;
X_{24} = mean annual 24-hour extreme rainfall (mm);
X_{PMP} = PMP for a 24-hour duration (mm); and
S = standard deviation for a 24-hour duration rainfall (mm).

The 24-hour summer-autumn PMP at site was determined to be 189 mm.

The hydrologic model used in the runoff analysis was HEC-HMS version 3.0.0, developed by U.S. Army Corps of Engineers. The US Soil Conservation Service (SCS) unit hydrograph method was applied to determine the runoff hydrograph from the design rainstorm. The SCS Type 1 distribution was selected to define the distribution of design rainfall total over 24 hours. The catchment area was subdivided into three sub-catchments: the direct sub-catchment of the tailings pond, the Cache Creek sub-catchment upstream of the tailings pond, and the pond area receiving direct precipitation. In general, the catchment area, mainly forested area in a condition between fair and poor, was underlain by mountain soil with brown wooded soil (NRCAN, 1957). Soil Type B, representing soil composed of shallow loess and sandy loam, was chosen for the study area. An antecedent moisture condition III (rain and low temperatures over the previous five days causing saturated conditions) was assumed. A curve number of 81 was estimated for the catchment area. Slopes, elevations and channel lengths were taken from topographic maps to estimate the time of concentration for each sub-catchment.

The peak inflows to the tailings pond during the 1000-year return period and during the summer-autumn PMP were determined to be 10.5 m^3/s and 71.6 m^3/s, respectively. In determining the combined summer-autumn IDF hydrograph, the following equation was used for each time step, adjusting the time origins of the floods so that both peaks coincided (CDA, 2007):

$$Q_{IDF} = Q_{1000} + C(Q_{PMF} - Q_{1000})$$

where Q_{IDF} = inflow design flood (m^3/s);

Q_{1000} = 1000-year flood (m^3/s)

C = coefficient (1/3 for High Consequence Classification dams).

The peak inflow to the tailings pond during the IDF was determined to be approximately 30.9 m^3/s. The summer-autumn IDF hydrograph is shown on Figure 6.3.

6.4.2 Spring IDF

The spring IDF was determined to be 1/3 between the 1000-year spring flood and the spring PMF, which is the maximum of the following two cases:

Case 1: PMF computed with 100-year snow accumulation and 24-hour spring PMF;

Case 2: PMF computed with PMSA and 100-year 24-hour rainstorm.

A regional analysis involving the application of an index flood method was used in determining the 1000-year spring flood. Flood frequency analyses were conducted for the regional hydrometric stations shown in Table 6.5 using Environment Canada's Consolidated Frequency Analysis (CFA) software version 3.0. To make use of all available peak flow data, the maximum instantaneous flow records were extended by applying an average maximum instantaneous to maximum daily flow ratio for the three largest floods at the stations. The distributions providing the best fit to the extended data records were selected in estimating the floods for various return periods at the stations. Results of the frequency analyses were then used in the index flood method, which determines a relationship between the unit mean annual discharge, usually with a return period of 2.33 years, and drainage area (Figure 6.4). An envelope curve was then drawn to determine the maximum unit mean annual discharge at site. The median ratios of floods for various return periods to the mean annual flood were calculated from the regional flood frequency analysis. The median ratios were based on the four hydrometric stations with the longest periods of record available: Big Salmon River (09AG001), Ross River at Ross River (09BA001), Pelly River at Pelly Crossing (09BC001), and Pelly River below Vangorda Creek (09BC004). The 1000-year flood, to be used in determining the spring IDF, for the study watershed (7 km^2) was estimated to be 7.5 m^3/s.

The Case 1 spring PMF was computed using the 24-hour spring PMP combined with 100-year snow accumulation. The ratio of average daily maximum rainfall in spring, to that in the summer-autumn season, was determined to be 0.52 based on all selected regional climate stations. This factor was applied to adjust the summer-autumn PMP to the spring PMP, resulting in a rainfall total of 98 mm. The SCS Type 1 rainfall distribution was assumed for the spring PMP. The 100-year snow accumulation was computed by performing a frequency analysis on available regional snow course data. A relationship between the 100-year snow accumulation and elevation was developed, and the 100-year snow accumulation in snow water equivalent at site was determined to be 625 mm.

The Case 2 spring PMF was computed using the 100-year 24-hour rainstorm combined with the Probable Maximum Snow Accumulation (PMSA). The 100-year 24-hour rainfall total was obtained from the regional rainfall intensity frequency data adjusted to the site elevation by applying the ratio of the average maximum daily rainfall during the spring season at site to that at the selected climate stations. The 100-year 24-hour rainfall depth was determined to be 47 mm. The SCS Type 1 rainfall distribution was assumed for the 100-year rainstorm. It was assumed in this study that the PMSA condition would have the 10,000-year return period, which was determined to be 737 mm in snow water equivalent. As a general check, the maximum winter season precipitation (from October to April) was determined at each selected regional climate station. The relationship between maximum winter season precipitation and elevation for the region produces a maximum winter season precipitation of 666 mm at site, which is higher than the 100-year snow accumulation and not significantly different from the 10,000-year snow accumulation. Due to the lack of long periods of record at climate stations at high elevations and as a conservative approach, the 10,000-year snow accumulation, or 737 mm, was used as the PMSA.

To simulate the rain-on-snow events during the spring PMFs, a hydrological model using PCSWMM Version 4.1.878 was developed. PCSWMM was chosen in view of its capability of modelling snowmelt using a heat budget equation for periods with rainfall, where melt rate increases with air temperature, wind speed and rainfall intensity. This simplified heat budget equation was considered to be more applicable than the temperature index method applied in HEC-HMS for extreme floods such as PMFs. Data requirements for the PCSWMM model in this study include temperature time series, wind speed data, snowmelt parameters, rainfall time series, sub-catchment characteristics, and snowpack conditions.

The 100-year temperature sequence was developed for determining the snowmelt during the spring PMFs. Annual maximum temperature in degree day over 5 days during the snowmelt season was determined at each selected regional climate station, followed by a frequency analysis to determine the 100-year temperature index in degree days over 5 days. A relationship of average maximum temperature versus elevation was developed to determine the ratio of the average maximum temperature at the site to that at each regional station. These ratios were applied to obtain the 100-year temperature index at site, and the average value was determined to be 83.1 in degree days over 5 days. This temperature index was then distributed using available hourly temperature patterns. The largest flood recorded at the King Creek hydrometric station occurred in 1976, and the hourly temperature pattern in this year was obtained from the Whitehorse A station, which is the closest station with such data available. The average monthly temperature in May was determined to be 2.16 deg. C based on available regional climate data. This temperature value was used prior to the start of the design rainstorm.

Wind speed data is also available from the climate normals at the Whitehorse A station, and the average monthly wind speeds for May and June were determined to be 12.6 km/hr and 11.5 km/hr, respectively. These wind speeds were converted to the study site based on a correlation between the wind data at the Whitehorse A station and that at the Ketza station (more details can be found in Section 7.4). The average monthly wind speeds for May and June used in the model were 9.5 km/h and 9.3 km/hr, respectively.

The snowmelt parameters and general snowpack conditions input for the snowmelt simulations are tabulated in Table 6.6. It should be noted that default and typical values (SWMM, 2005) were used in the model since no calibration could be carried out without local flow and climate data.

Table 6.6: Snowmelt Parameters and General Snowpack Conditions

Parameter	Value (Note)
Dividing Temperature between Rainfall and Snowfall	1 deg C (Typical)
Antecedent Temperature Index Weight	0.5 (Default)
Negative Melt Ratio	0.6 (Default)
Minimum Melt Coefficient	0.057 mm/hr/deg C (Typical for rural area)
Maximum Melt Coefficient	0.29 mm/hr/deg C (Typical for rural area)
Base Temperature	0 deg C (Typical)
Free Water Capacity	0.035 (Typical for a deep snowpack)
Initial Free Water	0 (zero for unknown value)

The sub-catchment characteristics input to the model are summarized in Table 6.7. It should be noted that Horton's infiltration method was used in the rainfall-runoff process. The maximum infiltration rate was assumed to be equal to the minimum infiltration rate (5.715 mm/hr) since the soil would be saturated during the snowmelt period.

Table 6.7: Sub-catchment Characteristics for PCSWMM

Parameter	Direct Drainage Area	Cache Diversion Area	Pond
Area (ha)	127.2	554	7.8
Percent Impervious	0%	0%	100%
Catchment Width (m)	1800	8600	900
Percent Slope	27.3%	15%	-
Storage (Imperv.)	0.05 (Default)	0.05 (Default)	0
Storage (Perv.)	0.5 (Typical value)	0.5 (Typical value)	0
Manning's N (Imperv.)	0.013 (for paved area)		
Manning's N (Perv.)	0.25 (for vegetated area)		
Infiltration Rate	5.715 mm/hr (average value for Soil Group B)		
Decay Coefficient	4.14		
Dry Time	7 days		

As a conservative approach, a 10-day period prior to the start of the design rainstorm (assumed to occur at the beginning of June) was included in the simulation such that the peak of the snowmelt would coincide with the peak of the rainfall event. The peak inflows to the tailings pond in the Case 1 spring PMF and the Case 2 spring PMF were determined to be 55.1 m^3/s and 24.9 m^3/s, respectively. In accordance with the CDA Guidelines, the peaks of the spring IDFs were determined to be 23.4 m^3/s in Case 1 and 13.3 m^3/s in Case 2. The total runoff volumes of the spring IDF in Case 1 and Case 2 over the simulated period were determined to be 553,000 m^3 and 832,000 m^3, respectively. Figure 6.5 presents the hydrographs associated with the spring IDFs.

7.0 HYDRAULIC ANALYSIS OF SPILLWAY

A hydrological model was developed to simulate water levels in the tailings pond during the IDF. The following sections provide a summary of the methodology and results of the hydraulic analysis.

7.1 Volume-Elevation Relationship

The volume-elevation relationship for the tailings pond was based on the bathymetric survey conducted by Yukon Engineering Services (YES) in August 2005. From this information and the elevation conversion requirement as described YNGC's 2011 memo, the tailings pond has a bottom elevation of 1297.4 m and a capacity of approximately 477,300 m^3 to the spillway crest at an elevation of 1309 m. It is understood that the pond could be drawn down to elevation 1305.4 m (approx. 3.6 m below the spillway crest) for flood control purposes (Water Resources Branch Yukon Environment, August 26, 2010). Figure 7.1 presents the volume-elevation relationship for the tailings pond.

7.2 Rating Curve

The emergency spillway has an average invert elevation of approximately 1309 m and a bottom width of about 4 m (YNGC, 2011). The emergency spillway is a broad-crested spillway with flat side slopes (13.5%). The effective spillway crest length therefore increases with the head above the spillway crest. The discharge for the emergency spillway was estimated based on the following general equation (Smith, 1995):

$$Q = CLH^{1.5}$$

where Q =discharge (m^3/s);

C =discharge coefficient, 1.705 for broad-crested spillways;

L =effective spillway crest length (m); and

H =head above spillway crest (m).

The rating curve of the emergency spillway, taking into account the increase in spillway crest length versus head, is shown on Figure 7.2.

7.3 Flood Routing

The flood routing was performed using the HEC-HMS model, which includes a routing component for flows through ponds. The starting water surface elevation was assumed to be at elevation of 1305.4 m during the passage of the Summer-Autumn IDF and at the spillway weir crest (1309 m) during the passage of the Spring IDFs. The results of the HEC-HMS flood routing are summarized in Table 7.1. Figures 7.3 to 7.5 present the results of the flood routing graphically.

Table 7.1: Results of Flood Routing

Scenario	Spillway Crest Elev.	Initial Pond Level	Peak Pond Level	Peak Storage	Peak Inflow	Peak Outflow	Dam Crest Elevation
(m)	(m)	(m)	(m)	(1000 m^3)	(m^3/s)	(m^3/s)	(m)
Summer Autumn	1309	1305.4	1309.80	431	30.9	9.2	1310.5
Spring Case 1	1309	1309	1310.11	455	23.4	14.9	1310.5
Spring Case 2	1309	1309	1310.01	448	13.3	13.0	1310.5

As shown in the above table, the Spring Case 1 is the governing case with a higher resulting peak pond level and peak outflow compared to the results from the Spring Case 2. Therefore, the results of the flood routing during the passage of the Spring Case 1 IDF will be used in the freeboard determination.

7.4 Freeboard Determination

In accordance with the 2007 CDA Guidelines, the freeboard at all dam structures should be evaluated for normal and extreme conditions. In general, the crest level of an embankment structure should be set so that the structure is protected against the most critical of the following cases (CDA 2007):

- No overtopping by 95% of the waves caused by the most critical wind with a frequency of 1/1000 year when the reservoir is at its maximum normal elevation
- No overtopping by 95% of the waves caused by the most critical wind when the reservoir is at its maximum extreme level during the passage of the IDF

For a High consequence dam, as in this case, the design return period of wind speed used for calculation of freeboard during IDF is 2 years.

A wind and wave analysis was performed to determine the freeboard requirements. Frequency analyses of wind data at the Whitehorse A and Faro A stations were both conducted. The local climate station near the Ketza mine has limited hourly data from 2006 to present. A comparison of the overlapping wind data from the Ketza, Whitehorse A and Faro A stations indicate that the wind data at Faro A is similar to those at Ketza and that the wind speed at Whitehorse A is consistently higher than that at Ketza. A correlation was determined to adjust the wind speed at Whitehorse A to that at Ketza. The winds blowing from the southwest and west were used since these winds travel directly towards the upstream face of the Northern Tailings Dam and the Southern Tailings Dam, respectively. An extreme event analysis using the methods described by Goda was used to calculate the wind speed for various return periods. Goda's extreme event

analysis uses a partial duration or peak-over-threshold data series. Thresholds of 10 m/s and 10.5 m/s were selected for the Faro A station for the southwest and west winds, respectively. Thresholds of 13.5 m/s and 11.5 m/s were selected for the Whitehorse A station for the southwest and west winds, respectively. The statistical distributions describing the extreme value analysis were produced. The 'best-fit' distributions where chosen to estimate the design event. Results of this wind analysis indicate that the extreme wind speeds based on the Faro A wind data provide relatively higher values, and such wind speed values were applied in the wave analysis as a conservative approach. Table 7.2 shows the Goda extreme event analysis results, with the Whitehorse A values adjusted to those at Ketza.

Table 7.2: Goda Extreme Event Analysis Results

Return Period (yr)	Faro A		Whitehorse A adjusted to Ketza	
	Wind from the Southwest (m/s)	Wind from the West (m/s)	Wind from the East (m/s)	Wind from the West (m/s)
2	9.1	10.7	9.5	8.9
5	9.7	11.5	9.6	9.1
10	10.6	12.4	9.7	9.3
20	11.2	13.1	10.1	9.5
50	11.8	13.8	10.6	9.7
100	12.5	14.7	11.1	10.4
1000	13.1	15.4	11.5	11.0

Setup and wave height were calculated using the 2-year and 1000-year wind values. The wind tide or setup is a phenomenon in which the water level at the dam rises due to the effect of wind blowing over the water. The setup was calculated using the following equation (Smith, 1985):

$$S = FV^2/63000D$$

where S = wind tide or setup (m)

F = fetch (km)

V = wind velocity (km/hr)

D = average reservoir depth (m)

The wave height was calculated using the following equation (Smith, 1985):

$$H_w = 0.00513V^{1.06}F_e^{0.56}$$

$$F_e = KL$$

where H_w = wave height (m)

F_e = effective fetch (km)

L = maximum straight unobstructed water length facing the dam (km)

K = fetch correction factor based on the relation between the average reservoir width and L.

The wave runup is the height above the mean water surface that a crest of a wave will interact with the barrier; the water runup is based on the design wave height. The factor of 1.37 was applied to the calculated significant wave height to obtain the design wave height, which is the average of the highest 5% waves, as recommended by CDA in freeboard calculations. According to the embankment slopes, the ratios of runup to the design wave height were determined to range from 1.30 to 1.33 (for gravelled dam surfaces with embankment slope of 2.5H:1V). Table 7.3 and Table 7.4 summarize the results of the wave analysis and the overall freeboard determination for the Summer-Autumn scenario and for the Spring scenario, respectively.

Table 7.3: Summary of Wind and Wave Analysis and Available Freeboard (Summer - Autumn Scenario)

Parameter	North Dam	North Dam	South Dam	South Dam
Pond Condition	Pond level at 1305.4 m	During passage of IDF	Pond level at 1305.4 m	During passage of IDF
Wind Frequency	1000-yr	2-yr	1000-yr	2-yr
Peak Pond Level (m)	1305.4	1309.8	1305.4	1309.8
Wind Setup (m)	0.001	0.001	0.002	0.001
Wave Runup (m)	0.35	0.23	0.41	0.27
Setup + Runup (m)	0.35	0.23	0.41	0.27
Avail. Freeboard (m)	5.1	0.7	5.1	0.7

Table 7.4: Summary of Wind and Wave Analysis and Available Freeboard (Spring Scenario)

Parameter	North Dam	North Dam	South Dam	South Dam
Pond Condition	Pond level at 1305.4 m	During passage of IDF	Pond level at 1305.4 m	During passage of IDF
Wind Frequency	1000-yr	2-yr	1000-yr	2-yr
Peak Pond Level (m)	1309.0	1310.11	1309.0	1310.11
Wind Setup (m)	0.001	0.001	0.002	0.001
Wave Runup (m)	0.35	0.23	0.41	0.27
Setup + Runup (m)	0.35	0.23	0.41	0.27
Avail. Freeboard (m)	1.5	0.39	1.5	0.39

Freeboard was computed as the difference between the design pond level and the dam crest elevation of 1310.5 m. It should be noted that the current analysis has assumed that low areas along the dam crest would be raised to the maximum dam crest elevation of 1310.5 m. The maximum normal elevation was chosen to be at elevation 1305.4 m during summer-autumn and at the spillway weir crest elevation during spring when combined with the 1000-year wind condition. The peak pond level during the passage of the IDF was applied when combined with the 2-year wind condition. During normal conditions, a freeboard of 5.1 m would be available during the summer-autumn season and a freeboard of 1.5 m would be available during the spring season. During the summer-autumn IDF, a freeboard of 0.7 m would be available. During the spring IDF, a freeboard of approximately 0.4 m would be available. In all cases, the amount of freeboard available is greater than needed for the sum of the wind setup and wave runup. Therefore, the freeboard is considered adequate since there will be no overtopping by 95% of the waves either caused by the most critical wind with a frequency of 1/1000 year when the reservoir is at its maximum normal elevation or caused by the most critical wind when the reservoir is at its maximum extreme level during the passage of the IDF.

7.5 Erosion Protection

The existing emergency spillway has a bottom width of 4 m and flat sideslopes. Outflow from the pond flows through the spillway followed by a channel with an average slope of 6% for a distance of about 100 m before joining a seepage channel. It should be noted that the alignment of the existing spillway, as derived from available airphoto, turns to the south with a radius of curvature about 60 m. The design of a protective riprap layer over the spillway and along the riprapped channel (chute) was conducted based on various design guidelines available in North America. Design parameters required for each method applied in the riprap design are shown in the following sections:

7.5.1 Riprap Design

Method 1 (US Army Corps of Engineers, 1994):

For slope riprap design, the stone size equation recommended by USAC E is:

$$D_{30} = 1.95S^{0.555}(qF_c)^{2/3}/g^{1/3}$$

where S = slope of channel bed = 6%

Q = unit discharge = design discharge/effective width of channel = 1.7 $m^3/s/m$

F_c = flow concentration factor of 1.25

g = gravitational constant of 9.81 m^3/s

The resulting D_{30}, (the size which 30% of the rocks are lighter than), was determined to be approximately 310 mm. For moderately graded riprap mixtures (D_{85}/D_{15}< 3 or so) and D_{50}, or the median rock size, is typically about 25% larger than D_{30} (MOELP, 2000). Consequently, the median rock size determined using Method 1 is 390 mm.

Limitation: This method is applicable for straight channels with sideslopes of 1V:2.5H or flatter, channel slopes from 2 to 20%, low unit discharge, and uniform flow on a downslope with no tailwater.

Method 2 (BC MOTH, 2001):

The BC Ministry of Transportation and Highways' riprap design is based on a chart that relates riprap class (expressed as the median weight of rock) to the velocity against the bank for side slopes ranging from 1H:1V to 12H:1V. It should be noted that the chart does not provide for interpolation; instead, the next larger riprap class is selected. Section 205 of the BC Ministry of Transportation and Highways' "Standard Specifications for Highway Construction" provides specifications for various riprap classes.

In order to apply Method 2, a simple hydraulic calculation using the FlowMaster program was performed to determine the design velocity. With a channel slope of 6%, Manning's n of 0.04 (rough rock), design discharge of 14.9 m^3/s, bottom width of 4 m, and sideslopes at 13.5%, the design velocity was determined to be 3.1 m/s. Based on the riprap design chart, a 25 kg class of riprap is required on the bottom of the channel. The corresponding D_{50} for this class of riprap is 300 mm.

Limitation: Method 2 is applicable for design velocity generally ranging from 1 to 6 m/s and velocity against the bank of the channel.

Method 3 (FHA, 2005):

This method is taken from Hydraulic Engineering Circular 11, Design of Riprap Revetments, by the US Department of Transportation Federal Highway Administration (1989). Permissible tractive force or shear stress method was used to evaluate a material's resistance to particle erosion. The sizing equation for D_{50} is shown below:

$$D_{50} > (SF)dS_o/(F(SG-1))$$

where SF = safety factor = 1.2

D = maximum channel depth = 0.58 m

S_o = channel slope = 6%

F = Shields' Parameter = 0.047

SG = specific gravity of rock = 2.65

The required median rock size determined using Method 3 is approximately 540 mm.

Limitation: This method is applicable for channels carrying uniform, gradually varying flow greater than 1.5 m^3/s.

Recommended Riprap Size and Thickness:

In view of the limitations in Methods 1 and 3, the average estimated median rock size from the three methods was selected for the design. Therefore, the recommended D_{50} is 410 mm. To accommodate the upper limit of D_{100} ($1.7D_{50}$ or 700 mm), the thickness of the riprap layer is recommended to be approximately 700 mm. It should be noted that the existing median rock size for the emergency spillway is 75 mm, which is not an adequate size to handle the design flow velocity during the passage of IDF.

7.5.2 Filter Design

When riprap is placed on top of sand or fine gravel, a filter layer is necessary to avoid loss of materials through voids in the riprap. The design procedure for a granular filter is consistent in various references. For granular filters, the following sizing criteria were applied (MOELP, 2000):

$$D_{15}/D_{85f} < 5 < D_{15c}/D_{15f} < 40$$

In which the subscripts c and f stand for the coarser and finer material, respectively.

The gradation envelopes for the riprap and granular filter layers are provided in Table 7.5.

Table 7.5: Riprap and Filter Design Gradation Envelopes

Material Type	1 – Riprap Layer (mm)	2 – Filter Layer (mm)
D_{100}	615 – 700	60 – 70
D_{85}	500 – 575	50 – 55
D_{50}	410 – 450	40 – 45
D_{15}	165 – 250	15 – 25
Layer Thickness	700	200

7.5.3 Outlet Protection

To allow energy dissipation at the outlet of the chute, the discharge area has to be sized to contain the hydraulic jump that would result from the approach flow. As shown on available airphotos, the outlet of the spillway chute joins a seepage channel followed by the Cache Creek Diversion. No detailed site information has been obtained regarding the condition of the outlet of the spillway chute. In the absence of further site information, the recommended protection requirements were determined. The following equation was applied in determining the design water depth downstream of the hydraulic jump (USBR, 1978):

$$D_2/D_1 = \tfrac{1}{2}((1+8F_1^2)^{0.5}-1)$$

where D_2 = water depth downstream of the hydraulic jump,

D_1 = approaching water depth upstream of the hydraulic jump

F_1 = Froude number = $V_1/(gD_1)^{0.5}$

(where V_1 = velocity of flow and g = acceleration of gravity = 9.81 m/s^2)

The resulting water depth downstream of the hydraulic jump was calculated to be 1.1 m. Therefore, the chute sides were designed to extend up to a minimum of 1.7 m including approximately 0.6 m of freeboard on the opposite bank of the receiving stream. To further minimize the potential of erosion, larger size rocks should also be placed along the eastern portion of the outlet area.

8.0 OTHER HYDRAULIC STRUCTURES

As part of the current study, conditions of other hydraulic structures around the tailings pond including the Northwest Runoff Interceptor (NWRI) ditch, the Lower Subsidiary Creek diversion ditch, the Cache Creek diversion ditch and the associated culvert crossings were assessed. The following sections provide information available for the diversion and interceptor channels /culvert crossings, and summarize the results and recommendations from the hydraulic analysis.

8.1 Existing Conditions

Northwest Runoff Interceptor Ditch

The NWRI ditch intercepts and conveys runoff from the catchment area northwest of the tailings pond. It is located along the northwest side of the mine access road with a drainage divide about halfway along the edge of the pond. Southwest of the drainage divide, the ditch has a bottom width of about 2 m with sideslopes of about 2H:1V; Northeast of the divide, the ditch is V-shaped with sideslopes of about 1H:1V (UMA, 2007). According to SRK's 2005 geotechnical inspection, debris had been accumulated in a number of locations along the ditch and the 600 mm diameter culvert under the mine access road was partially blocked. As reported in EBA's 2010 geotechnical inspection report, the channel and banks are in good condition, and the ditch has adequately conveyed all flows to Cache Creek. It should be noted, however, that the channel condition downstream of the mine access road culvert crossing to its confluence with the Cache Creek channel has not been addressed in previous studies. The exact alignment of this lower reach of the diversion channel has yet to be confirmed in the field.

Lower Subsidiary Creek Diversion Ditch

The Lower Subsidiary Creek diversion ditch diverts runoff around the southern perimeter of the tailings pond. The diversion channel has a bottom width of about 1 m with sideslopes of 2H:1V (EBA, 2010). The NWRI ditch flowing south to the Lower Subsidiary Creek diversion ditch joins with Lower Subsidiary Creek and discharges through two 600 mm diameter culverts. As reported in SRK's 2005 geotechnical inspection report, the outlet of the twin 600 mm diameter culvert crossing was partially silted up by subsidence and accumulated debris, causing ponding upstream of the culverts extending to the NWRI ditch. Further downstream, there is a new 900 mm CSP culvert with integral steel headwall where the creek diversion flows into the Cache Creek diversion ditch. The new culvert, increased in size, was required to mitigate the hazard of the culvert being blocked and flow being diverted into the tailings pond (EBA, 2010). As per the 2010 geotechnical inspection, the channel and banks are in good condition with sufficiently sized riprap for all flows experienced to date.

Cache Creek Diversion Ditch

The Cache Creek diversion ditch receives flow from Cache Creek and from the Lower Subsidiary Creek diversion channel. The channel has a bottom width of about 5 m with sideslopes of 2H:1V (EBA, 2010). The upper reach of the diversion ditch is protected by riprap with a median size of about 450 mm. The middle reach of the diversion has riprap protection extended about 1.2 m above the base of the channel. As noted in SRK's 2005 and EBA's 2010 geotechnical inspections, the majority of the channel and banks are in good condition except for two sections where instability was observed. The first section of instability is near the South Tailings Dam on the south side of the channel, likely due to the soil conditions. The second section of instability is located along the lower and steeper reach of the channel near the confluence with a seepage channel, likely caused by high flow conditions.

8.2 Hydrologic and Hydraulic Calculations

To determine the capacity and erosion protection requirements for the diversion/interceptor ditches and to determine the capacity of the existing culvert crossings, hydrologic and hydraulic calculations were carried out. Average channel geometry, channel slope and channel roughness were obtained from previous reports and available site data. The drainage area at each point of interest was delineated based on available mapping information.

Similar to the tailings dams, the diversion/interceptor ditches were evaluated in accordance with the 2007 CDA guidelines. Consistent with the hydraulic analysis of the spillway, it is assumed that the diversion/interceptor ditches will be overtopped during the inflow design flood of the tailings pond. Flows from these channels will discharge into the pond and routed through the spillway. The existing emergency spillway was determined to be adequate for the selected inflow design flood. The consequence classifications of the Northwest Runoff Interceptor ditch, the Lower Subsidiary diversion ditch and the Cache Creek diversion ditch were further determined to be Significant based on the following:

- No loss of life anticipated (Low);
- Minimal short-term loss and no long-term loss to environmental and cultural values (Low); and
- Losses to infrequently used transportation routes (Significant).

The consequence classifications were taken as the highest of the three types of incremental losses as listed above. For a structure with a Significant Consequence classification, the inflow design flood as suggested by the CDA guidelines ranges from the 100-year flood to the 1000-year flood. The 200-year flood was selected as the inflow design flood for the diversion/interceptor channels in view of the marginal difference between the 200-year flood and the 100-year flood, and the benefits of having the probability of occurrence for the design flood being reduced significantly.

The regional study approach, as described in Section 6.4, was applied in determining the 200-year peak discharges for the diversion ditches and culverts. Hydraulic calculations were performed to determine the 200-year water depth and velocity for each sub-reach in the system using flow directions, location of culvert crossings, and change in slope as boundary limits. Table 8.1 summarizes the input and output of the hydraulic analysis.

Table 8.1: Hydraulic Analysis of Diversion/Interceptor Channels

Name	Average Slope	Average Bottom Width (m)	Sideslope (Approx.)	Average Channel Depth (m)	Manning's n	Drainage Area (km^2)	Q_{200} (m^3/s)	d_{200} (m)	V_{200} (m/s)
NWRI Ditch (To Mine Access Rd)	2%	0	1H:1V	2.00	0.035	0.11	0.22	0.44	1.16
NWRI Ditch (to Cache Cr)	9%	0	1H:1V	2.00	0.035	0.23	0.39	0.41	2.35
NWRI Ditch (to South	1%	2	2H:1V	2.00	0.035	0.22	0.38	0.19	0.84
Lower Subsidiary Cr Div.	1%	1	2H:1V	1.00	0.035	1.13	1.35	0.51	1.32
Cache Cr Div. (Upper)	5%	5	2H:1V	2.00	0.045	6.75	5.44	0.42	2.22
Cache Cr Div. (Lower)	13%	5	2H:1V	2.00	0.045	6.75	5.44	0.30	3.28

Results of the hydraulic analysis indicate that the diversion/interceptor channels have sufficient capacity for the 200-year flood discharge, and there is no erosion concern along the NWRI ditches upstream of the tailings pond and along the Lower Subsidiary Creek diversion channel due to the relatively low flow velocities during the inflow design flood.

In addition to the diversion/interceptor ditches, there are three culvert crossings around the tailings pond. One of the crossings is on the NWRI ditch under the Mine Access Road, and the other two crossings are located near the upstream and downstream ends of the Lower Subsidiary Creek diversion. The drainage area and the 200-year peak discharge were determined at these three crossings. The capacities of the culvert crossings based on the existing culvert size information were determined, and where applicable, an additional culvert was recommended to meet the design HW/D ratio, which is typically 1.0. Table 8.2 presents the input and output of the hydraulic analysis for the culvert crossings.

Table 8.2: Hydraulic Analysis of Culverts

Name	Pipe Size (mm)	Type	Drainage Area (km^2)	Q_{200} (m^3/s)	HW/D	HW (m)	Required (mm)
NWRI Ditch at Mine Access Rd	600	CSP	0.11	0.22	0.80	0.48	600
Confluence of Lower Subsidiary Cr and NWRI Ditch	2 x 600	CSP	1.08	1.31	2.10	1.26	2 x 600 and 1 x 750
Lower Subsidiary Cr Div. to Cache Cr Div.	900	CSP with headwall	1.13	1.35	1.32	1.19	1 x 900 and 1 x 600

As shown in the above table, the existing pipe size under the mine access road is adequate for the design flow while the other two culvert crossings have HW/D greater than 1.0. In view of the frequent blockage issues as identified in previous geotechnical inspections, it is recommended that a new 750 mm diameter pipe be added to the existing twin 600 mm diameter culvert crossing near the upstream end of the Lower Subsidiary Creek diversion channel and that a new 600 mm diameter pipe be added to the existing 900 mm diameter culvert near the downstream end of the Lower Subsidiary Creek diversion. Regular monitoring and maintenance are recommended at these culvert crossings to minimize blockage issues.

8.3 Erosion Protection and Filter Design

Based on the results of the hydraulic analysis of the diversion/interceptor ditches, erosion protection requirements were determined for the Northwest Runoff Interceptor ditch downstream the mine access road culvert crossing and the Cache Creek diversion channel. The three methods in determining the required median riprap size as described in Section 7.5 were applied where applicable. The recommended riprap layer gradation and the granular filter layer gradation based on the resulting median riprap size, taken as the average of the methods applied, for each sub-reach of interest are tabulated in Table 8.3.

Table 8.3: Design Gradation Envelopes for Sub-reach of Interest

NWRI Ditch Downstream of Mine Access Road Crossing (@ 9% Slope)		
Material Type	**1 – Riprap Layer**	**2 – Filter Layer**
D_{100}	450 – 495 mm	45 – 50 mm
D_{85}	360 – 420 mm	35 – 40 mm
D_{50}	300 – 330 mm	30 – 35 mm
D_{15}	120 – 180 mm	10 – 20 mm
Layer Thickness	600 mm	200 mm
Cache Creek Diversion Upstream of Seepage Channel (@ 5% Slope)		
Material Type	3 – Riprap Layer	4 – Filter Layer
D_{100}	375 – 425 mm	40 – 45 mm
D_{85}	300 – 350 mm	30 – 35 mm
D_{50}	250 – 275 mm	25 – 30 mm
D_{15}	100 – 150 mm	10 – 15 mm
Layer Thickness	500 mm	200 mm

Table 8.3: Design Gradation Envelopes for Sub-reach of Interest

Cache Creek Diversion Downstream of Seepage Channel (@ 13% Slope)		
Material Type	5 – Riprap Layer	6 – Filter Layer
D_{100}	640 – 700 mm	60 – 70 mm
D_{85}	510 – 595 mm	50 – 55 mm
D_{50}	425 – 470 mm	40 – 45 mm
D_{15}	170 – 255 mm	15 – 25 mm
Layer Thickness	900 mm	200 mm

It should be noted that no information is available regarding the existing riprap size along the reach of the NWRI ditch downstream of the mine access road, and the actual alignment and channel slope have yet to be confirmed in the field. For the Cache Creek diversion channel, the existing riprap material size is also required to be confirmed. However, two locations of instability have been identified from previous geotechnical studies. In particular, the Cache Creek diversion channel just downstream of the outlet of the seepage channel is unstable because of high flows. This agrees with the results of the current hydraulic analysis that this particular sub-reach has a relatively steep slope and relatively high flow velocities during major events. It is recommended that remediation be implemented at these unstable locations and that the rest of the channel is protected by the suggested riprap materials where necessary.

9.0 CONCLUSIONS AND RECOMMENDATIONS

- A hydrotechnical assessment has been conducted in support of the current water license application for the Ketza River Mine Tailings Pond. The study involved a hydrologic assessment to determine the Inflow Design Flood (IDF), a flood routing and hydraulic analysis to assess the capacity of the dam to pass the IDF.
- Based on a review of previous studies and results of the current dam break analysis, the tailings dams are classified as High consequence dams. In accordance with the 2007 CDA Guidelines, the IDF for the tailings pond was chosen to the 1/3 between a 1000-year flood and the Probable Maximum Flood (PMF). Two IDF scenarios were considered: the summer-autumn scenario and the spring scenario. The summer-autumn IDF was determined to have a peak flow of 30.9 m^3/s. The governing spring IDF was determined to have a peak inflow of 23.4 m^3/s.
- Flood routing was performed to assess the capacity of the dams to pass the IDF. The existing spillway crest has an average elevation of 1309 m. With the existing configuration of the spillway, a minimum freeboard of 0.7 m would be available during the summer-autumn IDF, and a minimum freeboard of about 0.4 m would be available during the spring IDF.
- A wind and wave analysis was conducted in the freeboard determination of the existing spillway. Results indicate that there will be no overtopping by 95% of waves either caused by the most critical wind with a frequency of 1/1000 year when the reservoir is at its maximum normal elevation or caused by the most critical wind when the reservoir is at its maximum extreme level during the passage of the IDF. Therefore, the amount of freeboard available is considered adequate.

- A hydraulic analysis of the erosion potential of spillway and chute was conducted. Results of the analysis indicate that the existing rock size of the spillway is inadequate. It is recommended that the spillway and the chute be lined with riprap with a median rock size of 410 mm and granular filter with a median size of 40 mm. The required thickness for the riprap layer was determined to be 700 mm while that for the filter layer was determined to be 200 mm.
- No detailed site information has been obtained for the outlet of the spillway chute at the time of the study. However, general erosion protection requirements at the outlet of the spillway chute were determined. It is recommended that the chute sides be extended up to a minimum of 1.7 m on the opposite bank of the receiving stream. To further minimize the potential of erosion, larger size rocks should also be placed along the eastern portion of the outlet area.
- A hydraulic analysis of the Northwest Runoff Interceptor ditch, the Lower Subsidiary Creek diversion channel, the Cache Creek diversion channel and the associated culvert crossings was carried out. The diversion/interceptor channels were determined to be Significant consequence classification structures, and the 200-year flood was selected as the inflow design flood. Results of the hydraulic analysis indicate that all diversion/interceptor channels have sufficient capacities to handle the inflow design flood and that there is no erosion concern along the NWRI ditch upstream of the tailings pond and along the Lower Subsidiary Creek diversion.
- Conditions of the existing culvert crossings were also assessed, and it is recommended that a new 750 mm diameter culvert be added to the existing twin 600 mm diameter culvert crossing near the upstream end of the Lower Subsidiary Creek diversion and that a new 600 mm diameter culvert be added to the existing 900 mm diameter culvert near the downstream end of Lower Subsidiary Creek diversion. It is also recommended that regular monitoring and maintenance be carried out at these culvert crossings to minimize the blockage issues.
- The erosion protection requirements along the NWRI ditch downstream of the mine access road and along the Cache Creek diversion channel were determined. However, the existing riprap size, actual alignment and slope of this sub-reach of the NWRI ditch have yet to be confirmed in the field. Similarly, the existing riprap material size along the Cache Creek diversion channel has yet to be confirmed. Two locations of instability have been identified from previous geotechnical studies. In particular, the Cache Creek diversion channel just downstream of the outlet of the seepage channel has an instability issue because of high flows. It is recommended that remediation be implemented at these unstable locations and that the rest of the channel is protected by the suggested riprap materials where necessary.
- It is recommended that a site visit be conducted to get a better understanding of the spillway chute, its outlet condition, and the diversion/interceptor ditches and to refine the erosion protection requirements prior to any proposed works at the spillway and along the diversion/interceptor channels.

10.0 CLOSURE

We trust this proposal/report meets your present requirements. Should you have any questions or comments, please contact the undersigned at your convenience.

Respectfully submitted,
EBA, A TetraTech Company,

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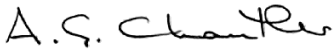
mlau@eba.ca

Reviewed by:



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ML/AGC/rbt

REFERENCES

BC Ministry of Transportation and Highway. "Supplement to TAC Geometric Design Guide." February 2001.

Canadian Dam Association. "Dam Safety Guidelines." 2007

Canadian Dam Association. "Technical Bulletin: Inundation, Consequences, and Classification for Dam Safety." 2007.

EBA Engineering Consultants Ltd. "Report to Yukon-Nevada Gold Corporation on 2010 Geotechnical Site Inspection Ketza River Gold Mine, Yukon." November 2010.

Hogg, W.D. and D.A. Carr. "Rainfall Frequency Atlas for Canada." 1985.

James, William. "User's Guide to SWMM." 2005.

Ministry of Environment, Lands & Parks. "Riprap Design and Construction Guide." March 2000.

Natural Resources of Canada. "The Atlas of Canada – Soil Regions. Circa 1957." 1957.

Smith C.D. Hydraulic Structures. 1995.

Steffen, Robertson & Kirsten Consulting Engineers. "Report to Wheaton River Minerals Limited on Ketza River Mine Abandonment Plan." February 1994.

Steffen, Robertson & Kirsten Consulting Engineers. "Report to YGC Resources Limited on Ketza River Mine Assessment of Risks Associated with Tailings Dams." December 1994.

Steffen, Robertson & Kirsten Consulting Engineers. "Report to YGC Resources Ltd. on Addendum to the 1994 Decommissioning Plan, Ketza River Mine, Tailings Management Facility, Yukon Territory." May 1996.

UMA Engineering Ltd. "Report to Government of Yukon Water Resources Branch on Ketza River Mine 2007 Geotechnical Inspections." February 2008.

US Army Corps of Engineers. "Hydraulic Design of Flood Control Channels (EM 1110-2-1601)." June 1994.

US Department of the Interior Bureau of Reclamation. "Hydraulic Design of Stilling Basins and Energy Dissipators." 1978.

US Department of Transportation, Federal Highway Administration. "Design of Riprap Revetments HEC-11." 1989.

Water Resources Branch, Environment Yukon. "Ketza Type A Water License Application Review Comments 2010-0080." August 26, 2010.

Yukon-Nevada Gold Corporation. "Inter-Office Memo on Ketza River Project Coordinate System and Elevation Issue from Mr. Ian Walkley." January 16, 2011.

FIGURES

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Figure 3.3 Tailings Impoundment Site Plan
Figure 5.1 Tailings Pond and Downstream Reaches
Figure 5.2 Inundation Map I
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Figure 6.3 Summer-Autumn IDF Hydrograph
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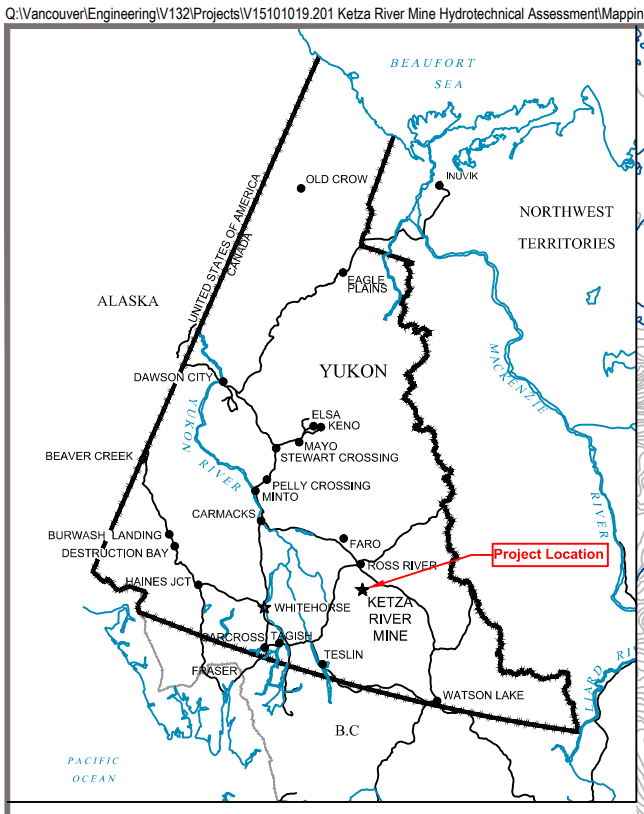
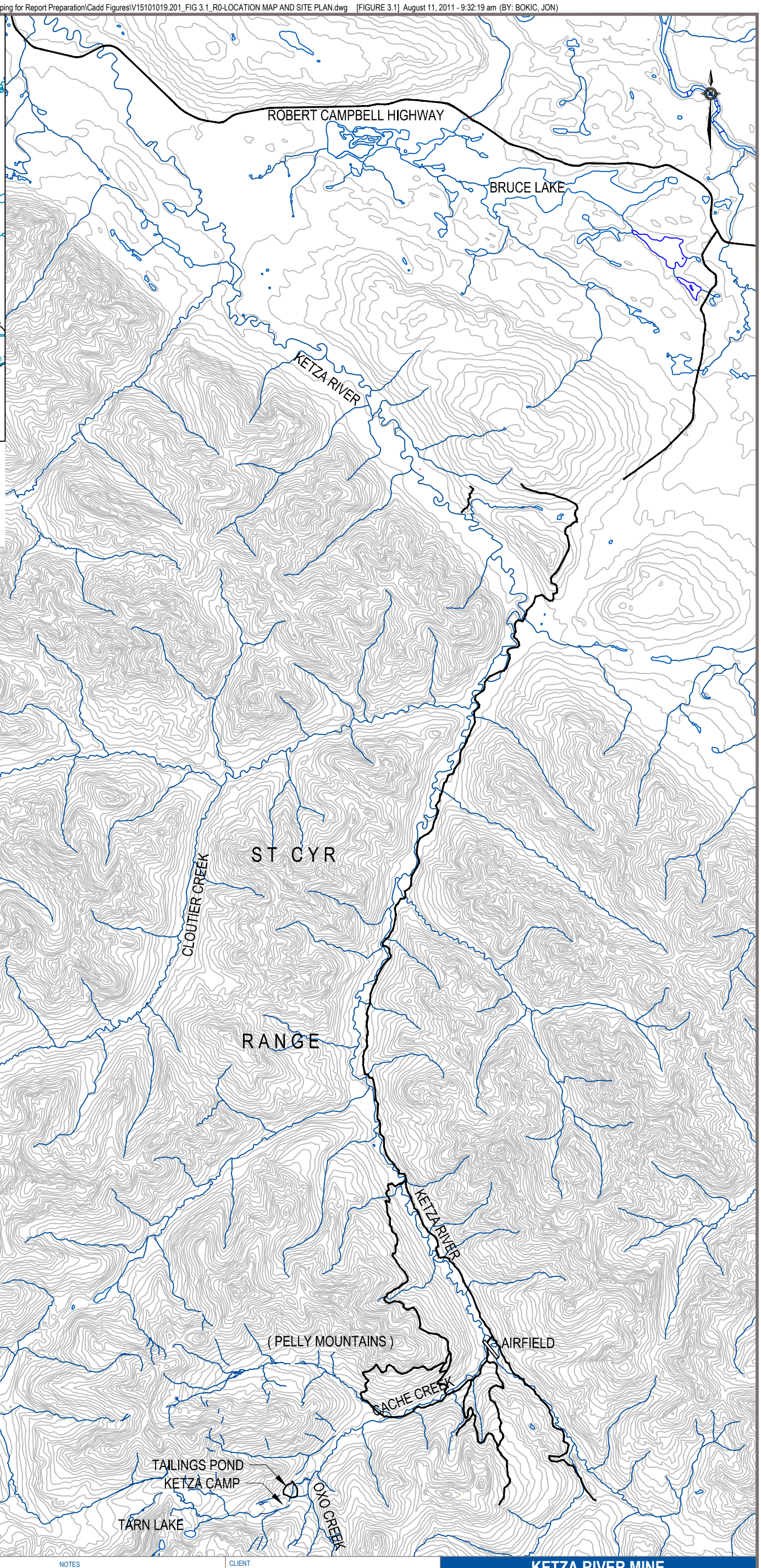
Figure 7.5 Results of Flood Routing (Spring Case 2)

Q:\Vancouver\Engineering\V132\Projects\V15101019.201 Ketza River Mine Hydrotechnical Assessment\Mapping for Report Preparation\Cadd Figures\V15101019.201_FIG 3.1_R0-LOCATION MAP AND SITE PLAN.dwg [FIGURE 3.1] August 11, 2011 - 9:32:19 am (BY: BOKIC, JON)



GENERAL LOCATION MAP



LEGEND

ROAD

RIVER

0 50 000

Scale: 1: 100 000 (metres)

NOTES

BASE DATA: 1:50,000 NTS NAD 83 MSL

CONTOUR INTERVAL: 100ft

ISSUED FOR USE

CLIENT

Yukon-Nevada Gold Corp.

A TETRA TECH COMPANY

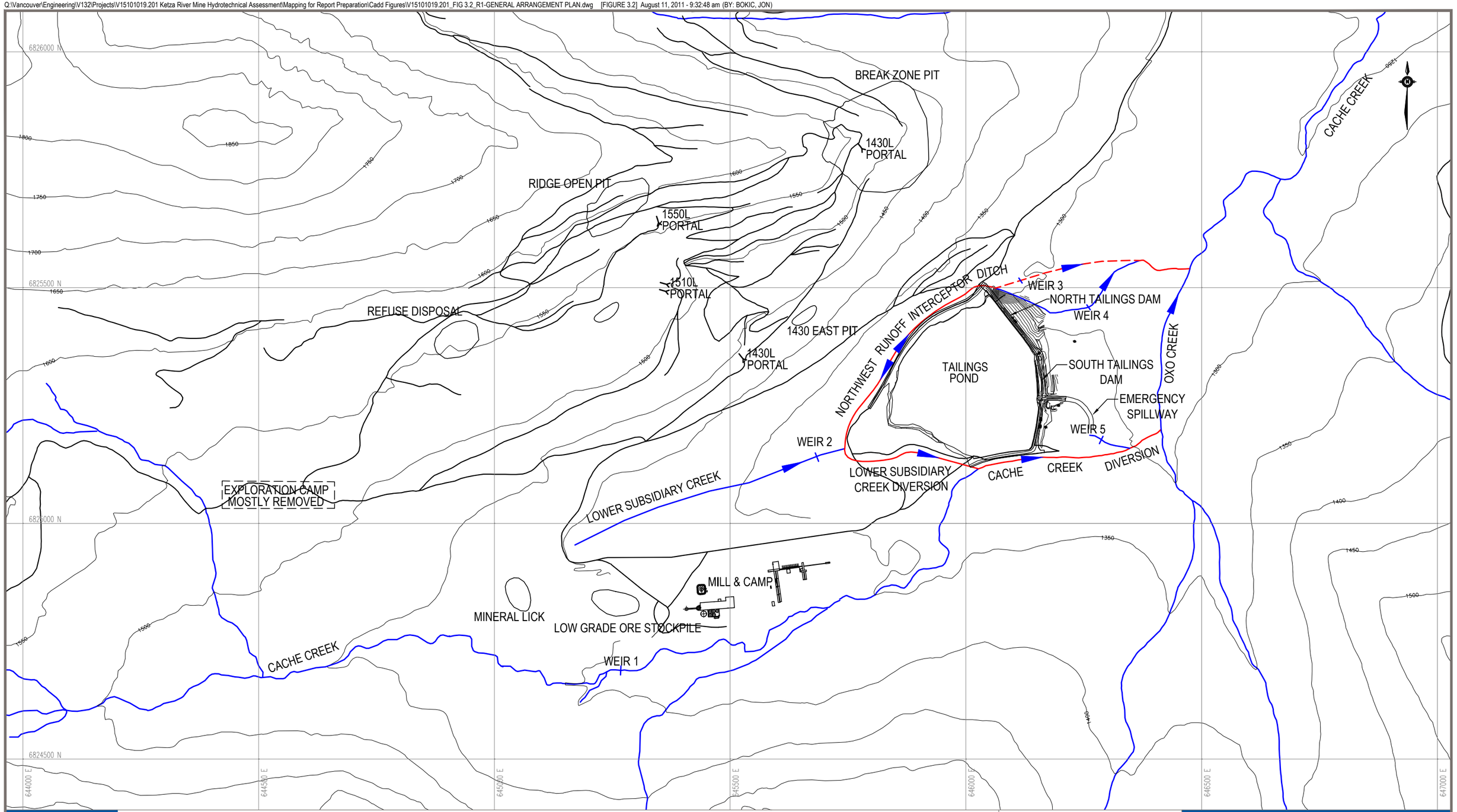
KETZA RIVER MINE HYDROTECHNICAL ASSESSMENT

LOCATION MAP AND SITE PLAN

PROJECT NO.	DWN	CKD	REV
V15101019.201	AD	ML	0

OFFICE	DATE
VANC	August 11, 2011

Figure 3.1



LEGEND

- PORTAL
- ROADWAY
- WATERCOURSE
- DIVERSION
- DIVERSION (APPROXIMATE ALIGNMENT)

0 250

Scale: 1: 7 500 (metres)

NOTES

BASE DATA: UTM NAD 27 HI2 MSL

CONTOUR INTERVAL: 50m

ISSUED FOR USE

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KETZA RIVER MINE HYDROTECHNICAL ASSESSMENT

GENERAL ARRANGEMENT PLAN

PROJECT NO.	DWN	CKD	REV
V15101019.201	AD	ML	1
OFFICE: VANC	DATE: August 11, 2011		

Figure 3.2

600mm DIA CSP CULVERT
(LOCATION APPROXIMATE)
WEIR 3
P90 - 10A & 10B
P89 - 1
P96 - 11A, 11B, 11C
WEIR 4
NORTH TAILINGS DAM
P89 - 6A & 6B
DITCH
INTERCEPTOR
RUNOFF
NORTHWEST
TAILINGS POND
1298.9
1301.4
1303.9
1306.4
1308.9
P90 - 8
P90 - 9
P89-5
EMERGENCY SPILLWAY
P96 - 12B & 12C
P96 - 12A
SOUTH TAILINGS DAM
P89-4
P90 - 7A, 7B & 7C
P98 - 3
WEIR 5
OXO CREEK
1300
LOWER SUBSIDIARY CREEK
WEIR 2
LOWER SUBSIDIARY CREEK DIVERSION
2 X 600mm DIA
CSP CULVERTS
NEW 900mm DIA
CSP CULVERT
CACHE CREEK DIVERSION
INSTABILITY AREA #1
INSTABILITY AREA #2
6825500 N
6825400 N
6825300 N
6825200 N
6825100 N
645600 E
645700 E
645800 E
645900 E
646000 E
646100 E
646200 E
646300 E
646400 E
646500 E
646600 E

LEGEND

- P89 - 3 PIEZOMETER (INSTALLED 1989)
- P96 - 12A MONITORING WELL (INSTALLED 1996)
- ROADWAY
- TOE BERM (CONSTRUCTED 2009)
- DIVERSION
- DIVERSION (APPROXIMATE ALIGNMENT)

0 100
Scale: 1: 2 500 (metres)

NOTES
BASE DATA: UTM NAD 27 HI2 MSL

ISSUED FOR USE

CLIENT
Yukon-Nevada Gold Corp.

KETZA RIVER MINE HYDROTECHNICAL ASSESSMENT

TAILINGS IMPOUNDMENT SITE PLAN

PROJECT NO.	DWN	CKD	REV
V15101019.201	AD	ML	1

OFFICE	DATE
VANC	August 11, 2011

Figure 3.3

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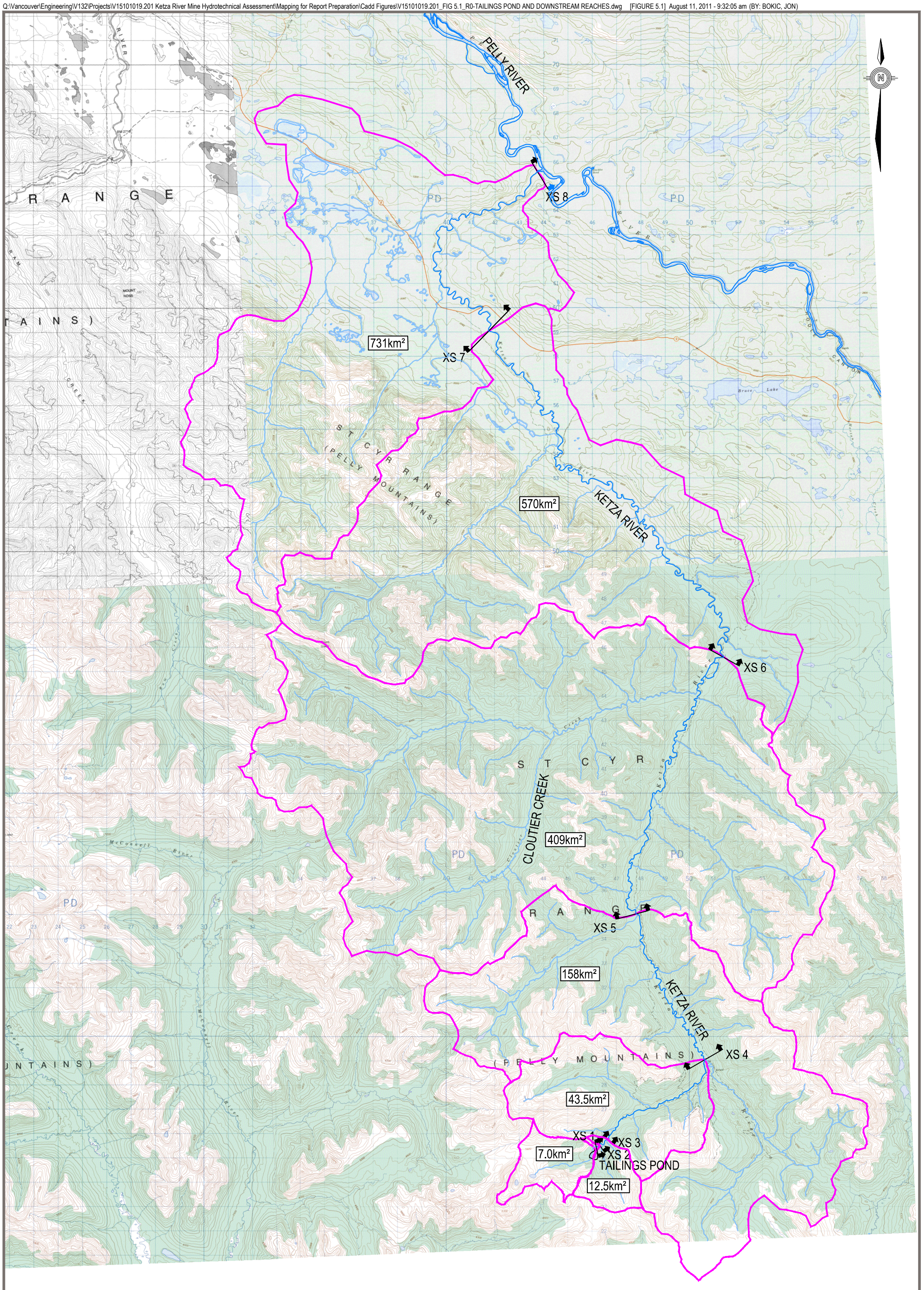
Q:\Vancouver\Engineering\V132\Projects\V15101019.201 Ketza River Mine Hydrotechnical Assessment\Mapping for Report Preparation\Cadd Figures\V15101019.201_FIG 5.1_R0-TAILINGS POND AND DOWNSTREAM REACHES.dwg [FIGURE 5.1] August 11, 2011 - 9:32:05 am (BY: BOKIC, JON)



LEGEND

WATERSHED BOUNDARY

0 5,000

Scale: 1: 150,000 (metres)

NOTES

BASE DATA: 1:50,000 NTS UTM NAD 83 MSL

ISSUED FOR USE

CLIENT

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KETZA RIVER MINE HYDROTECHNICAL ASSESSMENT

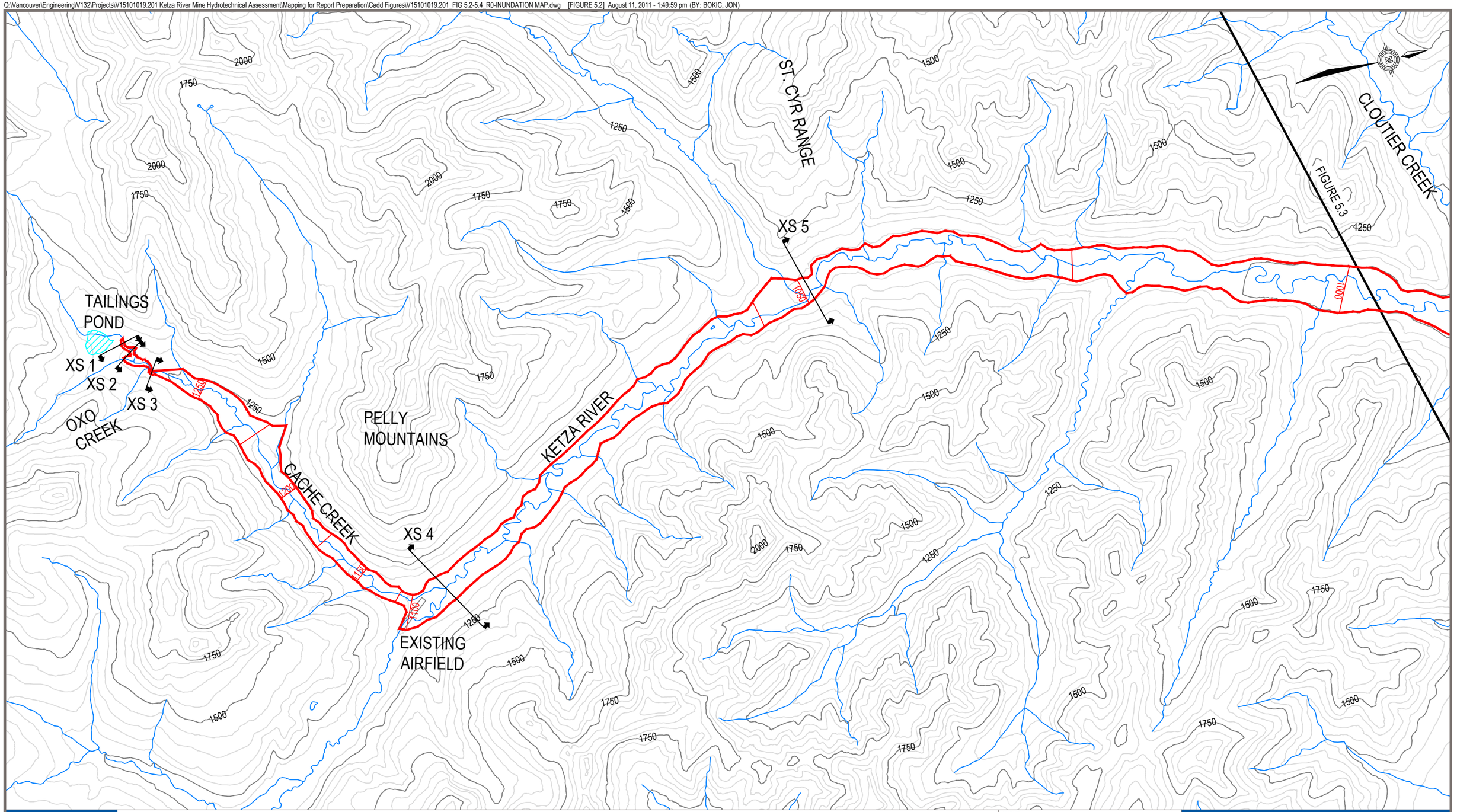
TAILINGS POND AND DOWNSTREAM REACHES

PROJECT NO.	DWN	CKD	REV
V15101019.201	AD	ML	0

OFFICE	DATE
VANC	August 11, 2011

Figure 5.1

Q:\Vancouver\Engineering\V132\Projects\V15101019.201 Ketza River Mine Hydrotechnical Assessment\Mapping for Report Preparation\Cadd Figures\V15101019.201_FIG 5.2-5.4_R0-INUNDATION MAP.dwg [FIGURE 5.2] August 11, 2011 - 1:49:59 pm (BY: BOKIC, JON)



LEGEND

- CONTOURS
- WATERCOURSE
- SECTION LINE
- FLOOD EXTENT
- FLOOD LEVEL ISOGRAMS
- LIMIT OF STUDY

0 2 500

Scale: 1: 50 000 (metres)

NOTES

BASE DATA: DERIVED FROM 1:50,000 NTS UTM NAD 83 MSL

CONTOUR INTERVAL: 50m AND 250m

ISSUED FOR USE

CLIENT

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KETZA RIVER MINE HYDROTECHNICAL ASSESSMENT

INUNDATION MAP I

PROJECT NO.	DWN	CKD	REV
V15101019.201	AD	ML	0

OFFICE: VANC

DATE: August 11, 2011

Figure 5.2

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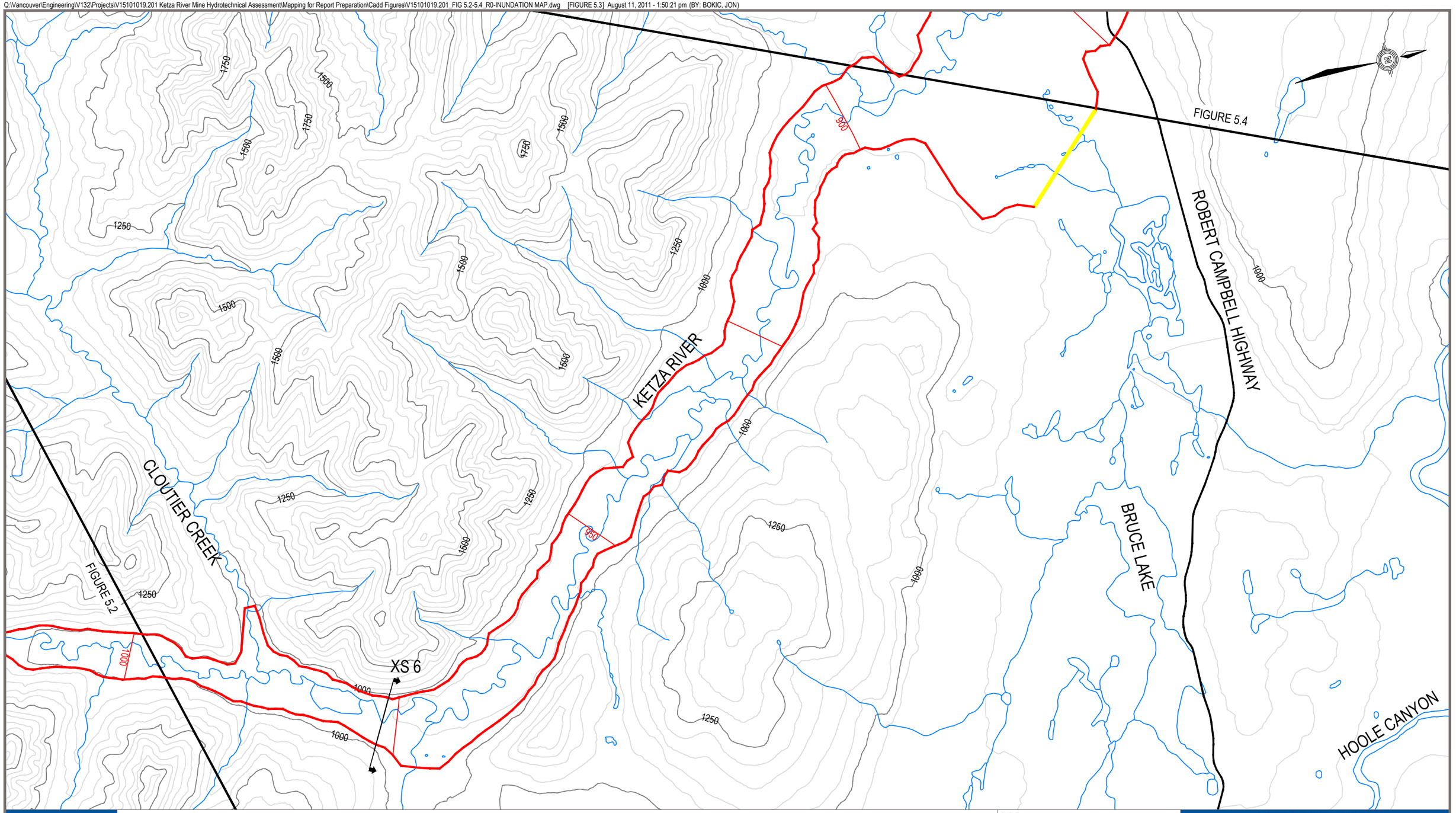

LEGEND

- CONTOURS
- WATERCOURSE
- SECTION LINE
- FLOOD EXTENT
- FLOOD LEVEL ISOGRAMS
- LIMIT OF STUDY

0 2 500

Scale: 1: 50 000 (metres)

NOTES

BASE DATA: DERIVED FROM 1:50,000 NTS UTM NAD 83 MSL

CONTOUR INTERVAL: 50m AND 250m

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KETZA RIVER MINE HYDROTECHNICAL ASSESSMENT

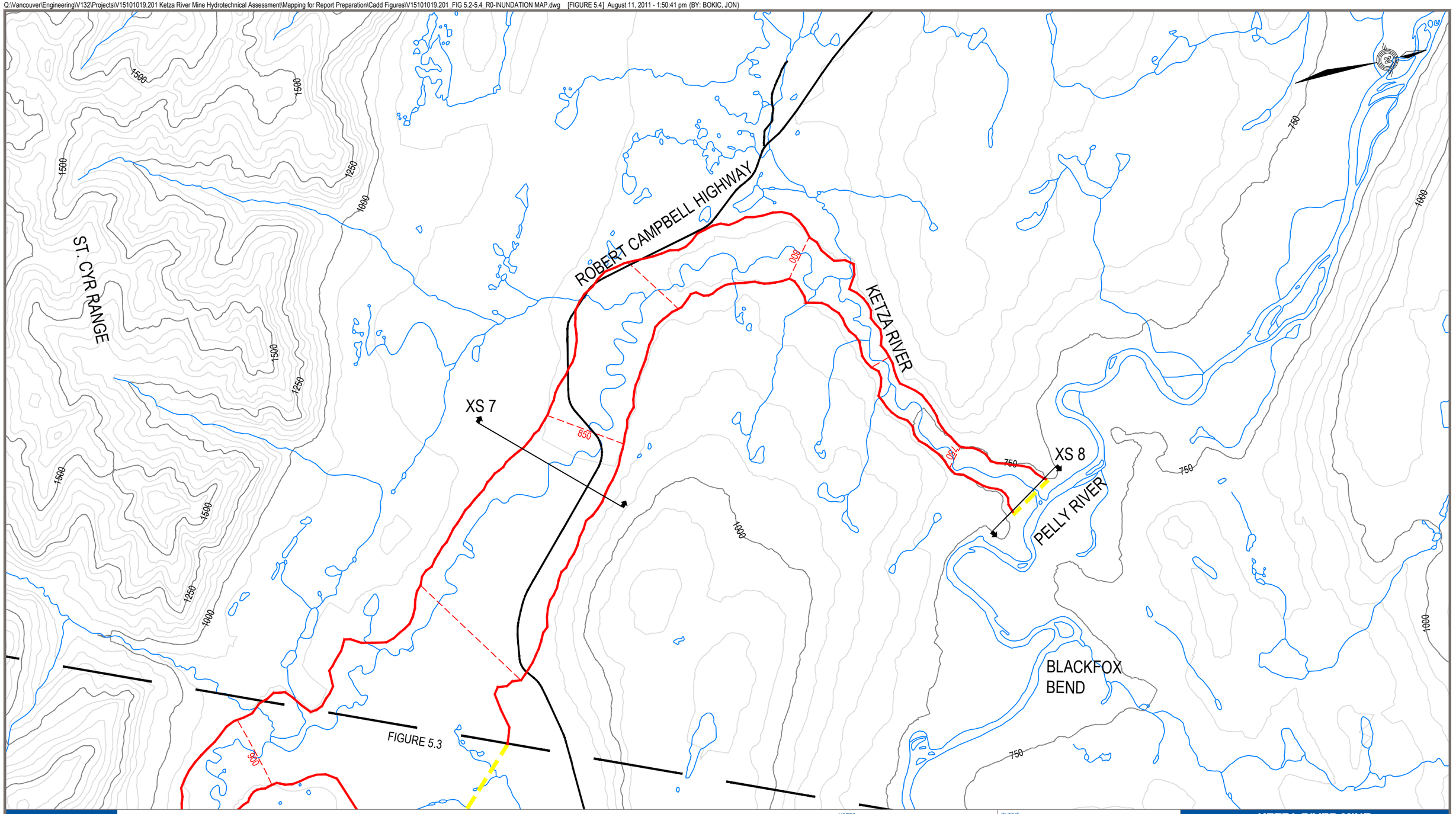
INUNDATION MAP II

PROJECT NO.	DWN	CKD	REV
V15101019.201	AD	ML	0

OFFICE	DATE
VANC	August 11, 2011

Figure 5.3

Q:\Vancouver\Engineering\V132\Projects\V15101019.201 Ketza River Mine Hydrotechnical Assessment\Mapping for Report Preparation\Cadd Figures\V15101019.201_FIG 5.2-5.4_R0-INUNDATION MAP.dwg [FIGURE 5.4] August 11, 2011 - 1:50:41 pm (BY: BOKIC, JON)



LEGEND

- CONTOURS
- WATERCOURSE
- SECTION LINE
- FLOOD EXTENT
- FLOOD LEVEL ISOGRAMS
- LIMIT OF STUDY

0 2 500

Scale: 1: 50 000 (metres)

NOTES

BASE DATA: DERIVED FROM 1:50,000 NTS UTM NAD 83 MSL

CONTOUR INTERVAL: 50m AND 250m

ISSUED FOR USE

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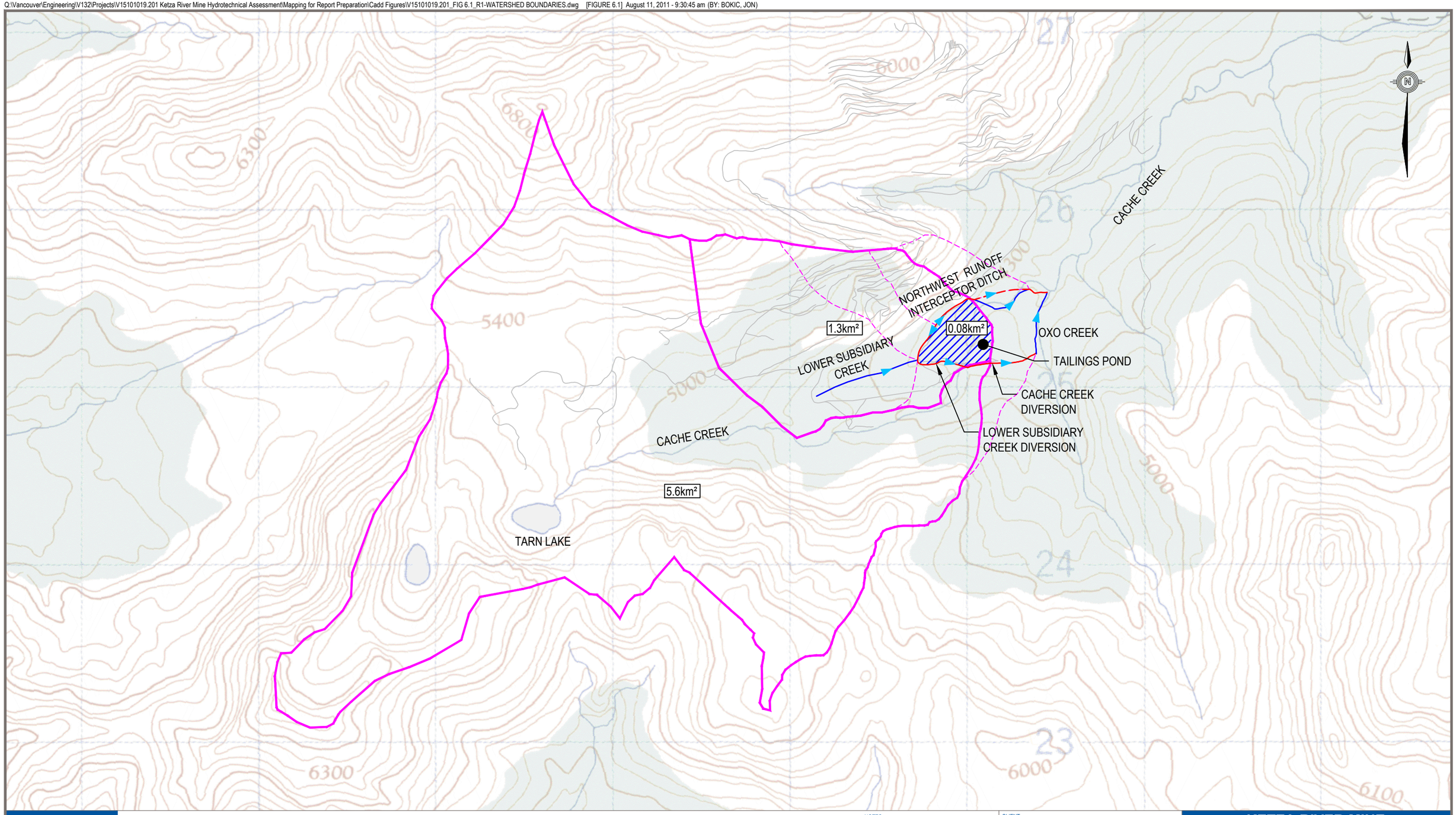
KETZA RIVER MINE HYDROTECHNICAL ASSESSMENT

INUNDATION MAP III

PROJECT NO.	DWN	CKD	REV
V15101019.201	AD	ML	0

OFFICE	DATE
VANC	August 11, 2011

Figure 5.4



LEGEND

- EXISTING ROAD
- WATERSHED BOUNDARY
- SUBWATERSHED BOUNDARY
- WATERCOURSE
- DIVERSION
- DIVERSION (APPROXIMATE ALIGNMENT)

0 1 000

Scale: 1: 20 000 (metres)

NOTES
BASE DATA: 1:50,000 NTS UTM NAD 83 MSL
CONTOUR INTERVAL: 100ft

ISSUED FOR USE

CLIENT
Yukon-Nevada Gold Corp.

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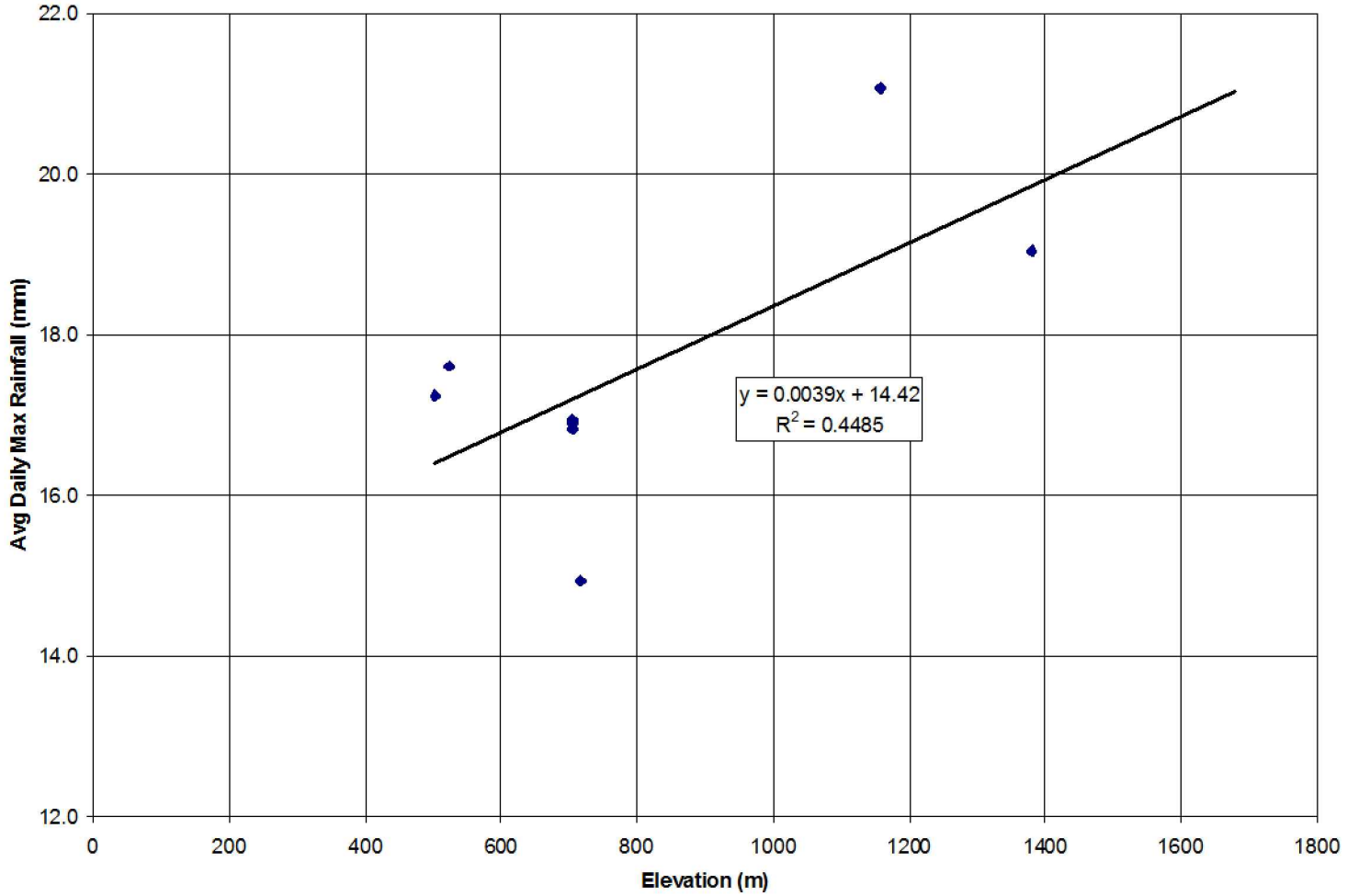
KETZA RIVER MINE HYDROTECHNICAL ASSESSMENT

WATERSHED BOUNDARIES

PROJECT NO.	DWN	CKD	REV
V15101019.201	AD	ML	1
OFFICE: VANC	DATE: August 11, 2011		

Figure 6.1



ISSUED FOR USE

CLIENT

Yukon-Nevada Gold Corp.

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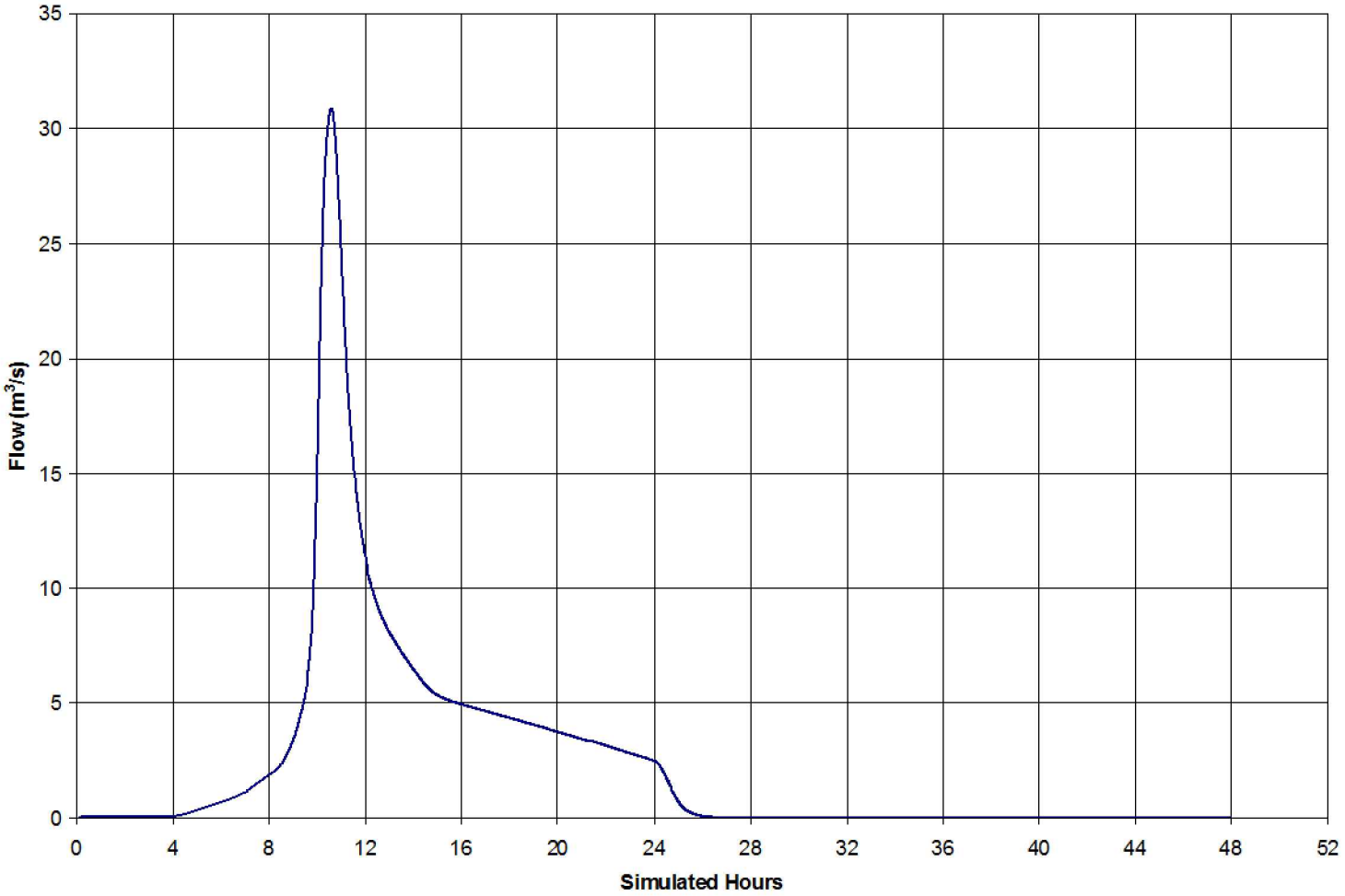
KETZA RIVER MINE
HYDROTECHNICAL ASSESSMENT

AVERAGE MAX DAILY RAINFALL
VERSUS ELEVATION (SUMMER-AUTUMN)

PROJECT NO.	DWN	CKD	REV
V15101019.201	ML	AGC	0
OFFICE	DATE		
VANC	August 11, 2011		

Figure 6.2



ISSUED FOR USE

CLIENT

Yukon-Nevada Gold Corp.

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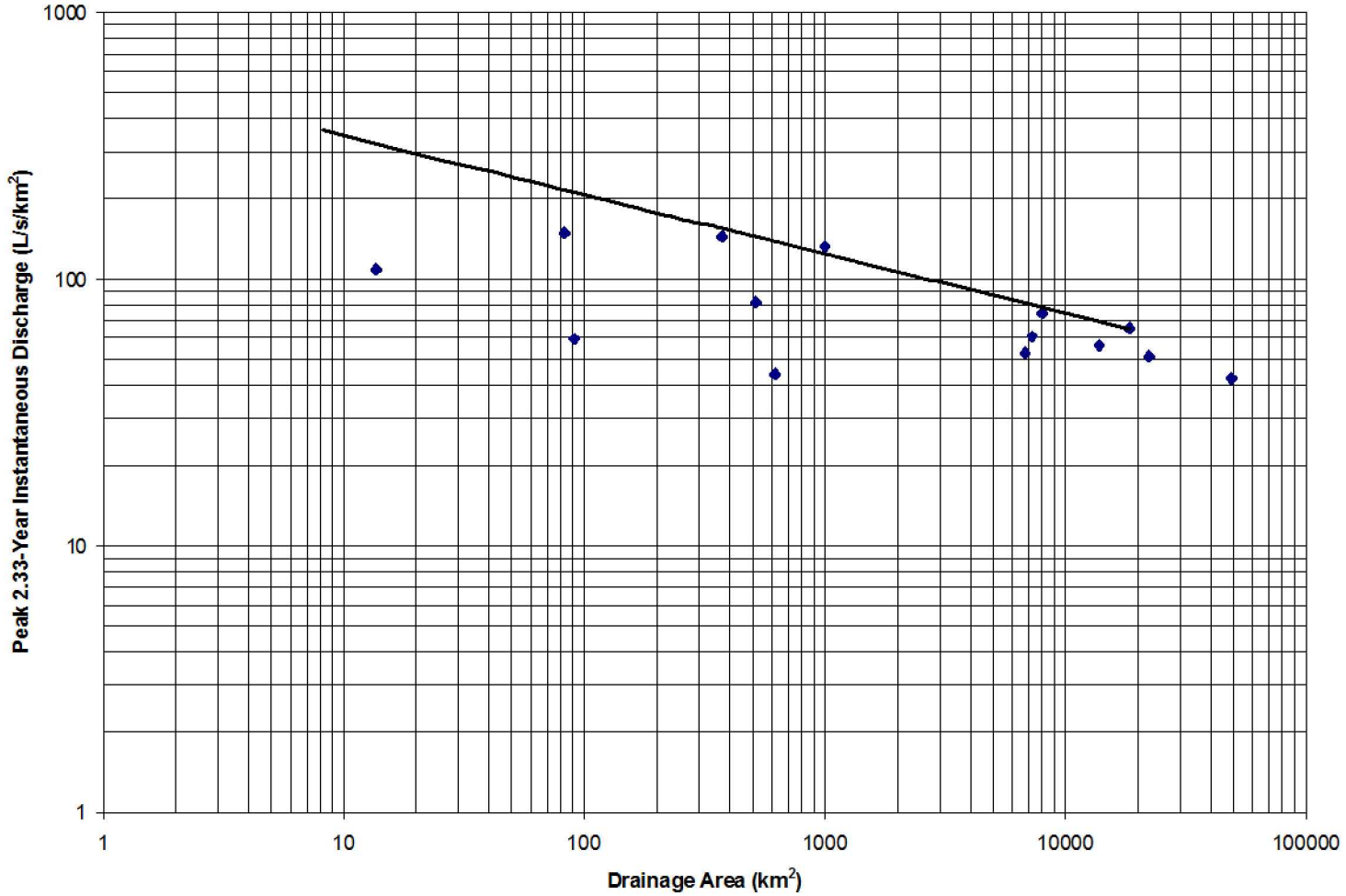
KETZA RIVER MINE
HYDROTECHNICAL ASSESSMENT

SUMMER-AUTUMN
IDF HYDROGRAPH

PROJECT NO.	DWN	CKD	REV
V15101019.201	ML	AGC	0

OFFICE	DATE
VANC	August 11, 2011

Figure 6.3



ISSUED FOR USE

CLIENT

Yukon-Nevada Gold Corp.

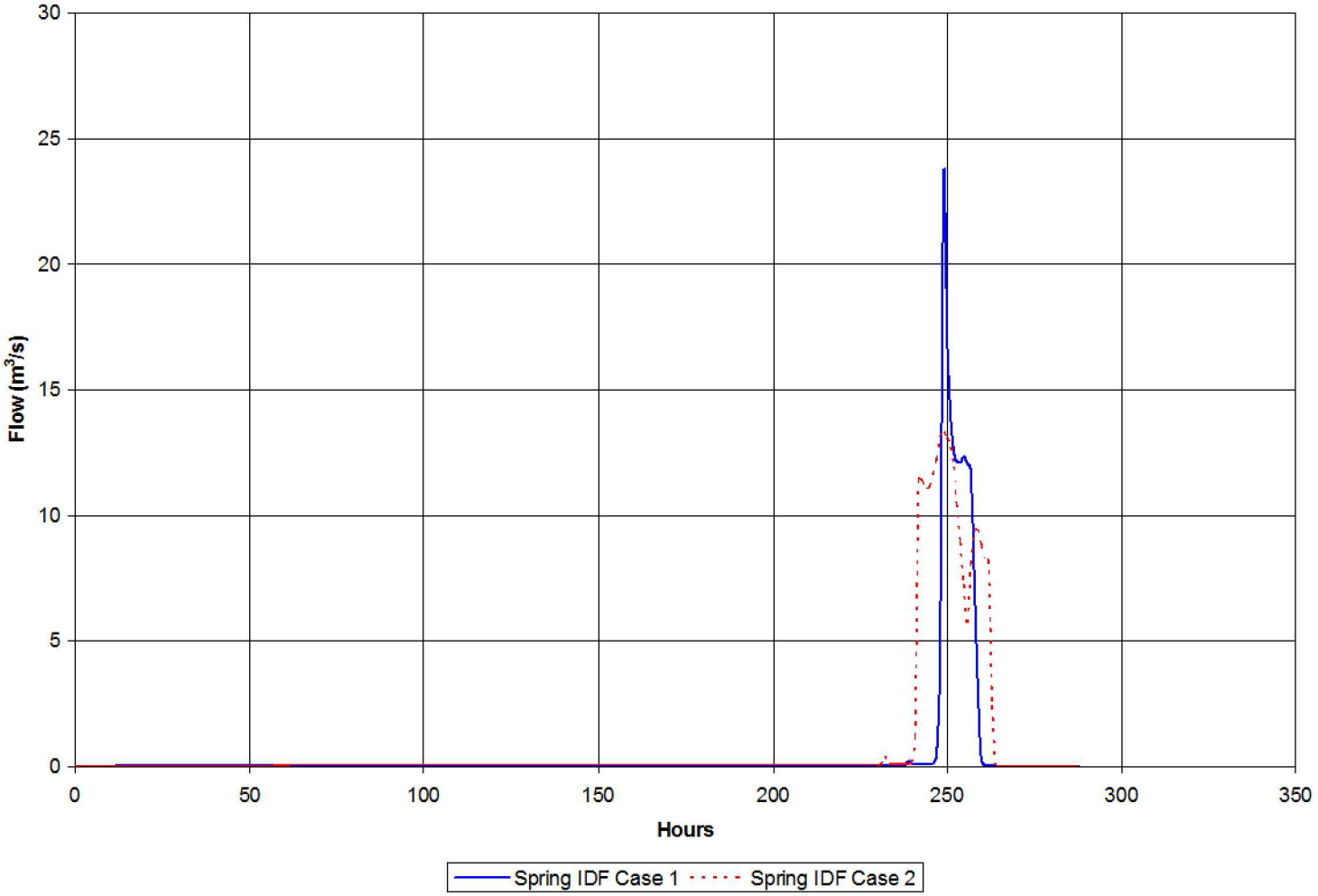
eba A TETRA TECH COMPANY

KETZA RIVER MINE HYDROTECHNICAL ASSESSMENT

REGIONAL ANALYSIS

PROJECT NO.	DWN	CKD	REV
V15101019.201	ML	AGC	0
OFFICE: VANC	DATE: August 11, 2011		

Figure 6.4



ISSUED FOR USE

CLIENT

Yukon-Nevada Gold Corp.

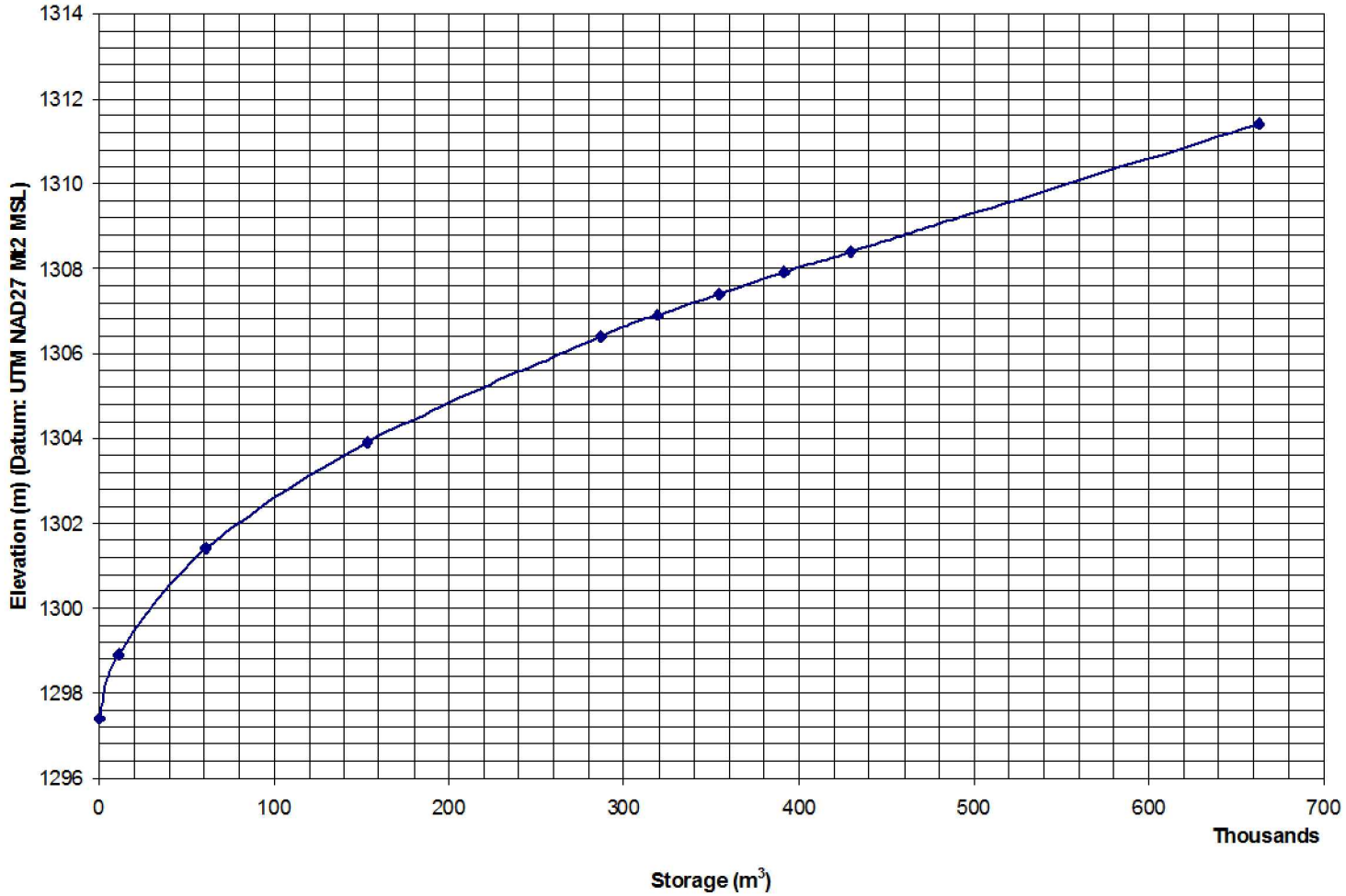
A TETRA TECH COMPANY

KETZA RIVER MINE
HYDROTECHNICAL ASSESSMENT

SPRING
IDF HYDROGRAPHS

PROJECT NO.	DWN	CKD	REV
V15101019.201	ML	AGC	0
OFFICE	DATE		
VANC	August 11, 2011		

Figure 6.5



ISSUED FOR USE

CLIENT

Yukon-Nevada Gold Corp.

A TETRA TECH COMPANY

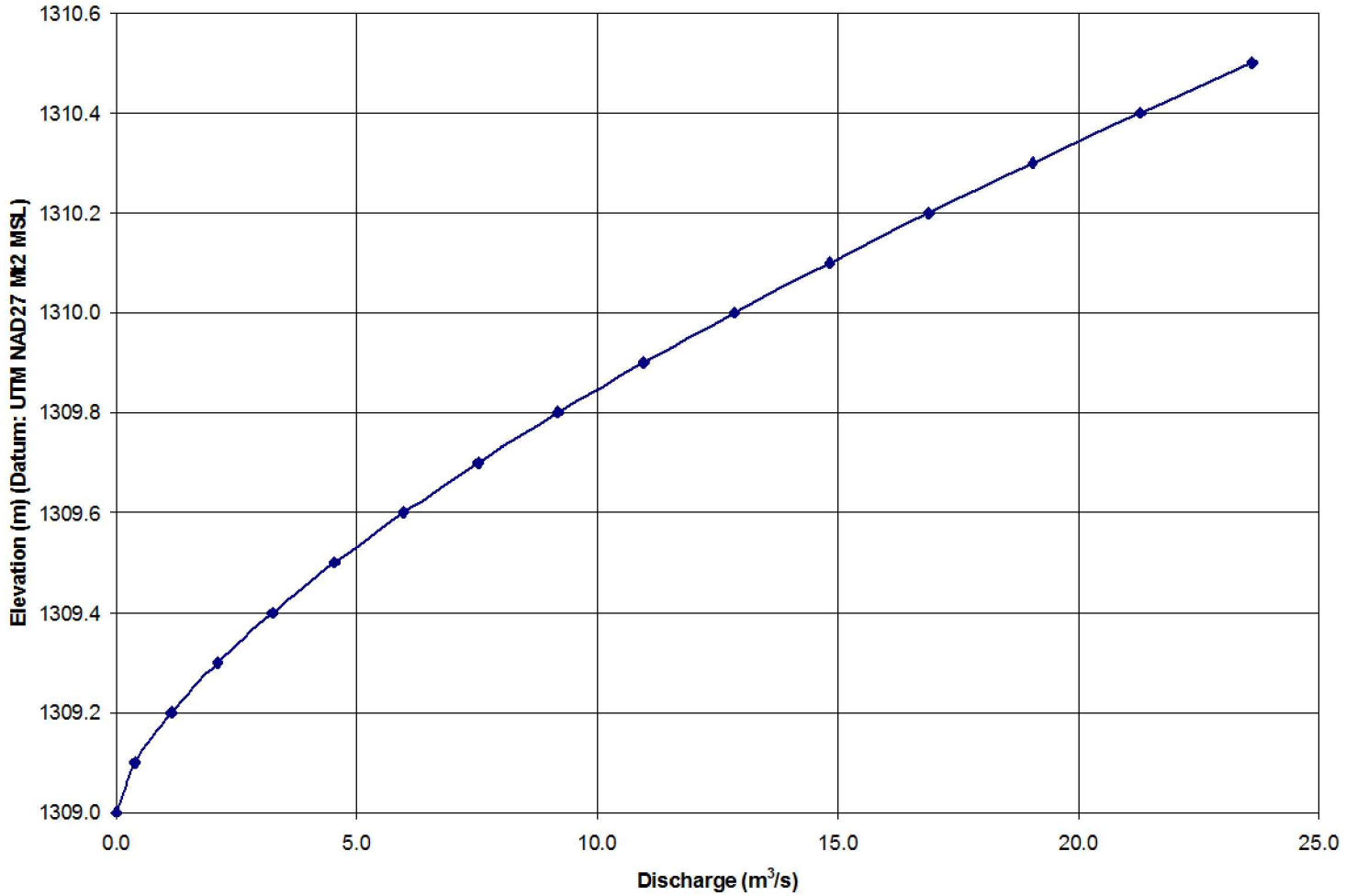
KETZA RIVER MINE
HYDROTECHNICAL ASSESSMENT

VOLUME ELEVATION RELATIONSHIP

PROJECT NO.	DWN	CKD	REV
V15101019.201	ML	AGC	0

OFFICE	DATE
VANC	August 11, 2011

Figure 7.1



ISSUED FOR USE

CLIENT

Yukon-Nevada Gold Corp.

A TETRA TECH COMPANY

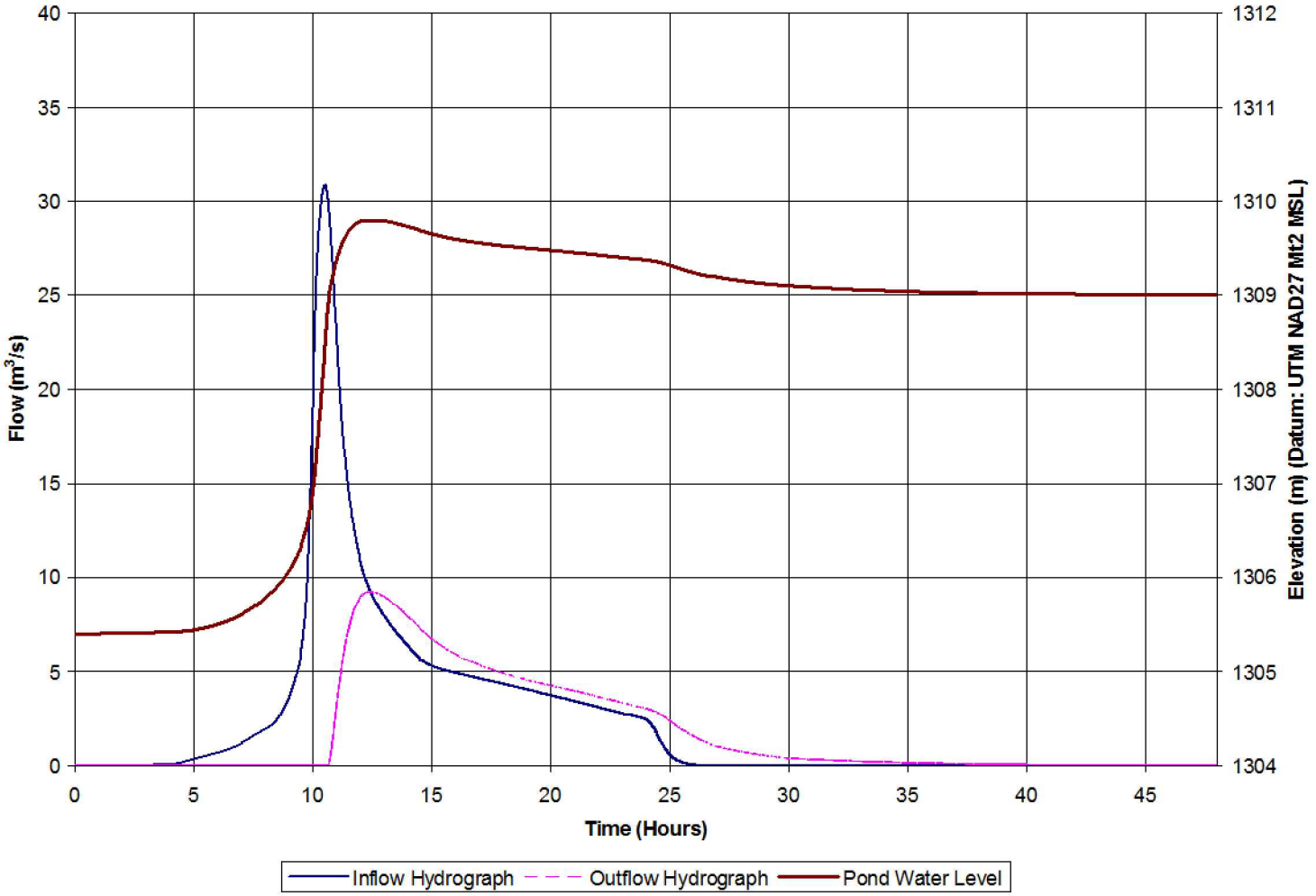
KETZA RIVER MINE HYDROTECHNICAL ASSESSMENT

RATING CURVE

PROJECT NO.	DWN	CKD	REV
V15101019.201	ML	AGC	0

OFFICE	DATE
VANC	August 11, 2011

Figure 7.2



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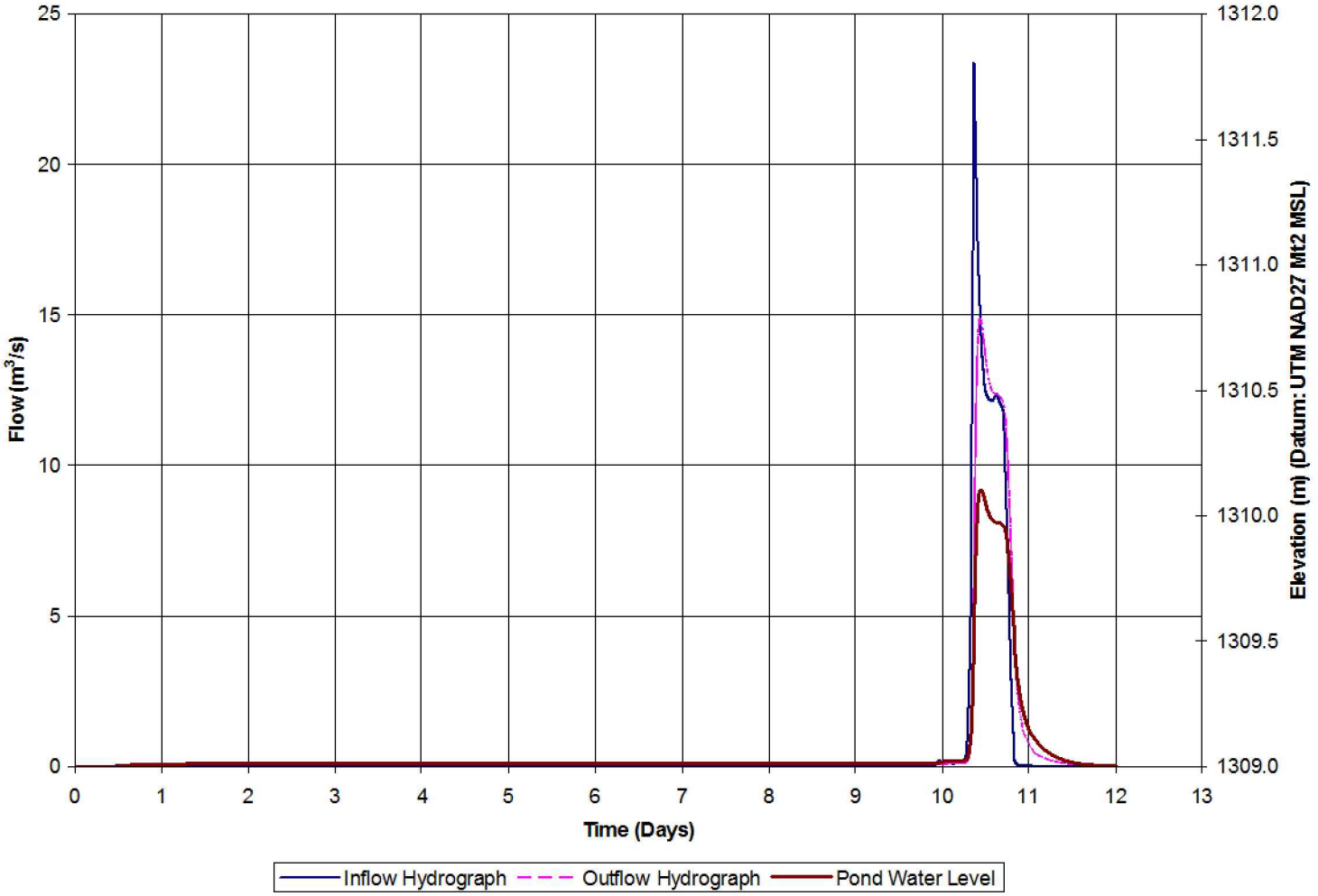
KETZA RIVER MINE
HYDROTECHNICAL ASSESSMENT

RESULTS OF FLOOD ROUTING (SUMMER-AUTUMN)

PROJECT NO.	DWN	CKD	REV
V15101019.201	ML	AGC	0

OFFICE	DATE
VANC	August 11, 2011

Figure 7.3



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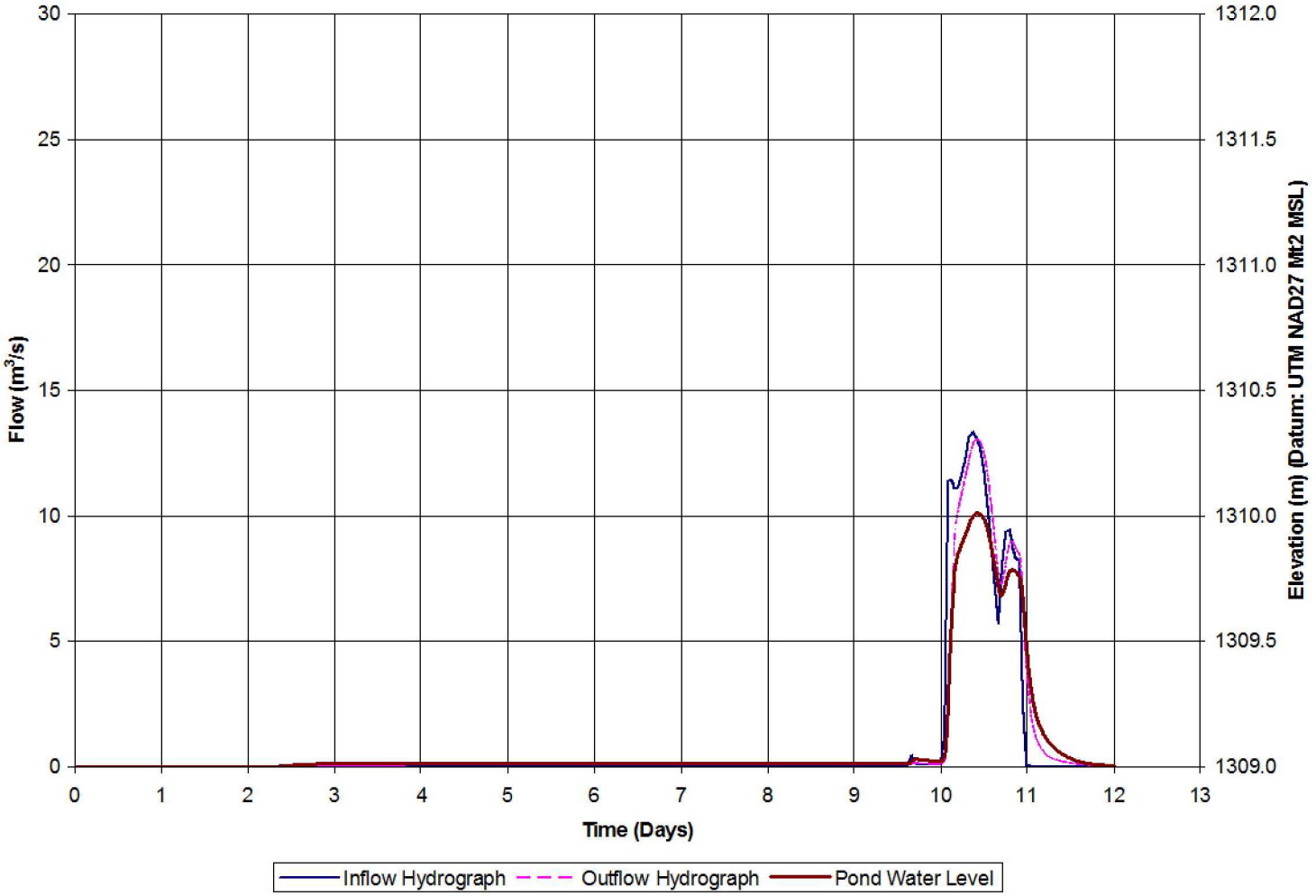
KETZA RIVER MINE
HYDROTECHNICAL ASSESSMENT

RESULTS OF FLOOD ROUTING
(SPRING CASE 1)

PROJECT NO.	DWN	CKD	REV
V15101019.201	ML	AGC	0

OFFICE	DATE
VANC	August 11, 2011

Figure 7.4



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KETZA RIVER MINE
HYDROTECHNICAL ASSESSMENT

RESULTS OF FLOOD ROUTING
(SPRING CASE 2)

PROJECT NO.	DWN	CKD	REV
V15101019.201	ML	AGC	0

OFFICE	DATE
VANC	August 11, 2011

Figure 7.5

APPENDIX A

APPENDIX A EBA'S GENERAL CONDITIONS

GENERAL CONDITIONS

DESIGN REPORT

This Design Report incorporates and is subject to these "General Conditions".

1.0 USE OF REPORT AND OWNERSHIP

This Design Report pertains to a specific site, a specific development, and a specific scope of work. The Design Report may include plans, drawings, profiles and other support documents that collectively constitute the Design Report. The Report and all supporting documents are intended for the sole use of EBA's Client. EBA does not accept any responsibility for the accuracy of any of the data, analyses or other contents of the Design Report when it is used or relied upon by any party other than EBA's Client, unless authorized in writing by EBA. Any unauthorized use of the Design Report is at the sole risk of the user.

All reports, plans, and data generated by EBA during the performance of the work and other documents prepared by EBA are considered its professional work product and shall remain the copyright property of EBA.

2.0 ALTERNATIVE 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 so stipulated in the Design Report, EBA was not retained to investigate, address or consider, and has not investigated, addressed or considered any environmental or regulatory issues associated with the project specific design.

4.0 CALCULATIONS AND DESIGNS

EBA has undertaken design calculations and has prepared project specific designs in accordance with terms of reference that were previously set out in consultation with, and agreement of, EBA's client. These designs have been prepared to a standard that is consistent with industry practice. Notwithstanding, if any error or omission is detected by EBA's Client or any party that is authorized to use the Design Report, the error or omission should be immediately drawn to the attention of EBA.

5.0 GEOTECHNICAL CONDITIONS

A Geotechnical Report is commonly the basis upon which the specific project design has been completed. It is incumbent upon EBA's Client, and any other authorized party, to be knowledgeable of the level of risk that has been incorporated into the project design, in consideration of the level of the geotechnical information that was reasonably acquired to facilitate completion of the design.

If a Geotechnical Report was prepared for the project by EBA, it will be included in the Design Report. The Geotechnical Report contains General Conditions that should be read in conjunction with these General Conditions for the Design Report.

6.0 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.

APPENDIX B

APPENDIX B OMS MANUAL

Ketza River Holdings

YUKON-NEVADA GOLD CORPORATION

KETZA RIVER GOLD MINE
OPERATION, MAINTENANCE AND SURVEILLANCE MANUAL
EXISTING TAILINGS IMPOUNDMENT

REPORT

AUGUST 2011
ISSUED FOR USE
EBA FILE: W23101051.104

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LIMITATIONS OF REPORT

This report and its contents are intended for the sole use of Yukon-Nevada Gold Corporation and their agents. EBA, A Tetra Tech Company, does not accept any responsibility for the accuracy of any of the data, the analysis, or the recommendations contained or referenced in the report when the report is used or relied upon by any Party other than Yukon-Nevada Gold Corporation, or for any Project other than the proposed development at the subject site. Any such unauthorized use of this report is at the sole risk of the user. Use of this report is subject to the terms and conditions stated in EBA's Services Agreement.

EBA, A Tetra Tech Company
150, 1715 Dickson Avenue
Kelowna, BC V1Y 9G6 CANADA
p. 250.862.4832 f. 250.862.2941

MANUAL REVISION SHEET

Revision Number	Version Date	Date Inserted	Inserted By

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To Be Updated by Owner as part of ongoing surveillance

APPENDICES

Appendix A Communication Directory
Appendix B Correspondence
Appendix C Example Dam Inspection Checklist
Appendix D Drawings
Appendix E Emergency Preparedness Plan

ACRONYMS AND ABBREVIATIONS

The following abbreviations and acronyms are used in this report.

ac ft	acre – foot
a.m.s.l.	Above Mean Sea Level
CDA	Canadian Dam Safety Association
CDSG	Canadian Dam Safety Guidelines
cfs	cubic feet per second
g	imperial gallon
ha	hectare
EPP	Emergency Preparedness Plan
km	kilometer
L	litre
m	metre
mi	mile
CSP	Corrugated steel pipe
EL	elevation
MWLAP	BC Ministry of Water, Land and Air Protection (after April 2001)
SCADA	Supervisory Control and Data Acquisition

1.0 INTRODUCTION

1.1 Preface

This manual contains operating, maintenance and surveillance instructions for the existing dam structures at the Ketza River Gold Mine owned and operated by Ketza River Holdings Ltd., a wholly owned subsidiary of Yukon-Nevada Gold Corporation (YNGC). The Ketza River Gold Mine is located in the Pelly Mountains close to the headwaters of Cache Creek, a major tributary of the Ketza River. The mine site is approximately five hours northeast by vehicle from Whitehorse, YT, as shown in Figure 1.

The structures covered by this manual include:

- Tailings Storage Facility;
- South Tailings Dam;
- North Tailings Dam;
- Cache Creek Diversion;
- Lower Subsidiary Creek Diversion; and
- Northwest Runoff Interceptor Ditch.

This Operation, Maintenance, and Surveillance Manual (OM&S Manual) is prepared primarily for the use of dam operators and immediate supervisors who are responsible for the physical operation of the dam. In addition, the instructions will permit responsible persons who are knowledgeable in reservoir operation, but unfamiliar with the conditions at this particular dam, to operate the dam and reservoir during emergency situations and at such other times when the regular operators cannot perform their normal duties.

The manual is organized into the following sections:

- Section 1 - Introduction;
- Section 2 - Description of Dams Structures;
- Section 3 – Tailings Storage Operations;
- Section 4 - Surveillance and Inspections of Dam Structures;
- Section 5 – Dams Structure Maintenance.

In the absence of Yukon specific regulations, this manual has been prepared in accordance with the requirements of the British Columbia Dam Safety Regulation (2000) (Regulation), specifically Section 3 Operation and Maintenance of a Dam.

1.2 Location of Dam Structures

The Ketza River Gold Mine is located in the Pelly Mountains close to the headwaters of Cache Creek, approximately five hours northeast by vehicle from Whitehorse, Yukon. Table 1.1 indicates the coordinates of the structures.

Table 1.1: Location of Dam Structures

Structure Name	UTM Coordinates (NTS 105, F/9, Zone 8)	Elevation, m amsl Dimensions
Tailings Pond	646000 E, 6825300 N	Water level varies, average in 2010: 1307.8
South Tailings Dam	646140 E, 6825150 N	Design Dam Crest EL. 1309.8 Lowest Dam Crest EL. 1309.354
North Tailings Dam	646100 E, 6825430 N	Design Dam Crest EL. 1,309.8 Lowest Dam Crest EL. 1309.358
Spillway	646200 E, 6825260 N	Design invert water level 1308.3 average grade 6%
Cache Creek Diversion	646250 E, 6825140 N	5 m wide, 2H:1V sideslopes
Lower Subsidiary Creek Diversion	645700 E, 6825150 N	2 m wide, 2H:1V sideslopes Twin 600 mm CSP culvert and a new 900 mm CSP culvert
Northwest Runoff Interceptor Ditch	645900 E, 6825420 N	1 m wide, 1.5H:1V sideslopes 600 mm CSP culvert

Access to the site is via mine access road from Campbell Highway. Two-wheel drive access is possible during summer months; four-wheel drive is normally required during spring, fall, and wet summer periods.

1.3 Dam Owner

Ketza River Holdings Ltd., a wholly owned subsidiary of The Yukon-Nevada Gold Corporation owns the pond, dams and related facilities.

The Owner's contact information is:

Ketza River Holdings Ltd.
c/o Yukon-Nevada Gold Corporation
900 – 688 West Hastings Street
Vancouver, BC V6B 1P1
Tel: 604.688.9427
Fax: 604.688.9426
Email: yngc@yngc.ca

105C Platinum Road
Whitehorse, YT Y1A 5M3
Tel: 867.456.4653
Fax: 867.456.4853

1.4 Authority

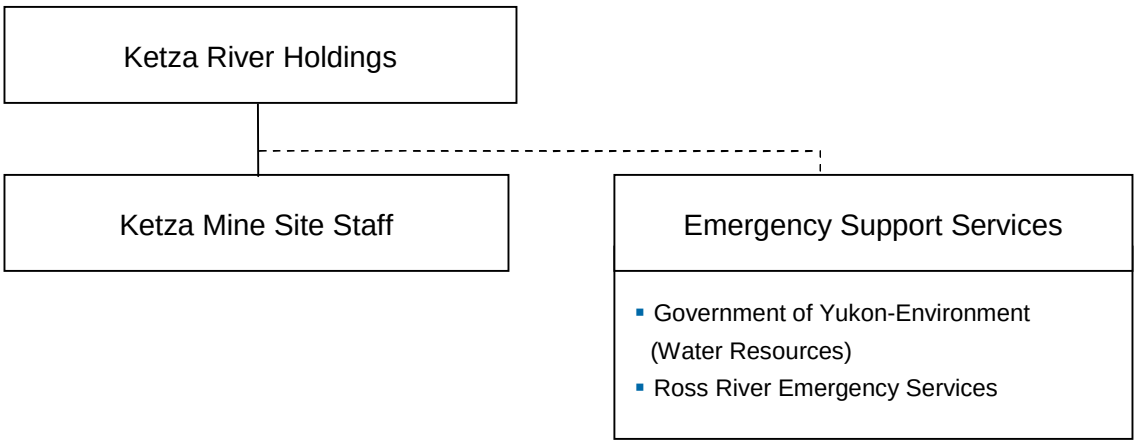
The Regulation assigns responsibility for operations and maintenance of the dams to Ketza River Holdings Ltd. During an emergency, the Ketza Mine Manager would be the Lead Responder to coordinate emergency response and work with government agencies, who would coordinate the repair, mitigation and technical aspects of the emergency response.

1.5 Operational Responsibility

Operational responsibility rests with Ketza River Holdings. Day-to-day operations and maintenance is provided by Ketza Mine site staff. Support resources during an emergency would be available from the Government of Yukon-Environment (Water Resources).

The figure below illustrates the operations organizational chart and available support resources in the event of an emergency. Current contact information for the personnel and agencies is contained in Appendix A.

Operational Responsibility



1.6 Water Licences

Yukon-Nevada Gold Corporation (YNGC) c/o Ketza River Holdings Ltd. (KRH) is currently applying for a Type A Water Licence for the Ketza mine site. The purpose of this water licence application is to allow for the continued storage of water in and discharge from the existing tailings pond. Current water use licence is: 0Z04-063.

1.7 Downstream Consequence Classification

The Regulation requires a downstream consequence classification for all dams. The Regulation classification guide considers loss of life, economic and social loss, and cultural loss factors in determining the consequence rating. Based on a review of the previous studies and results of the recent "Hydrotechnical Assessment for the Ketza River Gold Mine" completed by EBA (2011), the consequence classification for the tailings dams was established to be "High" in accordance with the 2007 CDA guideline.

1.8 Communications and Reporting

Communications regarding dam operations surveillance and maintenance shall be directed to the Government of Yukon-Environment (Water Resources). All surveillance, inspection, and maintenance reports shall be filed at the Ketza Mine office. A current communications directory is contained in Appendix A, and shall be updated annually by Ketza personnel.

1.9 Surveillance, Inspections and Reviews

Minimum inspection frequency is outlined in the Regulation. The following frequencies, shown in Table 1.2, apply.

Table 1.2: Minimum Inspection and Dams Safety Review Requirements

Item	Frequency
Site Surveillance	Weekly
Formal Inspection	Semi-Annually or Annually
Instrumentation	Per OM&S Manual
Test Operations of all Equipment	Annually
Update Communications Directory	Semi-Annually
Update OM&S Plan	Every 10 Years
Dam Safety Review	Every 10 Years, with Annual Review of Downstream Consequence Classification

Detailed surveillance and inspection procedures are described in Section 5.

1.10 Staff Training

To ensure that a dam is operated in an efficient and correct manner, the Owner is responsible for providing training to each dam operator. The objective is to acquaint the operator with the full range of operations required and dam safety procedures. The training should be specific in outlining the dam operator's responsibilities. It should also provide awareness working familiarity with all operating documents and emphasize the importance of accurate and complete record keeping. This may involve entries on forms, concise explanations in diary format, and taking photographs of conditions.

The training should provide sufficient information for the dam operator to make knowledgeable, correct, and prompt decisions concerning protection of facilities and downstream life property.

Dam operators should be familiar with the contents of this OM&S Manual, and should be trained before assuming full responsibility. This can be best accomplished in an assistant inspector position.

Training materials are available through the BC Dam Safety Regulation, Canadian Dam Safety Association, or the United States Bureau of Reclamation.

1.11 Operator and Public Safety

Dam operations personnel shall be familiar with and conform to safety regulations and procedures established by the Yukon Workers' Compensation Health and Safety.

Personnel shall carry appropriate first-aid equipment, and shall have means available to contact the operations office (radio). Operators should observe the condition of the tailing storage facility, including dams, spillway, creeks, ditches, access road and embankments.

1.12 Distribution and Revision of this Manual

Manuals shall be distributed and kept up to date by the persons or agencies listed in Table 1.3.

Table 1.3: Distribution of Manuals

Copy No.	Location	Manual Holder
1	Ketza Mine Site Offices	Mine Manager
2	YGNC Corporate Offices	Corporate Safety Officer
3	Government of Yukon-Environment (Water Resources)	Regional Manager
4	EBA, A Tetra Tech Company, Whitehorse, YK	Managing Engineer

Revisions shall be issued by the Ketza Mine Manager or delegate to the manual Holders in accordance with the schedule in section 1.10. The Ketza Mine shall maintain a master list of revisions. All Manual Holders shall note revisions added on the Manual Revision Sheet located at the front of the manual.

1.13 References

The following documentation, either obtained from EBA's previous work for the mine site or provided by YNGC, was reviewed to obtain relevant project background information:

- Canadian Dam Safety Association, Dam Safety Guidelines, 1999;
- British Columbia Dam Safety Regulation, 2000;
- AECOM, Report to Government of Yukon Water Resources Branch on Ketza Mine North Tailings Dam Toe Berm Assessment, December 2009;
- AECOM, Geotechnical Site Inspection Ketza River Gold Mine, Yukon, 2007;
- EBA, A Tetra Tech Company, Geotechnical Site Inspection Ketza River Gold Mine, Yukon, November 2010;
- EBA, A Tetra Tech Company, Hydrotechnical Assessment Ketza River Gold Mine, Yukon, February 2011;
- Golder Associates Ltd., Report to Canamax Resources Inc. on Ketza Mines Tailings Pond Operation Yukon Territories, September 1989;
- SRK Consulting Engineers and Scientists, Report to Government of Yukon, Department of Environment on Geotechnical Inspection Waste & Water Management Facilities, Ketza River Mine, Yukon Territory, September 2005;
- SRK Consulting Engineers and Scientists, Ketza River Mine Assessment, 1994;
- UMA Engineering Ltd., Geotechnical Inspections, February 2008;

- Water Resources Branch, Yukon Environment, Ketza Type A Water License Application Review Comments 2010-0080, August 26, 2010;
- Yukon Environment and Socio-economic Assessment Board, Designated Office Evaluation Report, Ketza Type A Water License Project Assessment 2010-0090, September, 2010;
- Yukon-Nevada Gold Corporation, Letter on Survey Dam Crest and Identify and Fill Areas below Design Elevation, September 2010;
- U.S. Department of Interior Bureau of Reclamation. Design of Small Dams. Water Resource Publications, LLC. 1987.

2.0 DESCRIPTION OF DAM STRUCTURES

2.1 Purpose of Tailing Impoundment and Background

The tailings impoundment was utilized by the Ketza River Gold Mine for the storage of tailings associated with processing of ore at the on-site mill. The facility was created by the construction of two dams (North and South), and the diversion of existing watercourses around the facility.

The two dams are separated by a ridge of native material. An emergency spillway has been excavated into the ridge, and it is fully contained within native material. The area covered by the impoundment at the spillway crest elevation (1309 m) is approximately 8 ha.

The tailings dams were designed by Golder Associates in 1986. The construction of the dams was completed in 1987, and tailings discharge to the impoundment commenced in 1988 (SRK 1994). As recommended in previous site inspection reports by EBA (2008), a free-draining berm was constructed in 2009 at the toe of the North Tailings Dam. The berm was designed by EBA; however, the construction was monitored by others and a completion report was prepared by AECOM in December 2009. As part of the toe berm construction, a small draw was in-filled below the toe berm.

2.2 Dam Access

The Ketza River Gold Mine is located in central Yukon, approximately 70 km south of the town of Ross River, as shown in Figure 1 and 2. Road access to the impoundment is shown in Figure 3.

The main access route from Whitehorse is as follows:

- Turn onto Alaska Hwy/Provincial Route 1 N/Provincial Route 2 N. Continue to follow Provincial Route 1 N/Provincial Route 2 N for approximately 12 km;
- Turn Right onto Provincial Route 2/Klondike Hwy/Mile 2 Mayo Rd. Continue to follow Provincial Route 2/Klondike Hwy for 166 km;
- Turn Right onto Provincial Route 4/Robert Campbell Hwy. Drive for 219 km;
- Turn Left onto Provincial Route 6. Drive for approximately 10 km to Ross River;
- From Ross River travel 40 km south along the Campbell Highway and then 40 km along the Ketza River Mine access road.

2.3 General Description of Dam Works

The North Tailings Dam has a length of approximately 210 m and is about 20 m high. The South Tailings Dam has a length of approximately 110 m and is about 10 m high. The dam crest elevation for both the North and South tailings dams ranges from a minimum of 1309.7 m to a maximum of 1310.5 m (YNGC 2011).

The emergency spillway separates the south dam from the north dam. It is assumed that the native material underlying this area is predominantly morainal sand and gravel (EBA 2010). As outlined in previous reports, the emergency spillway channel is lined with rip-rap, with a median diameter of approximately 75 mm. Based on available contour information, the average slope of the spillway chute was determined to be approximately 6%. The outlet of the spillway currently ties into a seepage channel prior to joining with the Cache Creek diversion channel.

A general arrangement plan of the Ketza River Mine site is shown in Figure 3. More details of the tailings impoundment can be found on Figure 4. As preferred by YNGC, unless noted otherwise, all elevations used in the current analysis are based on the UTM NAD27 Ht2 MSL coordinate and elevation system.

Table 2.1 provides dam works information.

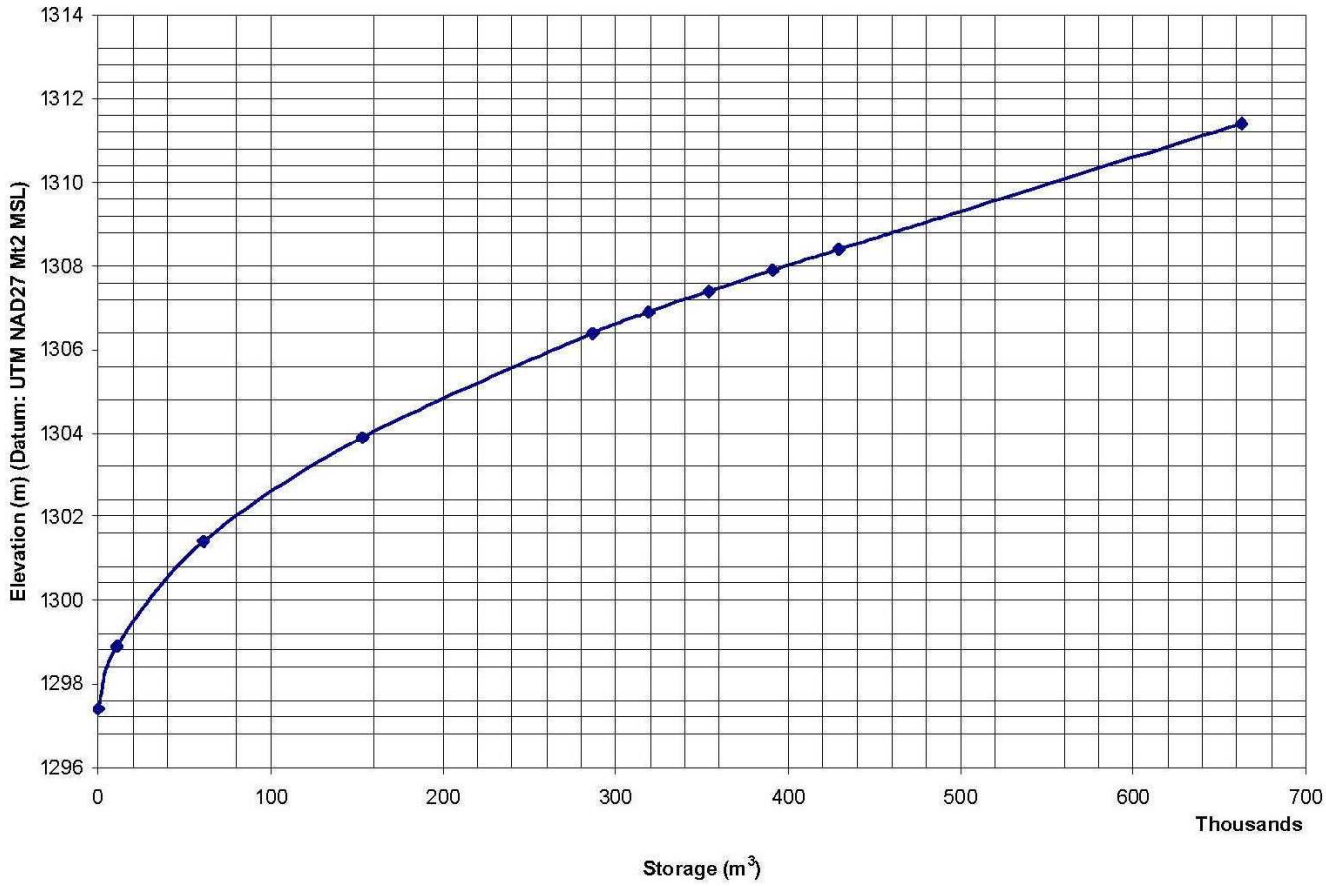
Table 2.1: Dam Works Information

Designed:	1986	**Constructed:**	1987
Structure Name:	**South Tailings Dam**		
Type:	earth embankment	**Seepage Rate:**	2.4 L/s
Crest Height:	10 m	**Crest Width:**	5 m min
Crest Length:	110 m	**Crest Elevation:**	1309.7 m min to 1310.5 m max
Upstream Slope:	2 : 1	**Downstream Slope:**	2.5 : 1
Armour Protection:	gravel	**Base Width:**	~35 m
Structure Name:	**North Tailings Dam**		
Type:	earth embankment	**Seepage Rate:**	1.6 to 2.4 L/s
Crest Height:	20 m	**Crest Width:**	5 m min
Crest Length:	210 m	**Crest Elevation:**	1309.7 m min to 1310.5 m max
Upstream Slope:	2 : 1	**Downstream Slope:**	2.5 : 1
Armour Protection:	gravel	**Base Width:**	~90 m
Structure Name:	**Spillway**		
Spill Elevation:	1,308.3 m amsl		
Flow:	**23.6 m^3/s**		
Armour Protection:	Riprap with D_{50} of 75 mm		
Slope:	6% average		
Structure Name:	**Tailings Pond**		
Watershed Area:	7 km^2		
Median Watershed Elevation:	1,630 m amsl		
Footprint:	0.08 km^2		
Capacity:	243,000 m^3		
Current Tailings Elevation:	1,308.3 m amsl		
Design Flood Elevation:	1,310.5 m amsl		

2.4 Tailings Storage Capacity

The Tailings Facility has an available storage capacity of 243,000 m3. Table 2.2 indicates storage versus reservoir water level. A reservoir elevation – storage curve is provided below.

Table 2.2: Tailings Pond Elevation – Storage Curve



2.5 Reference Drawings

Drawings of the dam and related structures at the Ketza River Gold Mine are included in Appendix D and listed in the following Table 2.3.

Table 2.3: Reference Drawings for the Ketza River Dam Structures

Drawing Title	Included in Appendix D
North Dam - Section A-A	Yes
South Dam - Section B-B	Yes
Location Plan and Key Plan	Yes
North Tailings Dam Toe Berm - Section and Detail	Yes
Tailings Pond - Site Conditions Encountered During Construction	Yes
Piezometer Details	Yes
V-Notch Weir	Yes
North and South Dam - Sections A-A and B-B	Yes
Tailings Impoundment - Site Plan	Yes
Stability Analyses – Summary of Results	Yes
North Dam Toe Buttress – Typical Section	Yes
Permanent Spillway – Section and Profile	Yes
Cache Creek – Diversion Profile M	Yes
Cache Creek – Diversion Profile N, O, & P	Yes
North Dam – Section A-A	Yes
Dam Sections B-B and C-C	Yes
Types A, B, and C Fill – Gradation Tolerances	Yes
Ditch – Typical Cross Section	Yes

2.6 Dam Instrumentation

The tailings facility includes the following instruments to monitor water levels within and below the embankments. The instrumentation also includes five surface water weirs that are used to monitor the quantity of surface water flowing into and out of the facility.

- P9007A
- P9007B
- P9007C
- P9008
- P9009
- P9610A
- P9610B
- P9611A
- P9611B
- P9611C
- P9612A
- P9612B
- P9612C
- MW10-01
- MW10-02

The location of the instruments are shown on Figure 4.

2.7 Tailings Storage Facility Design Flood

Based on a review of the previous studies and results of the current dam break analysis, the consequence classification for the tailings dams was established to be "High" in accordance with the 2007 CDA guidelines. For a dam with a High consequence classification, the Inflow Design Flood (IDF) is to be determined as 1/3 between the 1000-year event and the Probable Maximum Flood (PMF).

A flood-induced dam failure scenario either at the south or the north tailings dam was considered in the analysis. Input data requirements for the dam break scenario include parameters defining the geometry of the dam, reservoir and downstream valley, and timing of the breach. The dam breach parameters were determined from typical equations for earth embankments based on the conditions of the pond when either of the dams is overtopped. A summary of the overall dam breach parameters is provided in Table 2.4.

Table 2.4: Summary of Dam Breach Input

Parameter	Value (Note)
Type of Dam	Earth Embankment
Dam Breach Elevation (DBE)	1310.5 m (at dam crest, overtopping failure)
Final Breach Elevation	1297.4 m (at pond bottom from 2005 survey)
Volume of Reservoir at DBE	771,800 m^3 (including volume of tailings)
Surface Area of Reservoir at DBE	77,900 m^2 (at dam crest)
Final Breach Width	39 m
Non-Breach Flow	23.6 m^3/s (flow through spillway)
Breach Development Time	4.3 minutes

Natural floods with a return period of 200-year were assumed to occur during the dam breach event as a conservative approach. Overall results of the dam break analysis are presented in Table 2.5.

Table 2.5: Results of Dam Break Analysis

Distance from Dam (km)	Max Breach Flow (m^3/s)	200-year Flow (m^3/s)	Total Flow (m^3/s)	Approx. Channel Invert Elev. (m)	Max Water Elev. (m)	Max Water Depth (m)	Time to Reach Max Water Elev. (hrs)
0.00	2207	6	2213	1283.0	1288.7	5.7	0.07
0.18	2171	6	2177	1272.0	1276.7	4.7	0.08
0.72	1882	9	1891	1251.0	1256.3	5.3	0.08
6.9	1592	23	1615	1097.3	1098.2	0.9	0.37
17	1096	63	1159	1036.3	1038.3	2.0	1.2
33	783	132	915	975.4	976.2	0.8	3.2
62	775	172	946	853.4	854.0	0.6	7.9
76	767	208	975	731.5	732.3	0.7	9.6

It should be noted that the peak flow as a result of the dam breach, taking into account natural floods, varies from 2213 m^3/s at the dam to 975 m^3/s at the confluence of the Ketza River and the Pelly River. There is an attenuation of about 56% within this 76 km long study reach. In addition, the estimated times to reach the peak water elevation at the confluence of Cache Creek and the Ketza River and at the confluence of the Ketza River and the Pelly River are less than 1 hour and 9.6 hours, respectively (EBA 2011).

3.0 IMPOUNDMENT OPERATIONS

3.1 General Description of Tailings Impoundment Works

The tailings impoundment is located to the east and downstream of the mill site facilities in a natural depression at the confluence of Cache Creek and Subsidiary Creek. Bypass channels, or diversion ditches, have been constructed to divert these flows around the tailings impoundment area.

The only source of surface water ingress to the impoundment is direct precipitation within the confines of the diversion ditches. All other surface water from within the watershed is diverted around the facility and allowed to discharge to Cache Creek.

Some seepage continues to occur under and through both the North and South Dams. The quantity and quality of this seepage has been, and will continue to be, monitored. There has been no appreciable change in water quality or quantity in the last 2 years.

Water in the tailings pond is typically drained using a temporary, removable pump. It is understood that in the past water was drained via the pumphouse situated on the southwest side of the pond. Water from the pumphouse was discharged via a 150 mm line to the Cache Creek Diversion Channel (AECOM 2007). It is assumed that the permanent pump could be rehabilitated if necessary.

3.2 Operating Criteria and Limits

Key operating criteria are as follows:

Available Storage:	243,000 m^3
Maximum water level (spillway crest):	1,308.3 m

Annual operation records are to be kept on file at the Mine Site Office.

3.3 Operation of Spillway

The erosion protection requirements for the spillway, chute and its outlet were determined as part of the "Hydrotechnical Report for the Ketza River Mine" completed by EBA (2011). The current median rock size along the spillway as reported by others is 75 mm, which is not adequate to handle the design flow during the IDFs. It is recommended that the spillway and the spillway chute be lined using a 700 mm thick riprap layer with a median rock size of 410 mm underlain by a 200 mm thick granular filter layer with a median rock size of 40 mm.

The spillway must be kept clear of debris. There are no operating parts.

3.4 Operations During Peak Inflow Conditions

Peak inflow will occur during the freshet period April through June (normally in May). During this period the inflow diversion canal and spillway should be checked for erosion or blockage by ice debris.

4.0 SURVEILLANCE AND INSPECTIONS OF DAM STRUCTURES

4.1 Dam Embankment Surveillance

Operators should examine the dam embankments routinely during the summer and less frequently through the fall, spring, and winter.

Operators should be familiar with the following typical problem signs:

- Cracks on crest or slopes;
- Excessive or unusual vegetation growth on the embankments and toes;
- Debris floating or blocking the spillway channel;
- Settlement, sloughing, slides or bulges;
- Sinkholes;
- Displaced or broken down riprap armour;
- Wet areas or seepage on the downstream slopes and toes;
- Signs of burrowing animals;
- Erosion of spillway channel; and
- Spillway blockage.

These items will also be checked during scheduled dam inspections.

4.2 Tailings Pond Shoreline Surveillance

As the shoreline of impoundment is stable, landslides and sloughs should not occur. Annual examination of the shoreline after snowmelt is recommended.

4.3 Embankment Seepage Collection System

As noted, seepage is observed along the downstream toe of both dams. The current flow rate from the V-notch Weir 4 (Figure 5) is approximately 1.6 to 2.4 L/s, while seepage measured at Weir 5 is approximately 2.4L/s.

The seepage water should be examined, as well as the accumulated sediments behind the weirs for signs of fine particles in the seepage water. Any unusual increase in seepage rate or noticeable fine particles in the water must be reported to the Mine Manager and investigated immediately.

Several piezometers have been installed in the embankment to monitor seepage levels within the embankment fill. Piezometer monitoring well water elevations should be collected and reviewed at least monthly.

4.4 Dam Inspections

The Regulation requires that a formal dam inspection shall be conducted for the dam structures by the appropriate representative of the Owner on an annual basis. The formal dam structures inspections should be conducted by a qualified individual, and inspection records kept on file at Mine Office.

The inspector should take copies of previous inspection reports to the field so that comparison can be made with prior conditions while on site.

4.5 Dam Safety Review

The Regulation requires that a full Dam Safety Review be conducted every ten years. This involves collection of all available dam records, field inspections, detailed investigations, and laboratory testing. It includes a check of structural stability and operational safety of the dam, beginning with a reappraisal of basic features and assumptions. The level of detail required in a Dam Safety Review should commensurate with the importance and complexity of the dam, as well as the consequence of failure.

Dam Owners must also conduct an annual review of conditions downstream of their dam and notify a dam safety officer if the downstream consequence classification level increases.

5.0 DAM STRUCTURES MAINTENANCE

It is the responsibility of the dam Owner to properly maintain all of the components of the facility. A program of regular maintenance may prevent potential problems from occurring.

The purposes of a regular preventive dam maintenance program are to:

- Maximize assurance of a safe dam;
- Maximize assurance of uninterrupted service for the dam and tailings pond;
- Reduce long-term maintenance costs;
- Minimize the risk of an emergency situation occurring; and
- Maximize the useful life of the dam and components.

The recommended dam maintenance program consists of:

- Scheduled maintenance activities – to be conducted o a scheduled basis to ensure proper operation of components and to prevent long-term degradation of the dam; and
- Unscheduled or extraordinary maintenance activities – that will usually result from observations during a dam inspection / surveillance.

Records of all dam maintenance activities should be filed at the Mine Office.

5.1 Scheduled Maintenance Activities

Table 5.1 indicates scheduled maintenance activities for the dam structures.

Table 5.1: Scheduled Maintenance Activities for the Dam Structures

Component	Activity	Frequency
Tailings Pond	Water level readings.	monthly
	Intake inspection and repair of any winter damage.	annual, spring
South and North Dams	Piezometer readings. Weir 4 and 5 flow rate readings.	monthly
	Removal of trees and shrub growth in embankment and crest areas.	annual, fall
	Survey monuments installation on the crests and downstream slopes; survey monuments readings. Crest inspection, riling and erosion repair. Visual inspection if of slopes instability and erosion. Weir erosion repair.	6 months, spring and fall
Spillway	Spillway channel debris clearing.	annual, spring
Cache Creek Diversion	Cache Creek weir inspection and flow rate readings. Channel and banks inspection.	annual, spring
Lower Subsidiary Creek Diversion	Lower Subsidiary Creek weir inspection and flow rate readings. Channel and banks inspection.	annual - fall
	Inspection of the culverts along the channel.	monthly
Northwest Runoff Interceptor Ditch	Inspection of the culverts along the channel.	monthly

5.2 Unscheduled or Extraordinary Maintenance

Unscheduled or extraordinary maintenance items will be identified during dam structures surveillance or inspection activities.

Such maintenance items may include, but not limited to:

- Repair of the two areas of instability within Cache Creek Diversion;
- Repair of the piezometers on the downstream slope of north and south dams;
- Repair failed rip rap within the spillway channels;
- Embankment repairs, such as burrow areas and investigations of problem indicators; and
- Maintaining the access road surface and drainage ditches.

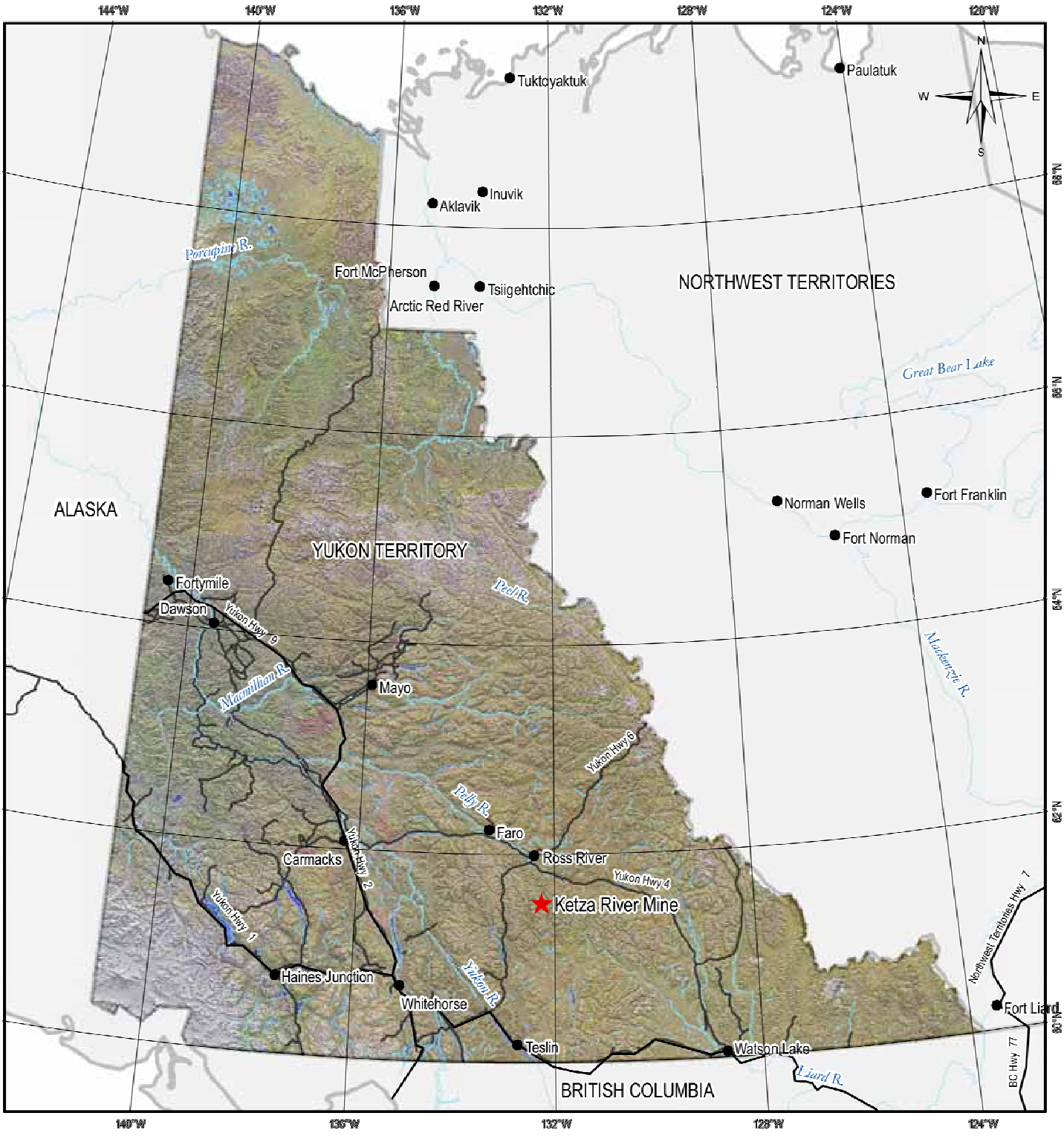
5.3 Emergency Preparedness Plan

If a dam is designed according to sound engineering principles and is well constructed and maintained, the possibility of failure is extremely remote. If, however, potential failure of a dam poses a hazard to life and property, the dam owner must have an emergency preparedness plan to deal with any potential problems.

For this purpose, an Emergency Preparedness Plan is included in Appendix E.

FIGURES

Figure 1 Site Location
Figure 2 Regional Map
Figure 3 Location Map and Site Plan
Figure 4 General Site Arrangement Plan
Figure 5 Tailings Impoundment Site Plan



Scale: 1:6,000,000

100 50 0 100

Kilometres

NOTES

Base data source: ESRI, Government of Yukon

LEGEND

- Site Location
- Cities
- Waterbodies
- Roads
- Political Boundaries

CLIENT

Yukon-Nevada Gold Corp.

KETZA RIVER GOLD MINE, TAILINGS STORAGE FACILITY, OMS MANUAL

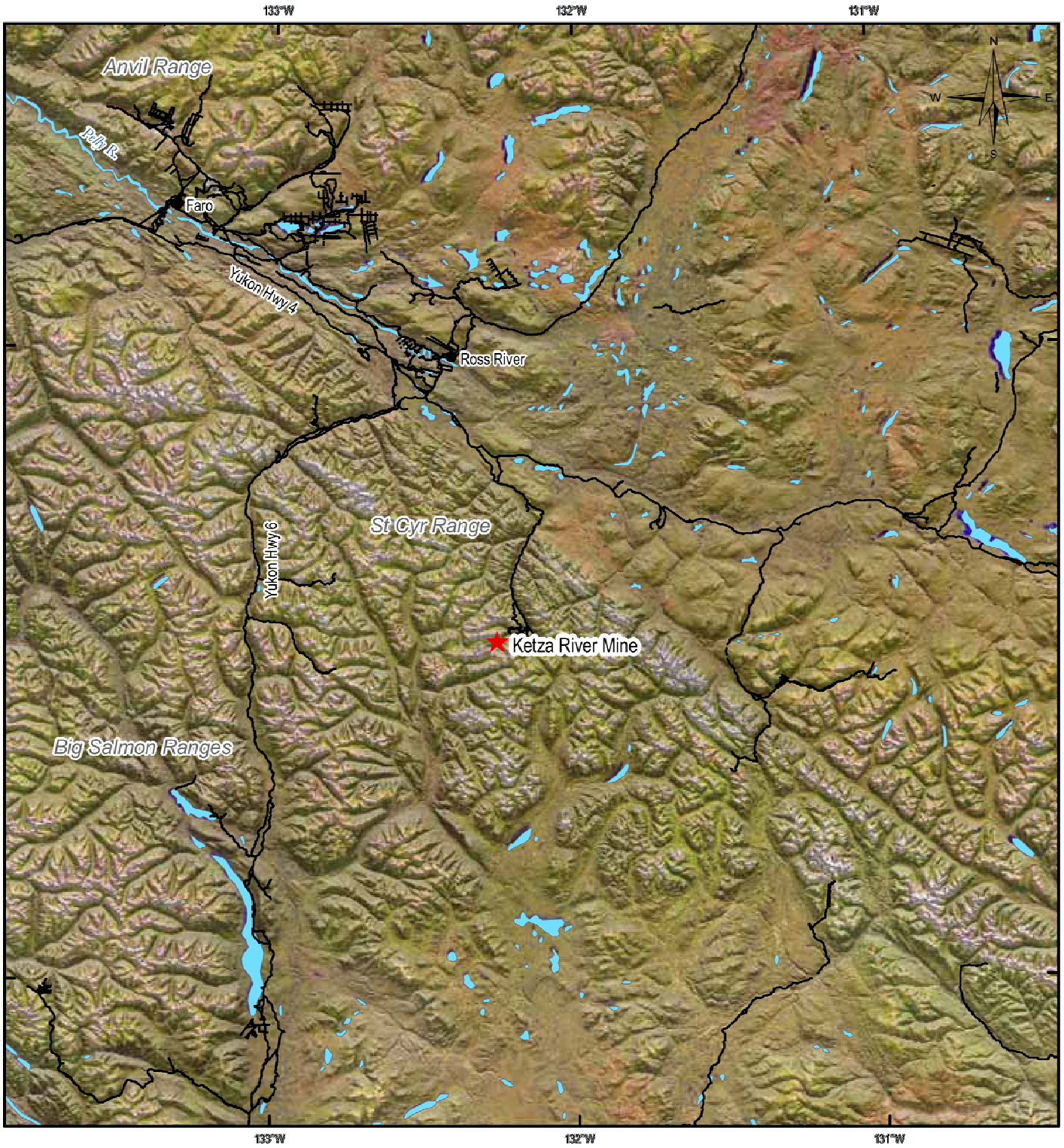
SITE LOCATION

eba A TETRA TECH COMPANY

PROJECT NO.	DWN	CKD	REV
W23101051.104.008	LM	MJL	0

OFFICE	DATE
EBA-KELOWNA	April 27, 2011

Figure 1



LEGEND

- Site Location
- Roads
- Waterbodies

NOTES

Base data source: ESRI, Government of Yukon

CLIENT

Yukon-Nevada Gold Corp.

KETZA RIVER GOLD MINE, TAILINGS STORAGE FACILITY, OMS MANUAL

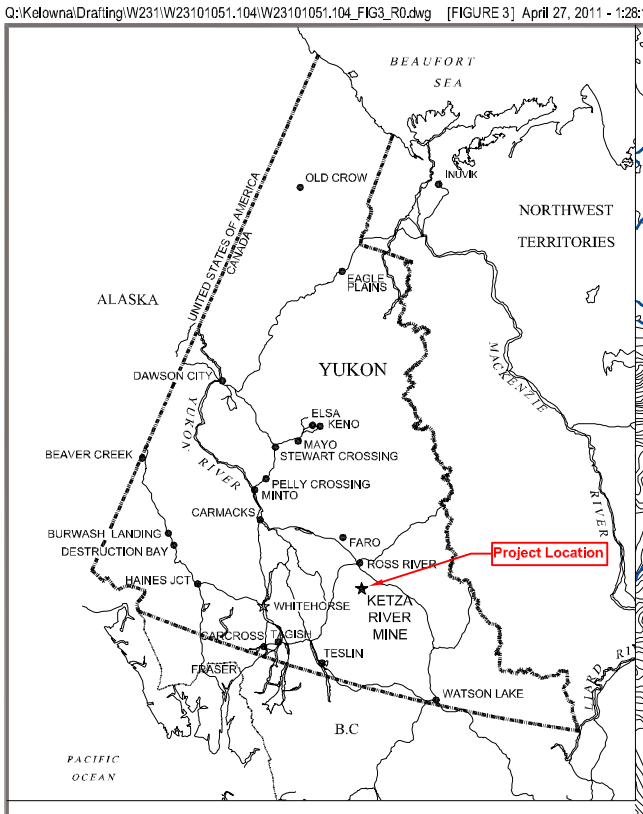
REGIONAL MAP

eba A TETRA TECH COMPANY

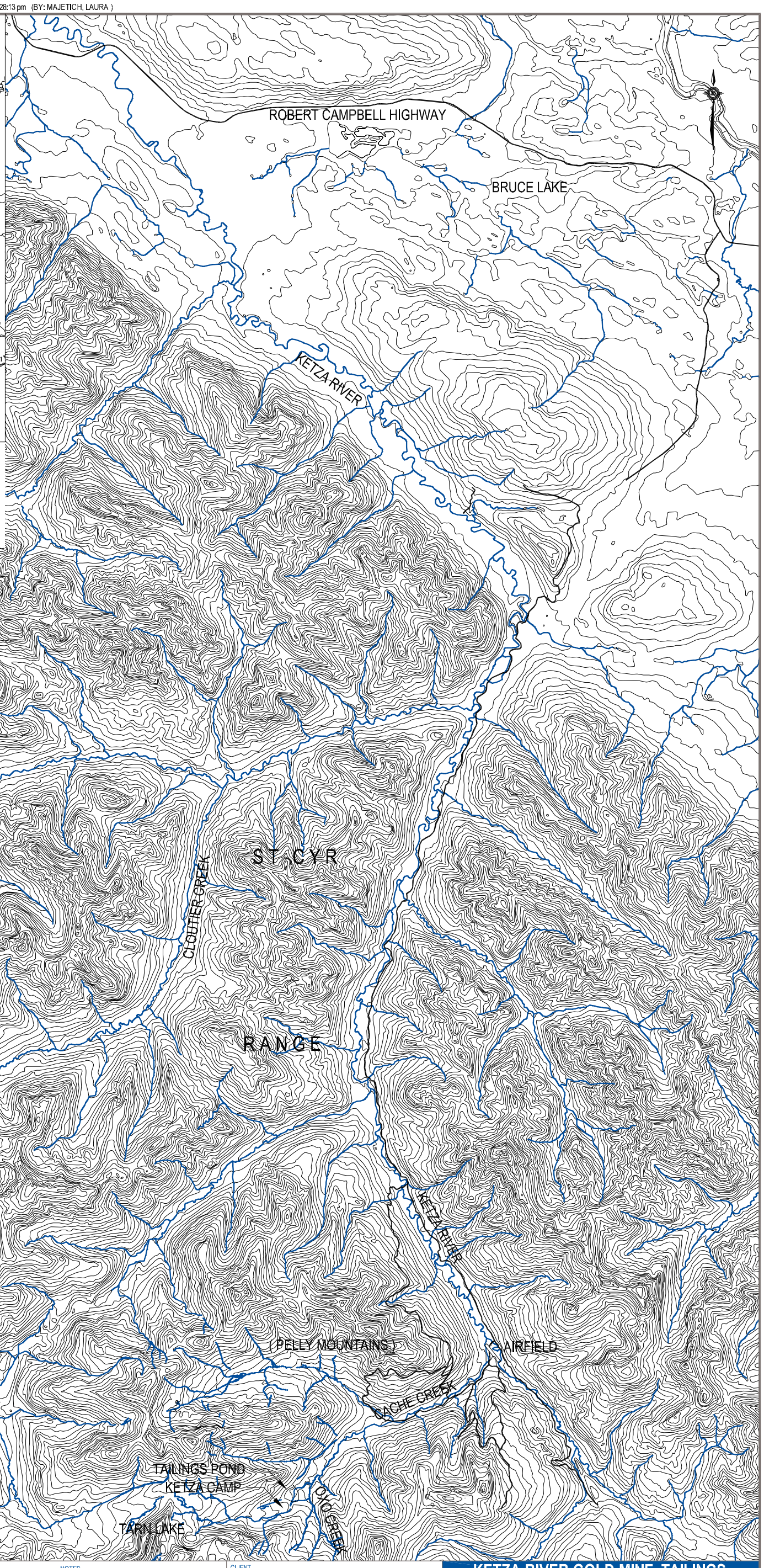
PROJECT NO.	DWN	CKD	REV
W23101051.104.008	LM	MJL	0

OFFICE	DATE
EBA-KELOWNA	April 27, 2011

Figure 2



GENERAL LOCATION MAP



LEGEND

ROAD

RIVER

0 50 000

Scale: 1: 100 000 (metres)

NOTES

BASE DATA: 1:50,000 NTS NAD 83 MSL

CONTOUR INTERVAL: 100ft

CLIENT

Yukon-Nevada Gold Corp.

A TETRA TECH COMPANY

KETZA RIVER GOLD MINE, TAILINGS STORAGE FACILITY, OMS MANUAL

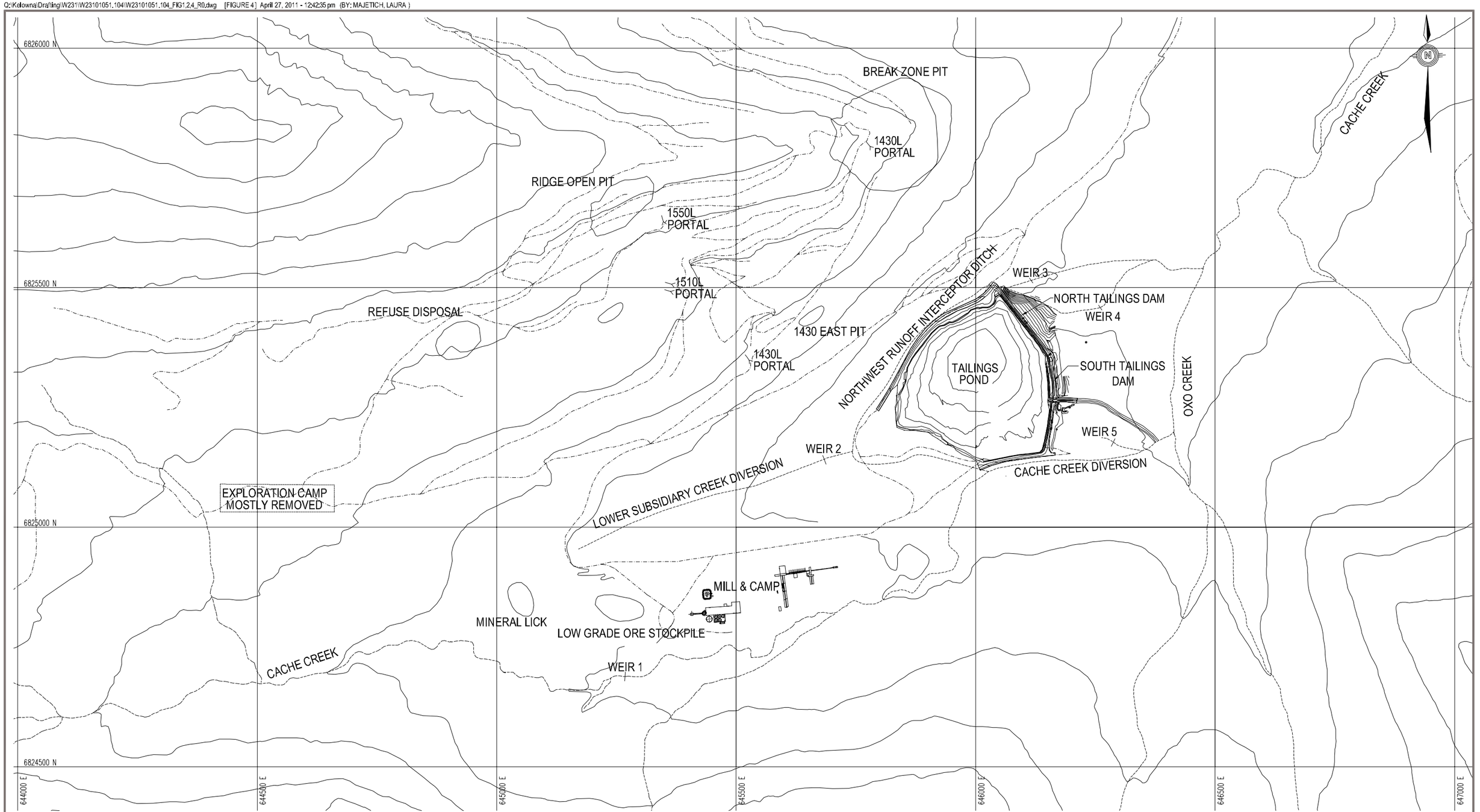
LOCATION MAP AND SITE PLAN

PROJECT NO.	DWN	CKD	REV
W23101051.104.008	LM	MJL	0

OFFICE	DATE
EBA-KELOWNA	April 27, 2011

Figure 3

Q:\Kelowna\Drafting\W231\W23101051.104\W23101051.104_FIG1,2,4_R0.dwg [FIGURE 4] April 27, 2011 - 12:42:35 pm (BY: MAJETICH, LAURA)



LEGEND

- PORTAL
- ROADWAY
- WATERCOURSE

0 200 500 1000 metres

SCALE = 1 : 7,500

CLIENT

Yukon-Nevada Gold Corp.

KETZA RIVER GOLD MINE, TAILINGS STORAGE FACILITY, OMS MANUAL

GENERAL SITE ARRANGEMENT PLAN

eba A TETRA TECH COMPANY

PROJECT NO.	DWN	CKD	REV
W23101051.104.008	LM	MJL	0

OFFICE	DATE
EBA-KELOWNA	April 27, 2011

Figure 4

600mm DIA CSP CULVERT
WEIR 3
NORTHWEST RUNOFF INTERCEPTOR DITCH
P90 - 10A & 10B
P89 - 1
P96 - 11A, 11B, 11C
WEIR 4
NORTH TAILINGS DAM
P89 - 6A & 6B
TAILINGS POND
P90 - 8
P90 - 9
OXO CREEK
P89-5
EMERGENCY SPILLWAY
P96 - 12B & 12C
P96 - 12A
SOUTH TAILINGS DAM
P89-4
P90 - 7A, 7B & 7C
P98 - 3
WEIR 5
DIVERSION
LOWER SUBSIDIARY CREEK
WEIR 2
2 X 600mm DIA CSP CULVERTS
NEW 900mm DIA CSP CULVERT
CACHE CREEK SOUTH DIVERSION
INSTABILITY AREA #1
INSTABILITY AREA #2
1298.9
1301.4
1303.9
1306.4
1308.9
6825500 N
6825400 N
6825300 N
6825200 N
6825100 N
645600 E
645700 E
645800 E
645900 E
646000 E
646100 E
646200 E
646300 E
646400 E
646500 E
646600 E

LEGEND

- P89 - 3 PIEZOMETER (INSTALLED 1989)
- P96 - 12A MONITORING WELL (INSTALLED 1996)
- ROADWAY
- WATERCOURSE
- TOE BERM (CONSTRUCTED 2009)

0 100
Scale: 1: 2 500 (metres)

NOTES
BASE DATA: UTM NAD 27 HI2 MSL

CLIENT
Yukon-Nevada Gold Corp.

KETZA RIVER GOLD MINE, TAILINGS STORAGE FACILITY, OMS MANUAL

TAILINGS IMPOUNDMENT SITE PLAN

eba A TETRA TECH COMPANY

PROJECT NO.	DWN	CKD	REV
W23101051.104.008	AD	MJL	0

OFFICE: EBA-KELOWNA
DATE: April 27, 2011

Figure 5

PHOTOGRAPHS

APPENDIX A

APPENDIX A COMMUNICATION DIRECTORY

APPENDIX A – COMMUNICATION DIRECTORY

▪ Yukon-Nevada Gold Corporation	604-688-9427
▪ Ketza Mine Manager	778-785-3193
▪ Yukon Highway Dept, Risk Management	867-667-5710
▪ RCMP, Watson Lake	867-536-5555
▪ Yukon Client Services and Inspections	867-456-3882
▪ Yukon Energy, Mines & Resources Inspector	867-667-3156
▪ Yukon Water Resources Inspector	867-667-3120
▪ Environment Canada Inspector	867-667-3470
▪ Department of Fisheries and Oceans	867-393-6722
▪ First Nations	876-969-2832 (RRDC)
	867-536-7901 (LFN)

APPENDIX B

APPENDIX B CORRESPONDENCE

APPENDIX C

APPENDIX C EXAMPLE DAM INSPECTION CHECKLIST

Deficiency Checklist

Are there any apparent:	Yes	No	Comment
Cracks			
embankment cracks on the crest?	Y	N	
embankment cracks on the u/s slope?	Y	N	
embankment cracks on the d/s slope?	Y	N	
Vegetation growth and debris			
excessive vegetation growth on the embankment?	Y	N	
floating debris?	Y	N	
vegetation or debris blocking the spillway channel?	Y	N	
Structural problems			
settlement on the crest?	Y	N	
slough, slides, or bulges on the u/s slope?	Y	N	
slough, slides, or bulges on the d/s slope?	Y	N	
slough, slides, or bulges on the reservoir shore?	Y	N	
slough, slide, or erosion of the spillway channel?	Y	N	
sinkhole on crest?	Y	N	
sinkhole on u/s slope?	Y	N	
sinkhole on d/s slope?	Y	N	
displaced or broken down rip rap armor ?	Y	N	
Seepage			
wet areas or seepage on the d/s slope or toe?	Y	N	
ponded water at the downstream toe?	Y	N	
wet areas or seepage along d/s abutments?	Y	N	
Animal Activity			
signs of livestock traffic across dam embankment?	Y	N	
rodent burrows in dam embankment?	Y	N	
beaver dams in reservoir or across spillway channel?	Y	N	
Outlet Problems			
outlet operating problems?	Y	N	
deterioration of the outlet conduit?	Y	N	
Spillway Problems			
spillway blockage?	Y	N	
channel blockage?	Y	N	
inadequate capacity?	Y	N	

Piezometer Readings

#	Piezometer	Date Recorded	Collar Elevation (m)	Casing Stickup (m)	Depth to Water (m)	Water Elevation (m)	Comments
1	P89-1						
2	P89-3						
3	P89-4						
4	P89-5						
5	P89-6A						
6	P89-6B						
7	P90-7A						
8	P90-7B						
9	P90-7C						
10	P90-8						
11	P90-9						
12	P90-10A						
13	P90-10B						
14	P96-10A						
15	P96-10B						
16	P96-11A						
17	P96-11B						
18	P96-11C						
19	P96-12A						
20	P96-12B						
21	P96-12C						
22	MW10-01						
23	MW10-02						

Inspection Checklist

Are the following components of your dam in satisfactory condition? (Circle Yes or No)			
Embankment	**Yes**	**No**	**Comments**
U/S Slope	**Y**	**N**	
Crest	**Y**	**N**	
D/S Slope	**Y**	**N**	
D/S Toe	**Y**	**N**	
Drains	**Y**	**N**	
Spillway			
Debris boom	**Y**	**N**	
Entrance	**Y**	**N**	
Sill	**Y**	**N**	
Apron	**Y**	**N**	
Walls	**Y**	**N**	
Channel	**Y**	**N**	
Channel Slopes	**Y**	**N**	
Gates	**Y**	**N**	
Are any of the following potential problem indicators found? (Circle Yes or No)			
Embankment	**Yes**	**No**	**Comments**
Seepage	**Y**	**N**	
External Erosion	**Y**	**N**	
Cracks	**Y**	**N**	
Settlement	**Y**	**N**	
Sloughing / Slides	**Y**	**N**	
Animal Activity	**Y**	**N**	
Excessive Growth	**Y**	**N**	
Excessive Debris	**Y**	**N**	
Spillway	**Yes**	**No**	
Seepage	**Y**	**N**	
External Erosion	**Y**	**N**	
Cracks	**Y**	**N**	
Settlement	**Y**	**N**	
Sloughing / Slides	**Y**	**N**	
Animal Activity	**Y**	**N**	
Excessive Growth	**Y**	**N**	
Excessive Debris	**Y**	**N**	

Dam Inspection Checklist

Infrastructure	Status		Comments or Concerns
	OK	CONCERN	
1) North Tailings Dam			
a) Crest	☐	☐	
b) Upstream Slope	☐	☐	
c) Downstream Slope	☐	☐	
d) Downstream Toe	☐	☐	
e) Drains	☐	☐	
f) Impoundment bottom	☐	☐	
g) Underdrains	☐	☐	
h) Dam perimeter road	☐	☐	
2) South Tailings Dam			
a) Crest	☐	☐	
b) Upstream Slope	☐	☐	
c) Downstream Slope	☐	☐	
d) Downstream Toe	☐	☐	
e) Drains	☐	☐	
f) Impoundment bottom	☐	☐	
g) Underdrains	☐	☐	
h) Dam perimeter road	☐	☐	
3) Emergency Spillway			
a) Debris boom	☐	☐	
b) Entrance	☐	☐	
c) Sill	☐	☐	
d) Apron	☐	☐	
e) Walls	☐	☐	
f) Channel	☐	☐	
g) Channel Slopes	☐	☐	
h) Gates	☐	☐	
4) Tailings Discharge			
a) Spigot Outlet(s)	☐	☐	
b) Pipeline	☐	☐	
c) Tailings Beach	☐	☐	
5) Diversion Ditches			
a) Northwest Runoff Interceptor Ditch	☐	☐	
b) Cache Creek Diversion	☐	☐	
c) Lower Subsidiary Creek Diversion	☐	☐	

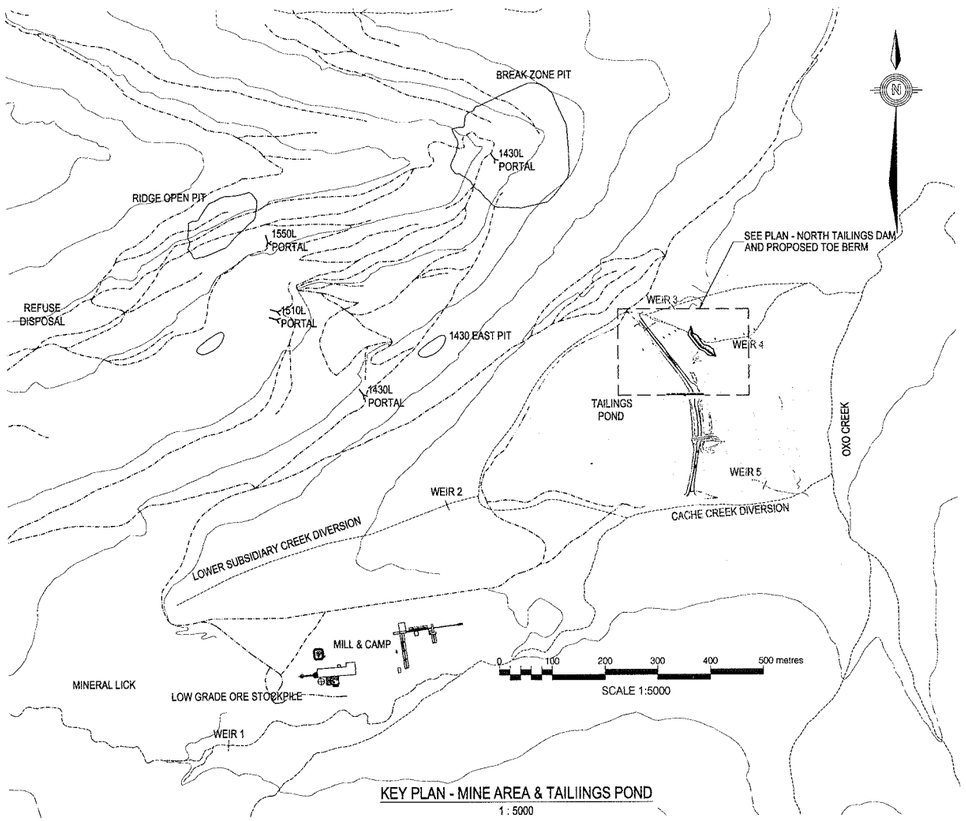
Weir Inspection

Weir	Date of Inspection	Flow (L/s)	Comments
1			
2			
3			
4			
5			

APPENDIX D

APPENDIX D DRAWINGS

LOCATION PLAN - KETZA RIVER MINE
1 : 4,000,000



KEY PLAN - MINE AREA & TAILIINGS POND
1 : 5000

LEGEND
ALL COORDINATES ARE REFERRED TO UTM NAD27 DATUM
- P89-1 PIEZOMETER (INSTALLED 1989)
- P96-11A MONITORING WELL (INSTALLED 1996)
- ROAD
- WATER COURSE
- PORTAL

DRAWING No	DRAWING TITLE	DATE	REV
REFERENCE DRAWINGS			

No.	DESCRIPTION	DATE	APPROVED
0	ISSUED FOR USE	APR 07/08	CJD
A	ISSUED FOR REVIEW	DEC 04/07	CJD
REVISION			

CLIENT
Ketza River Holdings

PERMIT

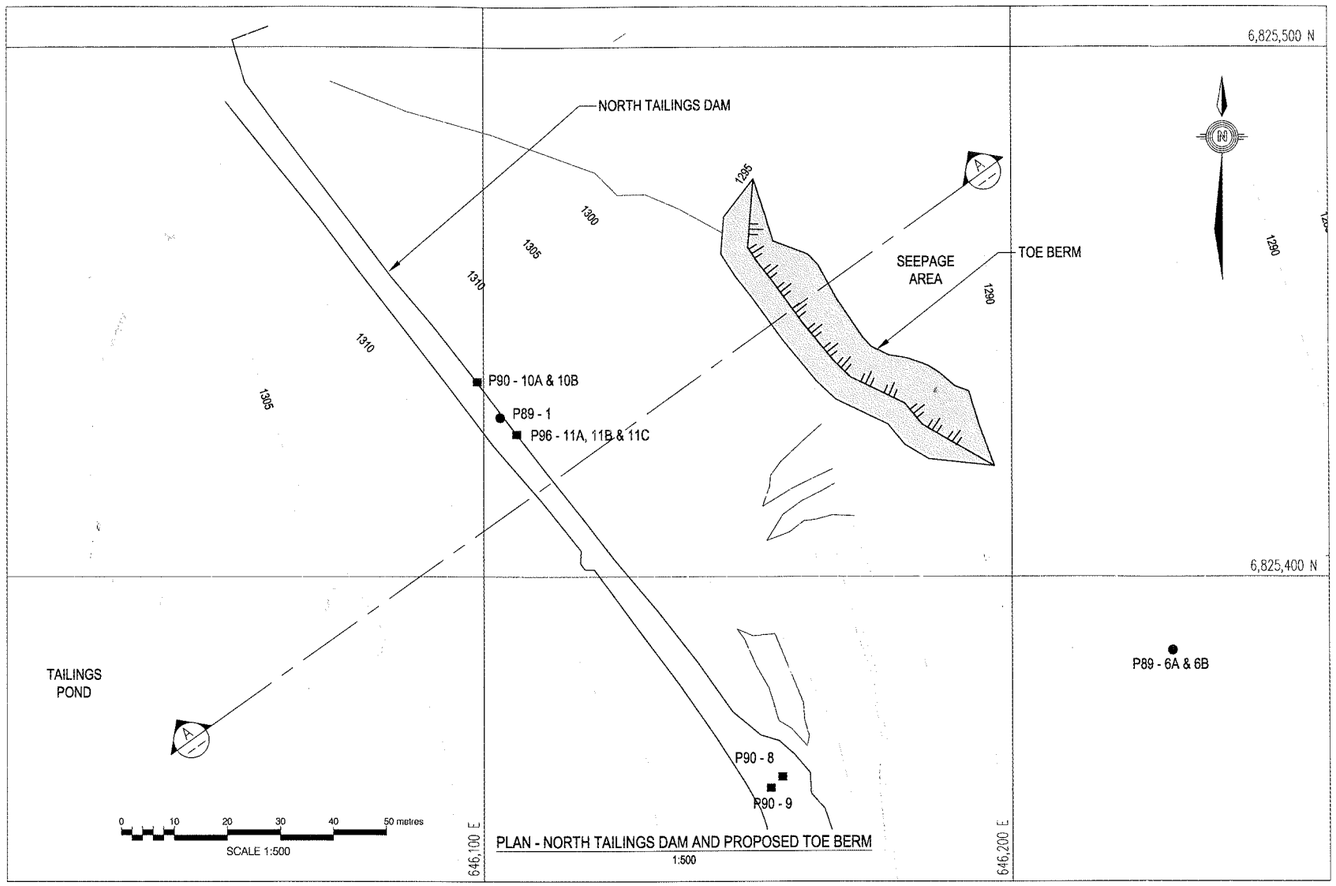
PROFESSIONAL SEAL

EBA Engineering Consultants Ltd.

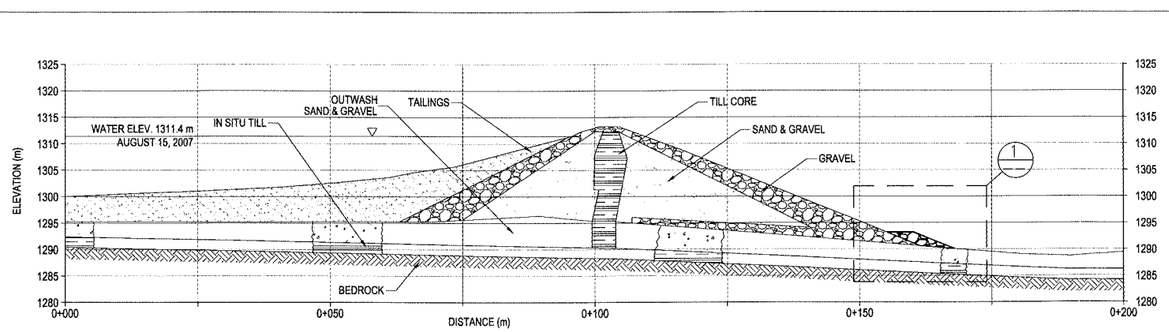
North Dam Toe Berm
Ketza River Gold Mine, YT

Location Plan and Key Plan

PROJECT NO./FILE NO	DWN	CKD	REV	DRAWING NO.
W14101051 W14101051 Fig_ND-TB-01 rev 0.dwg	KJT	CJD	0	ND-TB-01
OFFICE: EBA-WHSE	DATE: April 7, 2008			



PLAN - NORTH TAILINGS DAM AND PROPOSED TOE BERM
1:500



A NORTH DAM SECTION
1:500

DEFINITIONS
1. CONTRACTOR: The general contractor responsible for construction work.
2. ENGINEER: The EBA Engineering Consultants Ltd. (EBA) representative on site during construction or related activities.
3. OWNER: Yukon - Nevada Gold Corp.
4. SITE: The area in which construction of the Toe Berm or related activity is occurring.
5. UNSUITABLE: Not meeting the requirements stated in these drawings or not receiving the Engineers approval.

FILL MATERIALS
1. No material of any type shall be borrowed or excavated without the Owner's prior approval.
2. Pits and quarries shall be maintained and managed in accordance with the requirements set out in the Owner's Land Use and Quarry permits.
3. The Toe Berm fill shall be obtained from sources approved by the Owner, provided the final product meets the specified requirements.
4. Parent rock from which all fill materials are derived shall consist of sound, hard, durable material free from soft, thin, elongated or laminated particles and shall contain no unsuitable substances. The potential quarry source shall be approved by the Engineer.
5. Quarry source for Toe Berm fill shall be inspected by the Engineer throughout construction to ensure the Toe Berm fill meets the requirements stated in these drawings.
6. Toe Berm fill shall consist of hard, durable particles, shall be free of roots, top soil, and deleterious material and shall have the following particle size distribution:

TOE BERM FILL GRADATION	
SIEVE SIZE (mm)	% PASSING
300	100
200	60-100
100	25-75
50	15-45
25	5-25
5	0-10

7. Samples of the Toe Berm fill will be evaluated from time to time during construction to ensure the material gradation meets these specifications. A minimum of three samples per 1000 m³ of material placed shall be collected and tested for particle size distribution. Additional testing may be conducted at the discretion of the Engineer.

FILL PLACEMENT
1. Construction shall be performed in accordance with the best modern practice and with equipment best adapted to the work being performed. Embankment materials shall be placed so that each zone is homogeneous; free of stratifications, ice chunks, lenses or pockets; and layers of unsuitable material.
2. No fill material shall be placed on any part of the foundation until it has been prepared, as specified here, and approved by the Engineer. Placement of fill material shall conform to the lines, grades, and elevations shown in these drawings.
3. Toe Berm construction shall not proceed when work cannot be performed in accordance with these requirements. Any part of the Toe Berm that has been damaged by the action of rain, snow, or any other cause shall be removed and replaced with the appropriate material conforming to specifications stated here.
4. Stockpiling, loading, transporting, placing, and spreading shall be carried out in such a manner to avoid segregation. Segregated materials shall be removed and replaced with the materials meeting the specifications stated here or as required by the Engineer.
5. The Contractor shall remove all debris, vegetation or any other material not conforming to the requirements stated here. The Contractor shall dispose of these materials in an area and manner approved by the Owner.
6. Estimated quantities for the in-place material required to construct the Toe Berm are listed here. These quantities are in-place volumes and calculated to neat design lines. These quantities account only for the construction of what is shown on the Construction Drawings.

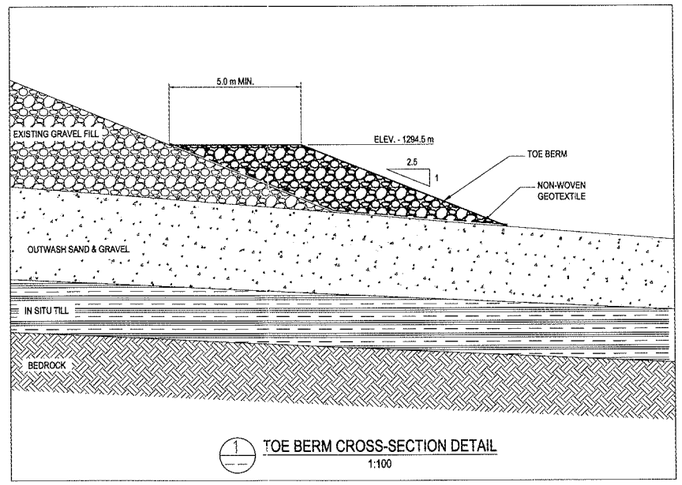
MATERIAL QUANTITY ESTIMATES
Toe Berm Fill - 900 m³
Geotextile - 900 m²*
*indicates 15% extra to account for overlap and waste

7. The Toe Berm fill shall be placed to the design elevation in lifts no greater than 600 mm in uncompacted thickness.
8. Moisture conditioning and compaction will be required. The optimum compaction method and procedure must be determined at the commencement of construction using proof roll and control strip tests, to demonstrate optimum compaction. Final compaction acceptance is at the discretion of the Engineer.

GEOTEXTILE
1. The geotextile shall be non-woven and have a weight of at least 542 g/m² (16 oz/yd²). The manufacturer shall, prior to shipment of materials, provide to the Engineer a signed manufacturing certification that materials to be shipped to site have test values that meet or exceed the following requirements.

PHYSICAL PROPERTY	MINIMUM AVERAGE ROLL VALUE (weakest principal direction)	
Thickness - Typical	4.1 mm	(165 mil)
Grab Tensile Strength	1690 N	(380 lbs)
Elongation at Failure	50%	
Trapezoidal Shear Strength	644 N	(145 lbs)
Puncture	1070 N	(240 lbs)
Apparent Opening Size	150 µm	(#100 sieve)
Weight - Typical	542 g/m²	(16 oz/yd²)

2. Any visible damage to the shipment of geotextile shall be noted on the freight receipt and project records.
3. Storage of geotextile rolls on site shall be in a secure location that will minimize exposure to the elements, sunlight and physical damage.
4. The geotextile should be placed with a minimum overlap of 300 mm (12") and connected at the seam by heat bonding or alternate method approved in advance by the Engineer. Horizontal seams should be kept to a minimum on the embankment slope. If horizontal seams are unavoidable, the overlap shall be capped with a 600 mm (24") wide strip centered on the seam and heat bonded to the underlying material on each side.
5. Any tears or holes made in the geotextile should be repaired by placing a patch of the same geotextile over the defect and heat bonded to the underlying material. The patch should extend at least 300 mm (12") beyond the defect in all directions.



1 TOE BERM CROSS-SECTION DETAIL
1:100

LEGEND
ALL COORDINATES ARE REFERRED TO UTM NAD27 DATUM
● P89-1 PIEZOMETER (INSTALLED 1989)
■ P96-11A MONITORING WELL (INSTALLED 1996)
ROAD
WATER COURSE

REFERENCE DRAWINGS

DRAWING No	DRAWING TITLE	DATE	REV

No	DESCRIPTION	DATE	APPROVED
0	ISSUED FOR USE	APR 07/08	CJD
A	ISSUED FOR REVIEW	DEC 04/07	CJD

REVISION

CLIENT
Ketza River Holdings

PERMIT

PROFESSIONAL SEAL

EBA Engineering Consultants Ltd.

North Dam Toe Berm
Ketza River Gold Mine, YT
North Tailings Dam Toe Berm
Section and Detail

PROJECT NO./FILE NO.	DSN	CKD	REV	DRAWING NO
W14101051 W14101051 Fig_ND-TB-01 rev 0.dwg	KJT	CJD	0	ND-TB-02
OFFICE: EBA-WHSE	DATE: April 7, 2008			

G:\Projects\W14101051\Engineering\Mine\Drawings\W14101051 Fig_ND-TB-01 rev 0.dwg 2008-04-07 14:11:13 Zoltan Jones

SITE CONDITIONS ENCOUNTERED DURING CONSTRUCTION

Figure 3

5500N

6000E

6500E

P1 - P6 Piezometer Holes

Permafrost encountered during construction

NORTH RUNOFF INTERCEPTOR DITCH

NORTHERN TAILINGS DAM

Bedrock (0 to 3.m below Ground Surface)

APPROX. LOCATION OF NEW ROAD

Maximum Operational Pond Elevation 1312.0m

1312

NORTHERN SEEPAGE POND

Sampling location

Permafrost encounted during construction

LOWER DIVERSION DITCH FOR SUBSIDIARY CREEK/ RUNOFF INTERCEPTOR DITCH

SEEPAGE BARRIER

Dyked containment area

SEEPAGE BARRIER

Spillway

SOUTHERN TAILINGS DAM

5000N

Sampling location

Bedrock encountered in base of Cache Creek Diversion Ditch

MAIN DIVERSION DITCH FOR CACHE CREEK

CACHE CREEK

Bedrock outcropping in Cache Creek

Permafrost encountered during construction

6000E

5000N

6500E

5500N

LEGEND:

- Seepage Areas
- Bedrock
- Permafrost
- Tailings Discharge Areas
- ③ Priority
- Winter Tailings Discharge

50 0 50 100

SCALE 1:2000

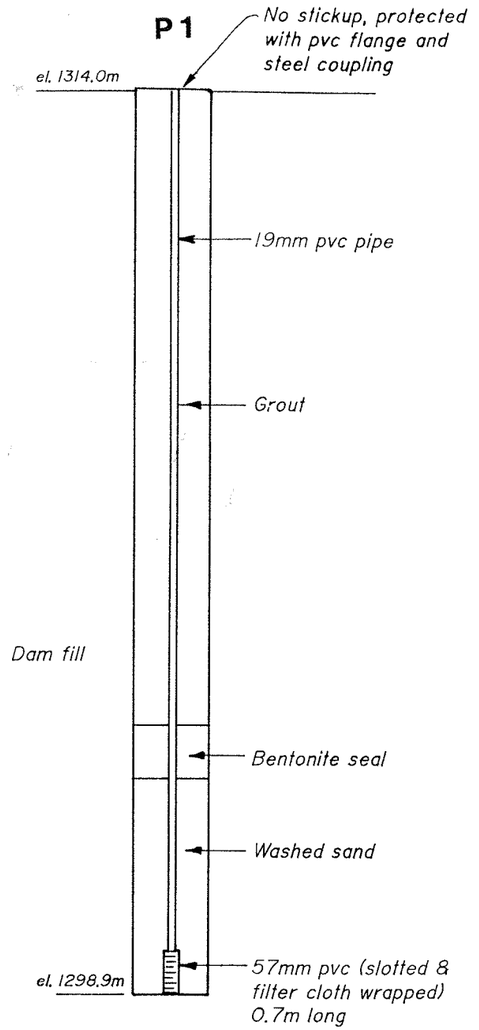
Reference: Dwg from Canamax Resources Inc "Ketza River Project, Yukon", titled "Plan of Topographic Survey of Proposed Plantsite & Tailings Containment Areas" Dated Dec. 31/85

CANAMAX RESOURCES INC.	
KETZA RIVER PROJECT, YUKON	
TAILINGS POND SITE	
Golder Associates	Ker Priestman & Associates Ltd.
Orocon Inc.	Sigma Resource Consultants Ltd.
Drawn: GA	Reviewed: AW / Rev.: 1
Date: Oct. '86	Scale: 1:2000 / Figure 862-1054-2

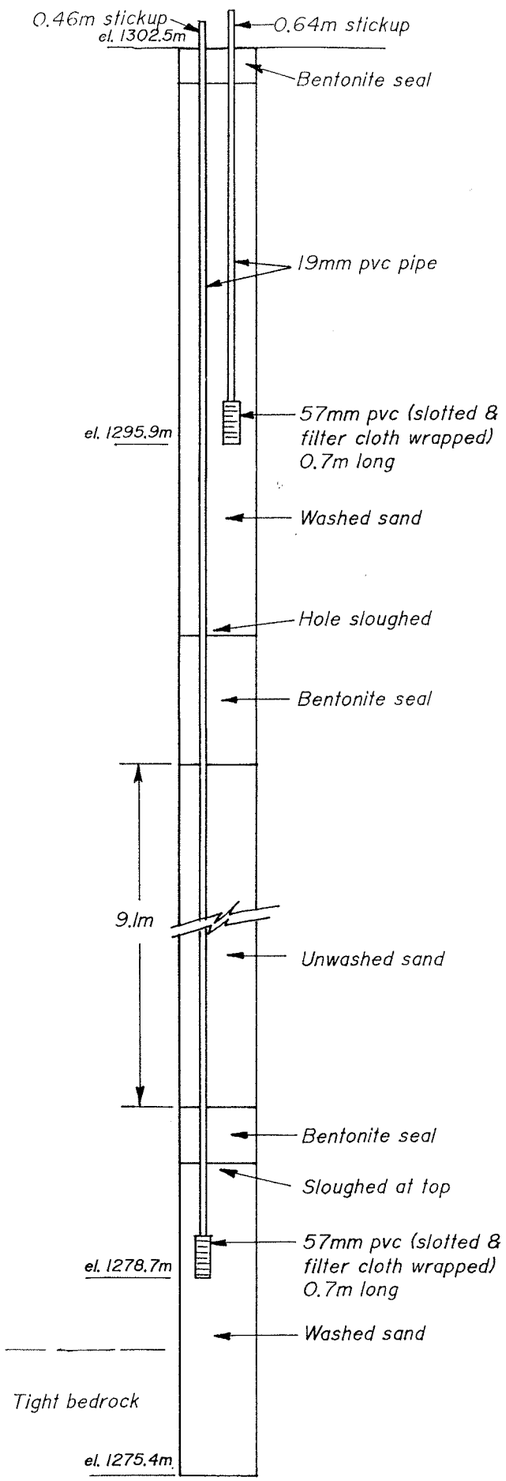
PIEZOMETER DETAILS

Figure 4

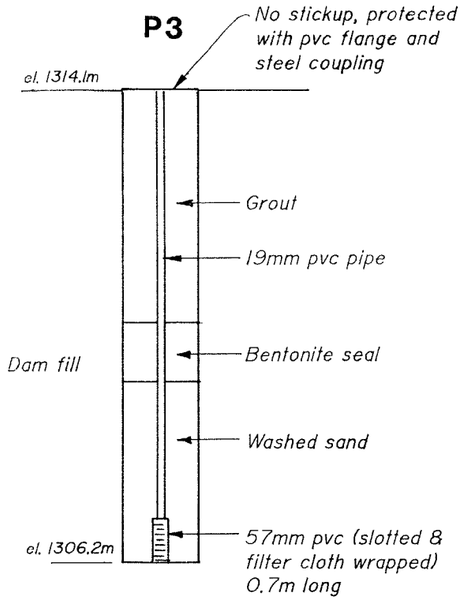
P1



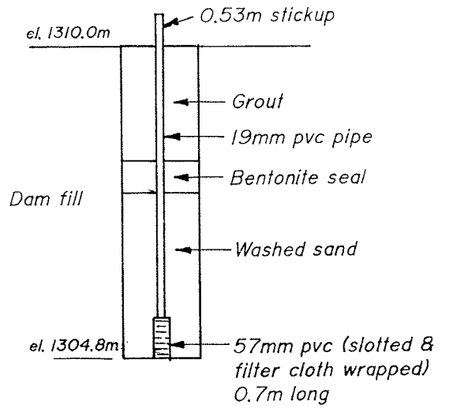
P6



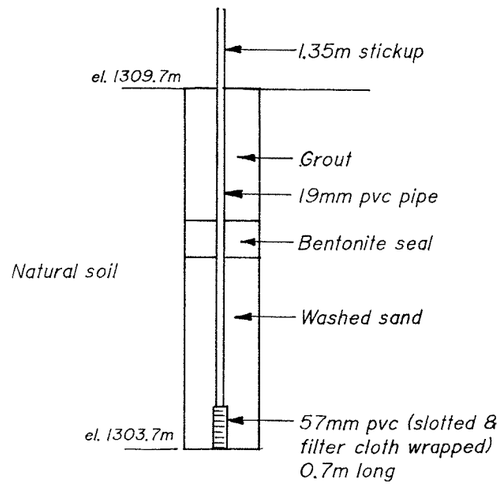
P3



P4



P5

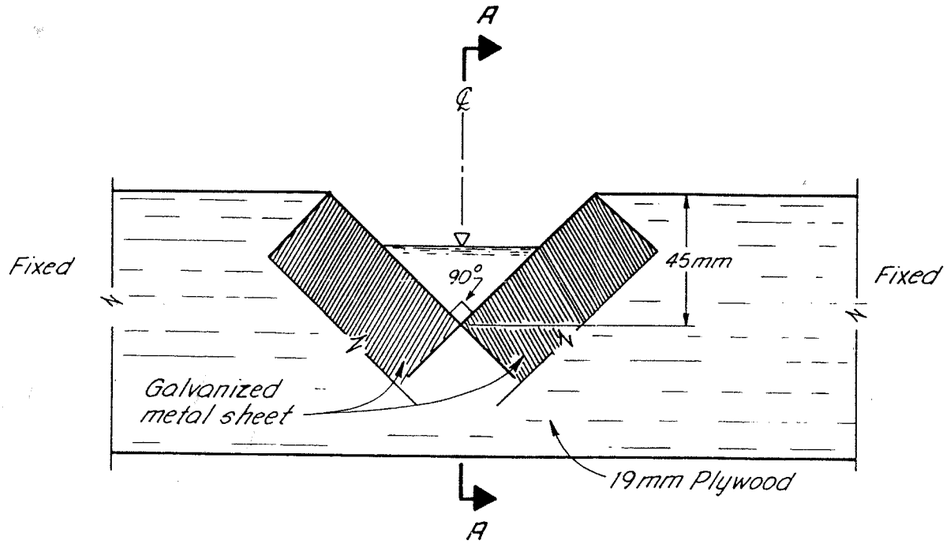


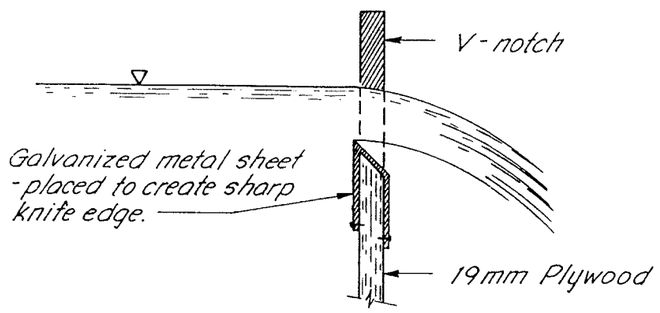
PROJECT NO. 892-1054 DRAWN MK REVIEWED DATE Sept '89

Golder Associates

V-NOTCH WEIR

Figure 4





SECTION A-A

NOTE:

1) V-notch weir installed in seepage ditches at the toe of the tailings dam.

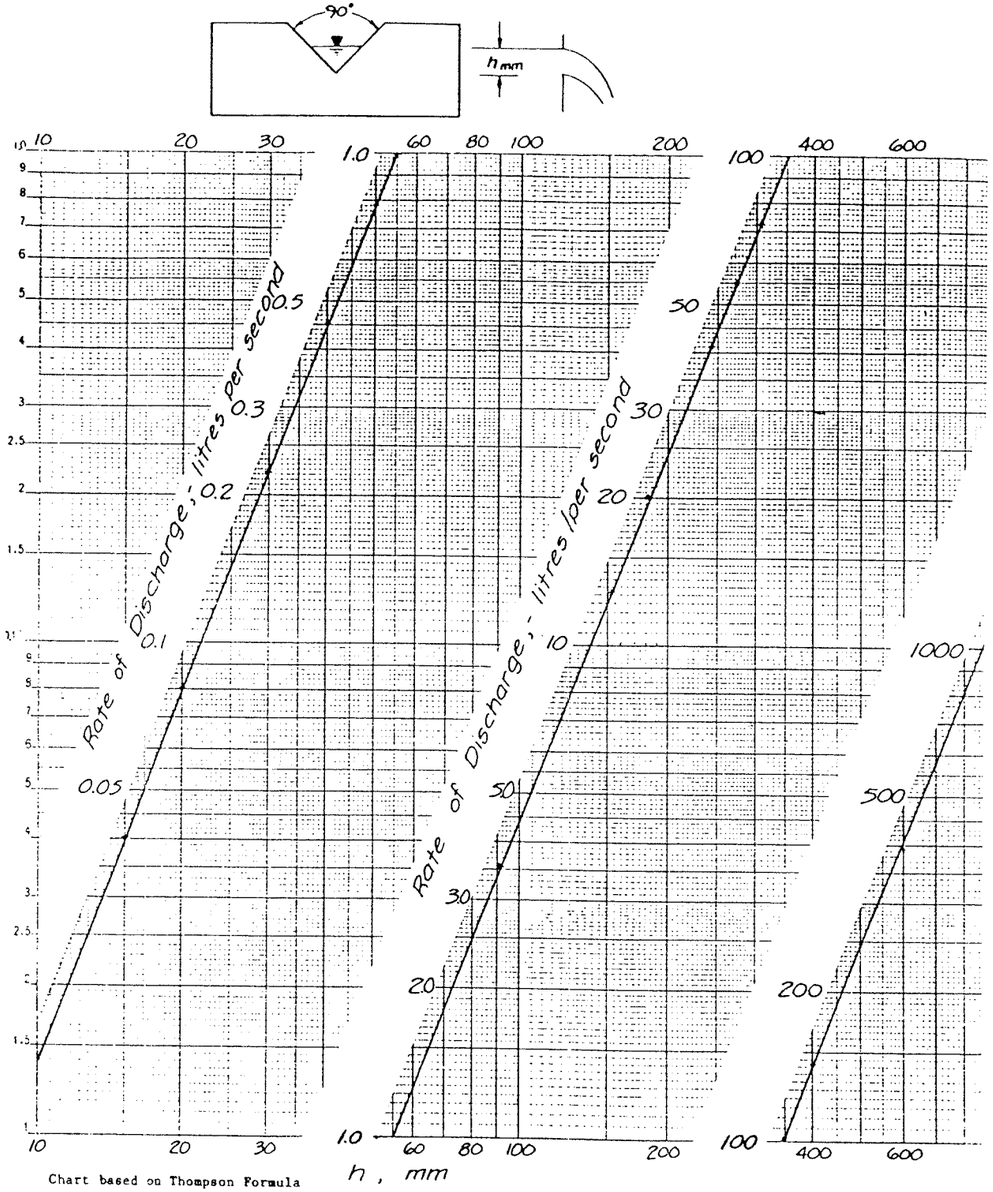


Chart based on Thompson Formula

$$Q = 2.54\, h^{5/2}$$

where: Q = discharge, ft^3/sec
h = head, ft

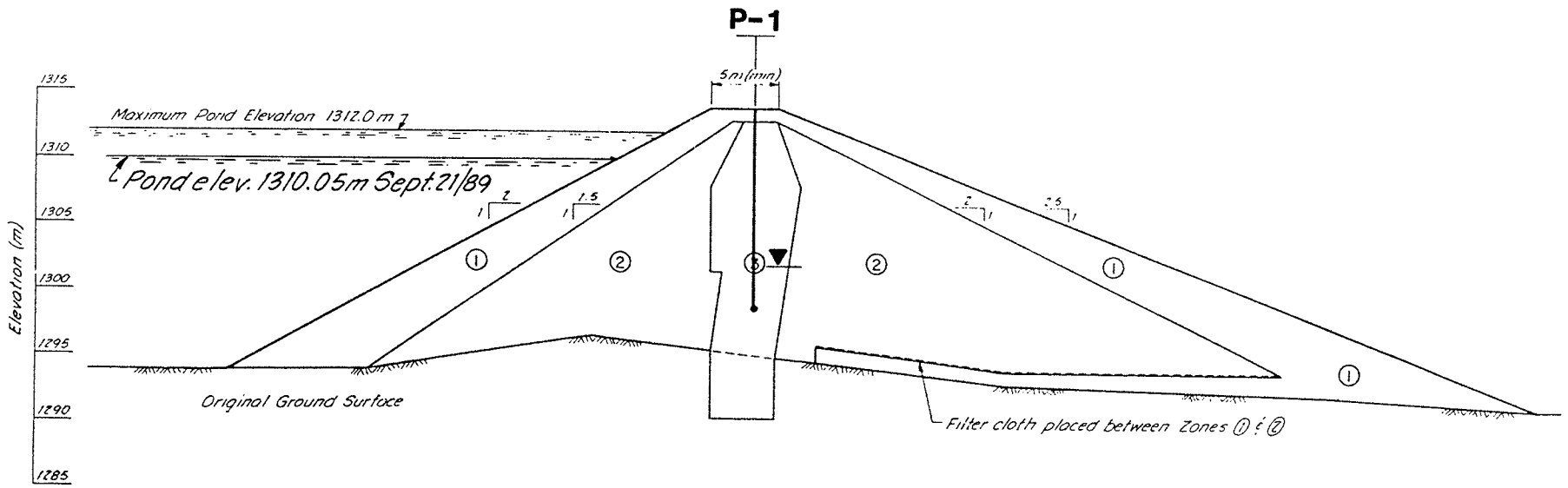
Q converted to l/sec
h converted to mm

DISCHARGE vs. HEAD FOR 90 deg. V-NOTCH WEIR

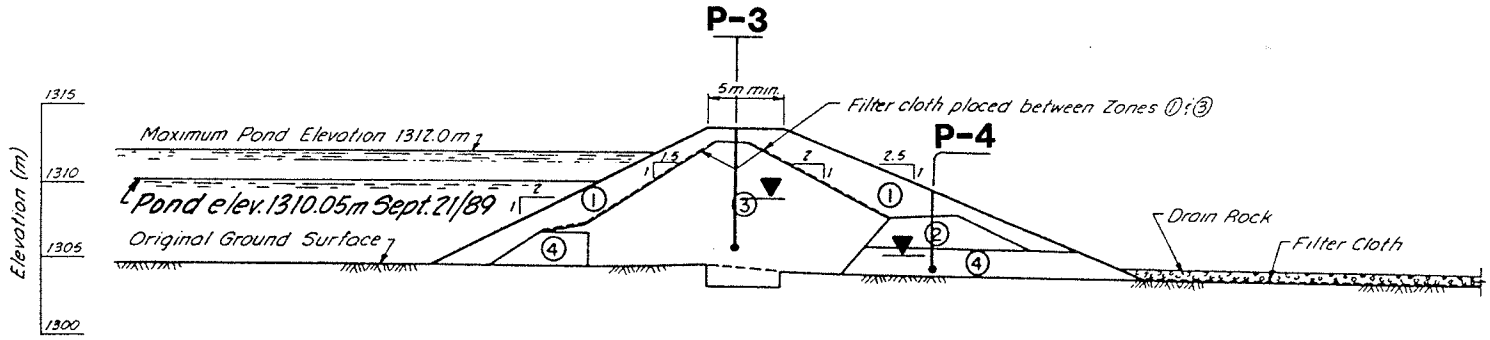
PROJECT NO. 867-1054A DRAWN ..... REVIEWED ..... DATE Nov. '87

Golder Associates

PROJECT NO. 862/054 DRAWN N.T. REVIEWED ..... DATE Sept '89



SECTION A-A



SECTION B-B

LEGEND

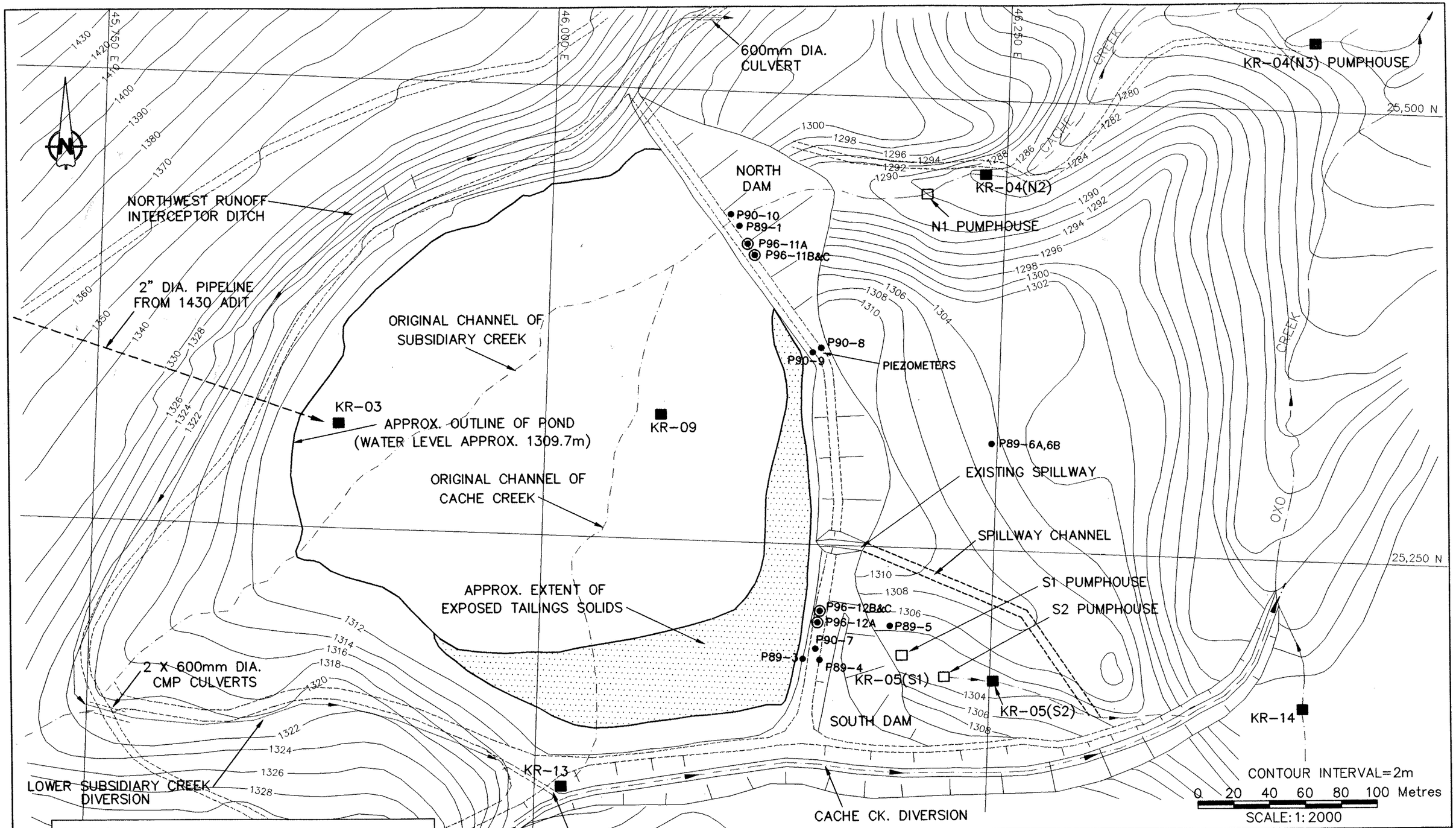
▼ Water level (Sept. 21, 1989)
For elev. refer to Table 1.

Not to Scale

TYPICAL SECTIONS

Figure 5

Golder Associates



LEGEND

KR-05(S1)	EXISTING PUMPHOUSE
KR-09	WATER QUALITY SAMPLING STATION
P89-3	EXISTING PIEZOMETER (INSTALLED 1989)
P96-11	MONITORING WELLS (INSTALLED 1996)

FILE REF:FIG-2-5

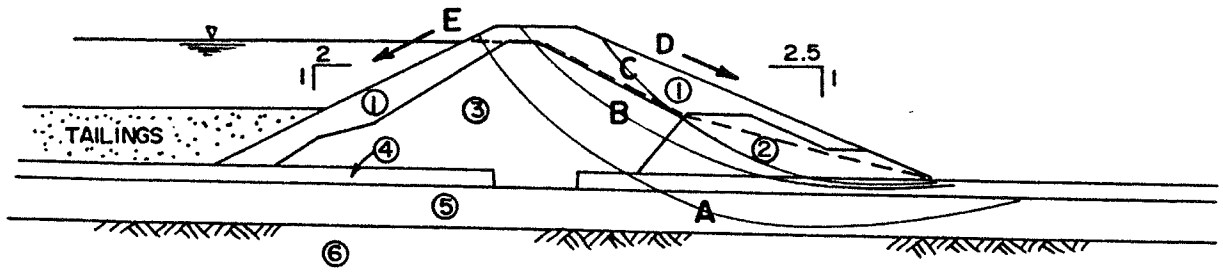
STEFFEN ROBERTSON AND KIRSTEN
Consulting Engineers

YGC RESOURCES LTD.

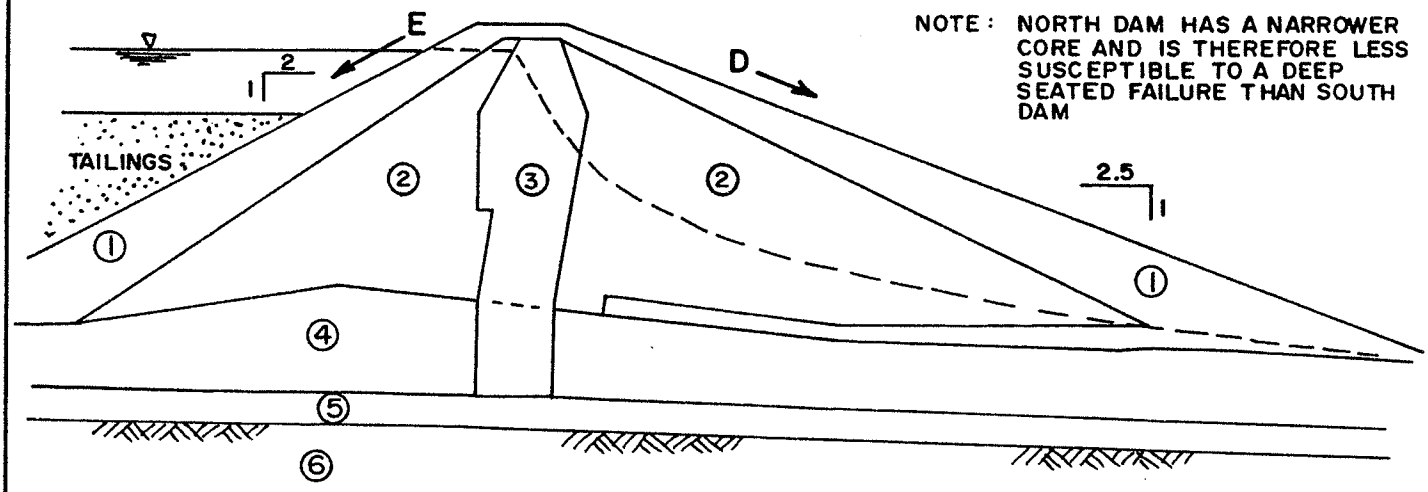
KETZA RIVER MINE

TAILINGS IMPOUNDMENT SITE PLAN

PROJECT NO.	DATE	APPROVED	FIGURE
Y101104	JAN. 1997		2



SOUTH DAM



NOTE: NORTH DAM HAS A NARROWER CORE AND IS THEREFORE LESS SUSCEPTIBLE TO A DEEP SEATED FAILURE THAN SOUTH DAM

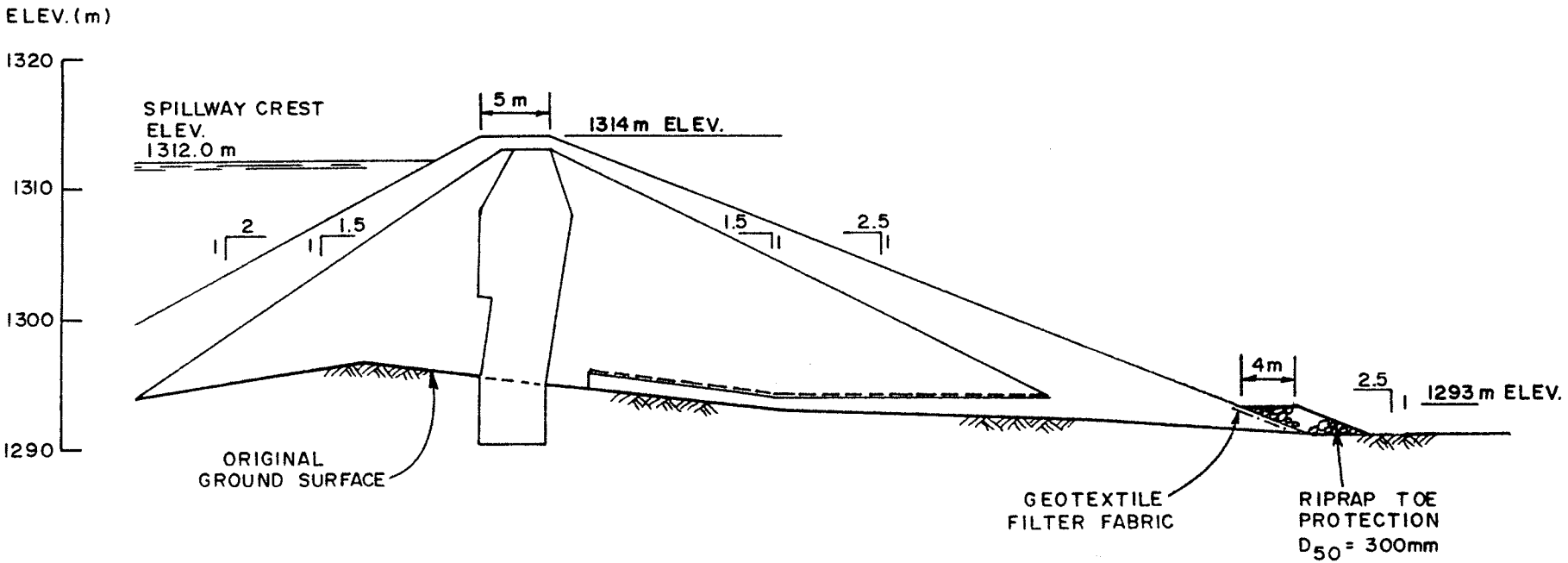
NORTH DAM

Scale - 1:500

ASSUMED MATERIAL PROPERTIES			
MATERIAL	NO.	COHESION	ø
GRAVEL	1	0	34°
SAND & GRAVEL	2	0	39°
TILL CORE	3	0	35°
OUTWASH SAND & GRAVEL	4	0	39°
IN SITU TILL	5	0	37°
BEDROCK	6	—	—

RESULTS OF STABILITY ANALYSES		
FACTOR OF SAFETY		
CIRCLE	STATIC	DYNAMIC
A	1.5	1.2
B	1.7	1.2
C	1.6	1.3
INFINITE SLOPE		
D	1.6	1.4
E	1.3	1.1

WHEATON RIVER MINERALS LIMITED	KETZA RIVER MINE	DATE FEB 1994
SUMMARY OF RESULTS FROM STABILITY ANALYSES		PROJ. NO. N106101
		APPROVED
		NO. 3.2
STEFFEN ROBERTSON & KIRSTEN, Consulting Engineers		

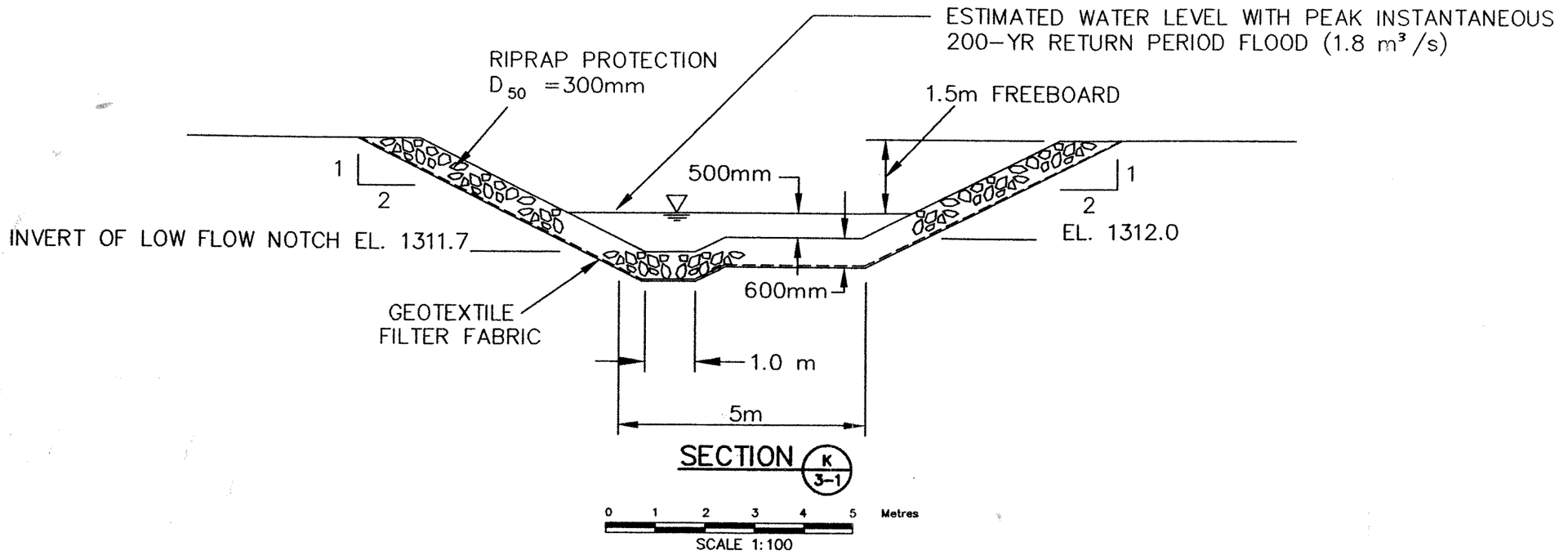


SECTION J
Scale - 1:500 3-1

NOTES:

1. EMBANKMENT SECTION FROM GOLDER ASSOCIATES REPORT 862-1054A, NOV. 1987, FIGURE 2, "AS BUILT CROSS SECTIONS".
2. CONCEPTUAL DESIGN ONLY. NOT TO BE USED FOR CONSTRUCTION.

WHEATON RIVER MINERALS LIMITED — KETZA RIVER MINE	DATE FEB. 1994
NORTH DAM TOE BUTTRESS TYPICAL SECTION	PROJ. NO. N106101
	APPROVED
	NO. 3-3
STEFFEN ROBERTSON & KIRSTEN, Consulting Engineers	



NOTES:

1. CONCEPTUAL DESIGN ONLY. NOT TO BE USED FOR CONSTRUCTION.

STEFFEN ROBERTSON AND KIRSTEN
Consulting Engineers

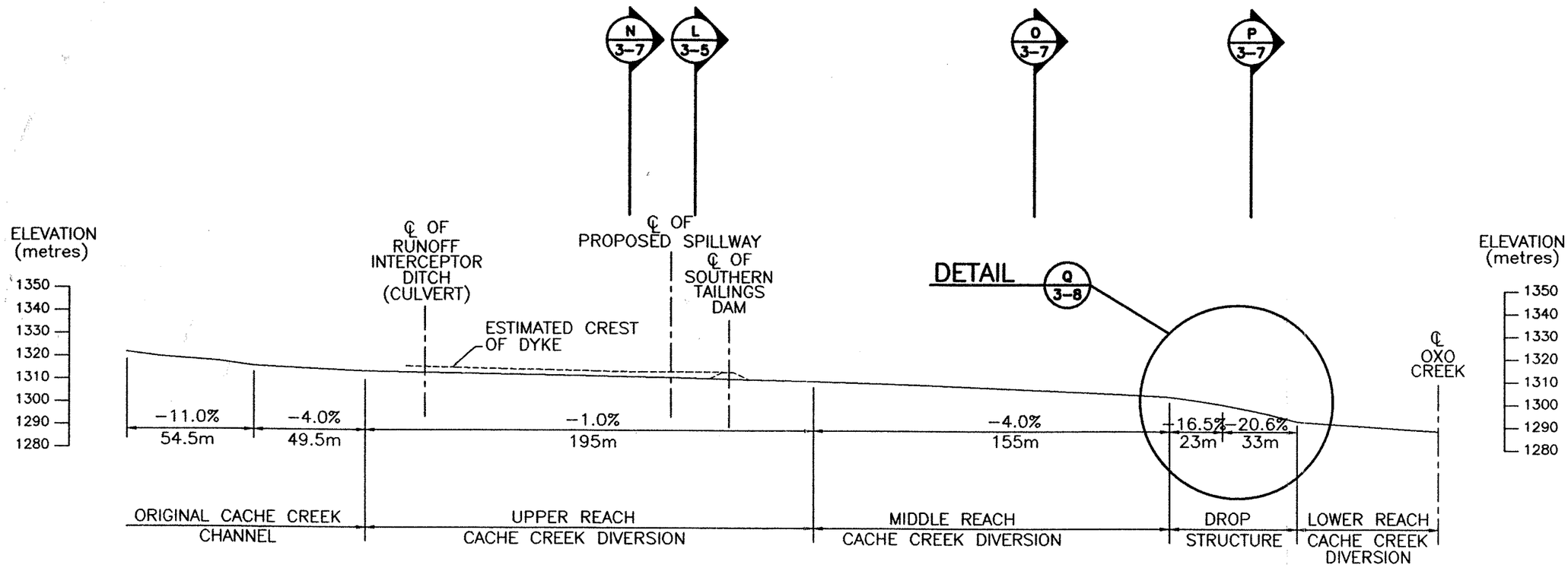
WHEATON RIVER MINERALS LIMITED

KETZA RIVER MINE

PERMANENT SPILLWAY SECTION AND PROFILE L

PROJECT NO.	DATE	APPROVED	FIGURE
N106101	FEB., 1994		3-5

FILE REF: FIG-3-5



0 20 40 60 80 100 Metres

SCALE 1:2000

FILE REF:FIG-3-6

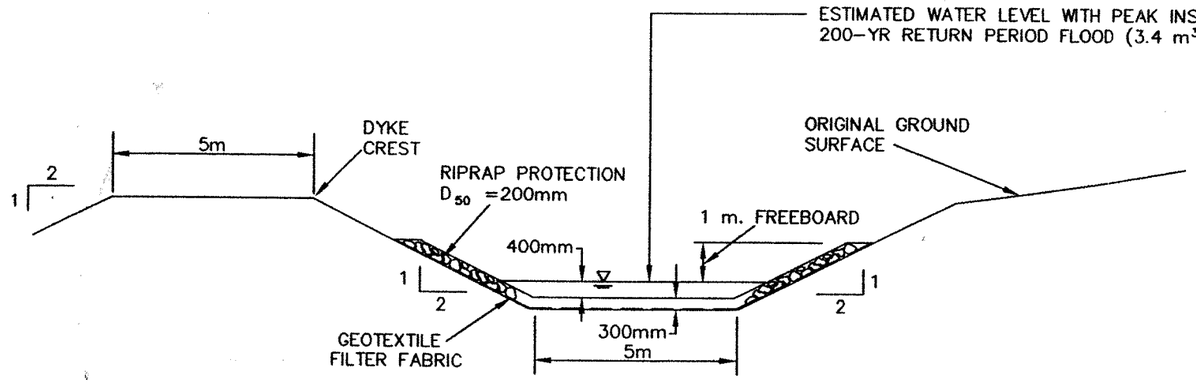
STEFFEN ROBERTSON AND KIRSTEN
Consulting Engineers

WHEATON RIVER MINERALS LIMITED

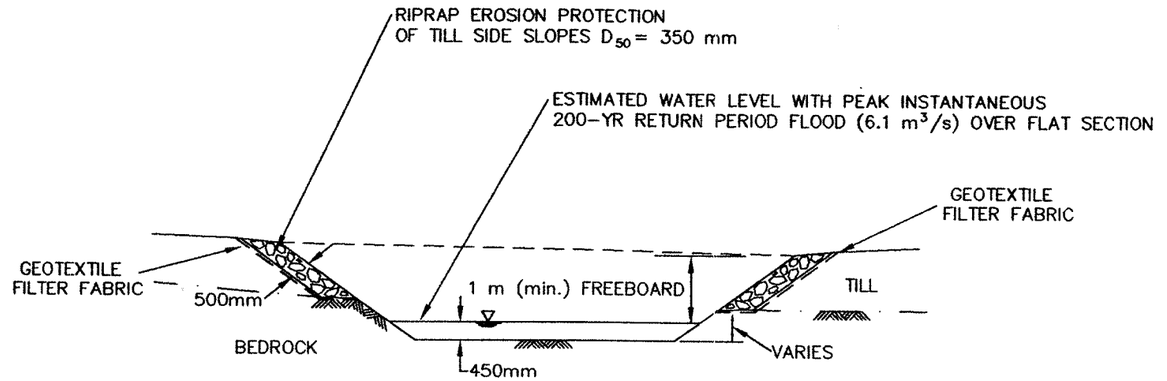
KETZA RIVER MINE

CACHE CREEK DIVERSION
PROFILE M

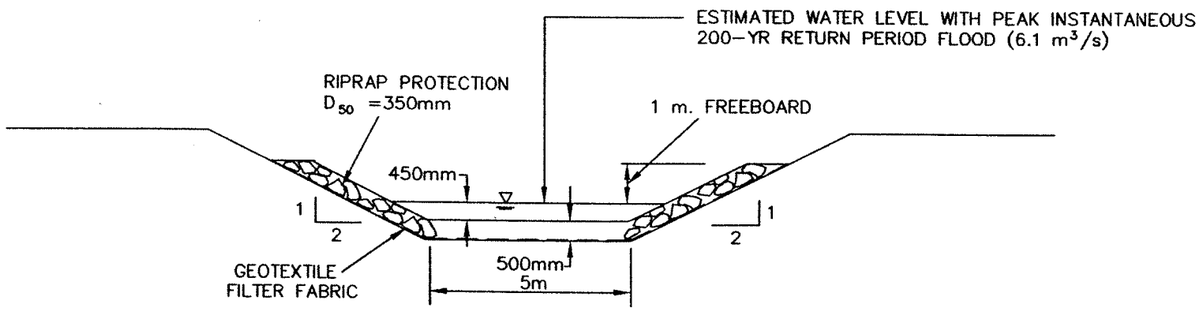
PROJECT NO.	DATE	APPROVED	FIGURE
N106101	FEB.,1994		3-6



SECTION N
SCALE 1:150 3–1



SECTION P
SCALE 1:150 3–1



SECTION O
SCALE 1:150 3–1

NOTES:

1. CONCEPTUAL DESIGN ONLY. NOT TO BE USED FOR CONSTRUCTION.

STEFFEN ROBERTSON AND KIRSTEN
Consulting Engineers

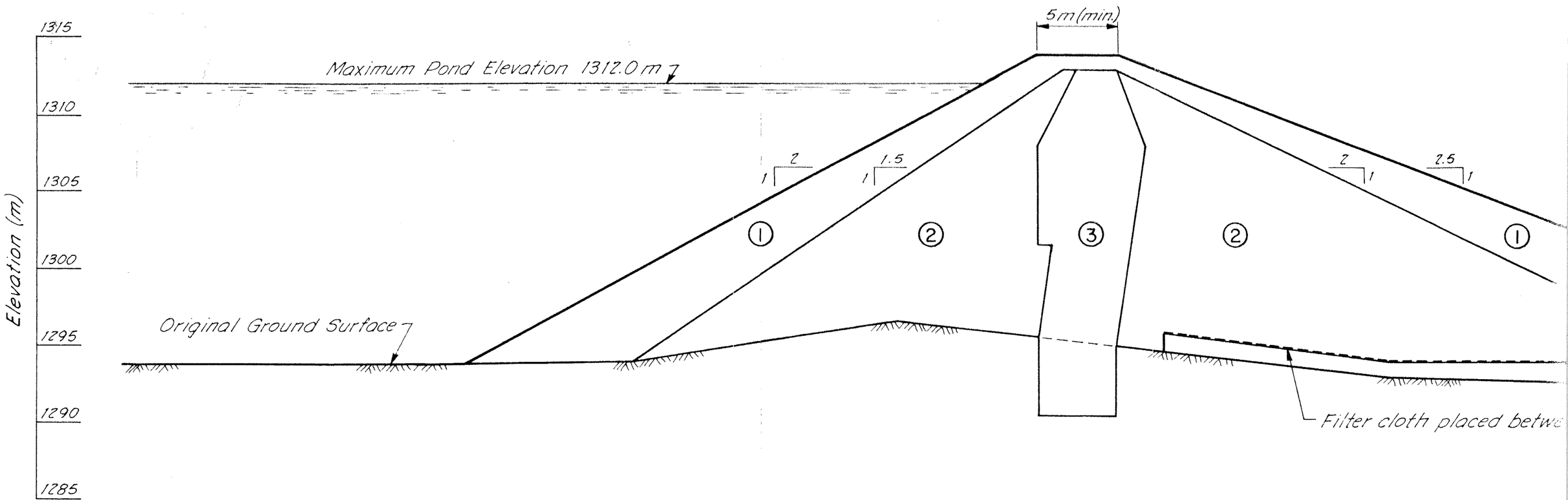
WHEATON RIVER MINERALS LIMITED

KETZA RIVER MINE

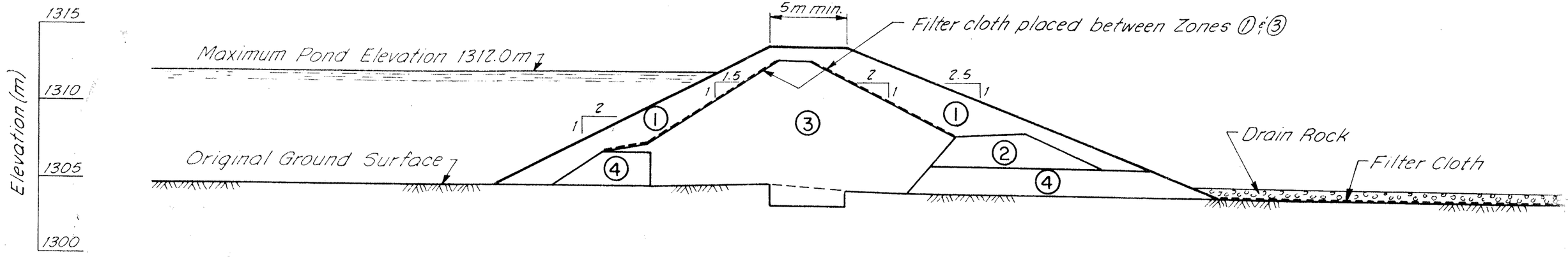
CACHE CREEK DIVERSION
SECTIONS N, O, & P

PROJECT NO.	DATE	APPROVED	FIGURE
N106101	FEB., 1994		3–7

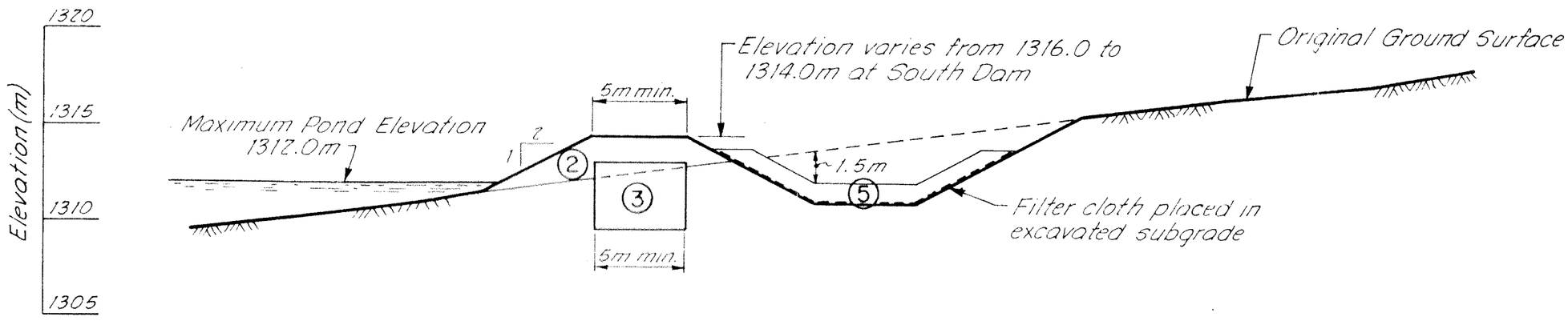
FILE REF: FIG-3-7



SECTION A-A
SCALE 1:250

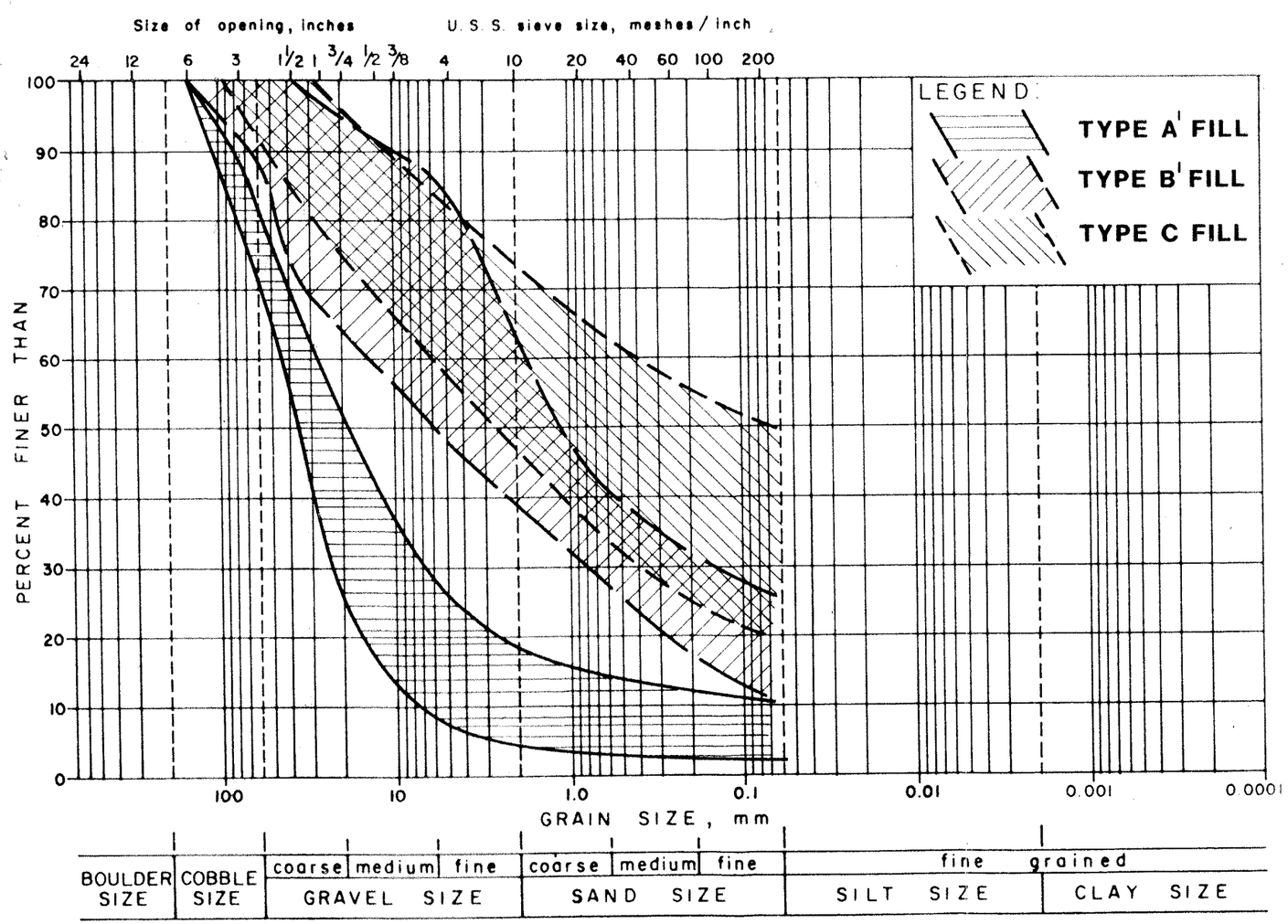


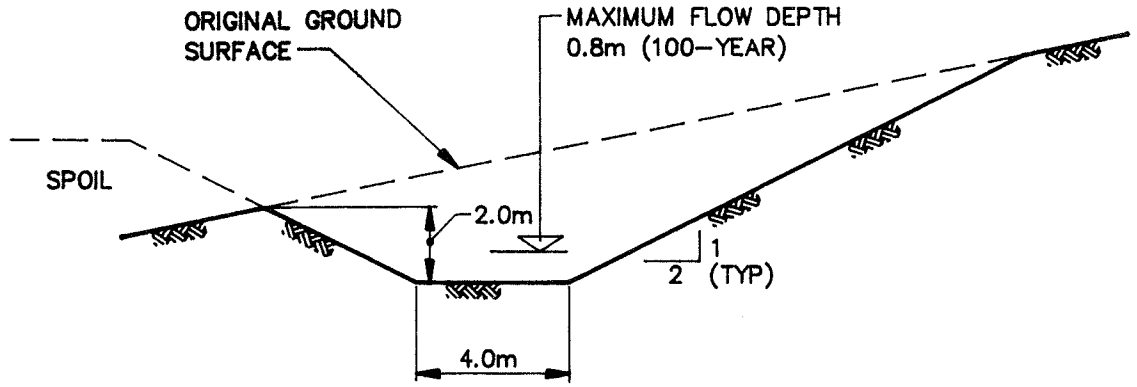
SECTION B-B
SCALE 1:250



SECTION C-C
SCALE 1:250

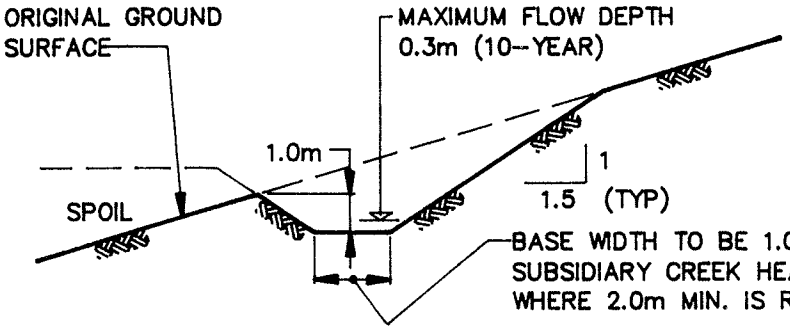
M.I.T. GRAIN SIZE SCALE





MAIN DIVERSION DITCH FOR CACHE CREEK

NTS



ALL OTHER DIVERSION DITCHES

NTS

NOTES

1) **MINIMUM GRADIENT** 0.5%
2) **PROTECTIVE ROCK** LINING TO BE **SPECIFIED BY ENGINEER.**

TYPICAL DITCH CROSS SECTION

YUKON TERRITORY
WATER BOARD
JAN 16 1987

FIGURE 3

KER, PRIESTMAN & ASSOCIATES LTD.

FILE NO. 25275.04 DATE NOVEMBER 86

APPENDIX E

APPENDIX E EMERGENCY PREPAREDNESS PLAN

EMERGENCY PREPAREDNESS PLAN

Project Name: Ketza River Gold Mine, Yukon
Dam Name: Existing Tailings Impoundment Water Licence No.: 0Z04-063
Owner's Name: Ketza River Holding Ltd., a wholly owned subsidiary of Yukon-Nevada Gold Corporation Phone #: 604-688-9427
Alternate Contact: Ketza Mine Manager Phone #: 778-785-3193
Stream Name: Cache Creek Diversion; Lower Subsidiary Creek Diversion
Reservoir Name: Ketza Mine Tailings Storage Facility
Dam Location: Latitude: 61.53 Longitude: 132.36 Map Sheet No.:

ACCESS TO DAM:

The Ketza River Mine is located in the Pelly Mountains close to the headwaters of Cache Creek, a major tributary of the Ketza River. The mine site is approximately five hours by vehicle from Whitehorse.

From Ross River

1. Head **south** on **Canol Rd/YT-6 S**
850 m

2. Slight right toward **Robert Campbell Hwy/YT-4 E**
8.3 km

3. Turn left onto **Robert Campbell Hwy/YT-4 E**
39.1 km

4. Turn right on Ketza Mine Access Road
38.5 km

Local Helicopter Company: Trans-North Helicopters Phone #: 867-668-2177

EMERGENCY ASSESSMENT:

- Richard Trimble,, P.Eng., Snr Geotech Eng.,: 867-668-3068
- Yukon Energy, Mines & Resources Inspector: 867-667-3156
- Yukon Water Resources Inspector: 867-667-3120

EMERGENCY ACTIONS: *(list phone #'s (work & home) of local contractors/equipment operators, local material suppliers and District Highways Office (access to equipment) etc.)*

Contractor's Name:	*Work & Home Phone #:*

Supplier's Name: *Work & Home Phone #:*

DOWNSTREAM NOTIFICATION:

- First Nations
    - 876-969-2832 (RRDC)
    - 867-536-7901 (LFN)
- Yukon Highway Dept, Risk Management: 867-667-5710
- RCMP, Watson Lake: 867-536-5555
- Environment Canada Inspector: 867-667-3470
- Department of Fisheries and Oceans: 867-393-6722

APPENDIX C

APPENDIX C DAM SAFETY REVIEW

Ketza River Holdings

YUKON – NEVADA GOLD CORPORATION

KETZA RIVER GOLD MINE
TAILINGS STORAGE FACILITY
DAM SAFETY REVIEW
2011

REPORT

AUGUST 2011
ISSUED FOR USE
EBA FILE: W23101051.104-9

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A TETRA TECH COMPANY

LIMITATIONS OF REPORT

This report and its contents are intended for the sole use of Yukon - Nevada Gold Corporation and their agents. EBA, A Tetra Tech Company, does not accept any responsibility for the accuracy of any of the data, the analysis, or the recommendations contained or referenced in the report when the report is used or relied upon by any Party other than Yukon - Nevada Gold Corporation, or for any Project other than the proposed development at the subject site. Any such unauthorized use of this report is at the sole risk of the user. Use of this report is subject to the terms and conditions stated in EBA's Services Agreement. EBA's General Conditions are provided in Appendix A of this report.

EBA, A Tetra Tech Company
150, 1715 Dickson Avenue
Kelowna, BC V1Y 9G6 CANADA
p. 250.862.4832 f. 250.862.2941

EXECUTIVE SUMMARY

EBA, a Tetra Tech Company was engaged by Yukon Nevada Gold Corporation (YNG) to undertake a dam safety review of the Ketza River Gold Mine Tailings Storage Facility (TSF) dams.

The Dam Safety Review was undertaken in general accordance with the requirements of the Canadian Dam Association (CDA) Dam Safety Guidelines (2007).

Conclusions and Recommendations

Based on the results of the investigation, analyses and assessment of the dams, a series of conclusions and recommendations were developed during the Dam Safety Review for each facility as summarized in the Dam Safety Review Conclusions and Recommendations Table.

Dam Safety Review Conclusions and Recommendations

Task	Conclusions	Recommendations
Background Review	▪ There is no in-situ strength data available for the dam materials. ▪ Based on the review of current and historical piezometer readings, no significant changes were noted and therefore it is assumed that the interior drainage of the dam is still functioning as intended.	There are no recommendations from this area review.
Site Reconnaissance	North Dam ▪ Minor erosion is occurring at the toe of Weir 4, allowing some water to seep under the weir and potentially affecting flow measurements. ▪ Piezometers P90-10A and P90-10B and P90-8 are damaged.	North Dam — The eroded area at the toe of Weir 4 should be backfilled to minimize seepage and armoured to prevent future erosion (High). South Dam — There are no recommendations from this are of review.
Consequence Classification	The North and South Dams are classified as a High Consequence Dam according to the CDA 2007 Guidelines.	There are no recommendations from this area of review.
Failure Mode Assessment	The plausible failure modes of the dam are; overtopping, downstream slope instability, piping through the embankment and foundation, soil liquefaction of the upstream slope and post-earthquake downstream and upstream instability.	There are no recommendations from this area of review.
Geotechnical Assessment	▪ In general, the shape of the seepage analysis flow fields determined by the steady state seepage analysis concurs with the historical observations at the embankment toe. ▪ The results of the stability analyses indicate that the upstream and downstream slope of the dam may not meet CDA minimum factors of safety for the post seismic event case. ▪ The magnitude of vertical settlement as a result of soil liquefaction for the design earthquake event is estimated to be less than 500 mm at the North Dam and 220 mm at the South Dam, which is within the available freeboard of the dam. ▪ Given the depositional nature (i.e. glacial) of the dam foundation, there is considered to be no risk of the dam foundation undergoing liquefaction during the design seismic event. ▪ A probabilistic piping risk assessment was conducted using the UNSW method that resulted in a calculated probability of piping failure developing of 4.59×10^{-5} North Dam and 6.39×10^{-5} South Dam.	In-situ strength testing (e.g. SPT's) and sampling should be undertaken on the embankment materials to better assess the liquefaction and post-earthquake stability of the embankments to determine whether this is within CDA criteria. This could be undertaken in conjunction with an instrumentation (piezometer) installation program. Should unacceptable factors of safety still be obtained, consideration to permanently lowering the reservoir level may be required (MEDIUM).
Hydrotechnical Assessment	▪ Based on a review of previous studies and results of the current dam break analysis, the tailings dams are classified as High Consequence Dams. In accordance with the 2007 CDA Guidelines, the IDF for the tailings pond was chosen to 1/3 between a 1000-year flood and the Probable Maximum Flood (PMF). Two IDF scenarios were considered: the summer-autumn scenario and the spring scenario. The summer-autumn IDF was determined to have a peak flow of 30.9 m^3/s. The governing Spring IDF was determined to have a peak inflow of 23.4 m^3/s. ▪ Flood routing was performed to assess the capacity of the dams to pass the IDF. The existing spillway crest has an average elevation of 1309 m. With the existing configuration of the spillway, a minimum freeboard of 0.7 m would be available during the summer-autumn IDF, and a minimum freeboard of about 0.4 m would be available during the spring IDF. ▪ A wind and wave analysis was conducted in the freeboard determination of the existing spillway. Results indicate that there will be no overtopping by 95% of waves either caused by the most critical wind with a frequency of 1/1000 year when the reservoir is at its maximum normal elevation or caused by the most critical wind when the reservoir is at its maximum extreme level during the passage of the IDF. Therefore, the amount of freeboard available is considered adequate. ▪ A hydraulic analysis of the erosion potential of the spillway and chute was conducted. Results of the analysis indicate that the existing rock size of the spillway is inadequate. ▪ A hydraulic analysis of the Northwest Runoff Interceptor ditch, the Lower Subsidiary Creek diversion channel, the Cache Creek diversion channel and the associated culvert crossings was carried out. The diversion/interceptor channels were determined to be Significant consequence classification structures, and the 200-year flood was selected as the inflow design flood. Results of the hydraulic analysis indicate that all diversion/interceptor channels have sufficient capacities to handle the inflow design flood and that there is no erosion concern along the NWRI ditch upstream of the tailings pond and along the Lower Subsidiary Creek diversion.	▪ It is recommended that the spillway and the chute be lined with riprap with a median rock size of 410 mm and granular filter with a median size of 40 mm. The required thickness for the riprap layer was determined to be 700 mm while that for the filter layer was determined to be 200 mm (Medium). ▪ No detailed site information has been obtained for the outlet of the spillway chute at the time of the study. However, general erosion protection requirements at the outlet of the spillway chute were determined. It is recommended that the chute sides be extended up to a minimum of 1.7 m on the opposite bank of the receiving stream. To further minimize the potential of erosion, larger size rocks should also be placed along the eastern portion of the outlet area (Medium). ▪ Conditions of the existing culvert crossings were also assessed, and it is recommended that a new 750 mm diameter culvert be added to the existing twin 600 mm diameter culvert crossing near the upstream end of the Lower Subsidiary Creek diversion and that a new 600 mm diameter culvert be added to the existing 900 mm diameter culvert near the downstream end of Lower Subsidiary Creek diversion. It is also recommended that regular monitoring and maintenance be carried out at these culvert crossings to minimize the blockage issues (Medium). ▪ The erosion protection requirements along the NWRI ditch downstream of the mine access road and along the Cache Creek diversion channel were determined. However, the existing riprap size, actual alignment and slope of this sub-reach of the NWRI ditch have yet to be confirmed in the field. Similarly, the existing riprap material size along the Cache Creek diversion channel has yet to be confirmed. Two locations of instability have been identified from previous geotechnical studies. In particular, the Cache Creek diversion channel just downstream of the outlet of the seepage channel has an instability issue because of high flows. It is recommended that remediation be implemented at these unstable locations and that the rest of the channel is protected by the suggested riprap materials where necessary (Medium). ▪ It is recommended that a site visit be conducted to get a better understanding of the spillway chute, its outlet condition, and the diversion/interceptor ditches and to refine the erosion protection requirements prior to any proposed works at the spillway and along the diversion/interceptor channels (High).

Dam Safety Review Conclusions and Recommendations

Task	Conclusions	Recommendations
Dam Safety Management	▪ Dam inspection documentation should be improved to include quantifying seepage rates and including comments on the clarity of seepage. ▪ Piezometers should be installed in the downstream slope of the dam.	**North Dam** ▪ Survey monuments should be installed on the crests of dams, downstream slopes and crest of the new toe berm. These monuments should be surveyed twice a year (March and September) to ensure that the slight bulge in the downstream slope is not changing (Medium). ▪ Piezometer/monitoring well water elevations should be collected and reviewed at least monthly (High). ▪ Flow rates from Weir 4 should be collected and reviewed monthly (High). ▪ Flow rates from Weir 5 should be collected and reviewed monthly (High). ▪ Piezometers P90-10A and P90-10B and P90-8 still require repair (High). ▪ The movement of instruments P90-8 and P90-9 should be surveyed every three months, so that it can be determined if the instruments are settling or heaving (High). ▪ Visual monitoring of the riling and erosion on the face of the dam should be undertaken quarterly to determine if the issue is increasing in severity (High). **South Dam** Piezometer/monitoring well water elevations should continue to be collected and reviewed at least monthly. Based on the data provided by YNG, it appears that the piezometers are currently being monitored roughly every second month (High).

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ACRONYMS AND ABBREVIATIONS

AEP	Annual Exceedance Probability
AMSL	Average Mean Sea Level
BC MoE	British Columbia Ministry of Environment
CDA	Canadian Dam Association
DSR	Dam Safety Review
EBA	EBA, A Tetra Tech Company
NBCC	National Building Code of Canada
PGA	Peak Ground Acceleration
PMF	Probable Maximum Flood
TSF	Tailings Storage Facility
YNG	Yukon Nevada Gold Corp

1.0 INTRODUCTION

1.1 General

Yukon-Nevada Gold Corporation (YNG) retained EBA, a Tetra Tech Company, (EBA) to undertake a Dam Safety Review (DSR) of the Ketza River Gold Mine, Tailings Storage Facility (TSF) Dams.

This report presents the technical findings of the Ketza River Gold Mine, TSF Dams DSR and it is understood that this is the first dam safety review of this facility.

The Dam Safety Review was undertaken in accordance with the requirements of the Canadian Dam Association (CDA) Dam Safety Guidelines (2007).

1.2 Site Description

The Ketza River Mine can be accessed from Ross River by travelling 40 km south along the Campbell Highway and then 40 km along the Ketza River Mine access road. Located in the Pelly Mountains, the mine is situated in the headwaters of Cache Creek, an easterly flowing tributary of the upper Ketza River. The Ketza River, in turn, flows into the Pelly River approximately 12 km south of Ross River.

The location of the Ketza River Gold Mine is shown in Figures 1 to 3. The locations of the specific structures at the mine site are shown in Figure 4, with an overview of the TSF shown in Figure 5 and Photo 1.

The TSF is located to the east and downstream of the mill site facilities in a natural depression at the confluence of Cache Creek and Subsidiary Creek. Bypass channels, or diversion ditches, have been constructed to divert these flows around the TSF area. The TSF comprises a single pond and tailings mass retained by two separate embankments, the North Tailings Dam and the South Tailings Dam. The two dams are separated by a ridge of native material. The spillway has been excavated into the ridge and is fully contained within native material. The area covered by the tailings pond at the spillway crest elevation (1,309 m) is approximately 8 ha.

The North Tailings Dam has a length of approximately 210 m and is about 20 m high. The South Tailings Dam has a length of approximately 110 m and is about 10 m high. The dam crest elevation for both the North and South Tailings Dams ranges from a minimum of 1,309.7 m to a maximum of 1,310.5 m (YNGC 2011).

2.0 SCOPE OF WORK

EBA's scope of work for the Dam Safety Review was to undertake the study in accordance with the requirements of the Canadian Dam Association (CDA) Dam Safety Guidelines (2007). In summary, the study included the following tasks:

- Background review.
- Site reconnaissance.
- Review of consequence classification.

- Hydrotechnical analysis including hydrological analysis, dam break analysis, flood routing and hydraulics.
- Geotechnical assessment, including embankment stability and seepage.
- Preparation of a Operation, Maintenance and Surveillance Manual.
- Preparation of an Emergency Preparedness Plan.
- Review of any public safety management strategies.
- Assessment of compliance with previous reviews.
- Assessment of compliance with CDA Principles.
- Development of conclusions and recommendations.

The results of each task are detailed in the following sections, with the exception of the hydrotechnical analysis, which are presented in the companion hydrotechnical report.

3.0 BACKGROUND REVIEW

3.1 Sources of Information

The background documentation reviewed as part of the DSR, were obtained either from EBA's previous work on the mine site or that provided by YNG.

A detailed list of the various documents reviewed is provided in Appendix A.

3.2 Geological Setting

The geology of the Ketza River property, as described by Hodgson (1991), is summarized below.

3.2.1 Regional Setting

The district is centred on the Ketza Uplift, an upfaulted and domed area near the eastern margin of the Ketza-Seagull Arch, a regionally extensive structural feature of the Pelly-Cassiar Platform.

The Ketza uplift, centred on the Ketza River Property, is cored by Late Proterozoic phyllite and quartzite strata, which are surrounded, by Lower Cambrian and younger Paleozoic carbonate and elastic strata. The Late Proterozoic strata, exposed over an area roughly 3 km in diameter, are variably metamorphosed (to hornfels) particularly in the southeast sector. A subjacent intrusion is inferred, although the only intrusive rocks in the general vicinity are minor syenite dykes, several kilometres east of the hornfelsed zone.

Structurally, the area is strongly dissected by east-west striking thrust faults and younger northerly-trending normal faults.

3.2.2 Property Geology

The property is underlain by Late Proterozoic and Cambrian strata, the latter present as an annulus peripheral to Late Proterozoic elastic strata, which occupy the area between Peel and Misery Creeks. Eight stratigraphic units are recognized on the property.

The oldest unit on the property, Late Proterozoic phyllite and quartzite, are subhorizontal, weathered and weakly magnetic due to the presence of minor disseminated pyrrhotite related to the hornfelsing.

Lower Cambrian limestone is a grey and uniformly bedded. Distinctive Archeocyathid fossils occur near the top of the unit. The unit is locally dolomitized and recrystallized in the immediate vicinity of mineralization.

Green mudstone directly overlies the Lower Cambrian limestone, and forms a distinct marker unit on the property.

Above the green mudstone, Upper Cambrian black carbonaceous shale grades upward into phyllitic limestone

All strata are generally flat-lying, although numerous open folds and fault offsets occur adjacent to thrust faults and younger normal faults.

3.3 Seismicity

The Geological Survey of Canada (GSC) has produced four probabilistic seismic hazard models "H", "R", "F" and "C" (Halchuk and Adams 2008) that form the basis of the seismic design provisions of the 2005 National Building Code of Canada (NBCC 2005). To capture epistemic uncertainty in source, two complete probabilistic seismic hazard models were created for Canada, with the "H" model considering relatively small source zones drawn around historical clusters of seismicity and the "R" model considering larger regional zones reflecting seismotectonic units. The "F" model was developed for the relatively aseismic central part of Canada and is based on global continental earthquake activity rates and the "C" model considers a line source with a magnitude 8.2 on the Cascadia subduction zone. The seismic design parameters provided in the NBCC 2005 are based on the highest value from the four models for each grid point assessed across Canada.

Peak Ground Accelerations (PGA) and Spectral Accelerations (Sa(T)) for a "Class C" site can be obtained from the Earthquakes Canada website (http://earthquakescanada.nrcan.gc.ca) for various return periods, with the PGA's values for the Ketza River mine site summarized in Table 1 below.

Table 1: Reference (Class C) Design PGA and Sa for Ketza River Mine, YT

Annual Exceedance Probability (AEP)	PGA	Sa(0.2)	Sa(0.5)	Sa(1.0)	Sa(2.0)
1/475	0.070g	0.130	0.080	0.040	0.024
1/2475	0.110g	0.212	0.128	0.066	0.039

The relative contribution of the earthquake sources to the seismic hazard in terms of distance and magnitude can be obtained by deaggregation of the seismic hazard result. The deaggragation data for the "H" and "R" GSC models have been obtained from Earthquakes Canada, which provides the mean and modal magnitude of the seismic hazard for the Ketza River mine site as summarized in Table 2 below.

The GSC model only considers relative contributions from the mean seismic hazard at the source, where as other models such as the USGS model for the continental US also considers various levels of epsilon (ε) where ε = 1 indicates the contribution from the mean plus one standard deviation. Typically for geotechnical analysis the mean magnitude plus ε = 1 is considered an appropriate design magnitude. In the absence of the calculation of ε, the standard deviation of the magnitudes of the earthquake sources contributing to the seismic hazard has been calculated from the GSC model, with the mean magnitude plus one standard deviation considered appropriate for geotechnical analysis as summarized in Table 2 below.

Table 2: Design Earthquake Magnitudes for Ketza River Mine

Annual Exceedance Probability (AEP)	Geological Survey Canada (GSC) Model	Peak Ground Acceleration (PGA)	Modal Magnitude	Mean Magnitude	Standard Deviation	Mean Plus 1 Standard Deviation
1/475	R	0.046	4.875	5.43	0.53	5.95
1/475	H	0.056	4.875	5.55	0.58	6.13
1/2475	R	0.095	4.875	5.52	0.57	6.10
1/2475	H	0.110	4.875	5.62	0.60	6.22

Note: The GSC "H" model forms the basis of the NBC 2006 seismic design provisions for the Ketza River Mine site.

3.4 Existing Drawings

A review of the existing documentation on the TSF dams indicates that several reports contain design or as-built drawings of the dams namely:

- The Golder Associates Ltd (Golder) 1986 report on the Geotechnical Design of the TSF contains design drawings of the two dams.
- The AECOM 2009 report on the construction of the North Dam toe berm provides as-built drawing of the toe berm.
- The YNG letter 2010 provides the results of a survey of the dams' crests.

A review of the existing drawings of the dams indicates the following details:

- Based on a review of the drawings, the North Dam has a length of approximately 210 m, crest width of approximately 5 m, and a maximum embankment height of approximately 20 m measured from the downstream toe to the crest, while the South Dam has a length of approximately 110 m, crest width of approximately 5 m and a maximum embankment height of approximately 10 m measured from the downstream toe to the crest. The crest elevation for both dams range from a minimum of 1,309.7 m to a maximum of 1,310.5 m (YNG 2010).
- The upstream and downstream slopes of each dam have gradients approximately of 2.5H:1V and 2H:1V respectively.
- The spillway has a sill elevation of approximately 1,309 m.
- There is no low-level outlet structure through either dam.

3.5 Design and Construction

The tailings dams were designed by Golder Associates in 1986 as zoned earthfill embankments. The construction of the dams was completed in 1987, and tailings discharge to the impoundment commenced in 1988 (SRK 1994). A free-draining berm was constructed in 2009 at the toe of the North Tailings Dam as recommended in previous dam inspection reports (EBA 2010). The berm was designed by EBA, however, the construction was monitored by others and a completion report was prepared by AECOM in December 2009. As part of the toe berm construction, a small draw was in-filled below the toe berm.

The emergency spillway separates the South Dam from the North Dam. It is assumed that the native material underlying this area is predominantly morainal sand and gravel (EBA 2010). As outlined in previous reports, the emergency spillway channel is lined with rip-rap with a median diameter of approximately 75 mm. Based on available contour information, the average slope of the spillway chute was determined to be approximately 6%. The outlet of the spillway currently ties into a seepage channel prior to joining with the Cache Creek diversion channel.

A plan of the TSF dams, sections of the embankment and a geotechnical section through the dam axes are shown on the attached Figures 5, 8, 9 and 10.

3.6 Instrumentation

A total of eleven and eight Piezometers are installed in and around the North and South Dams respectively to monitor hydrostatic conditions through the embankments and their abutments. V-notch weirs have also been installed beyond the toe of each dam to monitor seepage. The location of the instrumentation installed in each dam is shown on the attached Figure 5 with the historical Piezometer records provided in Appendix C.

Based on EBA's review of the dam instrumentation, key points are as follows:

- It is noteworthy that the majority of the piezometers are installed along the dam crests and no piezometers are situated in the downstream slope of either dam.
- No significant changes were noted in the piezometer readings and, therefore, it is assumed that the interior drainage of the dams is still functioning as intended.
- Historical seepage flows at the V-notch weirs have been poorly documented. Seepage flows at Weirs 4 and 5 should be recorded in conjunction with the piezometers and documented.

3.7 Dam Inspection Reports

A review was undertaken of available inspection reports (listed in Appendix A) undertaken by the Water Resources Branch of Yukon Environment, EBA, and other engineering consultants. Key points from EBA's review of the dam inspection reports are as follows:

- Seepage has been commonly observed at the toes of the North and South Dams.
- Tension cracks have been documented near the crest of the North Dam.

4.0 SITE RECONNAISSANCE

The inspections of the dams and diversions were carried out by Mr. Scott Martin, P. Eng. of EBA in October 2010. There was a thin, discontinuous "dusting" of snow during the October site visit, which did not significantly hinder the observations. Due to a camera malfunction, there are no photographs available from the October site visit specifically, however, photographs from a previous 2010 site visit have been included for illustrative purposes.

The structures and immediate surrounding areas at each site were visually examined for signs of settlement, seepage, cracking, and other indicators of distress. Noteworthy observations were recorded.

The elevation of the tailings pond at the time of the inspection was approximately 1,307.8 m average mean sea level (AMSL), which is roughly 1.2 m below the 1,308.3 m AMSL invert of the emergency spillway (using the KRH system implemented by Challenger).

4.1 North Dam

- The tension crack evident in the 2008 inspection was not apparent during this inspection and has likely "healed" over time. However, a new tension crack was observed approximately 1 to 2 m below the upstream crest of the dam. The crack starts at the north abutment and is approximately 25 m long and 15 mm wide. It is likely associated with the rapid draw down of the tailings pond water elevation during one of the recent water discharge events.
- A minor bulge in the upper third of the downstream slope that was noted in the 2008 inspection is still evident, however, there are no indications that it has increased or changed since the last inspection.
- Minor erosion rills are still present on the downstream face of the dam due to surface runoff.
- Seepage was observed to be emerging from beneath the new toe berm at the downstream toe of the dam. It is clear and there is no indication that fine-grained material is "piped" from within the embankment. The seepage is being channelled into a pond downstream of the dam and upstream of a V-notch weir, which was previously installed to monitor the seepage rate.
- At the time of the inspection, the measured head at the Weir 4 was 90 to 100 mm, which correlates to a flow rate of approximately 1.6 to 2.4 L/s, which is consistent with previous measurements.
- A free-draining berm was constructed in 2009 at the toe of the North Tailings Dam as recommended in previous inspection reports (SRK 2005). An overview of the new berm is shown in Photo 2.
- It also appears that a thin (<300 mm) lift of granular material was placed across the crest of the dam. It is understood that the new lift was placed to bring the crest elevation of the dam the current design elevation.

4.2 South Dam

- The entire crest, downstream face, and emergency spillway were visually inspected. In general, the slopes and crest of the dam are in good condition. No indications of instability or erosion were noted.
- Seepage was observed along the downstream toe of the dam. The seepage has created a pond immediately downstream of the dam and upstream of a V-notch weir (Weir 5) that was previously installed to monitor the seepage rate.
- At the time of the inspection, the measured head was approximately 100 to 105 mm at Weir 5, which correlated to a flow rate of approximately 2.4 L/s, which is roughly equivalent to previous readings.

5.0 CONSEQUENCE CLASSIFICATION

5.1 General

The 2007 CDA Dam Safety Review Guidelines provides consequence classification criteria as well as suggested design flood and earthquake levels as a function of dam consequence classification as reproduced as Table 3 below.

Table 3: CDA 2007 Consequence Classification Criteria and Design FQ and Flood

Dam Classification from CDA 2007	Loss of Life	Economic and Social Losses	Environmental and Cultural Losses	Annual Exceedance Probability Level	
				EQ Design Ground Motion	Inflow Design Flood
Extreme	>100	Extreme – Critical Infrastructure or Service	Major Loss of Critical Habitat – No Restoration Possible	1/10,000	PMF
Very High	10-100	Very High – Important Infrastructure or Services	Significant Loss of Critical Habitat – Restoration Possible	1/5,000	2/3 between 1/1000 year and PMF
High	1-10	High – Infrastructure, Public Transit and Commercial	Significant Loss of Important Habitat – Restoration Possible	1/2,500	1/3 between 1/1000 year and PMF
Significant	Unspecified	Temporary and Infrequent	No Significant Loss of Habitat – Restoration Possible	1/1,000	Between 1/100 and 1/1000 year
Low	0	Low	Minimal Short Term Loss	1/500	1/100 year

5.2 Previous Studies

A number of previous studies have discussed the consequence classification of the tailings dams. The section provides a summary of these previous assessments in chronological order.

Addendum to the 1994 Decommissioning Plan Ketza River Mine, Tailings Management Facility, Yukon Territory by SRK, 1996

The consequence classification of failure of the tailings impoundment was considered to be "High" in this previous study as part of the reconsideration of the design flow for the proposed spillway when the tailings facilities are decommissioned. The consequence classification was selected, in accordance with the 1995 CDA dam safety guidelines, on the basis that there would be "substantial increase in social, economic and/or environmental losses" as a result of failure, as compared to the consequences of the same event without dam failure. Consideration of potential loss of life leads to a "Low" consequence category while the economic, social and environmental considerations lead to a higher consequence category, and hence, the "High" designation was selected.

Ketza River Mine 2007 Geotechnical Inspections by UMA, February 2008

In this study, the tailings dams were classified using the 2007 CDA dam safety guidelines in terms of the reasonably foreseeable consequences of failure. The classifications were based solely on a cursory inspection and review of available background information with respect to the dams. Both North and South Tailings Dams were considered to be "High" consequence classification dams in view of the significant environmental impact that would occur with uncontrolled release of tailings pond water and tailings into the Cache Creek valley during a dam breach.

Ketza Type A Water License Application Review Comments by Water Resources Branch of Environment Yukon, August 2010

The Water Resources Branch (the Branch) of Environment Yukon provided review comments in regards to the Water Licence application of the tailings pond. The Branch, with assistance from Environment Yukon's Fish and Wildlife Branch, provided information on fisheries values downstream of the tailings dams and an assessment report of downstream water quality. Based on other previous environmental studies, the presence of three species of freshwater fish in Cache Creek and the Ketza River had been confirmed. A model of fish habitat suitability was also developed for the new Yukon Placer regime, identifying the Pelly River as a Chinook salmon production zone. Furthermore, the lower reaches of the Ketza River were classified as moderate-high habitat for Chinook salmon production. Along the upper reaches of the river, the habitat was classified as moderate-moderate, and most of the Ketza River was classified as moderate-low habitat for Chinook production. Most of Cache Creek was defined as "Freshwater Fisheries Production Zone". Discussion of tailings release with reference made to the 1994 SRK study was included in this review document. It was concluded that the consequence classification of the tailings dams should be "High" due to the "immediate destruction of all fish populations in the entire Ketza River drainage downstream of the dam and the long-term destruction of habitat through high levels of arsenic contamination for a long period in both the Ketza River and Cache Creek".

5.3 Consequence Classification Review

The Dam Safety Guidelines published by the Canadian Dam Association (CDA 2007) were reviewed to update the consequence classification of the Ketza River Gold Mine Tailings Pond Dams. In order to classify the consequence of a dam failure, the most likely path of the flood wave was analyzed as discussed in detail in the companion hydrotechnical report. During a dam breach, the breach outflow would travel along Cache Creek down to its confluence with the Ketza River in less than 1 hour and would continue along the Ketza River down to its confluence with the Pelly River in less than 10 hours. The area in the vicinity of the Robert Campbell Highway crossing would be inundated with a temporary potential population at risk. Therefore, the incremental loss related to loss of life is unspecified. The consequence classification using this criterion would be "Significant". However, in terms of the infrastructure and economic incremental losses, it was considered that the dams would be classified as "High". In view of the significant amount of tailings likely to be released during a dam breach, the short travel time of the flood wave from the dam site to the Pelly River, and the environmental values of the downstream reaches, the incremental losses to the environmental and cultural values were considered to be significant. The consequence classification of the tailings dams using this criterion would be "High".

Based on a review of the previous studies and results of the current dam break analysis, the consequence classification for the tailings dams was established to be "High" in accordance with the 2007 CDA guidelines. For a dam with a High consequence classification, the Annual Exceedance Probability (AEP) for the design Earthquake Ground Motion is 1 in 2,500 years and the Inflow Design Flood (IDF) is to be determined as 1/3 between the 1,000-year event and the Probable Maximum Flood (PMF).

6.0 FAILURE MODES ASSESSMENT

Foster et al. (2000a) reviewed a database on dam failures (up to 1986) worldwide prepared by the International Congress on Large Dams (ICOLD) and determined the most common modes of failure for an earthfill dam as presented below, with percentages of total failure in brackets:

a. Embankment overtopping (34%)

b. Piping through the embankment (33%)

c. Piping through the foundation (15%)

d. Downstream and upstream slope instability (4%)

e. Other causes (earthquake, 16% total)

The percentages presented above reflect the characteristics of that database, not the likelihood of those failures developing at the Ketza River Mine Tailings Pond Dam. It is important to note that the database presents cases where multiple modes of failure were believed to have occurred. As such, the percentage total is greater than 100%.

a. Embankment overtopping occurs when the spillway either has insufficient capacity to discharge flood flows, either due to inadequate size or due to blockage with debris. Embankment overtopping is addressed in the hydrotechnical assessment presented in Section 8.0.

b. and c. Piping is the progressive internal erosion of dam fill or foundation materials along preferential seepage paths. The seepage starts to erode finer soil particles at the toe of a dam or at an interface between dissimilar materials that are not compatible from a filtering perspective (such as a silty clay core adjacent to a coarse rock fill shell). With time and continued seepage erosion, "pipes" or voids will be created within the dam that grow in an upstream direction towards the reservoir with acceleration of seepage and rate of erosion. Eventually, collapse of overlying fill, breach of the dam and subsequent uncontrolled discharge of the reservoir will occur. Piping is discussed further in Section 7.0.

d. Slope instability. Gravitational, seepage and seismic forces can cause instability in earth dams when they exceed the available shear strength of the soil. Slope stability of the dam is discussed further in Section 7.0.

e. Other causes of dam failure included slope instability due to earthquake forces, liquefaction and failure of the spillway/gate (appurtenant works).

For the Ketza River Mine Tailings Pond Dams, the following failure modes are considered to be plausible:

- Overtopping – The spillway may be undersized for the design flood event.
- Downstream slope instability – High water levels within the dams, as evident by seepage at the toe of the downstream slopes, increases the risk of downstream slope instability, either during static conditions or during a significant seismic event.
- Soil Liquefaction – The upstream shell of the North and South Dams are constructed with sand and gravel which may be susceptible to deformation when subjected to the design earthquake.
- Post Seismic Upstream and Downstream slope instability – The sand and gravel materials comprising the upstream and downstream shells of the dams may undergo a loss of strength when subjected to the design earthquake resulting in embankment instability.
- Piping through the embankment or foundation – The central low permeability core of each dam was not extended to underlying bedrock, providing only a partial cut-off, which may place the dams at risk of a piping failure.

7.0 GEOTECHNICAL ASSESSMENT

7.1 General

The scope of work for the Ketza River Gold Mine Tailings Storage Facility Dam Safety Review did not include a detailed intrusive geotechnical assessment, (i.e., drilling, sampling, testing, etc.) to confirm the nature of the existing embankment materials. The current assessment is based on observations made during the site reconnaissance, available data on the existing dams, published geological data, and EBA's engineering judgment, and should therefore be considered preliminary in nature. The objective of this approach is to identify potential geotechnical issues so that any detailed geotechnical assessment can be tailored to the particular issue.

The following subjects will be discussed in this Section:

- Embankment Seepage
- Embankment Stability
- Liquefaction
- Potential for Piping

7.2 Geotechnical Parameters Estimation

Reference has been made to the 1986 Golder Geotechnical Design Report for the dams, which provides some geotechnical design parameters for the materials encountered during the original investigation. Parameters were also obtained from several publications that provide typical values for a range of different soil types, namely Craig (1992), which provides typical ranges of hydraulic conductivities in Table 2.1 (reproduced as Table 4 below) and Bowles (1988), which provides representative values of angle of internal friction in Table 2-6 (reproduced as Table 5 below).

Table 4: Coefficient of Permeability (m/s) from Craig (1992)

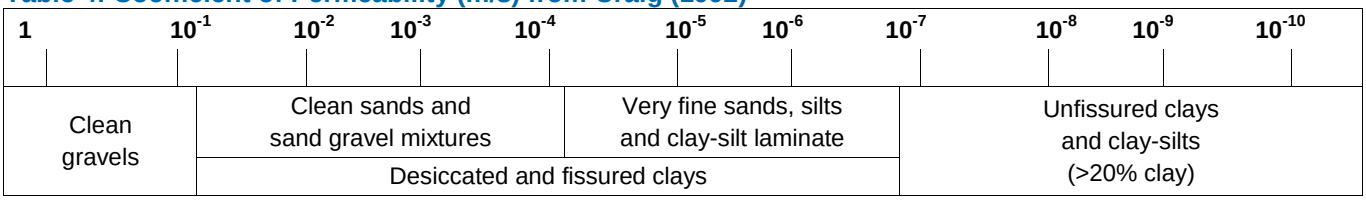


Table 5: Representative Values for Angle of Internal Friction Ø from Bowles (1988)

Soil Type	Angle of Internal Friction ø
Gravel	
Medium Size	40 – 50°
Sandy	35 – 50°
Sand	
Loose	27 – 35°
Dense	43 – 50°
Silt or silty sand	
Loose	27 – 30°
Dense	30 – 35°
Clay	20 – 42°

Based on review of the above references and available existing information on the dam the following geotechnical parameters were utilized in the various analyses as summarized in Table 6 below.

Table 6: Summary of Parameters Utilized in Geotechnical Analysis

Material	Soil Parameters			
	c' (kPa)	φ' (°)	γ_{sat} (kN/m^3)	k_{sat} (m/s)
Zone 1 – Gravel	0	34	22	0.01
Zone 2 and 4 – Silty Sand and Gravel	0	35	21	1 x 10-3
Zone 3 – Till Core	0	30	20.4	1 x 10^{-8}
Rock Toe Berm	0	40	22	0.01
Tailings	0	30	19.5	1 x 10^{-4}
Outwash Sand and Gravel	0	35	22	5 x 10^{-6}
In-Situ Till	0	30	21.4	1 x 10^{-8}
Bedrock				1 x 10^{-8}

c' = Effective Cohesion Intercept.
φ' = Internal Angle of Friction.
γ_{sat} = Saturated Unit Weight of Soil.
k_{sat} = Saturated Hydraulic Conductivity.

7.3 Seepage

Seepage at the downstream toe of the dams has been a commonly observed phenomenon; however, there has been very limited documentation of these flows during the history of the dams operation. At the time of our site inspection the seepage at the toe of the two dams was estimated to be in the order of 100 to 140 litres/minute.

Steady state seepage estimates were calculated using the two-dimensional finite element analysis program Seep/W. During the seepage analysis, an assessment of the sensitivity of the hydraulic conductivity parameter (k_{sat}) was undertaken to determine which material and/or layer had the greatest influence on the observed seepage at the toe of the dams. It was noted that the magnitude of seepage at the toe of the dams was primarily influenced by the hydraulic conductivity of the outwash sand and gravel layer that comprises the dam foundations.

The rate of toe seepage calculated for each dam is summarized in Table 7 below. It should be noted that the analyses were undertaken at the dam's maximum height and reduced seepage rates are anticipated where the embankment heights are less.

Table 7: Estimated Rate of Toe Seepage for Ketza River Gold Mine Tailings Storage Facility

Dam	Reservoir Level	Calculated Toe Seepage
North Dam	1,311.4	1.5 litres/minute/metre
South Dam	1,311.4	0.1 litres/minute/metre

The flow fields from the steady state seepage analysis of the dams are identified in Figures 11 and 19.

7.4 Embankment Stability Review

7.4.1 Criteria

The CDA Technical Bulletin, Geotechnical Consideration for Dam Safety provides accepted minimum slope stability factors of safety for various static and seismic loading conditions as reproduced in Tables 8 and 9 below.

Table 8: Acceptable Factors of Safety for Embankment Stability – Static Assessment

Loading Conditions	Minimum Factory of Safety	Slope
End of construction before reservoir filling.	1.3	Upstream and Downstream
Long-term (steady state seepage, normal reservoir level)	1.5	Downstream
Full or partial rapid drawdown	1.2 to 1.3	Upstream

Table 9: Acceptable Factors of Safety for Embankment Stability – Seismic Assessment

Loading Conditions	Minimum Factory of Safety	Slope
Pseudo-Static	1	Upstream and Downstream
Post-Earthquake	1.2 to 1.3	Upstream and Downstream

7.4.2 Methodology

The CDA Technical Bulletin, Geotechnical Consideration for Dam Safety, recommends a staged approach with respect to assessing the seismic stability of earth dams, beginning with simplified methods using suitably conservative input assumptions to demonstrate that a dam is safe; progressing to more sophisticated analysis methods should the simplified approach lead to unfavourable results. The first recommended stage of analysis undertaken is the pseudo-static method, in which the effects of an earthquake are applied as constant horizontal load via the use of dimensionless coefficients k_h equal to the peak ground acceleration for the earthquake return period under consideration. Should the embankment have a factor of safety in excess of 1.0 for this loading it is considered not to undergo any significant deformation during the design earthquake and therefore no further analysis is required. Should a factor of safety of less than 1.0 be obtained from the pseudo-static analysis then it is likely that the embankment will undergo deformation during the design earthquake event and a simplified deformation analysis (e.g., as per Newmark (1965), Bray (2007)) approach is recommend as the second stage of analysis to confirm that the embankment has adequate freeboard post the design earthquake event deformation. Should the second stage of analysis yield unfavourable results then a series of more sophisticated analysis approaches (e.g., Finite Element Analysis) are recommended.

Static and pseudo-static seismic global stability factors of safety for the existing embankments were calculated using the two-dimensional Limit State Equilibrium analysis program Slope/W.

Initial pore water pressure conditions in the embankments were determined by undertaking a steady state seepage analysis using the two-dimensional Finite Element analysis program Seep/W of each dam assuming the reservoir level was at 1,311.4 m and importing these into the Limit State Equilibrium analysis.

For the post-earthquake residual shear strength soil case, it was assumed that the sand and gravel comprising the shell of each dam, which was determined to be fully saturated in the seepage analysis, could liquefy. The undrained residual shear strength (Sr) of the soil was estimated in accordance with Figure 88 of Idriss and Boulanger (2008).

The stability review of the North and South Dams was considered at their maximum heights with the geometry and soil profile of the model based on the embankment cross sections shown on attached Figures 8 and 9. The results of the analysis are summarized are in Tables 10 and 11 below and are presented on the attached Figures 12 to 18 inclusive for the North Dam and Figures 20 to 26 inclusive for the South Dam.

Table 10: Factors of Safety – Slope Stability Assessment North Dam

Loading Conditions	Calculated Factor of Safety	Slope
Static long-term (steady state seepage, highest seasonal reservoir level)	1.68	Downstream
Static long-term (steady state seepage, highest seasonal reservoir level)	1.81	Upstream
Full or partial rapid drawdown[1]	n/a	Upstream
Seismic pseudo-static (steady state seepage, highest seasonal reservoir level)	1.26	Downstream
Seismic pseudo-static (steady state seepage, highest seasonal reservoir level)	1.28	Upstream
Post seismic residual shear strength (steady state seepage, highest seasonal reservoir level)	0.90	Downstream
Post seismic residual shear strength (steady state seepage, highest seasonal reservoir level)	0.65	Upstream

[1] Not considered an applicable loading condition as the dam does not have a low level outlet.

Table 11: Factors of Safety – Slope Stability Assessment South Dam

Loading Conditions	Calculated Factor of Safety	Slope
Static long-term (steady state seepage, highest seasonal reservoir level)	1.68	Downstream
Static long-term (steady state seepage, highest seasonal reservoir level)	1.58	Upstream
Full or partial rapid drawdown[1]	n/a	Upstream
Seismic pseudo-static (steady state seepage, highest seasonal reservoir level)	1.28	Downstream
Seismic pseudo-static (steady state seepage, highest seasonal reservoir level)	1.15	Upstream
Post seismic residual shear strength (steady state seepage, highest seasonal reservoir level)	1.03	Downstream
Post seismic residual shear strength (steady state seepage, highest seasonal reservoir level)	1.52	Upstream

[1] Not considered an applicable loading condition as the dam does not have a low level outlet.

7.5 Liquefaction and Post Seismic Deformation

No suitable historical geotechnical data (e.g., boreholes with in-situ testing) are available for the North and South Dams, to accurately quantify if there is a risk of the embankment undergoing deformation as a result of soil liquefaction during the design seismic event.

The shell of the North and South Dams comprises sand and gravel that could potentially be susceptible to liquefaction when subject to strong ground motion. As no geotechnical data are available for these dams, a preliminary liquefaction analysis utilizing lower bound material parameters and loading conditions was undertaken.

It is considered likely that the materials that comprise the shell of the dam were end-dumped with little or no compaction and are therefore somewhere between a loose to compact consistency. Conservatively assuming that a total stress over effective stress ratio of 2.1 exists for each dam, a cyclic shear stress ratio (CSR) of approximately 0.135 and 0.146 for the design earthquake event can be calculated for the North and South Dams, respectively.

Using the semi-empirical method developed by Tokimatsu and Seed (1987) of CSR versus, $(N_1)_{60}$ (in-situ standard penetration test results) and volumetric strain, volumetric strains and vertical settlements have been calculated for a range of $(N_1)_{60}$ as summarized in Tables 12 and 13 below.

Table 12: Estimated Vertical Settlement Due to Liquefaction for a Range of $(N_1)_{60}$ - North Dam

$(N_1)_{60}$	Estimated Volumetric Strain (ε)	Estimated Total Vertical Settlement[1]
10	2.5 %	500 mm
15	0.2 %	40 mm
20	0 %	0 mm

[1] At dam maximum height of ~20 m.

Table 13: Estimated Vertical Settlement Due to Liquefaction for a Range of $(N_1)_{60}$ - South Dam

$(N_1)_{60}$	Estimated Volumetric Strain (ε)	Estimated Total Vertical Settlement[1]
10	2.5 %	220 mm
15	0.2 %	10 mm
20	0 %	0 mm

[1] At dam maximum height of ~20 m.

Therefore, vertical settlements of no greater than 500 mm and 220 mm for a loose to compact soil profile are estimated for the sand and gravel shell of North and South Dams respectively for the design earthquake event, which is well within the available freeboard of these dams.

Given the depositional nature (e.g., glacial) of the dam's foundation materials there is considered to be very low risk of the dams' foundations undergoing liquefaction during the design seismic event.

The post seismic residual shear strength stability analysis resulted in a factor of safety of less than unity suggesting that the dam slopes are likely to undergo lateral deformation as a result of the design earthquake, assuming the saturated sands and gravels in the dam's shell are susceptible to liquefaction. Estimating the magnitude of this lateral deformation would require undertaking a more detailed liquefaction assessment based on the results of a field investigation and a dynamic finite element analysis, which is beyond the scope of this dam safety review.

7.6 Potential for Piping

Piping more frequently occurs within five years of first filling; however, there are many examples of dams where the effects of piping were only observed many years after first filling as presented in Foster et al. (2000b). Therefore, the North Tailings Dam and South Tailings Dam could still potentially develop piping failure, despite its history of relatively good performance.

Piping is typically accompanied by seepage containing suspended fines and sand. The seepage can be turbid (e.g., discoloured by suspended fines) and silt and sand is typically deposited at the toe of the dam where the seepage exits from the dam fill or foundation.

EBA has used a probabilistic method (the University of New South Wales (UNSW) method), for assessing the relative likelihood of failure of the dam by piping as presented in Foster et al. (2000b). This paper is included in Appendix D for reference. The UNSW method is based on a retrospective, critical review of dam failure case histories for piping failures that were included in the ICOLD database of dam failures. As a result of its dependence on judgement in selecting weighting factors and its semi-qualitative nature, the results of this assessment should be viewed as providing a general, high level indication of the likelihood of a piping failure occurring sometime in the future.

Based on EBA's application of the UNSW method, the total annual likelihood of piping failure under current conditions for North and South Dams are 4.59×10^{-5} (1 in 21,786 years) and 6.39×10^{-5} (1 in 15,649 years) respectively. This figure is the sum of individual probabilities for piping through the embankment, piping of the embankment into the foundation and piping of the foundation. The selection of the weighting factors for every piping mode is presented in Appendix D.

While this figure implies a high degree of accuracy, it is not possible to accurately estimate the likelihood of failure for North and South Dams given what is currently known about them. The implied accuracy is due to the statistics used in the Foster et al. (2000b) study. This probability confirms EBA's intuition that, while the performance of the North and South Dams to date is encouraging, there is still a small probability that piping failure could develop even if they experience the same loading conditions in the future as that they have been subjected to in the past. The results of this assessment will be considered further in Section 10.0 – Dam Safety Management.

Currently the calculated probability of a dam failure to occur due to piping is within the ALARP zone (see Section 9.6) shown on Figure 27 for the North and South Dams.

A significant seismic event could alter the structure of the dam by cracking the core, for instance, or its foundation. If this were to occur, the field performance of the dam could change, with an increased probability of a piping failure or dam safety incident. The satisfactory time record of dam performance would then start at the day of the significant seismic event (some time in the future), not the date of first filling of the reservoir. The probability of a piping failure developing in the dam in the first five years after an earthquake, as discussed in Section 7.6, is estimated from Foster et al. (2000b) to be more than ten times higher than the currently estimated probability. This will again be greater than the upper limit of the ALARP zone (see Section 9.6) shown on Figure 27, and would require further study and possibly rehabilitative measures to be taken.

8.0 HYDROTECHNICAL ASSESSMENT

The technical findings of the hydrotechnical assessment for the Ketza River Gold Mine TSF are contained in the companion hydrotechnical report.

The results of the flood routing through the tailings pond during the Inflow Design Flood (IDF) are summarized in Table 14 below.

Table 14: Results of Flood Routing

Scenario	Spillway Crest Elevation	Initial Pond Level	Peak Pond Level	Peak Storage	Peak Inflow	Peak Outflow	Dam Crest Elevation
(m)	(m)	(m)	(m)	(1,000 m^3)	(m^3/s)	(m^3/s)	(m)
Summer Autumn	1,309	1,305.4	1,309.80	431	30.9	9.2	1,310.5
Spring Case 1	1,309	1,309	1,310.11	455	23.4	14.9	1,310.5
Spring Case 2	1,309	1,309	1,310.01	448	13.3	13.0	1,310.5

Tables 15 and 16 summarize the results of the wave analysis and the overall freeboard determination for the summer-autumn scenario and for the spring scenario, respectively.

Table 15: Summary of Wind and Wave Analysis and Available Freeboard (Summer – Autumn Scenario)

Parameter	North Dam	North Dam	South Dam	South Dam
Pond Condition	Pond level at 1,305.4 m	During passage of IDF	Pond level at 1,305.4 m	During passage of IDF
Wind Frequency	1,000-yr	2-yr	1,000-yr	2-yr
Peak Pond Level (m)	1,305.4	1,309.8	1,305.4	1,309.8
Wind Setup (m)	0.001	0.001	0.002	0.001
Wave Runup (m)	0.35	0.23	0.41	0.27
Setup + Runup (m)	0.35	0.23	0.41	0.27
Avail. Freeboard (m)	5.1	0.7	5.1	0.7

Table 16: Summary of Wind and Wave Analysis and Available Freeboard (Spring Scenario)

Parameter	North Dam	North Dam	South Dam	South Dam
Pond Condition	Pond level at 1,305.4 m	During passage of IDF	Pond level at 1,305.4 m	During passage of IDF
Wind Frequency	1,000-yr	2-yr	1,000-yr	2-yr
Peak Pond Level (m)	1,309.0	1,310.11	1,309.0	1,310.11
Wind Setup (m)	0.001	0.001	0.002	0.001
Wave Runup (m)	0.35	0.23	0.41	0.27
Setup + Runup (m)	0.35	0.23	0.41	0.27
Avail. Freeboard (m)	1.5	0.39	1.5	0.39

Freeboard was computed as the difference between the design pond level and the dam crest elevation of 1,310.5 m. It should be noted that the current analysis has assumed that low areas along the dam crest would be raised to the maximum dam crest elevation of 1,310.5 m. The maximum normal elevation was chosen to be at elevation 1,305.4 m during summer-autumn and at the spillway weir crest elevation during spring when combined with the 1,000-year wind condition. The peak pond level during the passage of the IDF was applied when combined with the 2-year wind condition. During normal conditions, a freeboard of 5.1 m would be available during the summer-autumn season and a freeboard of 1.5 m would be available during the spring season. During the summer-autumn IDF, a freeboard of 0.7 m would be available. During the spring IDF, a freeboard of approximately 0.4 m would be available. In all cases, the amount of freeboard available is greater than needed for the sum of the wind setup and wave runup. Therefore, the freeboard is considered adequate since there will be no overtopping by 95% of the waves either caused by the most critical wind with a frequency of 1/1,000 year when the reservoir is at its maximum normal elevation or caused by the most critical wind when the reservoir is at its maximum extreme level during the passage of the IDF.

The erosion protection requirements for the spillway, chute and its outlet were determined. The current median rock size along the spillway as reported by others is 75 mm, which is not adequate to handle the design flow during the IDFs. It is recommended that the spillway and the spillway chute be lined using a 700 mm thick riprap layer with a median rock size of 410 mm underlain by a 200 mm thick granular filter layer with a median rock size of 40 mm. It should be noted that no detailed site data has been obtained for the outlet of the spillway chute at the time of the study. In general, it is recommended that the chute sides be extended up to a minimum of 1.7 m on the opposite bank of the receiving stream. To further minimize the potential of toe erosion, larger size rocks should be placed along the eastern portion of the outlet area.

The conditions of the diversion/interceptor channels around the tailings pond were also assessed. It was determined that these channels are Significant consequence classification structures, and the 200-year flood was selected as the IDF, which is consistent with CDA (2007) guidelines. Results of the analysis indicate that the channels are sufficient to handle the inflow design flood, and there is no erosion concern along the Northwest Runoff Interceptor (NWRI) ditch upstream of the pond and along the Lower Subsidiary Creek diversion channel.

The existing culvert crossings around the tailings pond were evaluated, and results show that the existing twin 600 mm diameter culvert near the upstream end of the Lower Subsidiary Creek diversion and the existing 900 mm diameter culvert located further downstream are inadequate for the design flow condition. In view of the frequent blockage issues at these crossings, it is recommended that a new 750 mm diameter culvert and a new 600 mm diameter culvert be added to the twin culvert crossing and the 900 mm diameter culvert crossing, respectively. Also, it is recommended that regular monitoring and maintenance be conducted for the culvert crossings around the pond to minimize blockage issues.

The erosion protection requirements for the NWRI ditch downstream of the mine access road and the Cache Creek diversion were determined; however, more site information such as the existing riprap material size along channels, the actual alignment and slope of this sub-reach of the NWRI ditch is required to confirm the need for erosion protection. For the unstable areas along the Cache Creek diversion as identified from previous geotechnical inspections, it is recommended that remediation be implemented. The rest of the Cache Creek diversion should also be protected by the suggested riprap materials where necessary.

9.0 DAM SAFETY MANAGEMENT SYSTEM

9.1 General

Dam safety management can be generally described to have five components (CDA Guidelines 2007):

- Owner commitment to safety.
- Regular inspections and Dam Safety Reviews with proper documentation and follow up.
- Implementation of effective Operations, Maintenance and Surveillance (OMS) practices.
- Preparation of effective Emergency Preparedness Plans.
- Management of Public Safety.

A general schematic of a dam safety management system is presented in Figure 25 EBA has assessed the dam safety management system in place for the Tailings Pond Dams and the results of this assessment are presented in this section.

9.2 Review of Operations, Maintenance, and Surveillance Manual

An Operations, Maintenance and Surveillance (OMS) Manual is a means to provide both experienced and new staff with the information they need to support the safe operation of a dam (CDA 2007).

As part of the scope of this DSR, EBA has prepared an OMS Manual for this facility.

9.3 Review of Emergency Preparedness Plan

The objective of an Emergency Preparedness Plan (EPP) is to provide the basic information that allows for the planning and coordination by municipalities, Royal Canadian Mounted Police, local police, provincial agencies, utility owners and transportation companies and other parties that would be affected by a major flood (CDA 2007).

As part of the scope of this DSR, EBA has prepared an EPP for this facility.

9.4 Public Safety Management

The 2007 CDA Guidelines contain a draft Technical Bulletin on Public Safety and Security around Dams. Public safety and security around dams is an emerging topic in the dam safety community in both Canada, and the world, that the CDA is leading. As this is an emerging topic, it is not surprising that there is no Public Safety or Security Management Plan in place. However, given the extremely isolated nature of the Ketza River Gold Mine Tailings Storage Facility dams, public interaction with the dams is not anticipated to present potential problems.

9.5 Dam Safety Expectations Assessment

The British Colombia Ministry of Environment (BC MoE) has developed a sample check sheet of Dam Safety Expectations, Deficiencies and Priorities (May 2010) which is based on the 2007 CDA Guidelines. A dam safety expectations assessment has been undertaken of the Tailings Pond Dams using the sample check sheet prepared by the BC MoE as presented in Appendix D.

The Dam Safety Expectations are divided into five categories:

- Dam Safety Analysis.
- Operations, Maintenance and Surveillance.
- Emergency Preparedness.
- Dam Safety Review.
- Dam Safety Management System.

A brief summary of the results of the Dam Safety Expectations are discussed below.

9.5.1 Analysis and Assessment

There is one actual deficiency (median rock size of the spillway is undersized) and one potential deficiency (the upstream shell of the dams are potentially liquefiable and the stability of the embankments may be insufficient following the design earthquake event).

9.5.2 Operations, Maintenance and Surveillance

There are nine non-conformances in this category, which all could be resolved by improving maintenance documentation and dam safety training of staff undertaking dam inspections.

9.5.3 Emergency Preparedness

There are two non-conformances in this category which could be resolved by undertaking an emergency exercise and training of staff involved.

9.5.4 Dam Safety Review

There are no deficiencies and non-conformances in this category. By commissioning this Dam Safety Review, YNG conforms to the dam safety expectations for this category.

9.5.5 Dam Safety Management System

There is one non-conformance in this category, which could be resolved by improving maintenance documentation.

9.6 Assessment of Dam Safety Based on ALARP Principal

9.6.1 General

Management of dam safety is the cornerstone of managing the liability associated with potential risk of dam failure. Societal tolerances for loss of life have generally been decreasing through the years.

In the case of the tailings pond dams, given the findings to date of this dam safety review, these questions need to be asked:

- "How safe is safe enough?"; and
- "How does YNG balance equity and efficiency?"

The first question deals with tolerance of risk of failure and defining a frequency or probability of failure beyond which it isn't practical to be concerned about. The second question deals with how to balance risk tolerance with financial costs associated with reducing risk.

The 2007 CDA Guidelines introduced the "ALARP" principal to the Canadian Dam Safety community with regard to tolerable risk. ALARP stands for **A**s **L**ow **A**s **R**easonably **P**racticable. This principal is demonstrated in Figure 27, which relates magnitude of loss of life to probability of loss of life. This chart shows the suggested relationship between probability of occurrence, potential loss of life and varying degrees of risk tolerability (broadly acceptable, ALARP and unacceptable).

EBA cannot advise YNG and other stakeholders (e.g., the community, utility owners, etc.) what their tolerance for risk of loss of life is. The level of risk accepted by the YNG and the stakeholders is up to them. Therefore, this section has been prepared to illustrate what generally accepted risk tolerance is within the dam community in Canada, as defined by the CDA.

EBA has applied the ALARP principal to the deficiencies and non-conformances identified during the dam safety review and the results of this assessment are presented in the following sections. For the purposes of this assessment, EBA has assumed that the maximum number of deaths that could occur is 10, which is the maximum magnitude of loss of life for a "High" consequence classification dam.

9.6.2 Stability of Embankment Slopes

Undertaking a probabilistic stability assessment of dams is not in the typical scope of a dam safety review given that current CDA acceptance criteria for stability is based on accepted minimum factors of safety, therefore it is currently not possible to predict a probability of failure causing loss of life associated for the dams at this time.

9.6.3 Piping Failure

EBA has considered the probability of failure due to a piping event as discussed in Section 7.6. The results of this semi-qualitative assessment are an annual probability of piping failure. The probability of one or more people being downstream of the tailings pond when a flood wave from dam failure passes down the valley is very small (<1).

Additionally, the probability of one or more people killed while being in the path of the flood wave is also considerably less than unity. The probability of one or more people killed by the flood wave is the product of all three probabilities as below.

$$P_{\text{loss of life}} = P_{\text{piping failure}} \times P_{\text{persons in way}} \times P_{\text{persons in way being killed}}$$

Assuming that no more than ten people could ever be killed downstream of the dam by a flood wave caused by dam failure due to piping, the maximum probability of failure causing loss of life would equal to the values presented in Section 7.6 and would plot just within the "ALARP" zone as shown on Figure 27. This depends on the assumption that the probability of people being in the path of a floodwave and being killed by it is certain, e.g., probability of 1.0. From a practical perspective, recognizing a reduction in the probability of loss of life associated with the latter two individual probabilities in the equation above, the probability of loss of life would therefore move comfortably to within the "ALARP" zone.

10.0 CONCLUSIONS

Presented below are conclusions reached during the Dam Safety Review of the North Dam and South Dam.

10.1 Background Review

- There is no in-situ strength data available for the dam materials.
- Based on the review of current and historical piezometer readings, no significant changes were noted and therefore it is assumed that the interior drainage of the dam is still functioning as intended.

10.2 Site Reconnaissance

10.2.1 North Dam

- Minor erosion is occurring at the toe of Weir 4, which allowing some water to seep under the weir and potentially affecting flow measurements.
- Piezometers P90-10A and P90-10B and P90-8 are damaged.

10.2.2 South Dam

Seepage observed at the toe of the South Dam does not appear to be affecting stability.

10.3 Consequence Classification

The North and South Dams are classified as "High" consequence dams according to the CDA 2007 Guidelines.

10.4 Failure Mode Assessment

The plausible failure modes of the dam are: overtopping, downstream slope instability, piping through the embankment and foundation, soil liquefaction of the upstream slope, and post-earthquake downstream and upstream instability.

10.5 Geotechnical Assessment

- In general, the shape of the seepage analysis flow fields determined by the steady state seepage analysis concurs with the historical observations at the embankment toe.
- The results of the stability analysis indicate that the upstream and downstream slope of the dam do not meet CDA minimum factors of safety for the post seismic event case.
- The magnitude of vertical settlement as a result of soil liquefaction for the design earthquake event is estimated to be less than 500mm North Dam and 220 mm South Dam, which is within the available freeboard of the dam.
- Given the depositional nature (i.e., glacial) of the dam foundation, there is considered to be no risk of the dam foundation undergoing liquefaction during the design seismic event.
- A probabilistic piping risk assessment was conducted using the UNSW method that resulted in a calculated probability of piping failure developing of 4.59×10^{-5} North Dam and 6.39×10^{-5} South Dam.

10.6 Hydrotechnical Assessment

- Based on a review of previous studies and results of the current dam break analysis, the tailings dams are classified as "High" consequence dams. In accordance with the 2007 CDA Guidelines, the IDF for the tailings pond was chosen to the 1/3 between a 1,000-year flood and the Probable Maximum Flood (PMF). Two IDF scenarios were considered: the summer-autumn scenario and the spring scenario. The summer-autumn IDF was determined to have a peak flow of 30.9 m^3/s. The governing spring IDF was determined to have a peak inflow of 23.4 m^3/s.
- Flood routing was performed to assess the capacity of the dams to pass the IDF. The existing spillway crest has an average elevation of 1,309 m. With the existing configuration of the spillway, a minimum freeboard of 0.7 m would be available during the summer-autumn IDF, and a minimum freeboard of about 0.4 m would be available during the spring IDF.
- A wind and wave analysis was conducted in the freeboard determination of the existing spillway. Results indicate that there will be no overtopping by 95% of waves either caused by the most critical wind with a frequency of 1/1,000 year when the reservoir is at its maximum normal elevation or caused by the most critical wind when the reservoir is at its maximum extreme level during the passage of the IDF. Therefore, the amount of freeboard available is considered adequate.
- A hydraulic analysis of the erosion potential of spillway and chute was conducted. Results of the analysis indicate that the existing rock size of the spillway is inadequate.
- A hydraulic analysis of the Northwest Runoff Interceptor ditch, the Lower Subsidiary Creek diversion channel, the Cache Creek diversion channel and the associated culvert crossings was carried out. The diversion/interceptor channels were determined to be Significant consequence classification structures, and the 200-year flood was selected as the inflow design flood. Results of the hydraulic analysis indicate that all diversion/interceptor channels have sufficient capacities to handle the inflow design flood and that there is no erosion concern along the NWRI ditch upstream of the tailings pond and along the Lower Subsidiary Creek diversion.

10.7 Dam Safety Management

- Dam inspection documentation should be improved to include quantifying seepage rates and including comments on the clarity of seepage.
- Piezometers should be installed in the downstream slop of the dam.

11.0 RECOMMENDATIONS

11.1 Background Review

There are no recommendations from this area of review.

11.2 Site Reconnaissance

11.2.1 North Dam

The eroded area at the toe of Weir 4 should be backfilled to minimize seepage and armoured to prevent future erosion. Seepage quantity and quality should be monitored regularly as outlined in the OMS Manual (High).

11.2.2 South Dam

Seepage observed at the toe of the South Dam should continue to be monitored for quantity and quality as outlined in the OMS Manual (High).

11.3 Consequence Classification

There are no recommendations from this area of review.

11.4 Failure Mode Assessment

There are no recommendations from this area of review.

11.5 Geotechnical Assessment

In-situ strength testing (e.g., SPT's) and sampling should be undertaken on the embankment materials to better assess the liquefaction and post-earthquake stability of the embankments to determine whether this is within CDA criteria. This could be undertaken in conjunction with an instrumentation (piezometer) installation program. Should unacceptable factors of safety still be obtained consideration to permanently lowering the reservoir level may be required (Medium).

11.6 Hydrotechnical Assessment

- It is recommended that the spillway and the chute be lined with riprap with a median rock size of 410 mm and granular filter with a median size of 40 mm. The required thickness for the riprap layer was determined to be 700 mm while that for the filter layer was determined to be 200 mm (Medium).

- No detailed site information has been obtained for the outlet of the spillway chute at the time of the study. However, general erosion protection requirements at the outlet of the spillway chute were determined. It is recommended that the chute sides be extended up to a minimum of 1.7 m on the opposite bank of the receiving stream. To further minimize the potential of erosion, larger size rocks should also be placed along the eastern portion of the outlet area (Medium).
- Conditions of the existing culvert crossings were also assessed, and it is recommended that a new 750 mm diameter culvert be added to the existing twin 600 mm diameter culvert crossing near the upstream end of the Lower Subsidiary Creek diversion and that a new 600 mm diameter culvert be added to the existing 900 mm diameter culvert near the downstream end of Lower Subsidiary Creek diversion. It is also recommended that regular monitoring and maintenance be carried out at these culvert crossings to minimize the blockage issues (Medium).
- The erosion protection requirements along the NWRI ditch downstream of the mine access road and along the Cache Creek diversion channel were determined. However, the existing riprap size, actual alignment and slope of this sub-reach of the NWRI ditch have yet to be confirmed in the field. Similarly, the existing riprap material size along the Cache Creek diversion channel has yet to be confirmed. Two locations of instability have been identified from previous geotechnical studies. In particular, the Cache Creek diversion channel just downstream of the outlet of the seepage channel has an instability issue because of high flows. It is recommended that remediation be implemented at these unstable locations and that the rest of the channel is protected by the suggested riprap materials where necessary (Medium).
- It is recommended that a site visit be conducted to get a better understanding of the spillway chute, its outlet condition, and the diversion/interceptor ditches and to refine the erosion protection requirements prior to any proposed works at the spillway and along the diversion/interceptor channels (High).

11.7 Dam Safety Management

11.7.1 North Dam

- Survey monuments should be installed on the crests of dams, downstream slopes and crest of the new toe berm. These monuments should be surveyed twice a year (March and September) to ensure that the slight bulge in the downstream slope is not changing (Medium).
- Piezometer/monitoring well water elevations should be collected and reviewed at least monthly (High).
- Flow rates from Weir 4 should be collected and reviewed monthly (High).
- Piezometers P90-10A and P90-10B and P90-8 still require repair (High).
- The movement of instruments P90-8 and P90-9 should be surveyed every three months, so that it can be determined if the instruments are settling or heaving (High).

- Visual monitoring of the riling and erosion on the face of the dam should be undertaken quarterly to determine if the issue is increasing in severity (High).

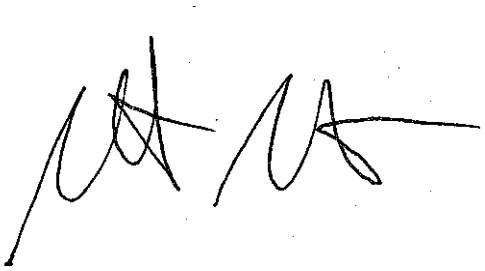
11.7.2 South Dam

Piezometer/monitoring well water elevations should continue to be collected and reviewed at least monthly. Based on the data provided by YNG, it appears that the piezometers are currently being monitored roughly every second month (High).

12.0 CLOSURE

We trust this proposal/report meets your present requirements. Should you have any questions or comments, please contact the undersigned at your convenience.

EBA, A Tetra Tech Company



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REFERENCES

Bowles, J.E., 1988. Foundation Analysis and Design – Forth Edition. McGraw-Hill Publishing Co.

British Columbia Ministry of Environment, 2010. Dam Safety Review Guidelines. – Version 2.

Canadian Dam Association (CDA), 1997. Dam Safety Guidelines.

Canadian Dam Association (CDA), 2002. Dam Safety Review Workshop, 2002 CDA Conference, Victoria, British Columbia.

Canadian Dam Association (CDA), 2004. Public Safety Around Dams Workshop, 2004 CDA Conference, Ottawa, Ontario.

Canadian Dam Association (CDA), 2007. Dam Safety Guidelines.

Canadian Dam Association (CDA), 2007. Technical Bulletin – Dam Safety Analysis and Assessment.

Canadian Dam Association (CDA), 2007. Technical Bulletin – Geotechnical Considerations for Dam Safety.

Canadian Dam Association (CDA), 2007. Technical Bulletin – Hydrotechnical Considerations for Dam Safety.

Canadian Dam Association (CDA), 2007. Technical Bulletin – Inundation, Consequences and Classification for Dam Safety.

Canadian Dam Association (CDA), 2007. Technical Bulletin – Seismic Hazard Considerations for Dam Safety

Craig, R.F., 1992. Soil Mechanics – Fifth Edition. Chapman and Hall.

Foster, M., Fell, R., and Spannagle, M., 2000. A method for assessing the relative likelihood of failure of embankment dams by piping. Can. Geotech. 5., Vol. 37, pp 1000-1024.

Foster, M., Fell, R., and Spannagle, M., 2000. The statistics of embankment dam failures. Can. Geotech. 5., Vol. 37, pp 1000-1024.

Halchuk, S., and Adams, J., 2008. "Fourth generation seismic hazard maps of Canada: Maps and grid values to be used with the 2005 National Building Code of Canada". Geological Survey of Canada Open File 5813.

Idriss, I.M. and Boulanger, R.W., 2008. Soil Liquefaction During Earthquakes. Earthquake Engineering Research Institute Monograph 12.

Kramer, S.L., 1996. Geotechnical Earthquake Engineering. Prentice Hall.

Tokimatsu, K. and Seed, H.B., 1987. Evaluation of settlements in sand due to earthquake shaking. J. of Geotechnical Engineering, ASCE. Vol. 113(8): 861-878.

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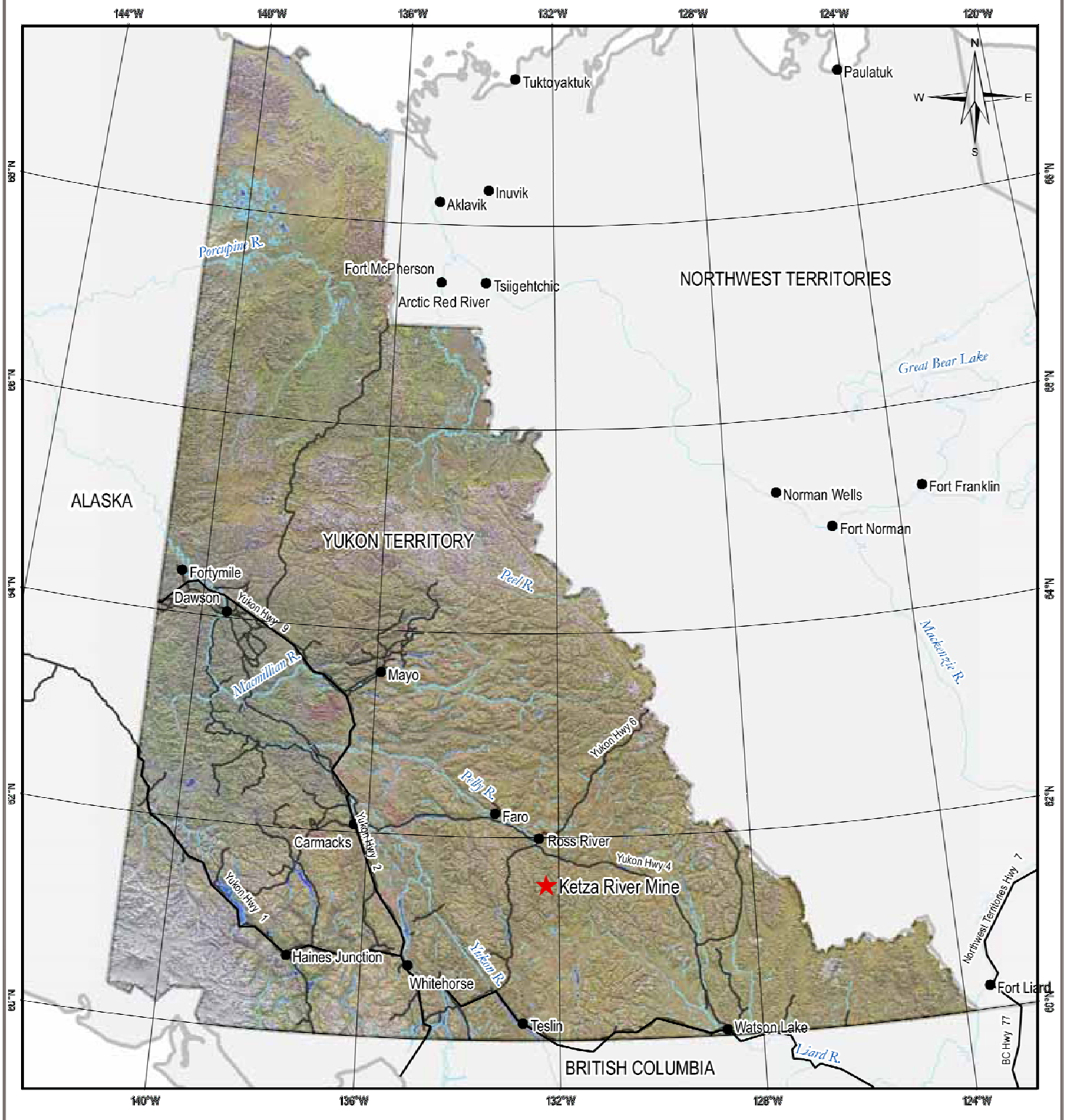

NOTES

Base data source: ESRI, Government of Yukon

LEGEND

- Site Location
- Cities
- Waterbodies
- Roads
- Political Boundaries

CLIENT

Yukon-Nevada Gold Corp.

KETZA RIVER GOLD MINE, TAILINGS STORAGE FACILITY, DAM SAFETY REVIEW

SITE LOCATION

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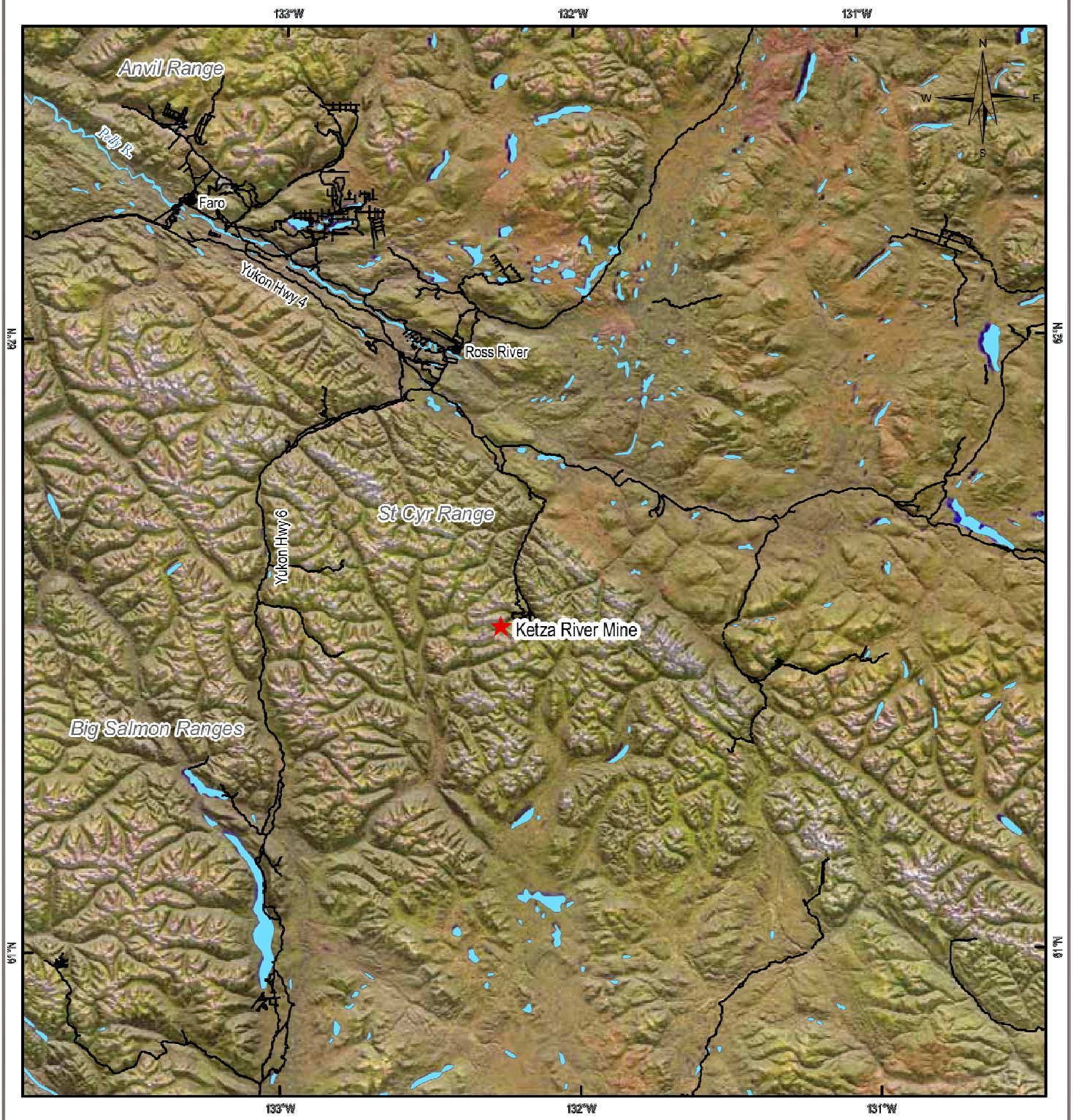
PROJECT NO.	DWN	CKD	REV
W23101051.104.009	LM	MJL	0

OFFICE	DATE
EBA-KELOWNA	April 27, 2011

Figure 1



Scale: 1:6,000,000

100 50 0 100

Kilometres

LEGEND

- Site Location
- Roads
- Waterbodies

NOTES

Base data source: ESRI, Government of Yukon

CLIENT

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KETZA RIVER GOLD MINE, TAILINGS STORAGE FACILITY, DAM SAFETY REVIEW

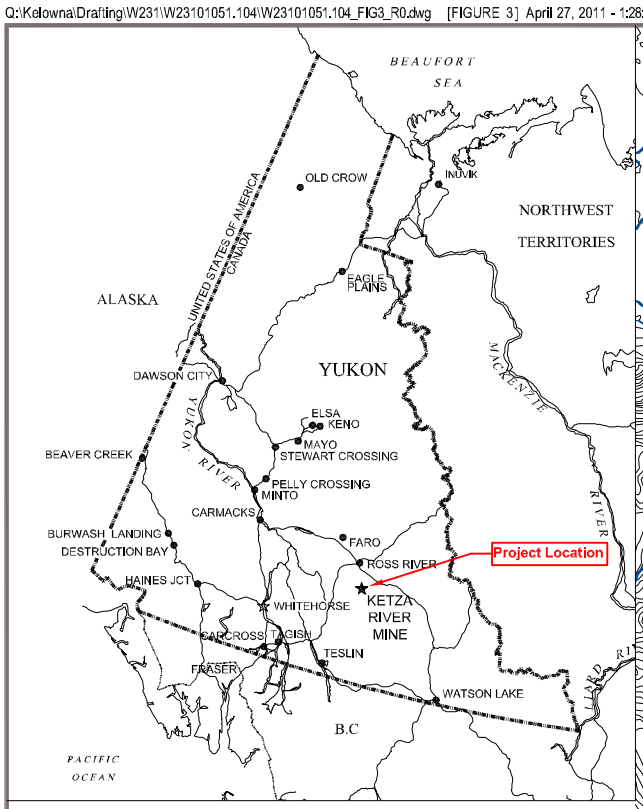
REGIONAL MAP

PROJECT NO.	DWN	CKD	REV
W23101051.104.009	LM	MJL	0

OFFICE: EBA-KELOWNA

DATE: April 27, 2011

Figure 2



GENERAL LOCATION MAP

LEGEND

- ROAD
- RIVER

0 50 000

Scale: 1: 100 000 (metres)

NOTES

BASE DATA: 1:50,000 NTS NAD 83 MSL

CONTOUR INTERVAL: 100ft

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KETZA RIVER GOLD MINE, TAILINGS STORAGE FACILITY, DAM SAFETY REVIEW

LOCATION MAP AND SITE PLAN

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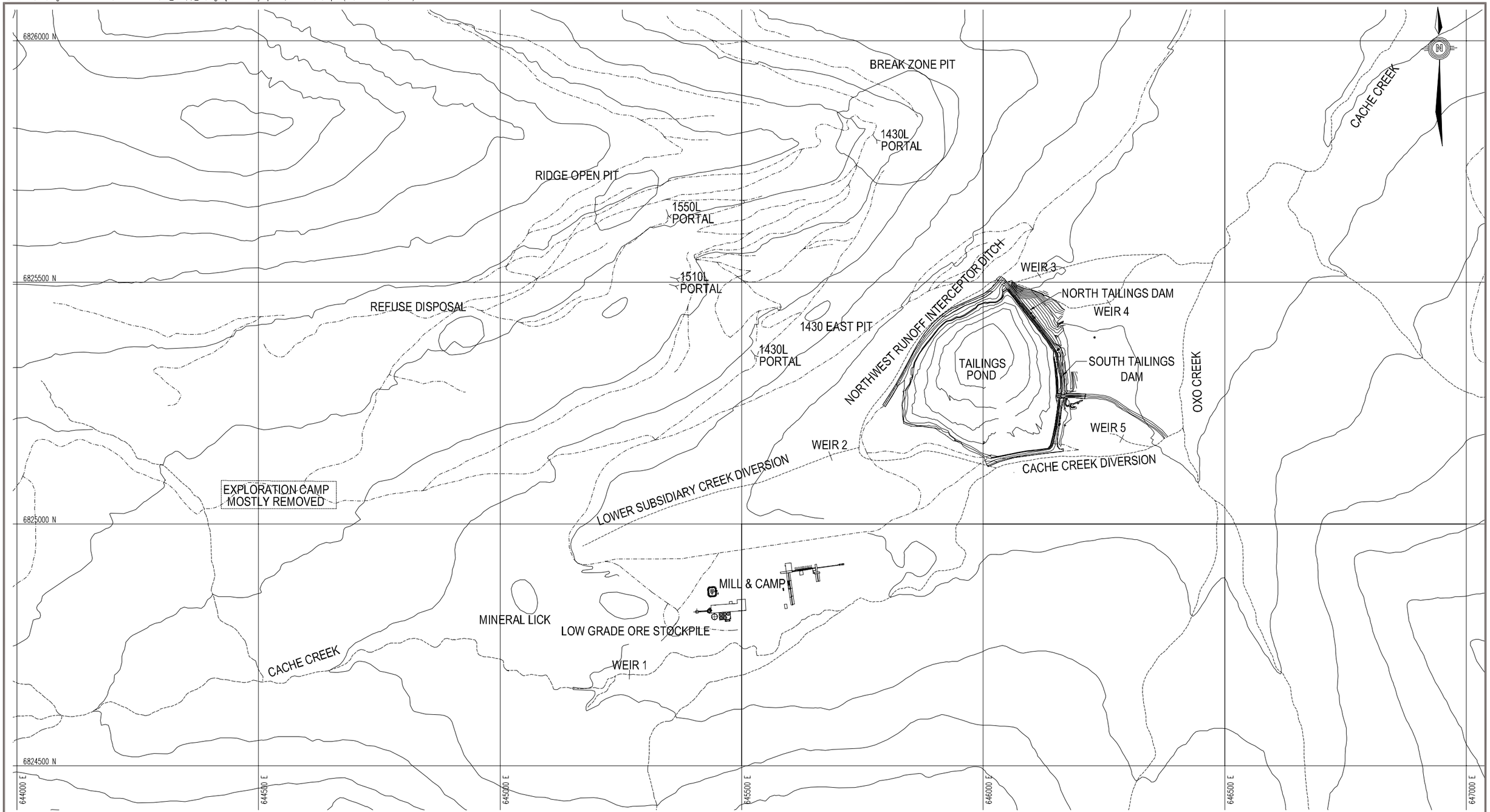
PROJECT NO.	DWN	CKD	REV
W23101051.104.009	LM	MJL	0

OFFICE	DATE
EBA-KELOWNA	April 27, 2011

Figure 3

O:\Kelowna\Drafting\W231\W23101051.104\W23101051.104_FIG1,2,4_R0.dwg [FIGURE 4] April 27, 2011 - 12:36:00 pm (BY: MAJETICH, LAURA)



LEGEND

- PORTAL
- ROADWAY
- WATERCOURSE

0 200 500 1000 metres

SCALE = 1 : 7,500

CLIENT

Yukon-Nevada Gold Corp.

KETZA RIVER GOLD MINE, TAILINGS STORAGE FACILITY, DAM SAFETY REVIEW

GENERAL SITE ARRANGEMENT PLAN

A TETRA TECH COMPANY

PROJECT NO.	DWN	CKD	REV
W23101051.104.009	LM	MJL	0

OFFICE	DATE
EBA-KELOWNA	April 27, 2011

Figure 4

Q:\Kelowna\Drafting\W231\W23101051.104\W23101051.104_FIG5_R0.dwg [FIGURE 5] April 27, 2011 - 1:22:22 pm (BY: MAJETICH, LAURA)

600mm DIA CSP CULVERT
WEIR 3
NORTHWEST RUNOFF INTERCEPTOR DITCH
P90 - 10A & 10B
P89 - 1
P96 - 11A, 11B, 11C
WEIR 4
NORTH TAILINGS DAM
P89 - 6A & 6B
TAILINGS POND
P90 - 8
P90 - 9
OXO CREEK
P89-5
EMERGENCY SPILLWAY
P96 - 12B & 12C
P96 - 12A
SOUTH TAILINGS DAM
P89-4
P90 - 7A, 7B & 7C
P98 - 3
WEIR 5
DIVERSION
LOWER SUBSIDIARY CREEK
WEIR 2
2 X 600mm DIA CSP CULVERTS
NEW 900mm DIA CSP CULVERT
CACHE CREEK SOUTH DIVERSION
INSTABILITY AREA #1
INSTABILITY AREA #2
1298.9
1301.4
1303.9
1306.4
1308.9
6825500 N
6825400 N
6825300 N
6825200 N
6825100 N
645600 E
645700 E
645800 E
645900 E
646000 E
646100 E
646200 E
646300 E
646400 E
646500 E
646600 E

LEGEND

- P89 - 3 PIEZOMETER (INSTALLED 1989)
- P96 - 12A MONITORING WELL (INSTALLED 1996)
- ROADWAY
- WATERCOURSE
- TOE BERM (CONSTRUCTED 2009)

0 100
Scale: 1: 2 500 (metres)

NOTES
BASE DATA: UTM NAD 27 HI2 MSL

CLIENT
Yukon-Nevada Gold Corp.

KETZA RIVER GOLD MINE, TAILINGS STORAGE FACILITY, DAM SAFETY REVIEW

TAILINGS IMPOUNDMENT SITE PLAN

eba A TETRA TECH COMPANY

PROJECT NO.	DWN	CKD	REV
W23101051.104.009	AD	MJL	0

OFFICE: EBA-KELOWNA
DATE: April 27, 2011

Figure 5

2005 National Building Code Seismic Hazard Calculation

INFORMATION: Eastern Canada English (613) 995-5548 français (613) 995-0600 Facsimile (613) 992-8836
Western Canada English (250) 363-6500 Facsimile (250) 363-6565

Requested by: Michael J Laws, EBA

April 06, 2011

Site Coordinates: 50.6944 North 119.3024 West

User File Reference: Salmon Arm, BC

National Building Code ground motions:
2% probability of exceedance in 50 years (0.000404 per annum)

Sa(0.2)	Sa(0.5)	Sa(1.0)	Sa(2.0)	PGA (g)
0.272	0.165	0.082	0.046	0.136

Notes. Spectral and peak hazard values are determined for firm ground (NBCC 2005 soil class C - average shear wave velocity 360-750 m/s). Median (50th percentile) values are given in units of g. 5% damped spectral acceleration (Sa(T), where T is the period in seconds) and peak ground acceleration (PGA) values are tabulated. Only 2 significant figures are to be used. ***These values have been interpolated from a 10 km spaced grid of points. Depending on the gradient of the nearby points, values at this location calculated directly from the hazard program may vary. More than 95 percent of interpolated values are within 2 percent of the calculated values.***

Ground motions for other probabilities:

Probability of exceedance per annum	0.010	0.0021	0.001
Probability of exceedance in 50 years	40%	10%	5%
Sa(0.2)	0.056	0.130	0.184
Sa(0.5)	0.036	0.080	0.112
Sa(1.0)	0.020	0.040	0.055
Sa(2.0)	0.012	0.024	0.032
PGA	0.032	0.070	0.095

References

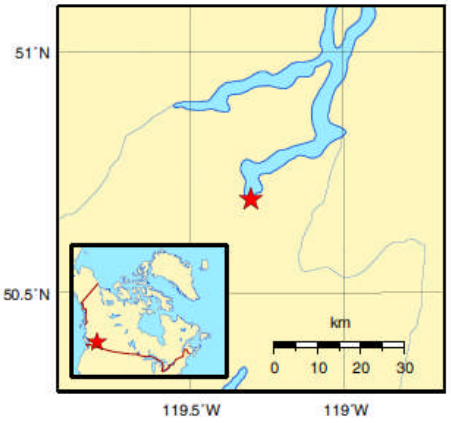
National Building Code of Canada 2005 NRCC no. 47666; sections 4.1.8, 9.20.1.2, 9.23.10.2, 9.31.6.2, and 6.2.1.3
Appendix C: Climatic Information for Building Design in Canada - table in Appendix C starting on page C-11 of Division B, volume 2

User's Guide - NBC 2005, Structural Commentaries NRCC no. 48192
Commentary J: Design for Seismic Effects

Geological Survey of Canada Open File xxxx
Fourth generation seismic hazard maps of Canada: Grid values to be used with the 2005 National Building Code of Canada (in preparation)

See the websites *www.EarthquakesCanada.ca* and *www.nationalcodes.ca* for more information

Aussi disponible en français



Natural Resources Canada | Ressources naturelles Canada

Canada

LEGEND

NOTES
From the Earthquakes Canada website (http://earthquakescanada.nrcan.gc.ca)

STATUS
ISSUED FOR USE

CLIENT
Yukon-Nevada Gold Corp.

A TETRA TECH COMPANY

KETZA RIVER GOLD MINE TAILINGS STORAGE FACILITY DSR

Reference Peak Ground Accelerations (PGA) and Spectral Accelerations (Sa(T))

PROJECT NO.	DWN	CKD	APVD	REV
W23101051.104.109	MJL	SM	SM	0

OFFICE	DATE
WHITEHORSE	May 27, 2011

Figure 6

\\kel-eb-dc002\scans\Politylo, Theresa\w23101051.104-9\Figures\Figure 6 - NBCSHC.doc

Seismic Hazard Deaggregation

calculated by the Canadian Hazards Information Service

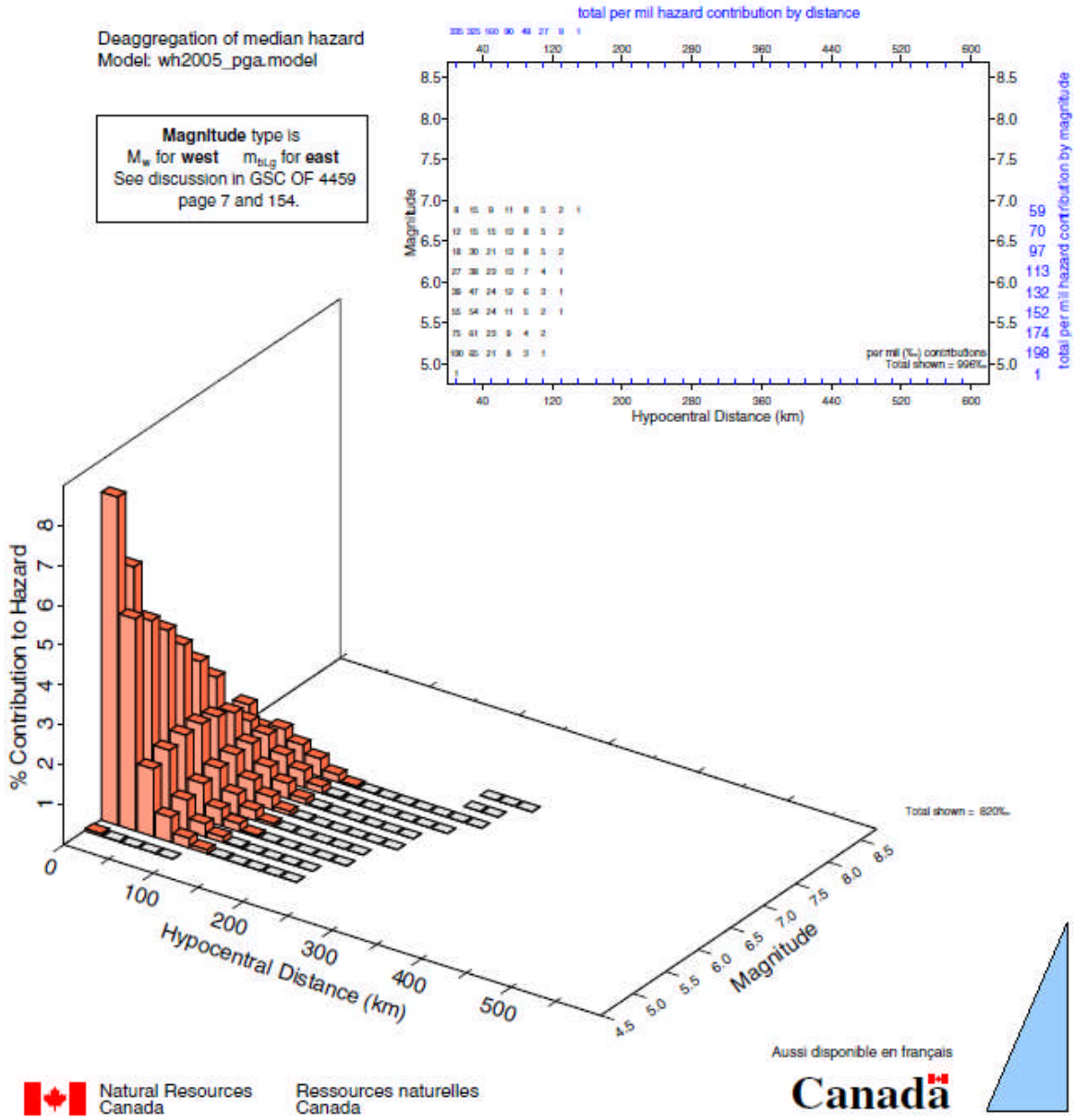
INFORMATION: *EarthquakesCanada.nrcan.gc.ca*
Eastern Canada (613) 995-5548 Western Canada (250) 363-6500

Deaggregation requested by: Michael Laws, EBA 2011/02/09
For site Ketza_River_Mine, YU at 61.535 N 132.257 W

For ground motion parameter: PGA, Peak ground acceleration for NBCC site class C
at a probability of 0.000404 per annum, seismic hazard = 0.108 g
Mean magnitude 5.63 Mean distance 34 km
Modal magnitude 4.875 Modal distance 10 km

Deaggregation of median hazard
Model: wh2005_pga.model

Magnitude type is
M_w for **west** m_{bLg} for **east**
See discussion in GSC OF 4459 page 7 and 154.



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Canada

LEGEND

NOTES
From the Earthquakes Canada website (http://earthquakescanada.nrcan.gc.ca)

STATUS
ISSUED FOR USE

CLIENT
Yukon-Nevada Gold Corp.

KETZA RIVER GOLD MINE TAILINGS STORAGE FACILITY DSR

Seismic Hazard Deaggregation 1 in 2574 Years

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PROJECT NO.	DWN	CKD	APVD	REV
W23101051.104.109	MJL	SM	SM	0

OFFICE	DATE
WHITEHORSE	May 27, 2011

Figure 7

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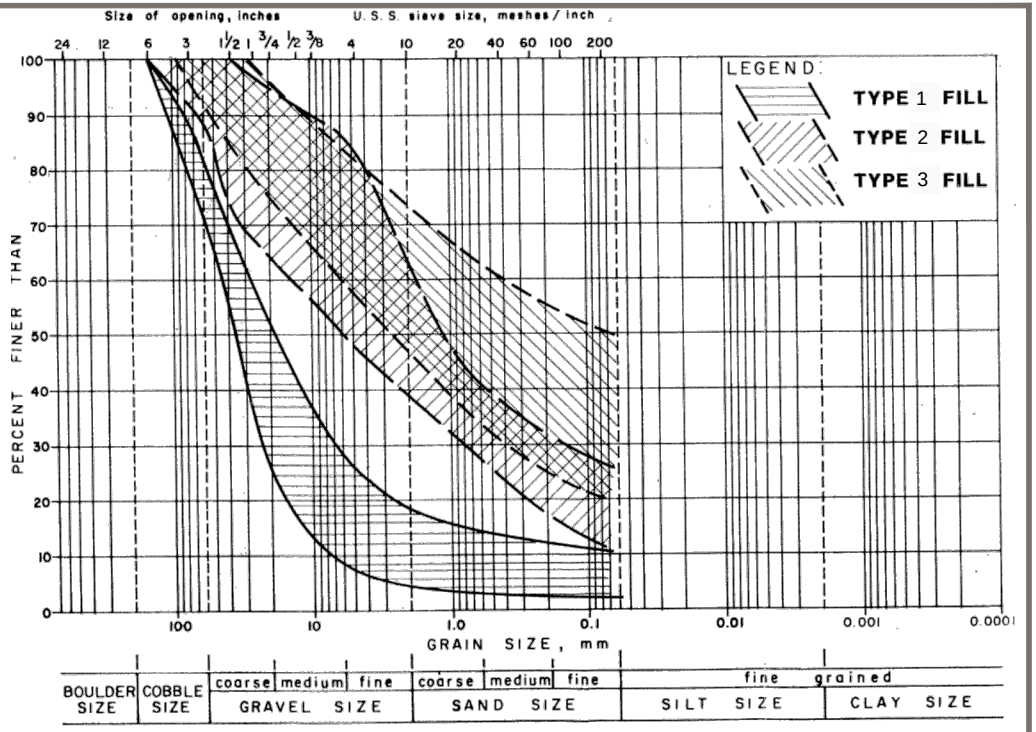
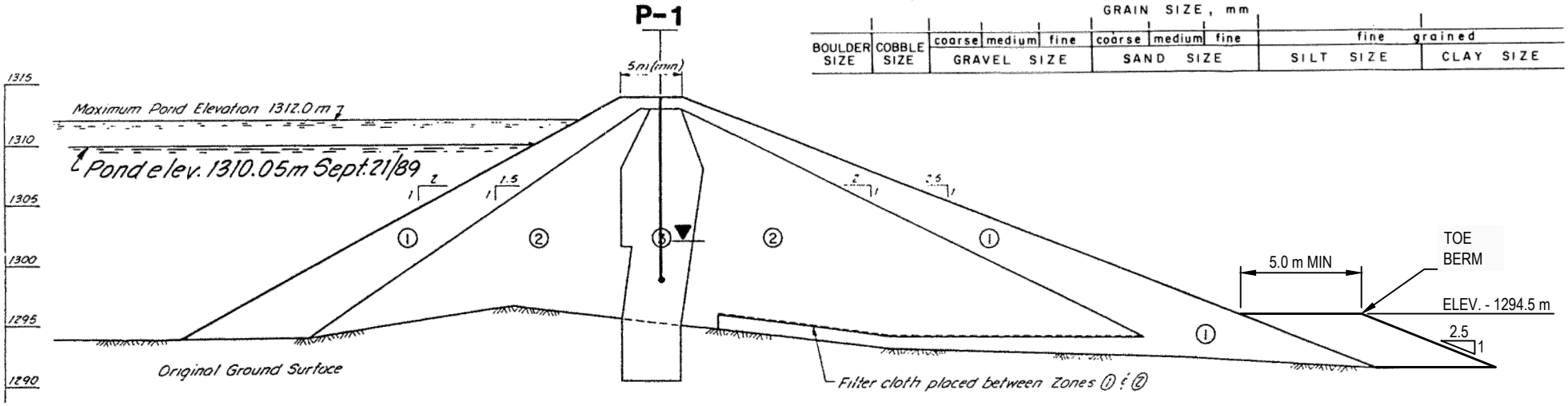


SECTION A-A



LEGEND

① GRAVEL

② SAND & GRAVEL

③ CLAY

NOTES

BASED ON FIGURE 5 OF GOLDER REPORT:

REPORT TO
CANAMAX RESOURCES INC.
ON
KETZA MINES
TAILINGS POND OPERATION
YUKON TERRITORIES

CLIENT

Yukon-Nevada Gold Corp.

KETZA RIVER GOLD MINE, TAILINGS STORAGE FACILITY, DAM SAFETY REVIEW

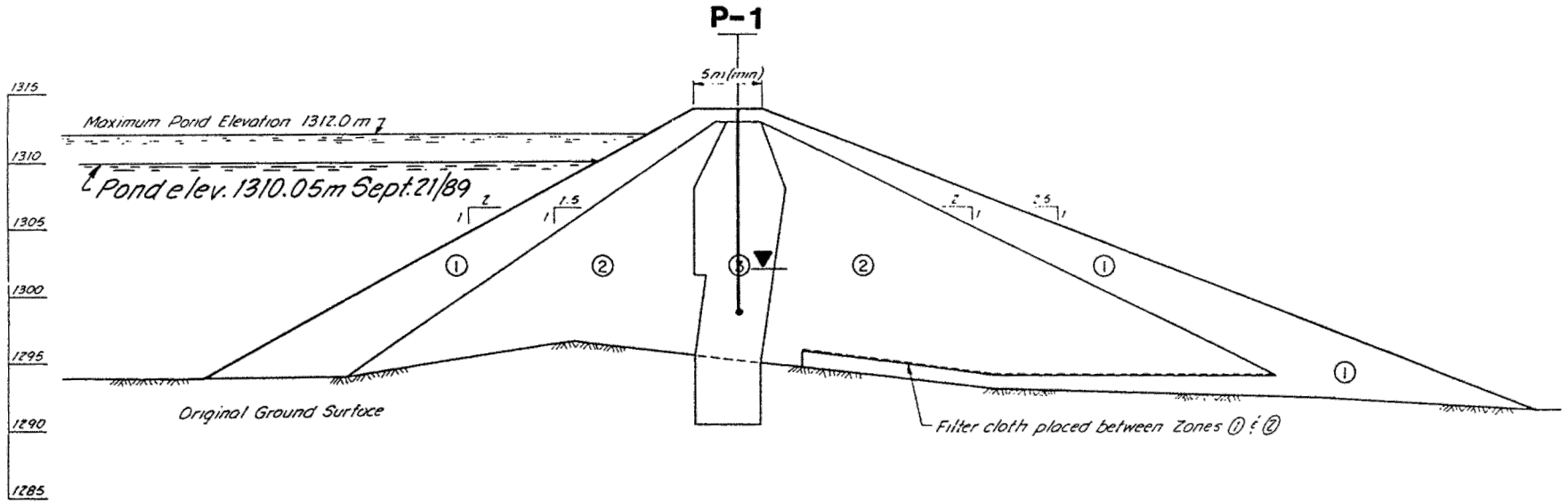
TYPICAL DAM CROSS SECTIONS NORTH DAM

A TETRA TECH COMPANY

PROJECT NO.	DWN	CKD	REV
W23101051.104.009	LM	MJL	0

OFFICE	DATE
EBA-KELOWNA	May 31, 2011

Figure 8



SECTION A-A

LEGEND

1. GRAVEL
2. SAND & GRAVEL
3. CLAY

NOTES
BASED ON FIGURE 5 OF GOLDER REPORT:

REPORT TO
CANAMAX RESOURCES INC.
ON
KETZA MINES
TAILINGS POND OPERATION
YUKON TERRITORIES

CLIENT
Yukon-Nevada Gold Corp.

A TETRA TECH COMPANY

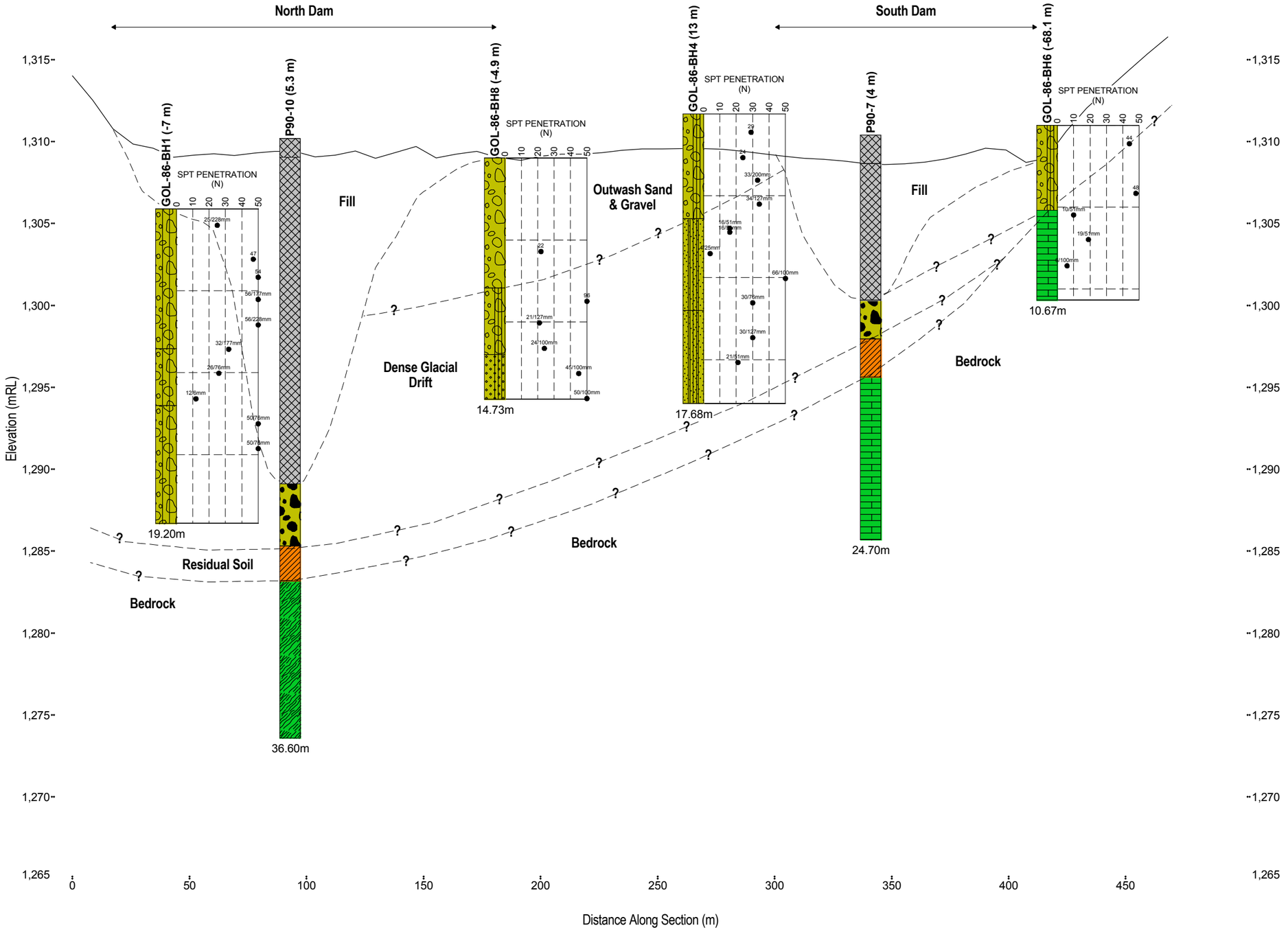
KETZA RIVER GOLD MINE, TAILINGS STORAGE FACILITY, DAM SAFETY REVIEW

TYPICAL DAM CROSS SECTIONS SOUTH DAM

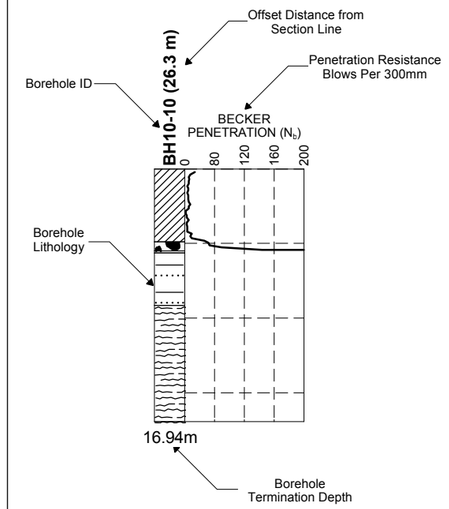
PROJECT NO.	DWN	CKD	REV
W23101051.104.009	LM	MJL	0

OFFICE	DATE
EBA-KELOWNA	May 31, 2011

Figure 9



LEGEND



- Silty Gravel
- Poorly-graded Gravel with silt
- Silt and Sand
- Limestone
- Poorly-graded Gravel
- Well-graded Sand with silt
- Fill (made ground)
- Well-graded Gravel
- Low plasticity Clay
- Phyllite
- Fill
- Colluvium
- Granular Alluvium/Glacial Drift
- Fine Grained Alluvium/Clay Till/Residual Soil
- Bedrock

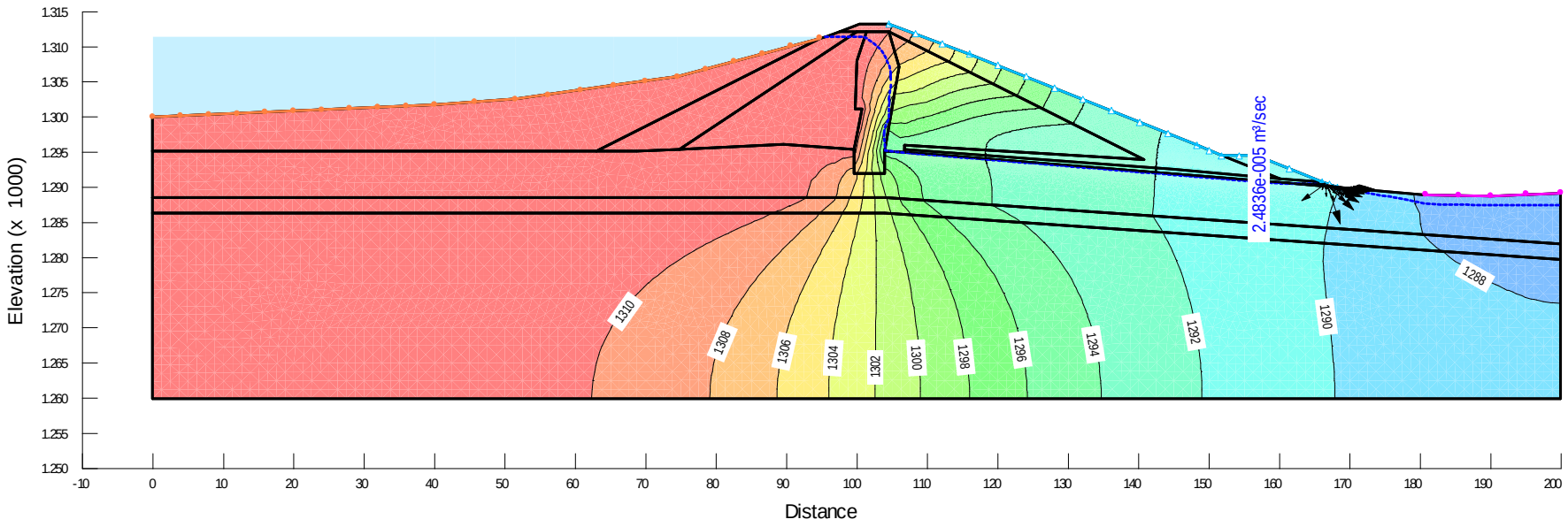
KETZA RIVER GOLD MINE TAILINGS STORAGE FACILITY DSR

NORTH & SOUTH DAM GEOTECHNICAL SECTION

PROJECT NO.	DWN	CKD	REV	CLIENT
W23101051.104.109	MJL	SM	0	Yukon-Nevada Gold Corp.
OFFICE: WHITEHORSE	DATE: May 25, 2011			
VERTICAL SCALE: 1:250	HORIZONTAL SCALE: 1:1750			

eba A TETRA TECH COMPANY

Figure 10



NOTES

1. Contours represent total pressure head (m).
2. Toe seepage of 2.15 m^3/day/m (1.5 l/min/m) calculated.

STATUS
ISSUED FOR USE

CLIENT
Yukon-Nevada Gold Corp.

A TETRA TECH COMPANY

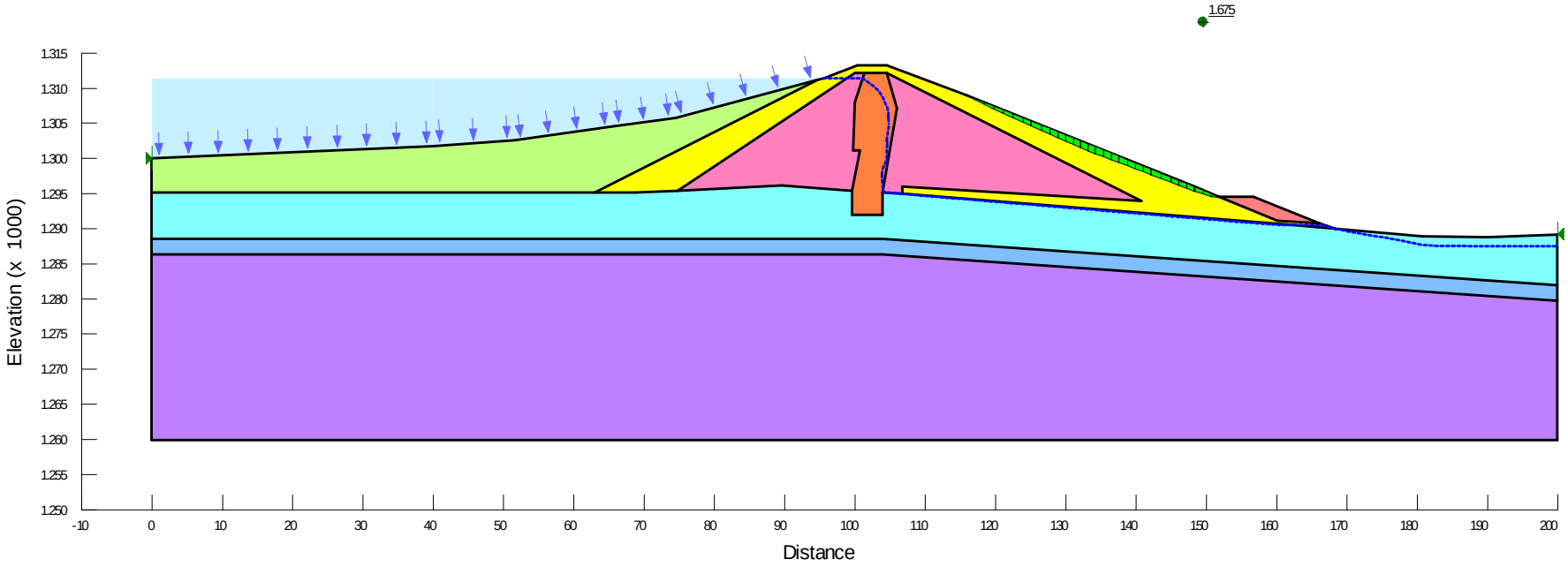
KETZA RIVE GOLD MINE TAILINGS STORAGE FACILITY DSR

NORTH DAM
STEADY STATE SEEPAGE ANALYSIS

PROJECT NO.	DWN	CKD	APVD	REV
W23101051.104.109	MJL	SM	SM	0

OFFICE	DATE
WHITEHORSE	MAY 27, 2011

Figure 11



NOTES

1. Critical slip surface shown.
2. Hydrostatic pressures obtained from seepage analysis.

STATUS
ISSUED FOR USE

CLIENT

Yukon-Nevada Gold Corp.

A TETRA TECH COMPANY

KETZA RIVE GOLD MINE TAILINGS STORAGE FACILITY DSR

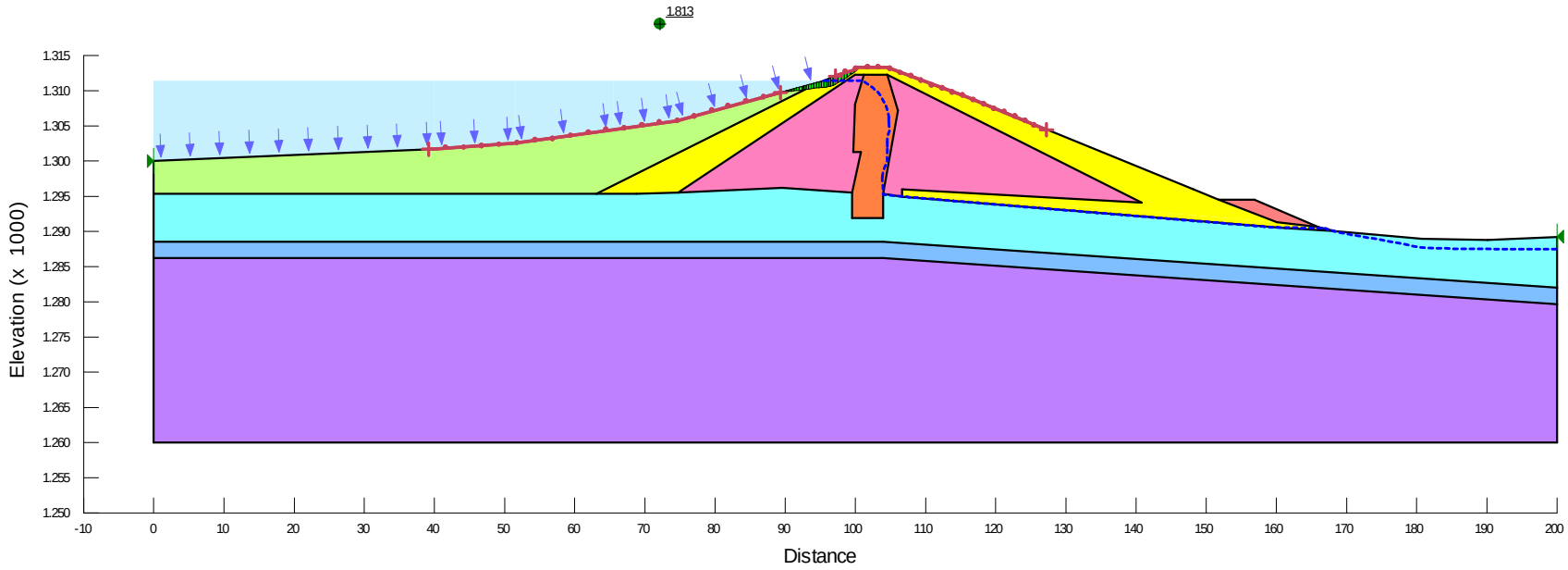
NORTH DAM
STEADY STATE STABILITY ANALYSIS
DOWNSTREAM SLOPE

PROJECT NO.	DWN	CKD	APVD	REV
W23101051.104.109	MJL	SM	SM	0

OFFICE	DATE
WHITEHORSE	MAY 27, 2011

Figure 12

\\kel-eb-dc002\scans\Politylo, Theresa\w23101051.104-9\Figures\Figure 12 - North Dam Steady State Downstream Stability.doc



NOTES

1. Critical slip surface shown.
2. Hydrostatic pressures obtained from seepage analysis.

STATUS
ISSUED FOR USE

CLIENT
Yukon-Nevada Gold Corp.

A TETRA TECH COMPANY

KETZA RIVE GOLD MINE TAILINGS STORAGE FACILITY DSR

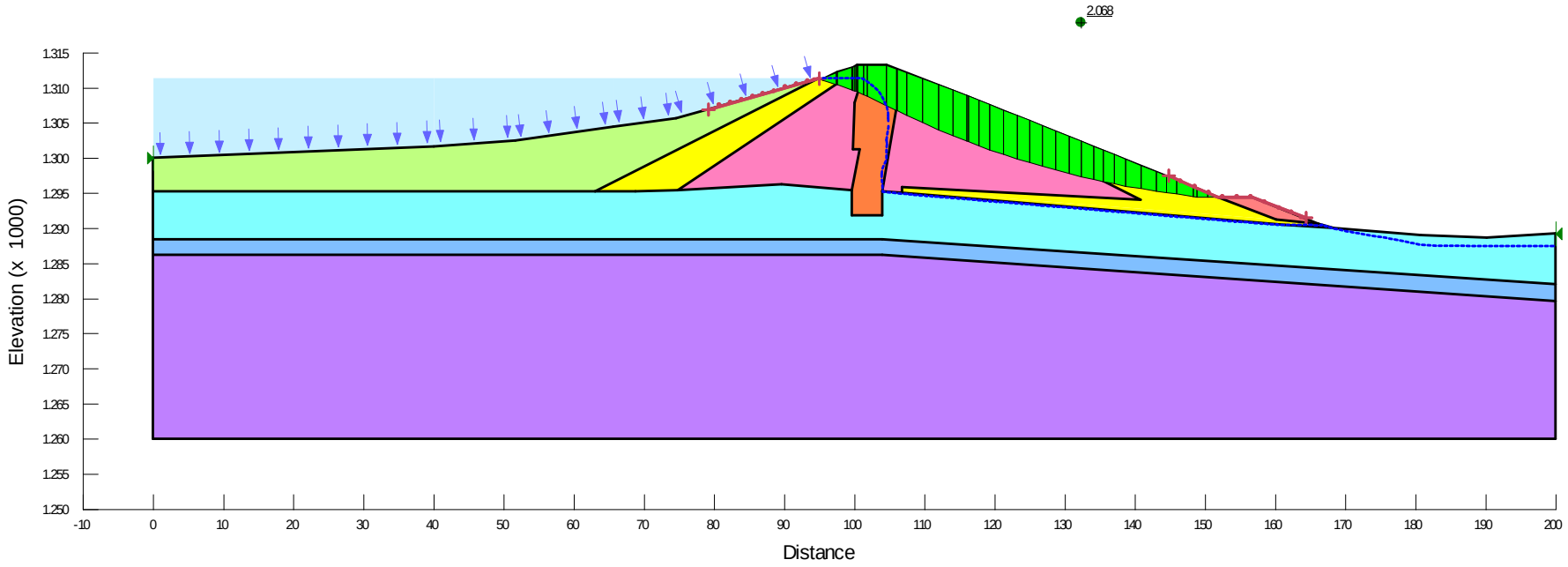
NORTH DAM
STEADY STATE STABILITY ANALYSIS
UPSTREAM SLOPE

PROJECT NO.	DWN	CKD	APVD	REV
W23101051.104.109	MJL	SM	SM	0

OFFICE	DATE
WHITEHORSE	MAY 27, 2011

Figure 13

\\kel-eb-dc002\scans\Politylo, Theresa\w23101051.104-9\Figures\Figure 13 - North Dam Steady State Upstream Stability.doc



NOTES

1. Critical slip surface that bi-sects the dam core shown.
2. Hydrostatic pressures obtained from seepage analysis.

STATUS
ISSUED FOR USE

CLIENT
Yukon-Nevada Gold Corp.

A TETRA TECH COMPANY

KETZA RIVE GOLD MINE TAILINGS STORAGE FACILITY DSR

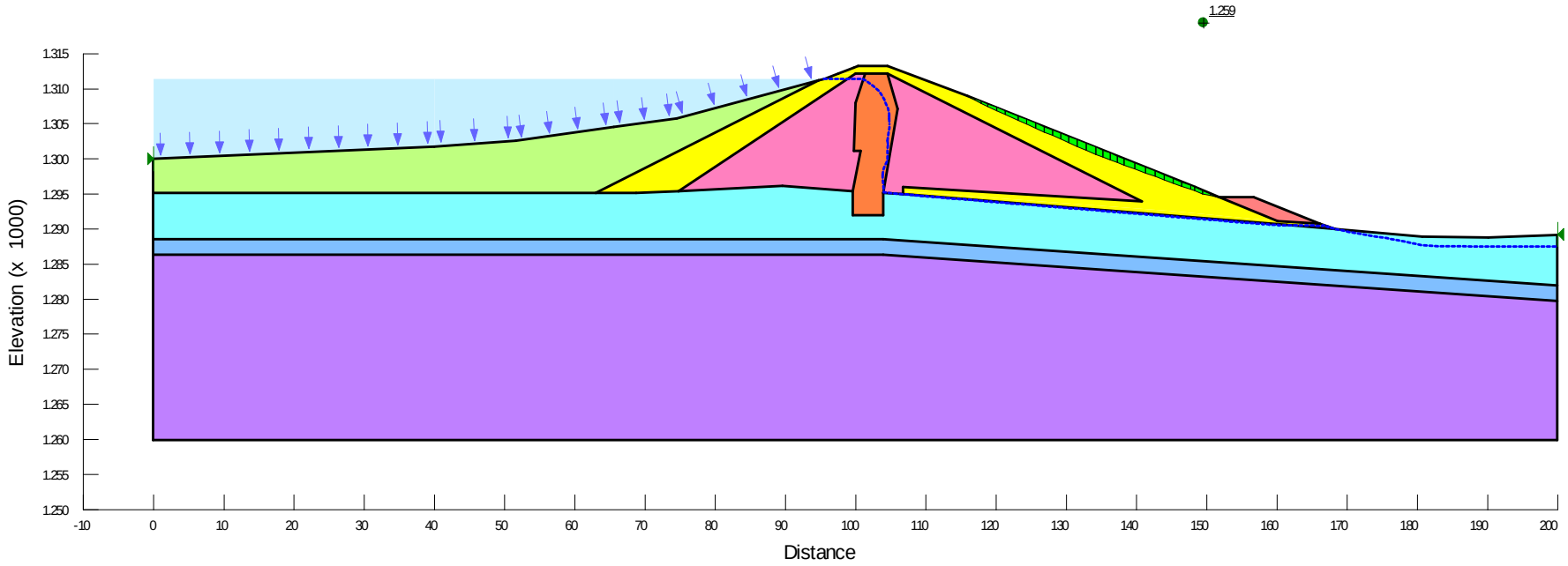
NORTH DAM
STEADY STATE STABILITY ANALYSIS THROUGH DAM CORE

PROJECT NO.	DWN	CKD	APVD	REV
W23101051.104.109	MJL	SM	SM	0

OFFICE	DATE
WHITEHORSE	MAY 27, 2011

Figure 14

\\kel-eb-dc002\scans\Politylo, Theresa\w23101051.104-9\Figures\Figure 14 - North Dam Steady State Stability Core.doc



NOTES

1. Critical slip surface shown.
2. Hydrostatic pressures obtained from seepage analysis.

STATUS
ISSUED FOR USE

CLIENT

Yukon-Nevada Gold Corp.

A TETRA TECH COMPANY

KETZA RIVE GOLD MINE TAILINGS STORAGE FACILITY DSR

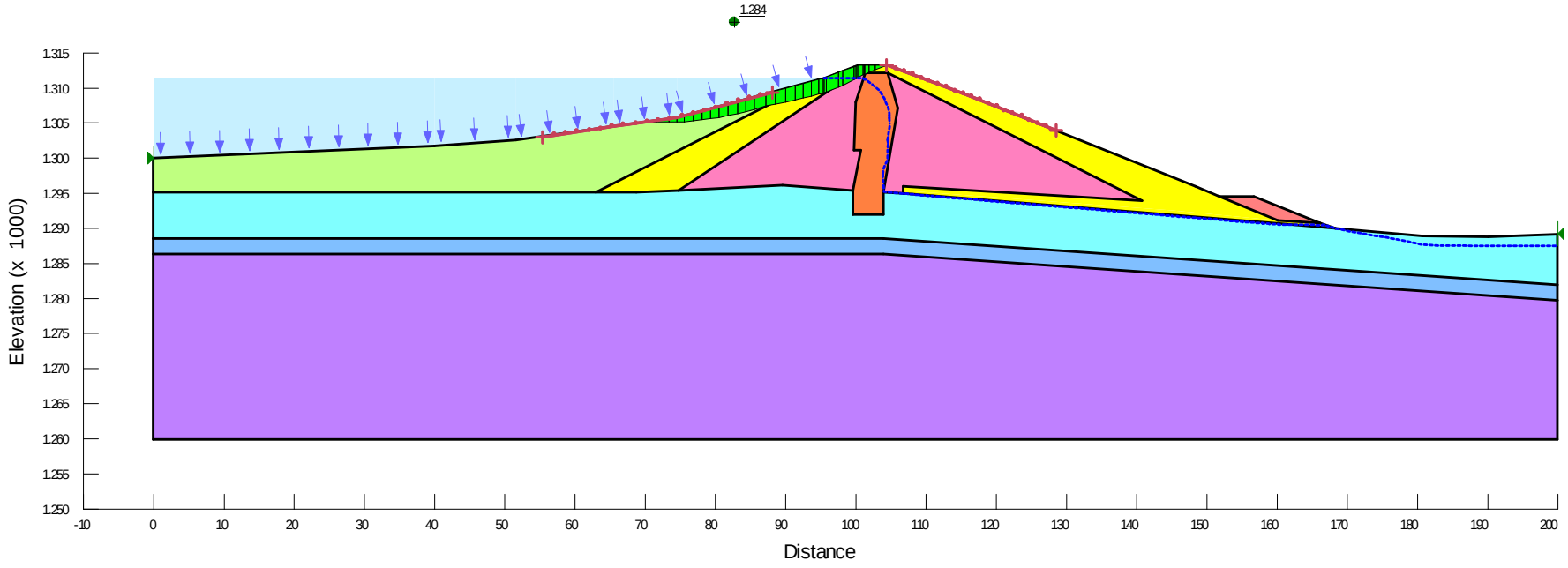
NORTH DAM
PSEUDO-STATIC SEISMIC STABILITY ANALYSIS
DOWNSTREAM EQ

PROJECT NO.	DWN	CKD	APVD	REV
W23101051.104.109	MJL	SM	SM	0

OFFICE	DATE
WHITEHORSE	MAY 27, 2011

Figure 15

\\kel-eb-dc002\scans\Politylo, Theresa\w23101051.104-9\Figures\Figure 15 - North Dam Downstream EQ Stability.doc



NOTES

1. Critical slip surface shown.
2. Hydrostatic pressures obtained from seepage analysis.

STATUS
ISSUED FOR USE

CLIENT

Yukon-Nevada Gold Corp.

A TETRA TECH COMPANY

KETZA RIVE GOLD MINE TAILINGS STORAGE FACILITY DSR

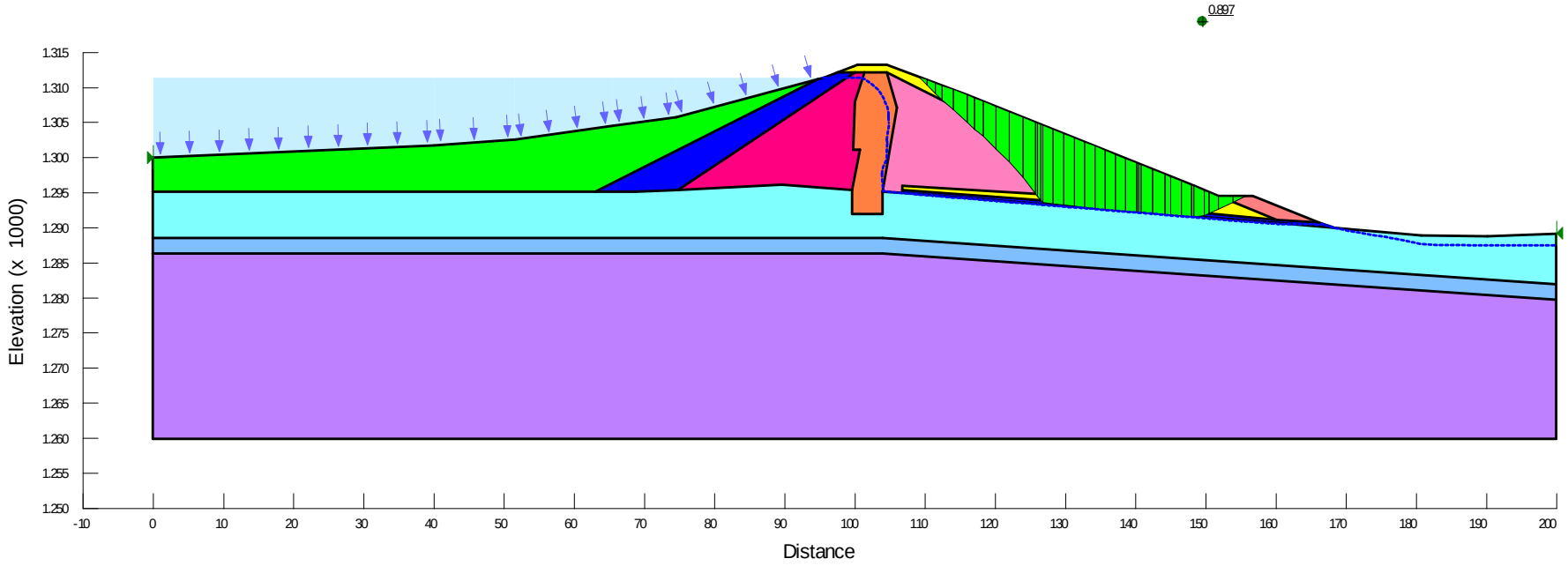
NORTH DAM
PSEUDO-STATIC SEISMIC STABILITY ANALYSIS
UPSTREAM EARTHQUAKE

PROJECT NO.	DWN	CKD	APVD	REV
W23101051.104.109	MJL	SM	SM	0

OFFICE	DATE
WHITEHORSE	MAY 27, 2011

Figure 16

\\kel-eb-dc002\scans\Politylo, Theresa\w23101051.104-9\Figures\Figure 16 - North Dam Upstream EQ Stability.doc



NOTES

1. Critical slip surface shown.
2. Hydrostatic pressures obtained from seepage analysis.
3. Undrained residual shear of soil, S_r estimated for an equivalent clean sand SPT corrected blow count of 10 from Figure 88 of Idriss & Boulanger (2008).

STATUS
ISSUED FOR USE

CLIENT
Yukon-Nevada Gold Corp.

A TETRA TECH COMPANY

KETZA RIVE GOLD MINE TAILINGS STORAGE FACILITY DSR

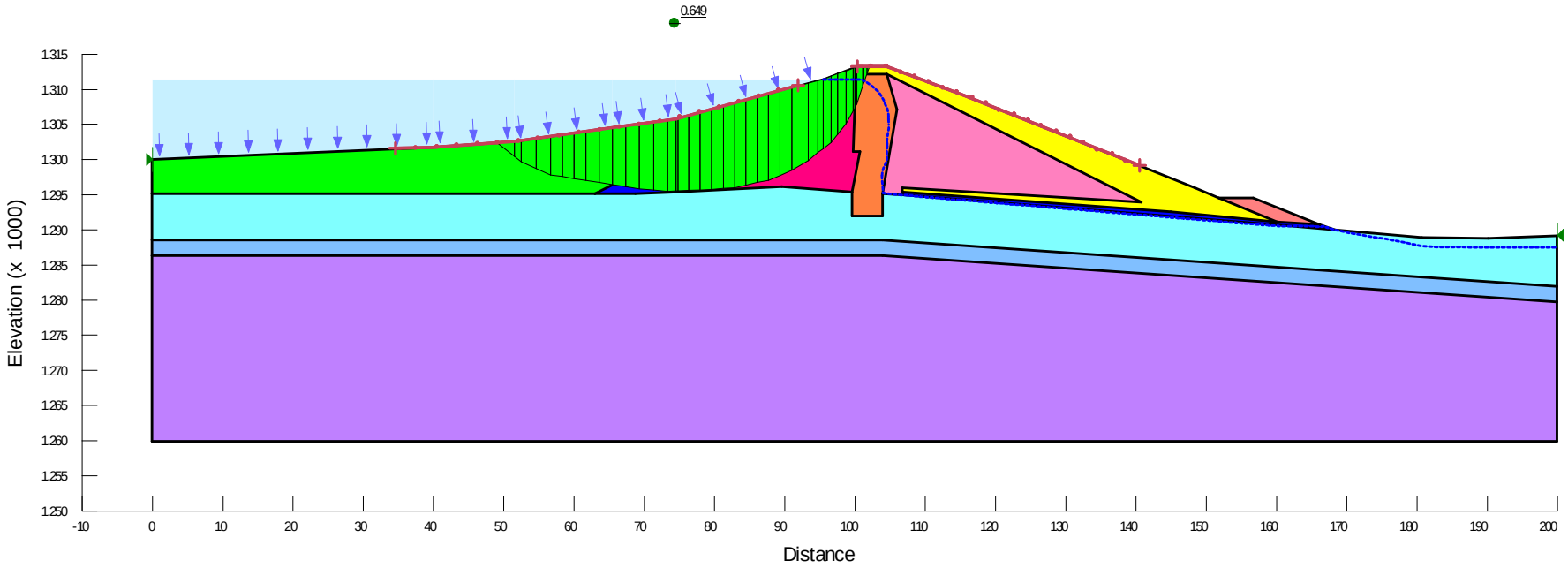
NORTH DAM
RESIDUAL STRENGTH OF LIQUEFIED SOIL POST EARTHQUAKE STABILITY ANALYSIS

PROJECT NO.	DWN	CKD	APVD	REV
W23101051.104.109	MJL	SM	SM	0

OFFICE	DATE
WHITEHORSE	MAY 27, 2011

Figure 17

\\kel-eb-dc002\scans\Politylo, Theresa\w23101051.104-9\Figures\Figure 17 - North Dam Residual Stability Downstream.doc



NOTES

1. Critical slip surface shown.
2. Hydrostatic pressures obtained from seepage analysis.
3. Undrained residual shear of soil, S_r estimated for an equivalent clean sand SPT corrected blow count of 10 from Figure 88 of Idriss & Boulanger (2008).

STATUS
ISSUED FOR USE

CLIENT
Yukon-Nevada Gold Corp.

A TETRA TECH COMPANY

KETZA RIVE GOLD MINE TAILINGS STORAGE FACILITY DSR

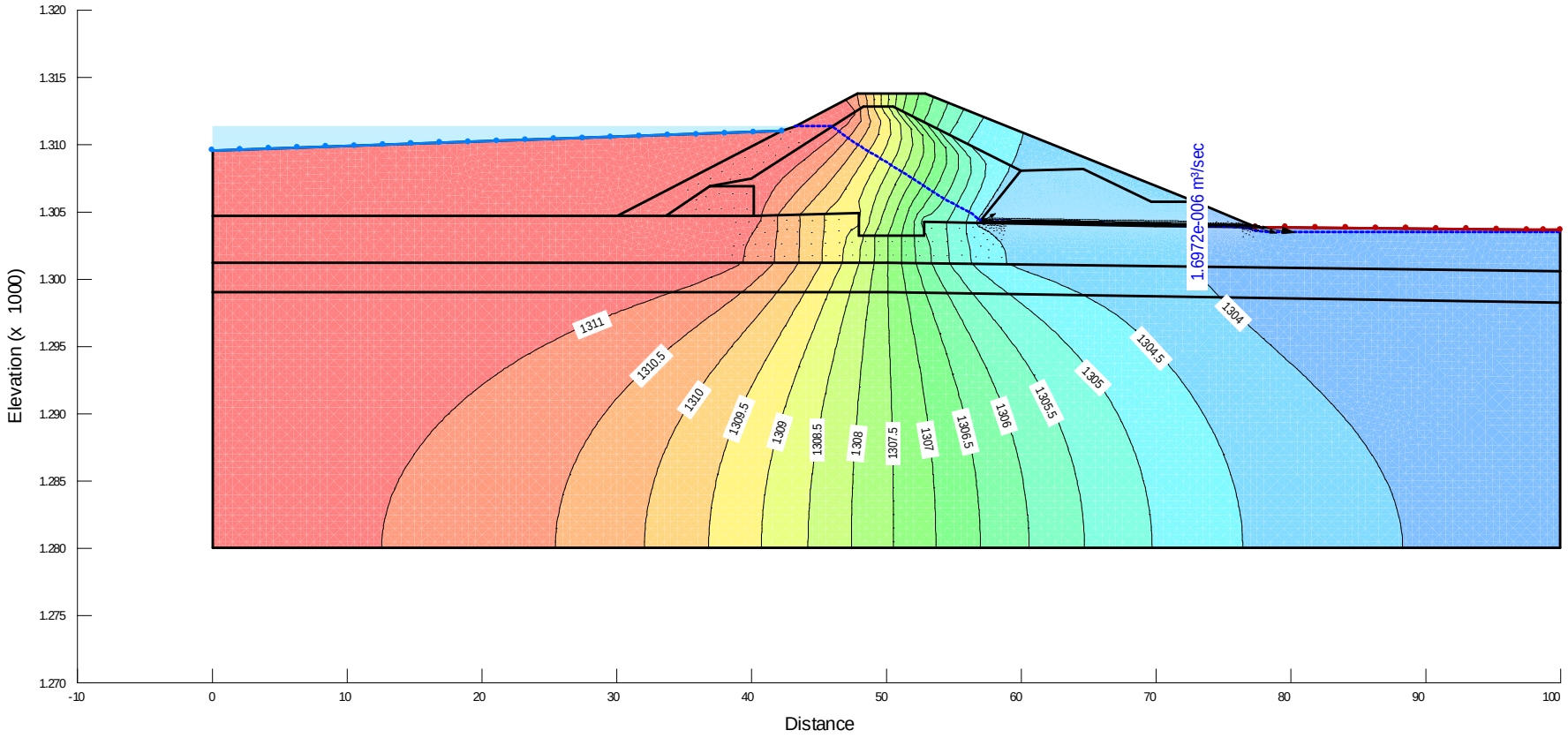
NORTH DAM
RESIDUAL STRENGTH OF LIQUEFIED SOIL POST EQ STABILITY UPSTREAM ANALYSIS

PROJECT NO.	DWN	CKD	APVD	REV
W23101051.104.109	MJL	SM	SM	0

OFFICE	DATE
WHITEHORSE	MAY 27, 2011

Figure 18

\\kel-eb-dc002\scans\Politylo, Theresa\w23101051.104-9\Figures\Figure 18 - North Dam Residual Stability Upstream.doc



NOTES

1. Contours represent total pressure head (m).
2. Toe seepage of 0.14 m^3/day/m (0.1 l/min/m) calculated.

STATUS
ISSUED FOR USE

CLIENT
Yukon-Nevada Gold Corp.

A TETRA TECH COMPANY

KETZA RIVE GOLD MINE TAILINGS STORAGE FACILITY DSR

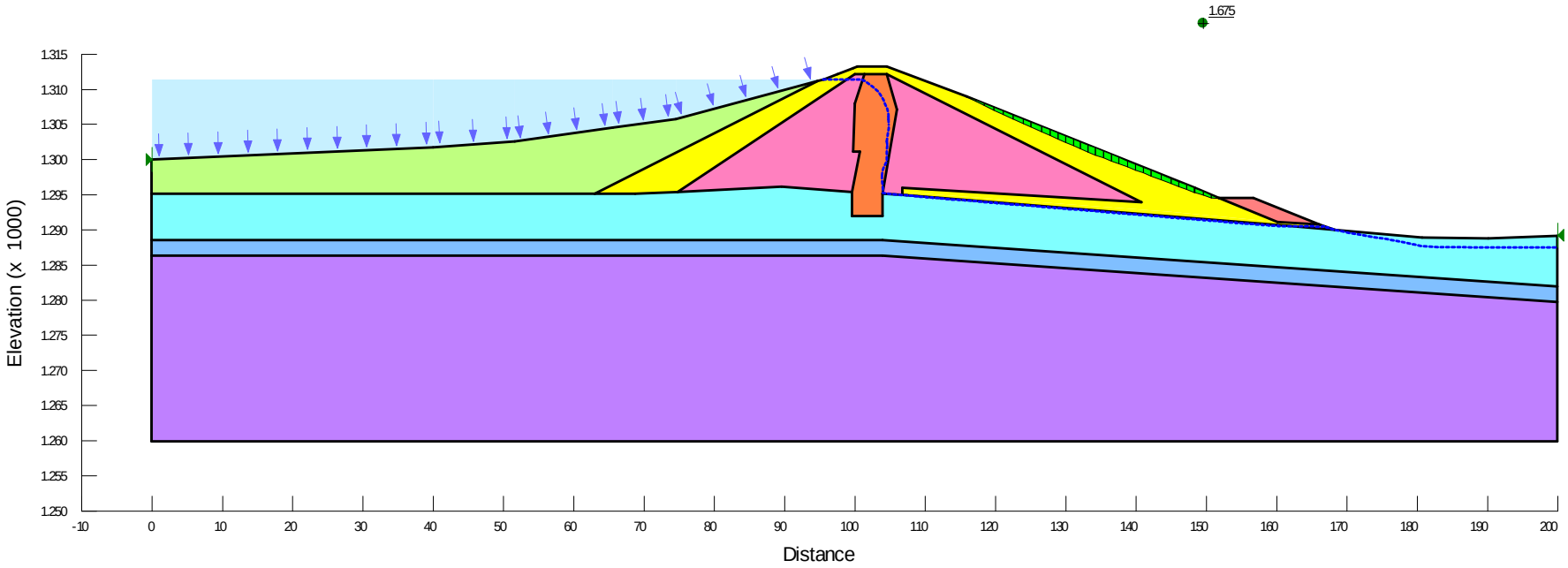
SOUTH DAM
STEADY STATE SEEPAGE ANALYSIS

PROJECT NO.	DWN	CKD	APVD	REV
W23101051.104.109	MJL	SM	SM	0

OFFICE	DATE
WHITEHORSE	MAY 27, 2011

Figure 19

\\kel-eb-dc002\scans\Politylo, Theresa\w23101051.104-9\Figures\Figure 19 - South Dam Steady State Seepage.doc



NOTES

1. Critical slip surface shown.
2. Hydrostatic pressures obtained from seepage analysis.

CLIENT

Yukon-Nevada Gold Corp.

KETZA RIVE GOLD MINE TAILINGS STORAGE FACILITY DSR

SOUTH DAM
STEADY STATE STABILITY ANALYSIS
DOWNSTREAM SLOPE

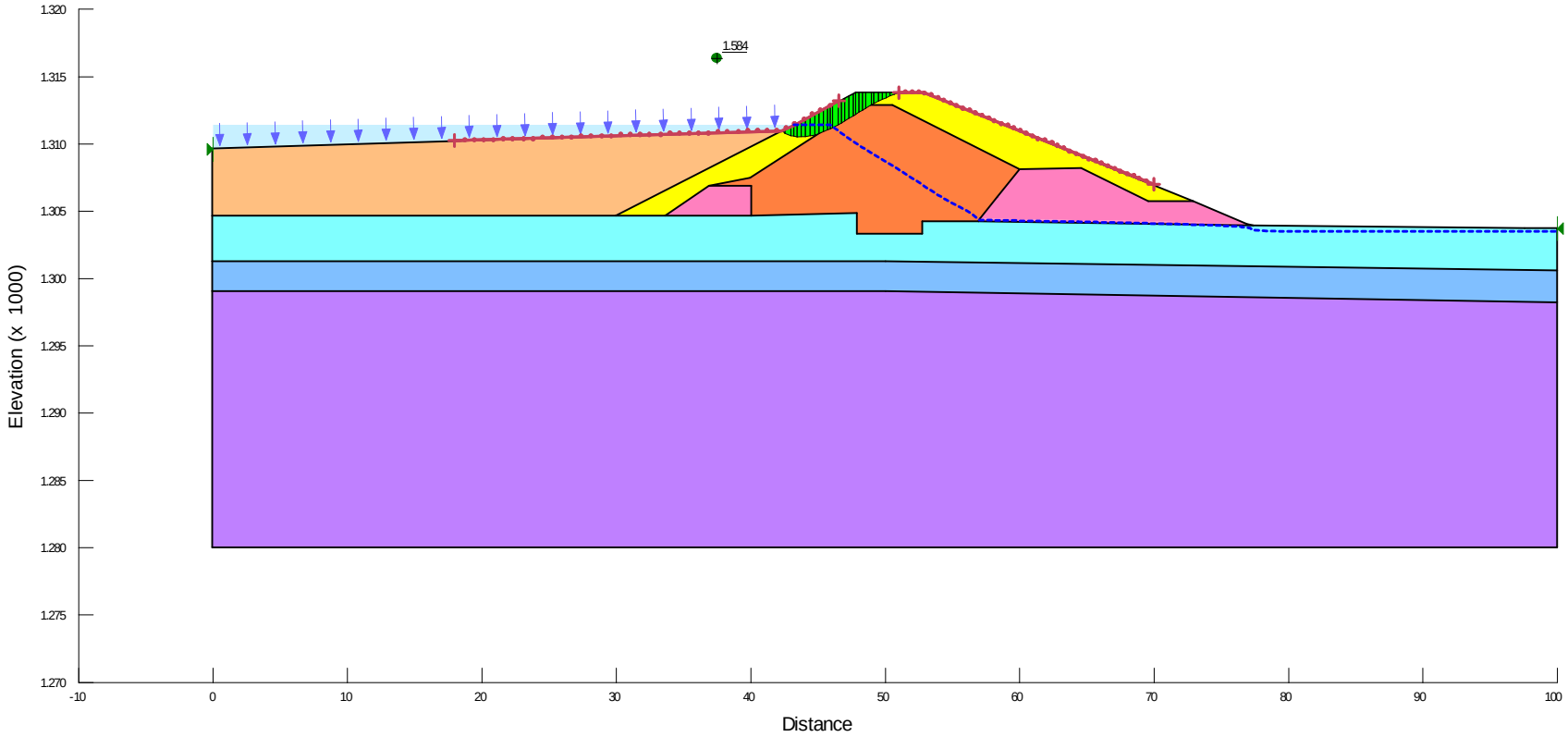
A TETRA TECH COMPANY

PROJECT NO.	DWN	CKD	APVD	REV
W23101051.104.109	MJL	SM	SM	0

OFFICE	DATE
WHITEHORSE	MAY 27, 2011

Figure 20

STATUS
ISSUED FOR USE



NOTES

1. Critical slip surface shown.
2. Hydrostatic pressures obtained from seepage analysis.

CLIENT

Yukon-Nevada Gold Corp.

KETZA RIVE GOLD MINE TAILINGS STORAGE FACILITY DSR

SOUTH DAM
STEADY STATE STABILITY ANALYSIS
UPSTREAM SLOPE

A TETRA TECH COMPANY

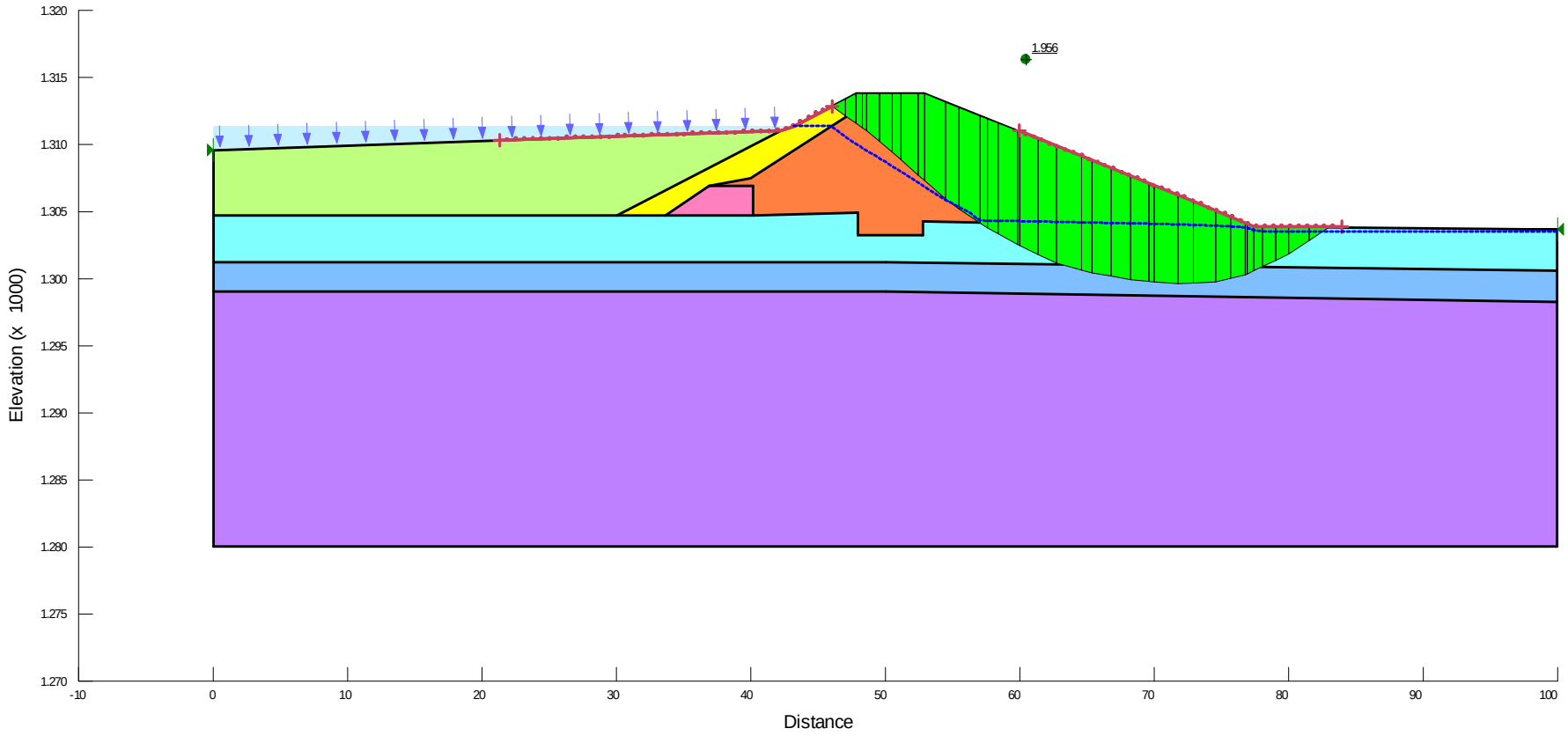
PROJECT NO.	DWN	CKD	APVD	REV
W23101051.104.109	MJL	SM	SM	0

OFFICE	DATE
WHITEHORSE	MAY 27, 2011

Figure 21

STATUS
ISSUED FOR USE

\\kel-eb-dc002\scans\Politylo, Theresa\w23101051.104-9\Figures\Figure 21 - South Dam Steady State Upstream Stability.doc



NOTES

1. Critical slip surface that bi-sects the dam core shown.
2. Hydrostatic pressures obtained from seepage analysis.

STATUS
ISSUED FOR USE

CLIENT
Yukon-Nevada Gold Corp.

A TETRA TECH COMPANY

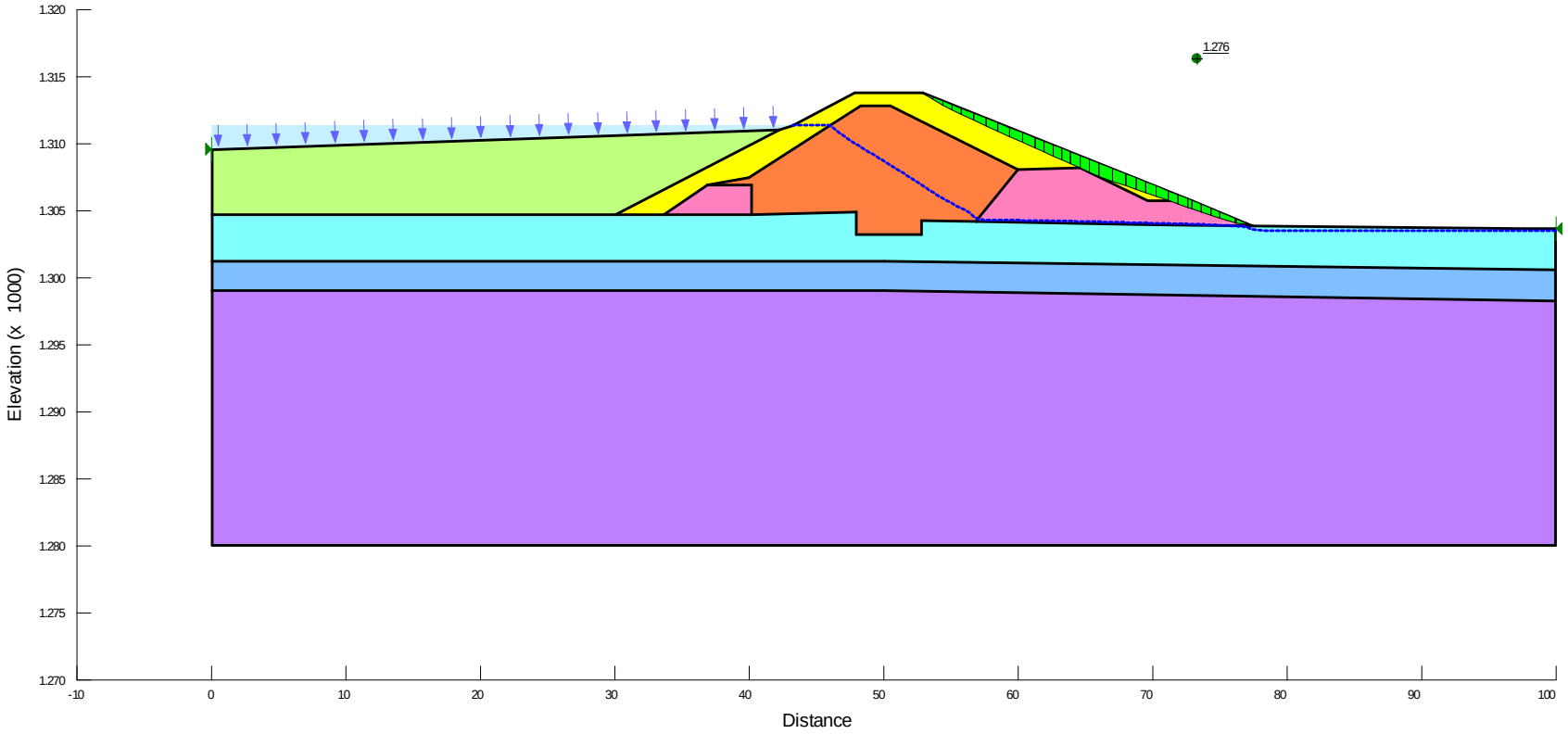
KETZA RIVE GOLD MINE TAILINGS STORAGE FACILITY DSR

SOUTH DAM
STEADY STATE STABILITY ANALYSIS THROUGH DAM CORE

PROJECT NO.	DWN	CKD	APVD	REV
W23101051.104.109	MJL	SM	SM	0

OFFICE	DATE
WHITEHORSE	MAY 27, 2011

Figure 22



NOTES

1. Critical slip surface shown.
2. Hydrostatic pressures obtained from seepage analysis.

CLIENT

Yukon-Nevada Gold Corp.

KETZA RIVE GOLD MINE TAILINGS STORAGE FACILITY DSR

SOUTH DAM
PSEUDO-STATIC SEISMIC STABILITY ANALYSIS
DOWNSTREAM EARTHQUAKE

PROJECT NO.	DWN	CKD	APVD	REV
W23101051.104.109	MJL	SM	SM	0

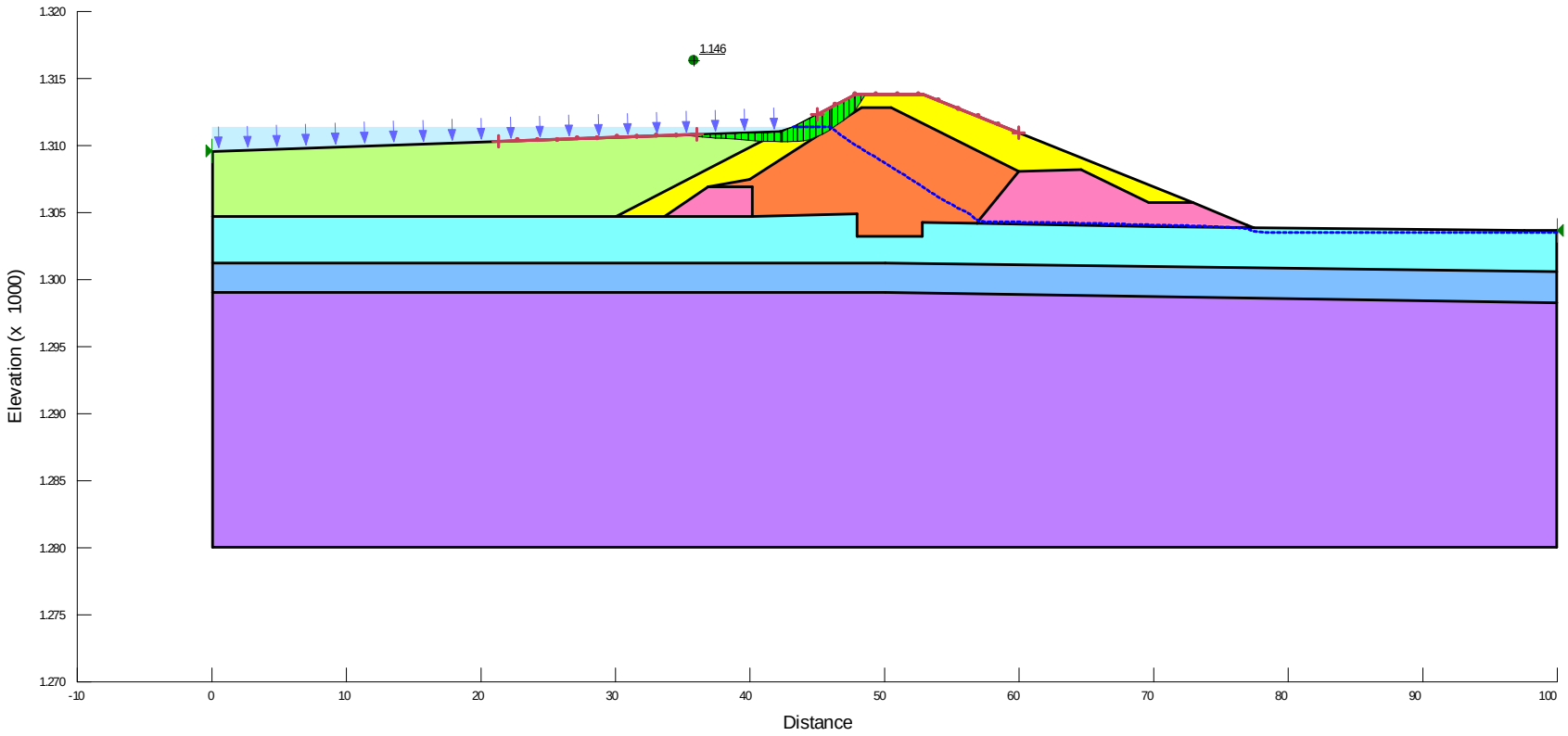
OFFICE	DATE
WHITEHORSE	MAY 27, 2011

Figure 23

STATUS
ISSUED FOR USE

eba
A TETRA TECH COMPANY

\\kel-eb-dc002\scans\Politylo, Theresa\w23101051.104-9\Figures\Figure 23 - South Dam Downstream EQ Stability.doc



NOTES

1. Critical slip surface shown.
2. Hydrostatic pressures obtained from seepage analysis.

CLIENT

Yukon-Nevada Gold Corp.

KETZA RIVE GOLD MINE TAILINGS STORAGE FACILITY DSR

SOUTH DAM
PSEUDO-STATIC SEISMIC STABILITY ANALYSIS
UPSTREAM EARTHQUAKE

PROJECT NO.	DWN	CKD	APVD	REV
W23101051.104.109	MJL	SM	SM	0

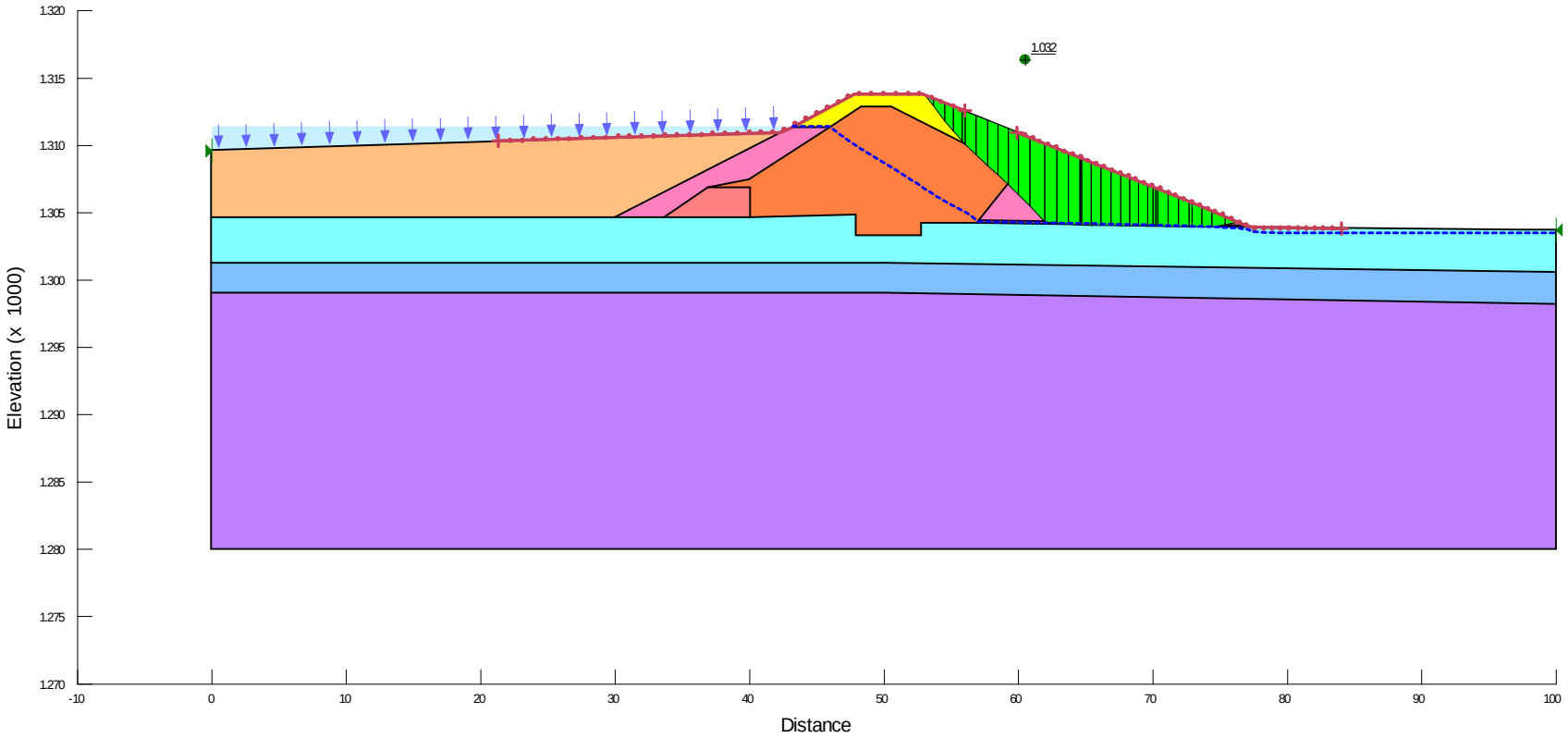
OFFICE	DATE
WHITEHORSE	MAY 27, 2011

Figure 24

STATUS
ISSUED FOR USE

eba
A TETRA TECH COMPANY

\\kel-eb-dc002\scans\Politylo, Theresa\w23101051.104-9\Figures\Figure 24 - South Dam Upstream EQ Stability.doc



NOTES

1. Critical slip surface shown.
2. Hydrostatic pressures obtained from seepage analysis.
3. Undrained residual shear of soil, S_r estimated for an equivalent clean sand SPT corrected blow count of 10 from Figure 88 of Idriss & Boulanger (2008).

STATUS
ISSUED FOR USE

CLIENT
Yukon-Nevada Gold Corp.

A TETRA TECH COMPANY

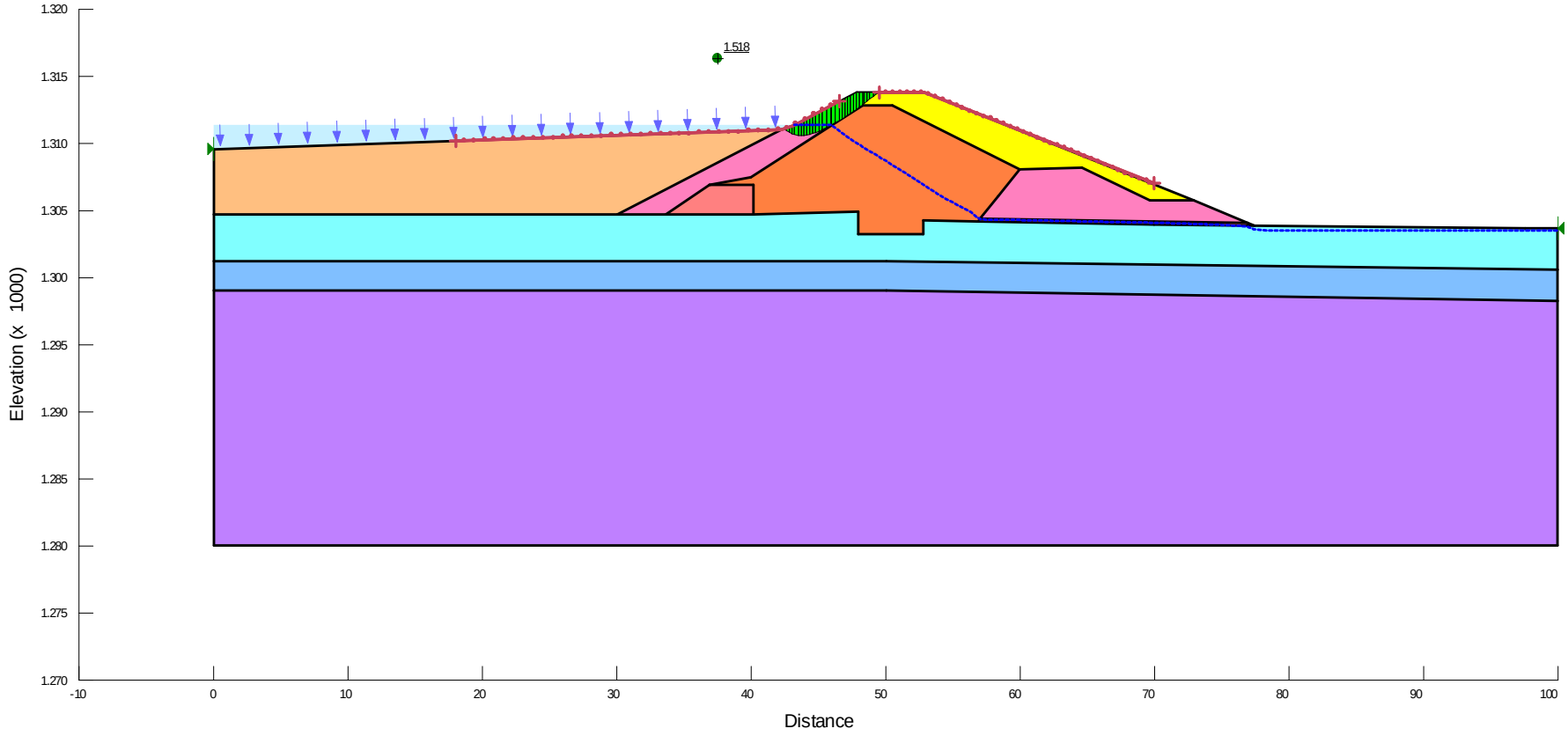
KETZA RIVE GOLD MINE TAILINGS STORAGE FACILITY DSR

SOUTH DAM
RESIDUAL STRENGTH OF LIQUEFIED SOIL POST EQ STABILITY ANALYSIS DOWNSTREAM

PROJECT NO.	DWN	CKD	APVD	REV
W23101051.104.109	MJL	SM	SM	0

OFFICE	DATE
WHITEHORSE	MAY 27, 2011

Figure 25



NOTES

1. Critical slip surface shown.
2. Hydrostatic pressures obtained from seepage analysis.
3. Undrained residual shear of soil, S_r estimated for an equivalent clean sand SPT corrected blow count of 10 from Figure 88 of Idriss & Boulanger (2008).

STATUS
ISSUED FOR USE

CLIENT
Yukon-Nevada Gold Corp.

A TETRA TECH COMPANY

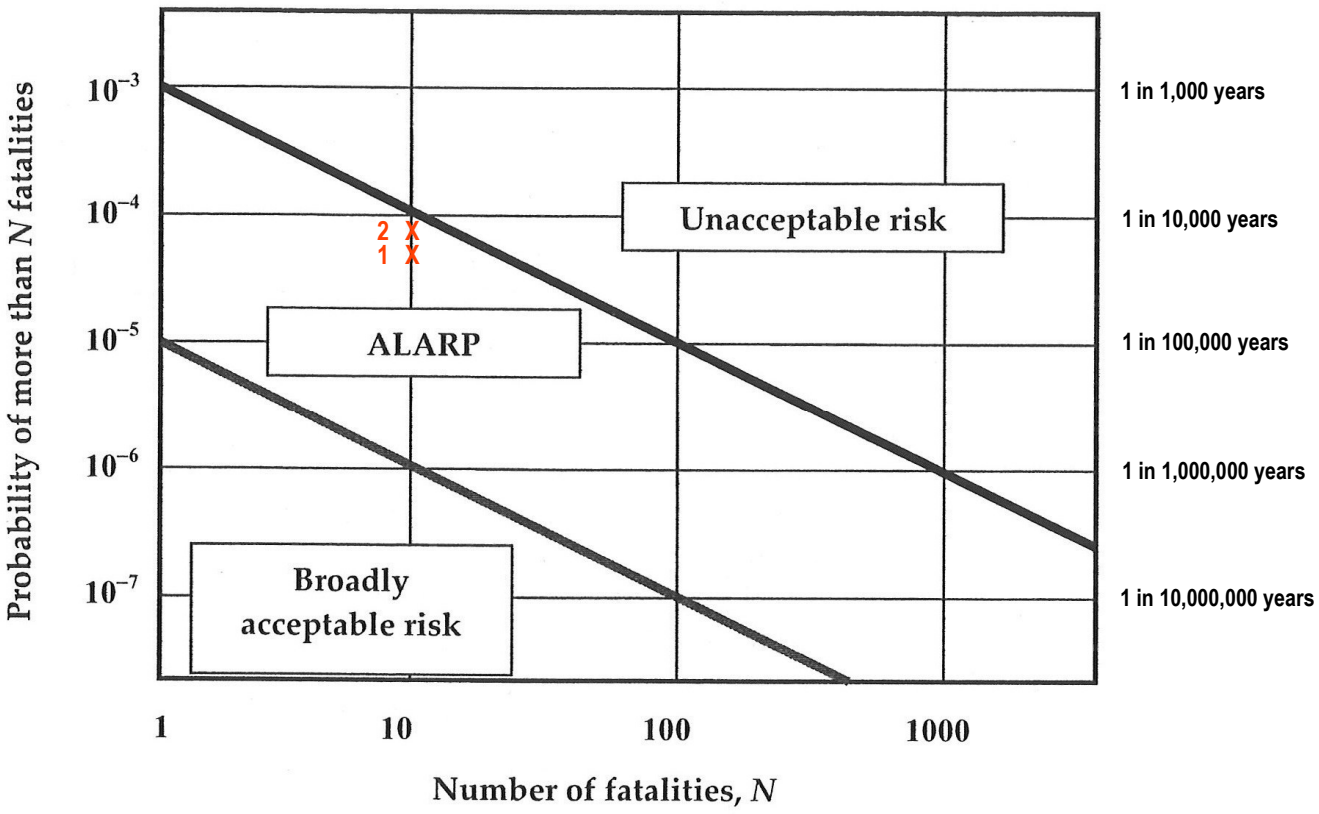
KETZA RIVE GOLD MINE TAILINGS STORAGE FACILITY DSR

SOUTH DAM
RESIDUAL STRENGTH OF LIQUEFIED SOIL POST EQ STABILITY ANALYSIS UPSTREAM

PROJECT NO.	DWN	CKD	APVD	REV
W23101051.104.109	MJL	SM	SM	0

OFFICE	DATE
WHITEHORSE	MAY 27, 2011

Figure 26



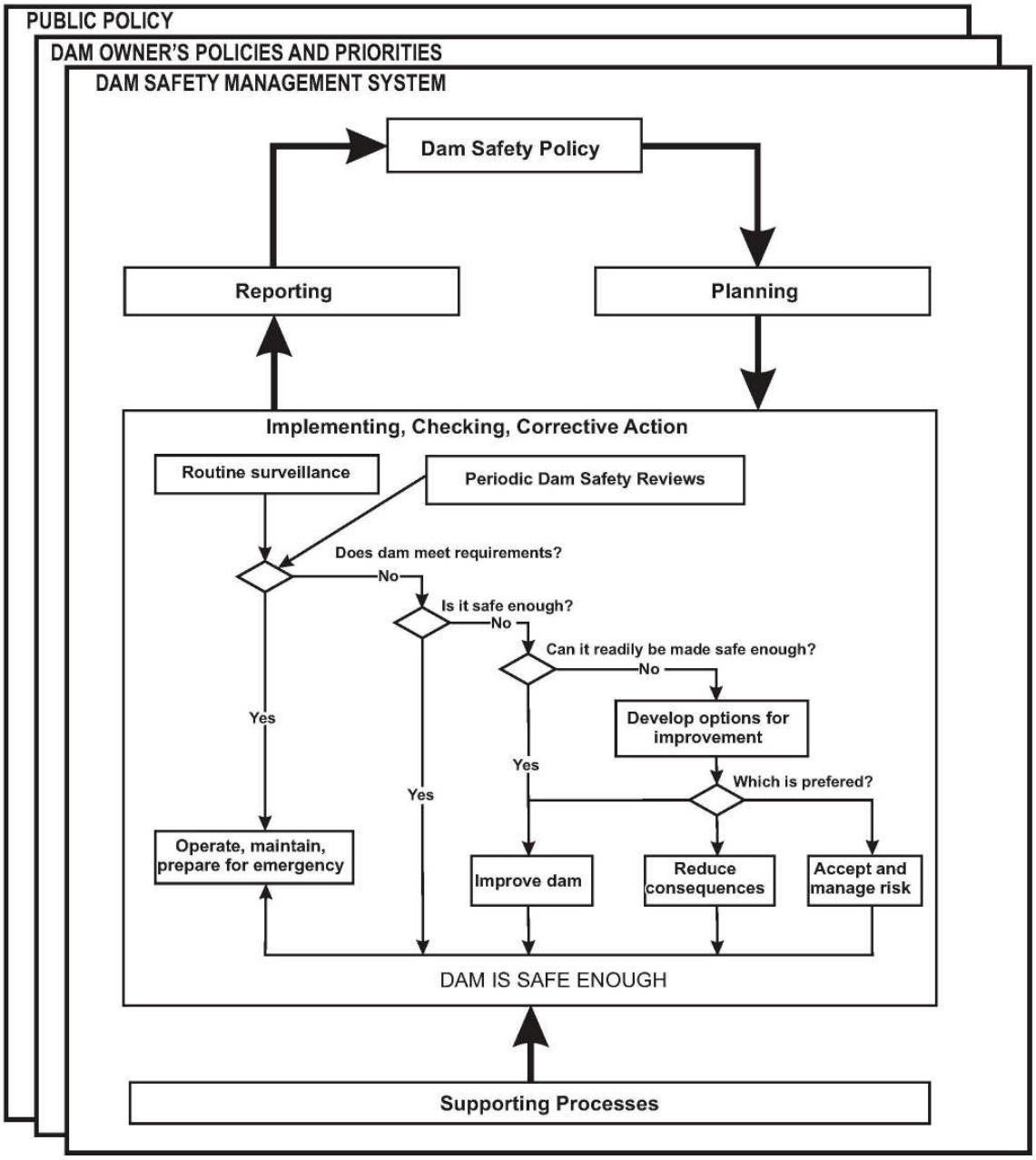
Calculated Annual Likelihood of Piping Failure:

1. North Dam
2. South Dam

LEGEND	**NOTES**	**CLIENT** Yukon-Nevada Gold Corp.	**KETZA RIVER GOLD MINE TAILINGS STORAGE FACILITY DSR** **Societal Risk Criteria for Dam Safety**
	STATUS ISSUED FOR USE	eba A TETRA TECH COMPANY	**PROJECT NO.** W23101051.104.109 · **DWN** TP · **CKD** MJL · **APVD** SM · **REV** 0 **OFFICE** WHITEHORSE · **DATE** May 31,2011

Figure 27

\\kel-eb-dc002\scans\Politylo, Theresa\w23101051.104-9\Figures\Figure 27 - Societal Risk Criteria for Dam Safety.doc



LEGEND

NOTES

STATUS
ISSUED FOR USE

CLIENT
Yukon-Nevada Gold Corp.

A TETRA TECH COMPANY

KETZA RIVER GOLD MINE TAILINGS STORAGE FACILITY DSR

Dam Safety Management System

PROJECT NO.	DWN	CKD	APVD	REV
W23101051.104.109	TP	MJL	SM	0

OFFICE	DATE
WHITEHORSE	May 31,2011

Figure 28

\\kel-eb-dc002\scans\Politylo, Theresa\w23101051.104-9\Figures\Figure 28 - Dam Safety Management System.doc

PHOTOGRAPHS

Photo 1	Tailings Impoundment Overview
Photo 2	New Toe Berm at North Tailings Dam
Photo 3	Heaved Piezometers in North Tailings Dam
Photo 4	Heave or Settlement around Piezometer in North Tailings Dam
Photo 5	North Tailings Dam upstream slope and crest
Photo 6	Cache Creek Diversion
Photo 7	Cache Creek Diversion area of instability

Photo 1: Tailings Impoundment Overview

Photo 2: New Toe Berm at North Tailings Dam

Photo 3: Heaved Piezometers in North Tailings Dam

Photo 4: Heave or Settlement Around Piezometer in North Tailings Dam

Photo 5: North Tailings Dam Upstream Slope and Crest

Photo 6: Cache Creek Diversion

Photo 7: Cache Creek Diversion Area of Instability

APPENDIX A

APPENDIX A BACKGROUND INFORMATION REVIEW

BACKGROUND INFORMATION REVIEW

The following documentation, either obtained from EBA's previous work for the mine site or provided by YNGC, was reviewed to obtain relevant project background information:

- AECOM, Report to Government of Yukon Water Resources Branch on Ketza Mine North Tailings Dam Toe Berm Assessment, December 2009
- EBA Engineering Consultants Ltd., Report to Yukon-Nevada Gold Corporation on 2007 Geotechnical Site Inspection Ketza River Gold Mine, Yukon, October 2007
- EBA Engineering Ltd., Letter Report to Ketza River Holdings Ltd. on Response to Comments Regarding the North Dam Toe Berm Ketza River Mine, Yukon, April 2008
- EBA Engineering Consultants Ltd., Report to Yukon-Nevada Gold Corporation on 2008 Geotechnical Site Inspection Ketza River Gold Mine, Yukon, February 2010
- EBA Engineering Consultants Ltd., Report to Ketza River Holdings Ltd. on 2009 Annual Water Licence Report Ketza River Mine, Yukon, February 2010
- EBA Engineering Consultants Ltd., Report to Yukon-Nevada Gold Corporation on 2010 Geotechnical Site Inspection Ketza River Gold Mine, Yukon, November 2010
- EBA, A Tetra Tech Company, Report to Yukon-Nevada Gold Corporation on 2011 Hydrotechnical Assessment, Ketza River Mine, Yukon, February 2011
- Fish and Wildlife Branch, Yukon Environment, Memo on Classification of Ketza River Mine Tailings Dams by Nathan Miller, 2008
- Fish and Wildlife Branch, Yukon Environment, Memo on Ketza Tailings Dam Hypothetical Failure and Downstream Water Quality by Bob Truelson, 2008
- Golder Associates, Report to Canamax Resources Inc. on Geotechnical Design of Tailings Disposal Facilities, Camp Site and Mill Site, Ketza River Project, Yukon, December 1986
- Golder Associates Ltd., Report to Canamax Resources Inc. on Ketza Mines Tailings Pond Operation Yukon Territories, September 1989
- Steffen Robertson & Kirsten (B.C.) Inc., Memorandum to Canamax Resources Inc. on Ketza River Tailings Impoundment, Revised Spillway Details and Issues Relating to the Stability of Dams for Decommissioning, August 29, 1990
- Steffen Robertson & Kirsten Consulting Engineers, Report to Wheaton River Minerals Limited on Ketza River Mine Abandonment Plan, February 1994
- Steffen, Robertson & Kirsten Consulting Engineers, Report to YGC Resources Limited on Ketza River Mine Assessment of Risks Associated with Tailings Dams, December 1994
- Steffen Robertson & Kirsten Consulting Engineers, Report to YGC Resources Ltd. on Addendum to the 1994 Decommissioning Plan, Ketza River Mine, Tailings Management Facility, Yukon Territory, May 1996

- SRK Consulting Engineers and Scientists, Report to Government of Yukon, Department of Environment on Geotechnical Inspection Waste & Water Management Facilities, Ketza River Mine, Yukon Territory, September 2005
- UMA Engineering Ltd., Report to Government of Yukon Water Resources Branch on Ketza River Mine 2007 Geotechnical Inspections, February 2008
- Water Resources Branch, Yukon Environment, Ketza River Inspection Report, August 9, 2010
- Water Resources Branch, Yukon Environment, Ketza Type A Water License Application Review Comments 2010-0080, August 26, 2010
- Yukon Environment and Socio-economic Assessment Board, Designated Office Evaluation Report, Ketza Type A Water License Project Assessment 2010-0090, September 16, 2010
- Yukon-Nevada Gold Corporation, Letter on Survey Dam Crest and Identify and Fill Areas below Design Elevation, September 2010
- Personal communications/2010 Spillway photos from Mr. Todd Johnson and Mr. Ian Walkley of YNG
- Yukon-Nevada Gold Corporation, Inter-Office Memo on Ketza River Project Coordinate System and Elevation Issue from Mr. Ian Walkley, January 16, 2011

APPENDIX B

APPENDIX B DAM INSPECTION NOTES

APPENDIX B1: SITE INSPECTION OBSERVATIONS OF KETZA RIVER GOLD MINE, TAILINGS STORAGE FACILITY NORTH DAM

GENERAL DESCRIPTION OF DAM			
Date:	October 6, 2010	**Attendees:**	Scott Martin, Chris Dixon
Weather:	Sun/Cloud, 4°C	**Location:**	646100E, 68525430N
Length:	~210 m	**Outlet type:**	n/a
Max. Height:	~ 20 m	**Sluice gate:**	n/a
Crest Elevation:	1309.7 to 1310.5 m	**Spillway:**	1308.3
Crest Width:	~ 5 m	**Spillway Crest Elevation:**	
Water Level:	**1307.8**	**Downstream Slope Angle:**	2.5H:1V
		Upstream Slope Angle:	2H:1V
Appurtenances:			

OBSERVATIONS	
Location	
Right Abutment	Natural knoll adjacent to spillway
Spillway	No erosion, no flow
Spillway	Check hydro report (2011) for recommendations RE: RIP RAP Size
Spillway	In native material
Crest	Tension crack near north abutment (25 m long x 15 mm wide) – ext
Crest	Old tension cracks noted in 2009 not apparent
Downstream Face	Minor bulge upper 1/3 rd. Has not changed since 2008
Downstream Face	Seepage clear and same quantity as 2009
Downstream Face	Minor erosion rills
Downstream Face	Vegetation removed
Downstream Face	Toe buttress appears to be allowing free drainage of seepage water
Upstream Face	Tension crack (see above) extends from crest across u/s face
Upstream face	Remainder appears stable

APPENDIX B2: SITE INSPECTION OBSERVATIONS OF KETZA RIVER GOLD MINE, TAILINGS STORAGE FACILITY SOUTH DAM

GENERAL DESCRIPTION OF DAM			
Date:	October 6, 2010	**Attendees:**	Scott Martin, Chris Dixon
Weather:	Sun/Cloud, 4oC	**Location:**	646140E, 6825150N
Length:	~110 m	**Outlet type:**	n/a
Max. Height:	~ 10 m	**Sluice gate:**	n/a
Crest Elevation:	1309.7 to 1310.5 m	**Spillway:**	Between north / south dam, native ground
Crest Width:	~ 5 m	**Spillway Crest Elevation:**	1308.3
Water Level:	**1307.8**	**Downstream Slope Angle:**	2.5H:1V
		Upstream Slope Angle:	2H:1V
Appurtenances:			

OBSERVATIONS	
Location	
Right Abutment	Access road
Spillway	No erosion, no flow
Spillway	Check hydro report (2011) for recommendations RE: RIP RAP Size
Spillway	In native material
Crest	No indications of instability
Downstream Face	Minor erosion rills
Downstream Face	Vegetation removed
Downstream Face	No signs of instability of piping
Downstream Face	Seepage clear and same quantity as 2009
Upstream Face	Covered by water and tails
Upstream Face	Minor erosion / slowing due to wave action

APPENDIX C

APPENDIX C INSTRUMENTATION DATA

WATER LEVEL ELEVATION MEASUREMENTS AT KR09

Date	Elevation	Notes
15-Jan-2008	1307.485	Measured with GPS inside KR09.
21-Jan-2008	1307.461	Measured with GPS inside KR09.
27-Jan-2008	1307.531	
4-Feb-2008	1307.427	
11-Feb-2008	1307.503	
18-Feb-2008	1307.307	
25-Feb-2008	1307.33	
5-Mar-2008	1307.218	
11-Mar-2008	1307.074	
24-Mar-2008	1307.082	
2-Apr-2008	1307.104	Holes in ice
25-Apr-2008	1307.112	
30-Apr-2008	1307.107	
11-May-2008	1307.306	Taken at road side ~645878E/6825361N.
19-May-2008	1307.417	
21-May-2008	1307.41	
27-May-2008	1307.556	
29-May-2008	1307.601	
30-May-2008	1307.655	
31-May-2008	1307.65	
2-Jun-2008	1307.68	
3-Jun-2008	1307.675	
4-Jun-2008	1307.689	
6-Jun-2008	1307.697	
9-Jun-2008	1307.724	
11-Jun-2008	1307.729	
13-Jun-2008	1307.743	
16-Jun-2008	1307.758	
24-Jun-2008	1307.745	
15-Jul-2008	1307.314	
22-Jul-2008	1307.133	
29-Jul-2008	1306.946	
4-Aug-2008	1306.802	
8-Aug-2008	1306.718	
11-Sep-2008	1306.387	
27-Sep-2008	1306.624	
9-Oct-2008	1306.735	
14-Oct-2008	1306.784	
13-Jul-2009	1308.45	
19-Jul-2009	1308.426	
26-Jul-2009	1308.385	
1-Aug-2009	1308.343	
8-Aug-2009	1308.254	

WATER LEVEL ELEVATION MEASUREMENTS AT KR09

Date	Elevation	Notes
16-Aug-2009	1308.111	
15-Sep-2009	1307.921	
25-Sep-2009	1308.056	
22-Nov-2009	1308.269	
8-Dec-2009	1308.105	
17-Feb-2010	1307.772	
3-Mar-2010	1307.789	
12-Mar-2010	1307.510	
18-Mar-2010	1307.812	
24-Mar-2010	1307.823	
25-Apr-2010	1307.736	
2-May-2010	1307.782	Ice thinning noticeably
9-May-2010	1307.843	
29-May-2010	1308.156	Ice gone.
9-Jun-2010	1308.222	
15-Jun-2010	1308.244	
22-Jun-2010	1308.263	
2-Jul-2010	1308.275	
14-Jul-2010	1308.245	
2-Aug-2010	1307.463	
12-Aug-2010	1307.394	
18-Aug-2010	1307.344	
27-Aug-2010	1307.398	
4-Sep-2010	1307.387	
11-Sep-2010	1307.372	
13-Oct-2010	1307.843	
24-Oct-2010	1307.498	

PIEZOMETER DATA

Piezometer	P89-1		P89-3		P89-4		P89-5		P89-6A		P89-6B		P90-7A		P90-7B		P90-7C		P90-8	
Alternative Well ID	P1		P3		P4		P5		P6A		P6B		P7A		P7B		P7C		P8	
Collar Elev. (m)	1314.00		1314.10		1310.00		1309.70		1302.50		1302.50		1313.88		1313.88		1313.88		1313.99	
Casing Stickup Above Ground (m)	0.00		0.00		0.52		1.34		2.46		2.62		0.00		0.00		0.00		0.00	
Constructed Depth of Casing Below Collar (m)	15.10		7.80		5.20		6.00		23.80		6.60		8.61		19.20		11.90		9.90	
Date	Depth to water (m)	Water Elev. (m)	Depth to water (m)	Water Elev. (m)	Depth to water (m)	Water Elev. (m)	Depth to water (m)	Water Elev. (m)	Depth to water (m)	Water Elev. (m)	Depth to water (m)	Water Elev. (m)	Depth to water (m)	Water Elev. (m)	Depth to water (m)	Water Elev. (m)	Depth to water (m)	Water Elev. (m)	Depth to water (m)	Water Elev. (m)
14-May-97	14.05	1299.95	Dry	Dry	5.03	1304.45	6.35	1302.01	10.76	1289.28	Dry	Dry	Plugged	Plugged	Plugged	Plugged	8.16	1305.72	8.15	1305.84
24-Jul-97	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
22-Jul-98	14.00	1300.00	Dry	Dry	Dry	Dry	6.66	1301.70	11.41	1288.63	Dry	Dry	Dry	Dry	8.77	1305.11	6.20	1307.68	6.50	1307.49
3-Aug-05	-	-	-	-	4.98	1304.50	6.07	1302.29	12.86	1287.18	-	-	6.33	1307.55	Plugged	Plugged	8.39	1305.49	7.00	1306.99
3-May-06	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7.83	1306.16
6-Jul-06	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	11.32	1302.56	0.00	-
7-Sep-06	-	-	-	-	-	-	-	-	-	-	-	-	6.61	1307.27	-	-	8.77	1305.11	7.58	1306.41
7-Nov-06	-	-	-	-	5.38	1304.10	-	-	-	-	-	-	7.59	1306.29	5.67	1308.22	8.86	1305.02	7.64	1306.35
3-Jan-07	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.33	1307.55	-	-	-	-
4-Jan-07	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	8.95	1304.93	7.77	1306.22
28-Feb-07	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.90	1307.98	8.99	1304.89	7.84	1306.15
8-May-07	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
26-Jun-07	-	-	Frozen	@ 1.9 m	5.05	1304.43	6.18	1302.18	12.23	1287.81	8.56	1291.32	Plugged	-	5.07	1308.81	8.51	1305.37	Frozen	-
15-Aug-07	-	-	6.49	1307.61	-	-	6.20	1302.16	-	-	-	-	-	-	-	-	8.62	1305.26	7.20	1306.79
8-Oct-07	-	-	6.30	1307.80	5.11	1304.37	6.30	1302.06	-	-	-	-	6.20	1307.68	5.17	1308.71	8.77	1305.11	7.31	1306.68
6-Nov-07	12.52	1301.48	7.58	1306.52	5.29	1304.19	6.59	1301.77	-	-	-	-	7.71	1306.17	5.30	1308.58	8.81	1305.07	7.42	1306.57
4-Dec-07	13.23	1300.77	Dry	Dry	5.40	1304.08	6.42	1301.94	-	-	-	-	Dry	Dry	5.66	1308.22	8.91	1304.97	7.63	1306.36
2-Jan-08	-	-	Dry	Dry	Dry	Dry	6.42	1301.94	-	-	-	-	Dry	Dry	5.69	1308.19	8.94	1304.94	7.68	1306.31
31-Jan-08	13.21	1300.79	Dry	Dry	Dry	Dry	-	-	-	-	-	-	Dry	Dry	5.78	1308.10	8.97	1304.91	7.75	1306.24
24-Mar-08	13.47	1300.53	Dry	Dry	5.49	1303.99	6.50	1301.86	-	-	-	-	Dry	Dry	5.93	1307.95	9.05	1304.83	7.86	1306.13
21-May-08	-	-	Frozen	-	4.88	1304.60	6.23	1302.13	-	-	-	-	Dry	Dry	5.56	1308.32	Blocked	-	Frozen	-
16-Jun-08	13.33	1300.67	Dry	Dry	5.05	1304.43	6.15	1302.21	-	-	-	-	8.18	1305.70	4.93	1308.95	8.49	1305.39	Blocked	-
13-Jul-08	-	-	5.73	1308.37	4.50	1304.98	6.25	1302.11	-	-	-	-	8.18	1305.70	5.22	1308.66	8.64	1305.24	Blocked	-
7-Aug-08	-	-	7.64	1306.46	5.37	1304.11	6.40	1301.96	12.47	1287.57	8.54	1291.34	7.31	1306.57	5.69	1308.19	8.88	1305.00	6.29	1307.70
20-Sep-10	11.76	1302.24	7.72	1306.38	5.55	1303.93	6.56	1301.80	-	-	-	-	Dry	Dry	5.87	1308.01	9.08	1304.80	7.62	1306.37

PIEZOMETER DATA (continued)

Piezometer	P90-9		P90-10A		P90-10B		P96-11A		P96-11B		P96-11C		P96-12A		P96-12B		P96-12C		Talings Pond
Alternative Well ID	P9		P10A		P10B		P11A		P11B		P11C		P12A		P12B		P12C		-
Collar Elev. (m)	1313.96		1314.08		1314.08		1314.24		1314.25		1314.25		1313.93		1313.95		1313.95		1307.98
Casing Stickup Above Ground (m)	-0.12		0.00		0.00		1.15		1.16		1.05		0.99		1.03		1.11		-
Constructed Depth of Casing Below Collar (m)	7.60		32.20		15.20		25.84		20.33		17.00		14.75		11.83		8.30		-
Date	Depth to water (m)	Water Elev. (m)	Depth to water (m)	Water Elev. (m)	Depth to water (m)	Water Elev. (m)	Depth to water (m)	Water Elev. (m)	Depth to water (m)	Water Elev. (m)	Depth to water (m)	Water Elev. (m)	Depth to water (m)	Water Elev. (m)	Depth to water (m)	Water Elev. (m)	Depth to water (m)	Water Elev. (m)	Water Elev. (m)
14-May-97	6.85	1307.23	12.98	1301.10	14.83	1299.25	-	-	-	-	-	-	-	-	-	-	-	-	Iced Over
24-Jul-97	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1310.98
22-Jul-98	7.94	1306.14	13.58	1300.50	15.03	1299.05	-	-	18.76	1294.33	Dry	Dry	8.86	1304.08	8.64	1304.28	Dry	Dry	-
3-Aug-05	6.06	1308.02	-	-	15.00	1299.08	18.98	1294.11	Dry	Dry	Dry	Dry	7.65	1305.29	7.49	1305.43	Dry	Dry	1311.60
3-May-06	6.03	1308.05	15.52	1298.56	0.00	-	19.43	1293.66	0.00	-	0.00	-	8.54	1304.40	8.42	1304.50	8.79	1304.05	-
6-Jul-06	7.06	1307.02	0.00	-	0.00	-	27.00	1286.09	0.00	-	0.00	-	9.47	1303.47	10.70	1302.22	10.57	1302.27	-
7-Sep-06	6.07	1308.01	-	-	-	-	19.24	1293.85	-	-	-	-	8.39	1304.55	8.25	1304.67	8.74	1304.10	-
7-Nov-06	6.14	1307.94	15.62	1298.46	14.83	1299.26	19.45	1293.64	6.61	1306.48	17.85	1295.35	8.52	1304.42	8.38	1304.54	7.82	1305.02	-
3-Jan-07	-	-	15.64	1298.44	14.92	1299.16	-	-	-	-	17.91	1295.29	-	-	-	-	-	-	-
4-Jan-07	6.16	1307.92	-	-	-	-	19.68	1293.41	-	-	-	-	8.59	1304.35	8.47	1304.45	8.85	1303.99	-
28-Feb-07	7.76	1306.32	15.44	1298.64	-	-	19.83	1293.26	-	-	17.92	1295.28	8.67	1304.27	8.50	1304.42	8.75	1304.09	-
8-May-07	6.20	1307.88	15.34	1298.74	-	-	-	-	-	-	17.94	1295.26	8.61	1304.33	8.50	1304.42	-	-	-
26-Jun-07	6.08	1308.00	15.93	1298.15	Dry	Dry	Frozen	@bailer	Frozen	@bailer	Frozen	@bailer	8.03	1304.91	Frozen	@bailer	Frozen	@bailer	1312.05
15-Aug-07	6.02	1308.06	-	-	-	-	19.32	1293.77	-	-	17.87	1295.33	7.98	1304.96	4.78	1308.14	8.35	1304.49	1311.41
8-Oct-07	6.03	1308.05	15.64	1298.44	14.75	1299.33	19.34	1293.75	4.79	1308.30	17.88	1295.32	8.20	1304.74	8.00	1304.92	7.78	1305.06	-
6-Nov-07	6.07	1308.01	15.52	1298.56	14.86	1299.22	19.34	1293.75	7.21	1305.88	17.89	1295.31	8.27	1304.67	8.15	1304.77	7.96	1304.88	
4-Dec-07	6.18	1307.90	15.53	1298.55	Dry	Dry	19.43	1293.66	Dry	Dry	Dry	Dry	8.46	1304.48	8.25	1304.67	8.27	1304.57	
2-Jan-08	6.12	1307.96	Blocked	-	Dry	Dry	19.39	1293.70	Blocked	-	Dry	Dry	8.47	1304.47	8.29	1304.63	8.63	1304.21	
31-Jan-08	6.10	1307.98	15.46	1298.62	Dry	Dry	19.42	1293.67	Dry	Dry	Dry	Dry	8.50	1304.44	8.33	1304.59	8.95	1303.89	
24-Mar-08	6.10	1307.98	15.64	1298.44	Dry	Dry	Blocked	-	Dry	Dry	Dry	Dry	8.62	1304.32	8.46	1304.46	9.09	1303.75	1307.08
21-May-08	6.08	1308.00	Blocked	-	Dry	Dry	Blocked	-	Dry	Dry	Dry	Dry	8.37	1304.57	8.19	1304.73	9.15	1303.69	1307.41
16-Jun-08	6.04	1308.04	15.37	1298.71	Dry	Dry	Blocked	-	Dry	Dry	Dry	Dry	8.00	1304.94	7.81	1305.11	9.04	1303.80	
16-Jun-08	6.10	1307.98	Blocked	-	9.87	1304.21	Blocked	-	Dry	Dry	Dry	Dry	8.24	1304.70	8.08	1304.84	8.85	1303.99	1307.31
7-Aug-08	6.29	1307.79	Blocked	-	14.81	1299.27	19.47	1293.62	4.88	1308.21	17.87	1295.33	8.57	1304.37	8.42	1304.50	8.47	1304.37	1306.72
20-Sep-10	6.10	1307.98	15.00	-	14.78	1299.30	19.11	1293.98	blocked	blocked	17.89	1295.31	8.21	1304.73	8.02	1304.90	8.46	1304.38	1306.80

APPENDIX D

APPENDIX D UNSW PIPING FAILURE RISK ASSESSMENT

UNSW PIPING FAILURE RISK ASSESSMENT

The UNSW method of assessing the probability of piping failure for dams involves the following steps:

- Assess the average annual frequencies of failure for embankment piping (Pe) foundation piping (Pf) and piping of the embankment into foundation (Pef). This includes consideration of whether the dam is greater than or less than 5 years in age as 2/3 of piping failures have been found to occur in the first five years following first filling.
- Calculate weighting factors for each of the aforementioned piping failure modes (wE, wF and wEF) which take into account dam characteristics such as core properties, compaction and foundation geology and past performance of the dam. The weighting factors are the product of a series of weighting factors for each particular characteristic of the dam or foundation.
- Calculate the annual likelihood of failure by piping (PP) using the following formula:

$$\mathbf{Pp = Pe \times wE + Pf \times wF + Pef \times wEF}$$

A drawback of the UNSW method is that is based on a retrospective study which tends to lump together the factors that influence the initiation and progression of piping and breach formation for historic failures and dam safety incidents (an event where the integrity of the dam has been compromised but failure has not occurred) documented in the ICOLD database of dam failures. As such, it is not possible to specifically isolate the influence of each factor. Another key consideration is the inherent assumption that the Ketza River Gold Mine Tailings Facility Dams will have enough similar characteristics to the population of dams within the database and that the findings of the database review are statistically relevant for the purposes of this assessment.

Based on the design information available for the Ketza River Gold Mine Tailings Facility Dams EBA has assumed the following zoning categories as defined in Table 1 from the Foster et al. (2000b):

- North Dam, Zoned earthfill.
- South Dam, Zoned earthfill.

The database figures for after the first 5 years of operation were selected due to the age of the dams.

The average annual probability of failure presented in Tables C1 & C2 for the Ketza River Gold Mine Tailings Facility Dams were selected from the Foster et al. (2000b) study and the weighting factors were calculated using the descriptors presented in the same paper. The tabulated weighting factors are presented below.

TABLE D1: CALCULATION OF ANNUAL LIKELIHOOD OF PIPING FAILURE - KETZA RIVER GOLD MINE TAILINGS STORAGE FACILITY NORTH DAM

Piping Failure Mode	Zoning Category	Average Annual Probability of Failure	Overall Weighting Facture	Weighted Likelihood of Piping Failure
Piping through embankment (P_e)	Zoned earthfill	$P_e = 25 \times 10^{-6}$	$w_E = 0.02$	$P_e \times w_E = 5 \times 10^{-7}$
Piping through the foundation (P_f)	Zoned earthfill	$P_f = 19 \times 10^{-6}$	$w_F = 2.3$	$P_f \times w_F = 43.7 \times 10^{-6}$
Piping from embankment into foundation (P_{ef})	Zoned earthfill	$P_{ef} = 4 \times 10^{-6}$	$w_{EF} = 0.43$	$P_{ef} \times w_{EF} = 1.72 \times 10^{-6}$
Annual Likelihood of Piping Failure (P_p)				**$P_p = 4.59 \times 10^{-5}$**

TABLE D1.1: WEIGHING FACTORS FOR PIPING THROUGH THE EMBANKMENT MODE OF FAILURE - CALCULATION OF w_E

Factor	North Dam	Weighting	Comment
Embankment Filters	Embankment filter present, well designed, well and constructed.	0.02	Golder Associates designed, supervised and documented the construction of the dam.
Core geological origin	Glacial.	0.5	No details provided in Golder Associates documentation, assumed to be a low plasticity silty Till.
Core soil type	Low-plasticity silts.	2.5	No details provided in Golder Associates documentation, assumed to be a low plasticity silty Till.
Compaction	Rolled, modest control.	1.2	No details provided in Golder Associates documentation, assumed to have had some compactive control during construction.
Conduits	No conduit through embankment.	0.5	No conduit through embankment.
Foundation treatment	No specific foundation treatment, dam constructed in u-shaped valley.	1.0	No specific foundation treatment, dam constructed in u-shaped valley, therefore neutral rating applied.
Observations of seepage	Leakage steady, clear.	1.0	Seepage rate documented, inspections have indicated seepage clear.
Monitoring and surveillance	Inspections monthly.	1.2	Inspections monthly (weather permitting), irregular seepage monitoring.
w_E, product of individual weighting factors		**0.02**	

TABLE D1.2: WEIGHTING FACTORS FOR PIPING THROUGH THE FOUNDATION MODE OF FAILURE - CALCULATION OF w_F

Factor	North Dam	Weighting	Comment
Filters	Foundation filter present.	0.8	Drawings indicate downstream foundation filter.
Foundation below cut off	Soil foundation.	5.0	Foundation soil's dense glacial drift.
Cutoff (soil foundation)	Shallow cutoff trench.	1.2	Drawings indicate shallow cutoff trench.

TABLE D1.2: WEIGHTING FACTORS FOR PIPING THROUGH THE FOUNDATION MODE OF FAILURE - CALCULATION OF w_F

Factor	North Dam	Weighting	Comment
Soil geology, below cutoff	Glacial.	0.5	Foundation soil's cohesive Till deposits.
Observations of seepage	Leakage steady, clear.	1.0	Seepage rate documented, inspections have indicated seepage clear.
Observations of pore pressures	Low pore pressures in foundation.	0.8	Piezometers indicate low pore water pressures in foundation.
Monitoring and surveillance	Inspections monthly.	1.2	Inspections monthly (weather permitting), irregular seepage monitoring.
wF, product of individual weighting factors		**2.30**	

TABLE D1.3: WEIGHTING FACTORS FOR PIPING FROM THE EMBANKMENT INTO THE FOUNDATION MODE OF FAILURE - CALCULATIONS OF w_{EF}

Factor	North Dam	Weighting	Comment
Filters	Factor doesn't influence piping through foundation.	1	
Foundation cut off trench	Shallow cutoff trench.	1.2	Drawings indicate shallow cutoff trench.
Foundation	Founding on or partly on soil foundations.	0.5	Foundation soil's dense glacial drift.
Erosion control measures of foundation	Good to very good erosion control measures present and good foundation.	0.2	Downstream filter present and rock toe berm in place.
Grouting	Soil foundation only, not applicable	1.0	
Soil geology types	Glacial	2.0	Foundation soil's dense glacial drift.
Core geological origin	Glacial	0.5	No details provided in Golder Associates documentation, assumed to be a low plasticity silty Till.
Core soil type	Low-plasticity silts	2.5	No details provided in Golder Associates documentation, assumed to be a low plasticity silty Till.
Core compaction	Rolled, modest control	1.2	No details provided in Golder Associates documentation, assumed to have had some compactive control during construction.
Foundation treatment	No specific foundation treatment, dam constructed in u-shaped valley	1.0	No specific foundation treatment, dam constructed in u-shaped valley, therefore neutral rating applied.
Observations of seepage	Leakage steady, clear.	1.0	Seepage rate documented, inspections have indicated seepage clear.
Monitoring and surveillance	Inspections monthly.	1.2	Inspections monthly (weather permitting), irregular seepage monitoring.
w_{EF}, product of individual weighting factors		**0.43**	

TABLE D2: CALCULATION OF ANNUAL LIKELIHOOD OF PIPING FAILURE - KETZA RIVER GOLD MINE TAILINGS STORAGE FACILITY SOUTH DAM

Piping Failure Mode	Zoning Category	Average Annual Probability of Failure	Overall Weighting Facture	Weighted Likelihood of Piping Failure
Piping through embankment (P_e)	Zoned earthfill	$P_e = 25 \times 10^{-6}$	$w_E = 0.02$	$P_e \times w_E = 5 \times 10^{-7}$
Piping through the foundation (P_f)	Zoned earthfill	$P_f = 19 \times 10^{-6}$	$w_F = 2.88$	$P_f \times w_F = 54.72 \times 10^{-6}$
Piping from embankment into foundation (P_{ef})	Zoned earthfill	$P_{ef} = 4 \times 10^{-6}$	$w_{EF} = 2.16$	$P_{ef} \times w_{EF} = 8.64 \times 10^{-6}$
Annual Likelihood of Piping Failure (P_p)				**P_p=6.39 x 10^{-5}**

TABLE D2.1: WEIGHING FACTORS FOR PIPING THROUGH THE EMBANKMENT MODE OF FAILURE - CALCULATION OF w_E

Factor	South Dam	Weighting	Comment
Embankment Filters	Embankment filter present, well designed, well and constructed.	0.02	Golder Associates designed, supervised and documented the construction of the dam.
Core geological origin	Glacial.	0.5	No details provided in Golder Associates documentation, assumed to be a low plasticity silty Till.
Core soil type	Low-plasticity silts.	2.5	No details provided in Golder Associates documentation, assumed to be a low plasticity silty Till.
Compaction	Rolled, modest control.	1.2	No details provided in Golder Associates documentation, assumed to have had some compactive control during construction.
Conduits	No conduit through embankment.	0.5	No conduit through embankment.
Foundation treatment	No specific foundation treatment, dam constructed in u-shaped valley.	1.0	No specific foundation treatment, dam constructed in u-shaped valley, therefore neutral rating applied.
Observations of seepage	Leakage steady, clear.	1.0	Seepage rate documented, inspections have indicated seepage clear.
Monitoring and surveillance	Inspections monthly.	1.2	Inspections monthly (weather permitting), irregular seepage monitoring.
w_E, product of individual weighting factors		**0.02**	

TABLE D2.2: WEIGHTING FACTORS FOR PIPING THROUGH THE FOUNDATION MODE OF FAILURE - CALCULATION OF w_F

Factor	South Dam	Weighting	Comment
Filters	No foundation filter.	1.0	Drawings indicate no downstream foundation filter.
Foundation below cut off	Soil foundation.	5.0	Foundation soil's dense glacial drift.
Cutoff (soil foundation)	Shallow cutoff trench.	1.2	Drawings indicate shallow cutoff trench.

TABLE D2.2: WEIGHTING FACTORS FOR PIPING THROUGH THE FOUNDATION MODE OF FAILURE - CALCULATION OF w_F

Factor	South Dam	Weighting	Comment
Soil geology, below cutoff	Glacial.	0.5	Foundation soil's cohesive Till deposits.
Observations of seepage	Leakage steady, clear.	1.0	Seepage rate documented, inspections have indicated seepage clear.
Observations of pore pressures	Low pore pressures in foundation.	0.8	Piezometers indicate low pore water pressures in foundation.
Monitoring and surveillance	Inspections monthly.	1.2	Inspections monthly (weather permitting), irregular seepage monitoring.
wF, product of individual weighting factors		**2.88**	

TABLE D2.3: WEIGHTING FACTORS FOR PIPING FROM THE EMBANKMENT INTO THE FOUNDATION MODE OF FAILURE - CALCULATIONS OF w_{EF}

Factor	South Dam	Weighting	Comment
Filters	Factor doesn't influence piping through foundation.	1	
Foundation cut off trench	Shallow cutoff trench.	1.2	Drawings indicate shallow cutoff trench.
Foundation	Founding on or partly on soil foundations.	0.5	Foundation soil's dense glacial drift.
Erosion control measures of foundation	No erosion control measures present, good foundation conditions.	1.0	No downstream filter present or toe berm in place.
Grouting	Soil foundation only, not applicable	1.0	
Soil geology types	Glacial	2.0	Foundation soil's dense glacial drift.
Core geological origin	Glacial	0.5	No details provided in Golder Associates documentation, assumed to be a low plasticity silty Till.
Core soil type	Low-plasticity silts	2.5	No details provided in Golder Associates documentation, assumed to be a low plasticity silty Till.
Core compaction	Rolled, modest control	1.2	No details provided in Golder Associates documentation, assumed to have had some compactive control during construction.
Foundation treatment	No specific foundation treatment, dam constructed in u-shaped valley	1.0	No specific foundation treatment, dam constructed in u-shaped valley, therefore neutral rating applied.
Observations of seepage	Leakage steady, clear.	1.0	Seepage rate documented, inspections have indicated seepage clear.
Monitoring and surveillance	Inspections monthly.	1.2	Inspections monthly (weather permitting), irregular seepage monitoring.
w_{EF}, product of individual weighting factors		**2.16**	

APPENDIX E

APPENDIX E DAM SAFETY EXPECTATIONS ASSESSMENT

CHECK SHEETS FOR DAM SAFETY EXPECTATIONS DEFICIENCIES AND PRIORITIES

Deficiencies and non-conformances identified during the Dam Safety Review have been evaluated in accordance with the sample check sheet for Dam Safety Expectations Deficiencies and Priorities developed by BC MoE (May 2010). Deficiencies are classified into Actual Deficiencies and Potential Deficiencies and there are a variety of non-conformances. These classifications are described as follows.

Definitions of Deficiencies and Non-Conformances

1. Deficiencies

   a) Actual – An unacceptable dam performance condition has been confirmed, based on the CDA Guidelines, or other specified safety standard. Identification of an actual deficiency generally leads to an appropriate corrective action or directly to a capital improvement project:

      i) (An) Normal Load – Load which is expected to occur during the life of a dam.

      ii) (Au) Unlikely Load – Load which could occur under unusual load (large earthquake or flood).

   b) Potential – There is a reason to expect that an unacceptable condition might exist, but has not been confirmed. Identification of a potential deficiency generally leads to a Deficiency Investigation:

      i) (Pn) Normal Load – Load which is expected to occur during the life of a dam.

      ii) (Pu) Unlikely Load – Load which could occur under unusual load (large earthquake or flood).

      iii) (Pq) Quick – Potential deficiency that cannot be confirmed but can be readily eliminated by a specific action.

      iv) (Pd) Difficult - Potential deficiency that is difficult or impossible to prove or disprove.

2. Non-Conformances

   Established procedures, systems and instructions are not being followed, or, they are inadequate or inappropriate and should be revised:

   a) Operational (NCo), Maintenance (NCm), Surveillance (NCs).

   b) Information (NCi) – information is insufficient to confirm adequacy of dam or physical infrastructure for dam safety.

   c) Other Procedures (NCp) – other procedures, to be specified.

DAM SAFETY EXPECTATIONS – KETZA RIVER GOLD MINE TAILINGS STORAGE FACILITY NORTH AND SOUTH DAMS

	DAM SAFETY EXPECTATIONS	Yes	N/A	No	Deficiencies		Non-Conformances	Comments
					Actual	Potential		
1.0	**Dam Safety Analysis**							
1.1	Records relevant to dam safety are available including design documents, historical instrument readings, inspection and testing reports, operational records and investigation results.	X						Documentation of seepage observations at v-notch weirs needs to be improved, anticipated to be addressed in the new OMS Manual. Installation of survey monuments to monitor embankment deformation recommended.
1.2	The Dam is classified appropriately in terms of the consequences of failure including life, environmental, cultural and third-party economic losses	X						
1.3	Inundation study adequate to determine consequence classification. Flood and "sunny day" scenarios assessed.	X						
1.4	Hazards external and internal to the dam have been defined.	X						
1.5	The potential failure modes for the dam and the initial conditions downstream from the dam have been identified.	X						
1.6	All other components of the water barrier (retaining walls, saddle dams, spillways, road embankments) are included in the dam safety management process.	X						
1.7	The MDE selected reflects current seismic understanding.	X						
1.8	The IDF is based on appropriate hydrological analyses.	X						
1.9	The dam is safely capable of passing flows as required for all applicable loading conditions (normal, winter, earthquake, flood).	X						
1.10	The dam has adequate freeboard for all applicable operating conditions (normal, winter, earthquake, flood).	X						
1.11	The analyses are current.	X				Pu		The upstream shells of the dams are potentially liquefiable under the design earthquake event and the stability of the embankments also maybe insufficient following the design earthquake event. No in-situ strength data is available on the embankment materials to accurately quantify this hazard.
1.12	The approach and exit channels of discharge facilities are adequately protected against erosion and free of any obstructions that could adversely affect the discharge capacity of the facilities.			X	An			The current median rock size along the spillway is not adequate to handle the design IDF.
1.13	The dams, abutments and foundations are not subject to unacceptable deformation or overstressing.	X						
1.14	Adequate filter and drainage facilities are provided to intercept and control the maximum anticipated seepage and to prevent internal erosion.	X						
1.15	Hydraulic gradients in the dams, abutments, foundations and along embedded structures are sufficiently low to prevent piping and instability.	X						Probabilistic piping hazard assessment has been undertaken.
1.16	Slopes of an embankment have adequate protection against erosion, seepage, traffic, frost and burrowing animals	X						
1.17	Stability of reservoir slopes are evaluated under all conditions and unacceptable risk to public safety, the dam or its appurtenant structures is identified.	X						Reservoir sides slopes are relatively gently sloping therefore present no perceived risk.
1.18	The need for reservoir evacuation or emergency drawdown capability as a dam safety risk control measure has been assessed.		X					No low level outlet structure.
2.0	**Operation, Maintenance and Surveillance**							
2.1	Responsibilities and authorities are clearly delegated within the organization for all dam safety activities.	X						An OMS Manual is being prepared as part of the scope of this DSR.

DAM SAFETY EXPECTATIONS – KETZA RIVER GOLD MINE TAILINGS STORAGE FACILITY NORTH AND SOUTH DAMS

	DAM SAFETY EXPECTATIONS	Yes	N/A	No	Deficiencies		Non-Conformances	Comments
					Actual	Potential		
2.2	Requirements for the safe operation, maintenance and surveillance of the dam are documented with sufficient information in accordance with the impacts of operation and the consequences of dam failure.	X						An OMS Manual is being prepared as part of the scope of this DSR.
2.3	The OMS Manual is reviewed and updated periodically when major changes to the structure, flow control equipment, operating conditions or company organizational structure and responsibilities have occurred.	X						An OMS Manual is being prepared as part of the scope of this DSR.
2.4	Documented operating procedures for the dam and flow control equipment under normal, unusual and emergency conditions exist, are consistent with the OMS Manual and are followed.	X						An OMS Manual is being prepared as part of the scope of this DSR.
	Operation							
2.5	Critical discharge facilities are able to operate under all expected conditions.							
a.	Flow control equipment is tested and is capable of operating as required.		X					No low level outlet structure.
b.	Normal and standby power sources, as well as local and remote controls, are tested.		X					No low level outlet structure.
c.	Testing is on a defined schedule and test results are documented and reviewed.		X					No low level outlet structure.
d.	Management of debris and ice is carried out to ensure operability of discharge facilities.		X					No low level outlet structure.
2.6	Operating procedures take into account:							
a.	Outflow from upstream dams.		X					No upstream dam.
b.	Reservoir levels and rates of drawdown.	X						
c.	Reservoir control and discharge during an emergency.	X						
d.	Reliable flood forecasting information.	X						
e.	Operator safety.	X						
	Maintenance							
2.7	The particular maintenance needs of critical components or subsystems, such as flow control systems, power supply, backup power, civil structures, drainage, public safety and security measures and communications and other infrastructure have been identified.	X						To be documented in the OMS Manual.
2.8	Maintenance procedures are documented and followed to ensure that the dam remains in a safe and operational condition.	X						To be documented in the OMS Manual.
2.9	Maintenance activities are prioritized and carried out with due consideration to the consequences of failure, public safety and security.			X			NCm	Assumed non-conformance, no evidence of a maintenance schedule provided.
	Surveillance							
2.10	Documented surveillance procedures for the dam and reservoir are followed to provide early identification and to allow for timely mitigation of conditions that might affect dam safety.	X						To be documented in the OMS Manual & EPP.
2.11	The surveillance program provides regular monitoring of dam performance, as follows:							
a.	Actual and expected performances are compared to identify deviations.	X						The dam has piezometers and v-notch weirs installed to monitor pore pressures and seepage flows.
b.	Analysis of changes in performance, deviation from expected performance or the development of hazardous conditions.	X						Dam instrumentation shows no variation from historical readings.

DAM SAFETY EXPECTATIONS – KETZA RIVER GOLD MINE TAILINGS STORAGE FACILITY NORTH AND SOUTH DAMS

	DAM SAFETY EXPECTATIONS	Yes	N/A	No	Deficiencies		Non-Conformances	Comments
					Actual	Potential		
c.	Reservoir operations are confirmed to be in compliance with dam safety requirements.	X						
d.	Confirmation that adequate maintenance is being carried out.			X			NCs	Assumed to be a non-conformance, no maintenance documentation was provided.
2.12	The surveillance program has adequate quality assurance to maintain the integrity of data, inspection information, dam safety recommendations, training and response to unusual conditions.			X			NCs	Assumed to be a non-conformance, no supporting documentation was provided.
2.13	The frequency of inspection and monitoring activities reflects the consequences of failure, dam condition and past performance, rapidity of development of potential failure modes, access constraints due to weather or the season, regulatory requirements and security needs.	X						Dams inspected weekly, weather permitting and documented.
2.14	Special inspections are undertaken following unusual events (if no unusual events then acknowledge that requirement to do so is documented in OMS).	X						To be documented in the OMS Manual.
2.15	Training is provided so that inspectors understand the importance of their role, the value of good documentation, and the means to carry out their responsibilities effectively.			X			NCs	Assumed to be a non-conformance as there is no indication if regular dam safety training is provided to the inspector(s). As a minimum staff responsible for the EPP should attend a suitable seminar on dam safety and inspections, such as the provide annually by the BCMoE in most areas of BC,
2.16	Qualifications and training records of all individuals with responsibilities for dam safety activities are available and maintained.			X			NCs	As Assumed to be a non-conformance as there is no indication if regular dam safety training is provided to the inspector(s).
2.17	Procedures document how often instruments are read and by whom, where the instrument readings will be stored, how they will be processed, how they will be analyzed, what threshold values or limits are acceptable for triggering follow-up actions, what the follow-up actions should be and what instrument maintenance and calibration are necessary.	X						To be documented in the OMS Manual.
3.0	**Emergency Preparedness**							
3.1	An emergency management process is in place for the dam including emergency response procedures and emergency preparedness plans with a level of detail that is commensurate with the consequences of failure.	X						An EPP is being prepared as part of the scope of this DSR.
3.2	The emergency response procedures outline the steps that the operations staff is to follow in the event of an emergency at the dam.	X						An EPP is being prepared as part of the scope of this DSR.
3.3	Documentation clearly states, in order of priority, the key roles and responsibilities, as well as the required notifications and contact information.	X						An EPP is being prepared as part of the scope of this DSR.
3.4	The emergency response procedures cover the full range of flood management planning, normal operating procedures and surveillance procedures.	X						An EPP is being prepared as part of the scope of this DSR.
3.5	The emergency management process ensures that effective emergency preparedness procedures are in place for use by external response agencies with responsibilities for public safety within the floodplain.	X						An EPP is being prepared as part of the scope of this DSR.
3.6	Roles and responsibilities of the dam owner and response agencies are defined.	X						An EPP is being prepared as part of the scope of this DSR.
3.7	Inundation maps and critical flood information are appropriate and are available to downstream response agencies.	X						An EPP is being prepared as part of the scope of this DSR. Inundation map is also contained in the DSR companion hydrotechnical report.
3.8	Exercises are carried out regularly to test the emergency procedures.			X			NCp	Assumed to be a non-conformance, no documentation that exercises have been undertaken was provided.
3.9	Staff are adequately trained in the emergency procedures.			X			NCp	Assumed to be a non-conformance, no documentation that staff have been undertaken training was provided.
3.10	Emergency plans are updated regularly and updated pages are distributed to all plan holders in a controlled manner.	X						An EPP is being prepared as part of the scope of this DSR.

DAM SAFETY EXPECTATIONS – KETZA RIVER GOLD MINE TAILINGS STORAGE FACILITY NORTH AND SOUTH DAMS

	DAM SAFETY EXPECTATIONS	Yes	N/A	No	Deficiencies		Non-Conformances	Comments
					Actual	Potential		
4.0	**Dam Safety Review**							
4.1	A safety review of the dam ("Dam Safety Review") is carried out periodically based on the consequences of failure.	X						YNG commissioned this dam safety review. This is the first Dam Safety review for these structures. Another Dam Safety Review should be conducted in seven years (2018), however YNG should endeavor to implement the recommendations contained in this review before that time.
5.0	**Dam Safety Management System**							
5.1	The dam safety management system for the dam is in place incorporating:							
a.	Policies.	X						
b.	Responsibilities.	X						
c.	Plans and procedures including OMS, public safety and security.	X						
d.	Documentation.	X						
e.	Training and review.			X			NCp	Assumed to be a non-conformance no supporting documentation provided.
f.	Prioritization and correction of deficiencies and non-conformances.	X						Prioritization and corrections of deficiencies and non-conformances are documented in this Dam Safety Review.
g.	Supporting infrastructure.	X						
5.2	Deficiencies are documented, reviewed and resolved in a timely manner. Decisions are justified and documented.	X						Deficiencies are documented in this Dam Safety Review.
5.3	Applicable regulations are met.	X						

APPENDIX F

APPENDIX F GEOTECHNICAL REPORT – GENERAL CONDITIONS

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.

APPENDIX D

APPENDIX D EBA'S GENERAL CONDITIONS

Ketza River Holdings

GENERAL CONDITIONS

GEO-ENVIRONMENTAL REPORT

This report incorporates and is subject to these “General Conditions”.

1.0 USE OF REPORT AND OWNERSHIP

This 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 those to which it refers. Any variation from the site or proposed development would necessitate a supplementary investigation and assessment.

This report and the assessments and 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 analysis 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.

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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. The Client warrants that 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 NOTIFICATION OF AUTHORITIES

In certain instances, the discovery of hazardous substances or conditions and materials may require that regulatory agencies and other persons be informed and the client agrees that notification to such bodies or persons as required may be done by EBA in its reasonably exercised discretion.

4.0 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.