APPENDIX B.1A: Concordance Table to the Executive Committee's Request for Supplementary Information

VOLUME B.I: PROJECT INTRODUCTION & OVERVIEW

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CASINO MINING CORPORATION

CASINO PROJECT

CONCORDANCE TABLE TO THE EXECUTIVE COMMITTEE'S REQUEST FOR

SUPPLEMENTARY INFORMATION No. 2

On January 27, 2015, the Executive Committee requested that CMC provide supplementary information to the Casino Project (YESAB Project No. 2014-0002) to enable the Executive Committee to commence Screening. The Executive Committee considered comments from various First Nations, Decision Bodies and regulators on the adequacy of the Project Proposal in the preparation of the Adequacy Review Report (ARR). CMC provided a Supplementary Information Report (SIR-A) on March 16, 2015. Subsequently, the Executive Committee issued a second Adequacy Review Report (ARR No.2) on May 15, 2015 following a second round of review.

The Executive Committee has 224 requests for supplementary information related to the Project Proposal submitted on January 3, 2014 and to the Supplementary Information Report submitted on March 16, 2015. These requests are listed in the concordance table with the corresponding location of the supplementary information within the SIR.

Request #	Request for Supplementary Information	Response
R2-1	A framework and associated details for the establishment of the IGRP including its structure, scope and timing. The framework shall include relevant details such as expert reviewers' qualifications, their roles and continued involvement over the mine life. This framework will demonstrate a commitment to those aspects of the Project where external review from the IGRP will be obtained. At a minimum the IGRP will provide oversight for the following: a. alternatives assessment for tailings and waste rock management; b. risk assessment for the chosen method for tailings and waste rock management; c. design of tailings and waste rock management infrastructure; d. change management framework; e. technical review framework; f. hazard classification and rationale for the proposed TMF dam; and g. dam breach/inundation study. The Proponent will provide outcomes from the IGRP's work prior to entering the screening process.	Section B.4.2.1.1
R2-2	Frameworks for a change management procedure and an associated technical review procedure which will define processes for making and approving changes to designs or operating plans, such as may occur when conditions encountered in the field during construction or operations differ from design assumptions. Describe aspects of the project design for which engineering design changes will be overseen by the IGRP. These frameworks will also describe how regulators, First Nations, and other interested parties will be involved in the review processes.	Section B.4.2.2.1
R2-3	A detailed description and assessment of alternatives to or alternative ways of undertaking the Project with respect to tailings and waste rock management. This alternatives assessment should be comprehensive, provide transparent rationale and give consideration to the following: a. Full life-cycle costs and all phases of the proposed TMF dam (i.e. in perpetuity);	Section B.4.3.1.1

Request #	Request for Supplementary Information	Response
	b. Risks of the proposed TMF dam (i.e. as per risk assessment); c. Potential significant adverse effects of the proposed TMF dam to environmental values (i.e. wildlife, water and aquatic resources) and socio-economic values (i.e. health, social, heritage and economic); d. Identification and comparison of best practices and best-available technologies for tailings management; e. Options for managing water balance to ensure safety and reduce probable risks of structural and/or non-structural TMF dam failure (i.e. as determined by the risk assessment); f. Technically-sound engineering solutions that mitigate potential significant adverse effects based on actual site conditions (e.g. permafrost, climate change, construction challenges); and g. A clear and transparent evaluation of the factors that support the proposed TMF dam.	
R2-4	A risk assessment for the TMF dam.	Section B.4.3.2.1
R2-5	Describe the involvement of independent professional engineers in: the ongoing review of monitoring data; the evaluation of site infrastructure performance with respect to design parameters; and any necessary adaptive response measures.	Section B.4.3.2.2
R2-6	Information on the feasibility and limitations of using “on-stream analyzers” on a continuous basis to monitor sulphur removal from the NAG tailings stream.	Section B.4.4.1
R2-7	Discussion on the implications related to the estimate that 25 percent of the processed supergene ore would produce non-PAG rougher tailings.	Section B.4.4.2
R2-8	One of the following: a. Responses to previous Adequacy Review Report requests as they relate to the Freegold Road upgrade and Carmacks by-pass: • R13 and R14 (in relation to the camp for the upgrade), • R18 (including safety, wildlife, and maintenance), • R27 (in relation to traffic in Carmacks and the by-pass), • R297 (in relation to clear span bridges for the upgrade), • R298 (in relation to decommissioning of abandoned structures along the alignment), • R299 (in relation to the Nordenskiold River bridge and pier), • R300 (in relation to available habitat at the Nordenskiold River bridge) • R410 (in relation to a cabin near the project footprint), or b. A modified project proposal that excludes the Freegold Road upgrade and Carmacks by-pass but includes a revised description of activities, transportation plan, and effects assessment.	Section B.4.5.1.1
R2-9	Camp details including: a. Information regarding surface water within the camp footprint and any diversions, b. Supporting information on the appropriateness of a septic system, c. Details for reclamation of camp site, and	Section B.4.5.1.2

Request #	Request for Supplementary Information	Response
	d. Volumes of vegetation to be cleared and disposal methods.	
R2-10	A description and assessment of the two possible scenarios for the Freegold Road extension: a. Road closure and reclamation including methods, objectives, and timelines, b. Continued road use including management, access, and effects.	Section B.4.5.1.3
R2-11	Clarification if project traffic predictions and the project effects assessment include empty vehicles, and if not, updated predictions and corresponding effects assessments.	Section B.4.5.1.4
R2-12	An analysis of potential effects along the Klondike Highway, for all affected sections.	Section B.4.5.1.5
R2-13	An assessment of and mitigations for potential effects due to traffic in Carmacks and Carcross.	Section B.4.5.1.6
R2-14	Additional analysis regarding the appropriate PMP value for the design of the mine facilities. Specifically, utilize the full period of rainfall record as discussed by EcoMetrix (YOR 2014-0002-399-1), discuss the PMP contours presented in TP-47, and utilize other available methods of predicting PMP such as more recent publications regarding PMP estimates for eastern interior Alaska.	Section B.4.6.1.1
R2-15	Typical cross-sections and design drawings of alignments for diversion ditching across the project site with particular focus around the HLF including: a. confining embankment; b. access road section; and c. event ponds area.	Section B.4.6.1.2
R2-16	Details and rationale on the selection of return period design criteria for all the WMP components during all phases of the Project, including long-term closure. Details should include calculation of the failure probabilities.	Section B.4.6.2.1
R2-17	Additional supporting evidence to demonstrate the sufficiency of a 30 cm thick soil liner based on the actual conditions at the mine site (e.g. shear strength, slope stability, stack height, bedrock conditions).	Section B.4.7.1.1
R2-18	An outline of plausible mitigation strategies (e.g. intermediate liners; additional and/or higher standard liners) to ensure performance objectives of the HLF are achieved.	Section B.4.7.1.2
R2-19	Clarification on how one portion of the pad versus another portion will be isolated if a leak is detected. In addition, please provide a full detail design diagram of the components used in the heap leach facility including placement of the LDRS components and how they interact.	Section B.4.7.2.1
R2-20	Details on the maintenance and repair of LDRS sumps.	Section 0
R2-21	Details on the pipelines, pumps, and related infrastructure connecting the components of the HLF including SART, cyanide, and gold extraction facilities. Include details on pipeline alignments and leak detection measures.	Section B.4.7.3.1

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R2-22	Clarify whether CMC intends to seek certification under the International Cyanide Management Code and conduct independent third-party auditing of its conformance with the cyanide management standards of practice. If so, clarify whether results of independent audits would be made available for review by interested stakeholders.	Section B.4.7.3.2
R2-23	Indication when results are expected from the additional test work and how these results will be provided in a timely manner iteratively throughout the screening process.	Section B.4.7.4.1
R2-24	An updated TMF dam hazard classification that is informed by the IGRP-overseen risk assessment and related dam breach/inundation study. Where relevant, also include details regarding the impacts to dam design and mitigation strategies as a result of this additional work.	Section B.4.8.1.1
R2-25	Additional comparison information about natural analogies within similar environments. Include estimates of the hydraulic gradient(s) for the TMF dam, throughout its lifecycle (i.e. in perpetuity), and include a discussion that reflects on the findings of the Bjelkevik (2005) report (i.e. compare the estimated hydraulic gradient of the TMF with the hydraulic gradient of natural analogies that have demonstrated long-term stability).	Section B.4.8.1.2
R2-26	Additional information regarding the factor of safety including: a. The factor of safety under pseudo-static condition, since the minimum factor of safety for slope stability under seismic loading is 1.0 and not less than 1.0 (refer to Table 6-3 of Canadian Dam Safety Guideline, 2007). b. Was the excess pore pressure during the construction period and before the embankment rise considered? c. Confirmation that the stability analysis during different stages of construction and impounding meets the minimum factor of safety proposed by CDA such that: the minimum factor of safety of 1.3 “Before the reservoir feeling” and FOS of 1.5 at the “normal reservoir level”.	Section B.4.8.1.3
R2-27	A conceptual operations, maintenance and surveillance (OM&S) plan to demonstrate how the TMF will be managed in both the operational and closure periods. At a minimum, this plan will meet the current Mining Association of Canada’s (MAC) guidance material for tailings management facilities. The OM&S plan must: a. Comprehensively address how custodial transfer will occur for all liability associated with this project. This aspect of the plan will include criteria for custodial transfer (e.g. to whom; timing; security funding; other obligations) and consider scenarios such as abandonment and end-of-mine life transfer. Provide examples of successful custodial transfer of comparable projects. b. Include supporting information that addresses monitoring and remediation activities that may be required during closure including the extent of remediation required in event of a maximum design earthquake. The plan must also consider response to multiple maximum design earthquakes that may occur considering the TMF is proposed to remain in perpetuity. c. Evaluate the potential effects of climate change on the Project through all phases, in perpetuity.	Section B.4.8.1.4

Request #	Request for Supplementary Information	Response
R2-28	Detail on the care and maintenance costs in perpetuity. This estimate will be supported by the OM&S plan, which will document the ongoing care and maintenance requirements during the closure and post-closure period. This estimate must consider costs for all liability associated with the mine site infrastructure including accidents and malfunctions	Section c
R2-29	Demonstrate how the TMF dam will be able to achieve a steady state condition for passive care during the post-closure of this project (i.e. in perpetuity).	Section B.4.8.1.6
R2-30	A dam breach analysis with water/tailings inundation modeling. Include information related to the IGRPs oversight and review of this work. The analysis must be consistent with the Canadian Dam Association's (2007) dam safety guidelines and include: a. probable maximum flood inundation map showing the maximum extent of flooding relating to a sudden full storage embankment breach extending to when expected flooding is within the natural water channels; b. an assessment of environmental and human impacts associated with a release of tailings; c. an assessment of potential impacts to First Nation Settlement Lands; d. an assessment of impacts to downstream infrastructure; e. mitigation measures in the event of a tailings breach; and, f. for each proposed breach scenario, a cross section of the critical TMF embankment, proposed loading factors, and each scenario's factor of safety.	Section B.4.8.2.1
R2-31	Detailed information on the sources and quantities for all borrow materials that are required for all mine site infrastructure, the airstrip and airstrip access road, and the Freegold road upgrade and extension, throughout all phases. This information will be based on site investigations and will include: confirmation of the depth and areal extent of the proposed aggregate borrow sources; and, characterization of the physical and chemical variability of materials (i.e. quality and suitability for intended use) required for mine site infrastructure.	Section B.4.8.3.1
R2-32	An explanation on the likelihood and implications of saturation of the TMF dam's foundation, drains, and lower portions.	Section B.4.8.4.1
R2-33	The references used to guide the factor of 1.5 and a discussion about the applicability of the reviewed cases to this project.	Section B.4.8.4.2
R2-34	The measured shear wave velocity for the foundation material.	Section B.4.8.4.3
R2-35	Mean PGA as derived from EZ-FRISK.	Section B.4.8.4.4
R2-36	Information regarding PMP and the IDF including: a. An updated PMP estimate using more robust storm expansion techniques. This modelling must be done by a trained meteorologist with a background in PMP derivation; b. Justification for using the 100 year snowpack combined with the PMP for computing the PMF instead of a more conservative return period; and c. Evidence demonstrating that the IDF represents the worst case in terms of volume of inflow.	Section B.4.8.5.1

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R2-37	Following an updated dam hazard classification as requested in section 2.7.1 include a description of how the IDF design will protect the TMF dam from overtopping.	Section B.4.8.6.1
R2-38	Further discussion on the implications of ice build-up in the spillway and how this will be monitored and managed. In addition to ice build-up, describe how the spillway will be monitored and maintained in perpetuity post-closure – this must consider any changing circumstances and/or conditions that may compromise the function of the spillway.	Section B.4.8.6.2
R2-39	Mitigations, with appropriate thresholds for implementation, and monitoring activities for closure spillway related erosion, both in the spillway channel and downstream water bodies.	Section B.4.8.6.3
R2-40	Ensure that the risk assessment requested in section 2.2.2 considers the likelihood and consequence of an HLF failure that results in displacement of water in the TMF.	Section B.4.8.7.1
R2-41	An expansion of CMC's response related to core and filter thickness by providing a review of comparable designs. Also, provide a detailed analysis that describes the deformation response of the core and the downstream filter during different stages of construction.	Section B.4.8.8.1
R2-42	A comprehensive description of the tailings beach design including but not limited to: beach length, width, slope, deposition strategies, construction QA/QC and monitoring/maintenance requirements in perpetuity.	Section B.4.8.8.2
R2-43	Quantification of the reduction of seepage and hydraulic gradient throughout the various phases of the TMF dam based on the chosen design. Provide an estimate of how the seepage and hydraulic gradient may change in perpetuity.	Section B.4.8.8.3
R2-44	The results of laboratory tests conducted to assess whether 12 percent fines sand would be free-draining including under the very high stresses in the proposed dam and frost susceptible of this material. Additionally, if applicable, provide the implications of the 12 percent fines sand not being free-draining or being frost susceptible.	Section B.4.8.9.1
R2-45	Information regarding sand properties including: a. Explanation why the more conservative 30° angle of internal friction for angular sands was not selected for the Casino dam design; b. Explanation why the same value can be assumed to apply to the tailings generated from processing of all of the three ore types; and, c. Implications if the more conservative value of 30° is applied to the tailings generated from processing of all of the three ore types. d. Confirmation whether the maximum anticipated stress for placed cyclone sand is supported by completed testing.	Section B.4.8.9.2
R2-46	Identification the actual source of the discrepancy present in the specific gravity values for the tailings sand products through repeat testing. If repeat testing is not possible, describe the implications of this discrepancy using conservative assumptions.	Section B.4.8.9.3

Request #	Request for Supplementary Information	Response
R2-47	A response to the concerns articulated by EcoMetrix regarding 2 m lifts.	Section B.4.8.9.4
R2-48	Supporting evidence for the absence or presence of faults and fractures within the TMF and embankment areas including their activity. Specifically: a. Confirm whether lidar data has been collected to determine the presence or absence of young faults near the tailings dam; b. Provide the detailed joint surveying along the dam foundation and the abutments and update the seepage analysis report; and, c. Provide a geostatistical model that represents the permeability characteristics of the bedrock below the dam foundation.	Section B.4.8.9.5
R2-49	Additional drill results and associated foundation characterization (e.g. packer testing, trenching), with detailed analysis and discussion, to provide an accurate characterization of the hydraulic conductivity and identification of fault/shear zones within the embankment foundation.	Section B.4.8.9.5
R2-50	A description of how grouting can be successfully performed given the challenges presented by permafrost. Also, update the responses for R89 a – e of the ARR in accordance with the response to R2-49.	Section B.4.8.9.5
R2-51	The rationale behind “the material is assumed to be isotropic” knowing the horizontal permeability is greater than vertical permeability in embankment dams that is constructed in several stages. Also assuming an isotropic permeability for the rock, will not be a valid assumption due to preferential seepage in the rock mass.	Section B.4.8.9.5
R2-52	The justification on why no seepage barrier is proposed for the dam foundation despite the calculated seepage rate.	Section B.4.8.9.5
R2-53	The anticipated seepage problems surrounding the storage area.	Section B.4.8.9.5
R2-54	Details regarding permafrost and permafrost conditions in relation to the TMF, including: a. confirmation that an assessment of the hydraulic properties of the permafrost under the embankment structures studies will be conducted during the detailed design; b. a winter construction execution plan that details measures and procedures for embankment placement of fill that ensures the fill soils are not frozen at the time of placement and compaction; c. QA/QC plan for construction during the cold season; d. details on permafrost conditions of the foundation materials before the construction and during the embankment raise; e. a discussion regarding the potential segregation of solids and water fractions, with the formation of discrete ice lenses within the tailings mass and its implication for tailings management; and, f. a discussion regarding the integrity implications of the potential frozen and unfrozen fill co-existing within the structure.	Section B.4.8.9.5
R2-55	A detailed schedule for the works required to construct the TMF before and during operations. Consideration should be given to key QA/QC requirements and	Section B.4.8.9.5

Request #	Request for Supplementary Information	Response
	contingency planning for scheduling delays and freezing conditions.	
R2-56	QA/QC measures during the lifetime of the embankment to ensure the effectiveness of insulation and the core structure will not be affected by the action of freezing. Please also provide confirmation regarding if permafrost aggradation potential has been considered into the TMF containment structure? If permafrost aggradation has not been considered, provide a discussion regarding the potential of permafrost aggradation into the TMF.	Section B.4.8.9.5
R2-57	Additional detail to understand the implication of shorter than expected construction windows for the TMF dam and specifically: a. Describe the implications of suspensions in fill placement operations if CMC is unable to operate in November and/or March. Also consider the implications of not being able to operate for additional months should they prove too cold. Describe how CMC will manage these implications. b. Clarification if the likelihood of one or more very cold years for the construction window has been evaluated. If so, describe the implications. Describe how CMC will manage these implications.	Section B.4.8.9.6
R2-58	Further detail on the referenced examples provided in response to R94. Demonstrate how these examples are applicable to this project and how they support the proposed construction schedule and methodology. Include details regarding the equipment and infrastructure required to facilitate winter construction.	Section B.4.8.9.7
R2-59	Discuss the implications of potentially incorporating frozen layers within the embankment (e.g. discrete ice lenses within the tailings mass; layers of frozen and unfrozen fill) to the stability and integrity of this infrastructure.	Section B.4.8.9.8
R2-60	Provide comprehensive characterization of the depth, extent and nature of permafrost where the TMF is to be constructed. Based on this characterization, confirm that excavation of all permafrost soils will be practical and how this excavation will successfully be achieved.	Section B.4.8.10.1
R2-61	Details regarding: a. A clear definition of ice-rich soils and rock; b. Characterization of the ice content of the near surface soils and rock to assess the potential volume of ice-rich materials to be excavated and disposed; c. A well-defined and rational methodology and decision making process to identify and characterize permafrost soils and rock that can be used to guide all excavation and stripping work; d. A detailed permafrost hazard map (predictive) and associated methodology that identifies type, nature, and magnitude of permafrost related hazards in the study area; e. If the TMF is situated on permafrost soils that are too deep to excavate, consideration of creep deformation of those permafrost soils resulting from placement of the TMF; and, f. Based on the map above, identification of specific risks to the Project (i.e. minesite infrastructure and the Northern Freegold Road) from identified permafrost hazards. The map should include consideration of climate change, as well, over the life of the Project.	Section B.4.8.10.2

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R2-62	Based on the risk identified in response to the questions above, please provide general options and considerations for engineering design to mitigate the identified risks.	Section B.4.8.10.3
R2-63	Provide a comprehensive assessment of how groundwater flow may be affected due to changing thermal conditions (i.e. melting permafrost). Consideration should be given to all stages of the Project, including in perpetuity for post-closure.	Section B.4.8.10.4
R2-64	Provide further justification of the validity of the baseline model calibration and its potential impact on groundwater flows in the Mine Effects models ensuring permafrost is considered in the calibrations.	Section B.4.8.10.5
R2-65	Confirm how the dam core will be insulated during construction and include comprehensive details (e.g. properties and characteristics of insulation; methodology for installing insulation; objectives and adaptive management). Provide relevant examples to support the proposed methodology.	Section B.4.8.11.1
R2-66	An explanation on how the additional transition zones can affect the current analysis.	Section B.4.8.12.1
R2-67	Identification of potential hazards of wildfire to LNG facilities at the Casino Mine site and a quantitative assessment of the related risk to those facilities. Ensure that risks and procedures associated with forest fires are discussed.	Section B.4.9.1.1
R2-68	For the diesel facilities and fueling stations, provide: a. a detailed description for all facilities related to diesel including location, design, construction, operation and closure; b. measures for the safety of project personnel including separation distances from office and living areas; and c. design measures and operating procedures to prevent a cascading accident.	Section B.4.9.2.1
R2-69	Further analysis of closure options including long-term and short-term costs, care and maintenance requirements, and long-term environmental risks. The options analysis should include: a. open pit; b. tailings management facility; c. heap leach facility; d. stockpile areas; and e. water management and treatment.	Section B.4.10.1.1
R2-70	Discussion and, if necessary, an update to the conceptual closure plan to take into account the most recent Government of Yukon Reclamation and Closure Planning for Quartz Mining Projects, Plan Requirements and Closure Costing Guidance (Government of Yukon, 2013). Details should include: a. additional closure methodology that demonstrates that the open pit water can passively flow to the TMF without continued intervention; and b. identification of closure methodologies that have been demonstrated effective in northern environments, and that clearly meet the objectives described in Section 5 of the guidance document.	Section B.4.10.1.2
R2-71	In relation to examples of successful similar treatment systems provided in	Section

Request #	Request for Supplementary Information	Response
	Appendix A.4H (Cold Climate Passive Treatment Systems Literature Review), a discussion on flow rates relative to those for the proposed project.	B.4.10.2.1
R2-72	In relation to plans on field studies to support and refine the effectiveness of the wetland water treatment system, details on: a. what benchmarks (e.g. CCME WQO or SSWQO identified in proposal) will serve as the performance objectives for the overall passive treatment system; b. what performance triggers (i.e. clear indication that the current strategy will not achieve treatment objectives) will be used during the development of the passive treatment system to identify when contingency treatment methods, such as development of bioreactors in the case of the HLF, will need to be investigated.	Section B.4.10.2.2
R2-73	Contingency, alternative, or additional treatment options that could achieve water quality objectives should the passive treatment system not be viable or perform as required. Details should include: a. identification of alternative treatment methodologies that can be employed at the site with best practicable technologies that is supported by comprehensive technical information; b. a conventional water treatment option within the framework of the water treatment plan for temporary and final closure. This should include the circumstances and triggers under which this treatment option would be developed; and c. a full alternatives assessment to demonstrate how alternative treatment technologies (that do not include wetland systems) were considered.	Section B.4.10.2.3
R2-74	In order to evaluate the potential effects related to the worst case scenario of an ineffective passive treatment, prediction of a worst case scenario of downstream water quality assuming no treatment system. Predictions should extend as far downstream as necessary to demonstrate no further exceedances of the CCME surface water quality objectives attributed to the mine (or 90th percentile of background for those constituents that naturally exceed CCME).	Section B.4.10.2.4
R2-75	A discussion and rationale on how the design of the north end of the tailings management facility wetlands will accommodate a range of possible flows from the pit lake. Identify how residence time can be controlled when flows are expected to be so highly variable, and how the proposed control valves could be relied upon in such a remote area.	Section B.4.10.2.5
R2-76	Details and design considerations for the remotely operated solar powered decant valves. Details should include: a. contingency planning related to malfunctions, inappropriate feedback and interaction; and b. examples where such systems are effectively used in similar northern or cold climate conditions.	Section B.4.10.2.6
R2-77	Details regarding potential impacts to pit water quality, and demonstrate water treatment capabilities in the TMF are sufficient, if a pit wall fails and there is a spike in metals and/or acidity in pit water.	Section B.4.10.3.1
R2-78	Examples of successful heap rinsing at comparable sites where materials of a similar nature, mass and northern location have been encountered.	Section B.4.10.4.1

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R2-79	A description how the liner in the HLF will be perforated following completion of the rinsing stage. Include a description of how drainage flowing from the HLF through the perforated liner will be captured by the TMF.	Section B.4.10.4.2
R2-80	Details on the design of the HLF cover. Details should include: a. details of construction materials and methods being proposed (e.g. on-site borrow material and/or geosynthetic liner) and supported by on-site characterization; b. consideration of other mine-site facility requirements for low-permeability material; and c. stability and long-term maintenance requirements if incorporating a geosynthetic liner.	Section B.4.10.5.1
R2-81	Feasibility level design details for the water management pond cut-off wall and cut-off trench/barrier. Include a discussion of how the structures are to be constructed. Details should include: a. details on how CMC will ensure that all groundwater seepage is collected in the water management pond as designed and modelled; b. what monitoring will be set up to ensure that the water management pond is performing as predicted, including groundwater and seepage monitoring; and c. contingencies for all project phases, in case the water management pond does not perform as expected, including if groundwater/seepage is found to by-pass the water management pond.	Section B.4.10.6.1
R2-82	Additional details about the water management pond dam should include: a. cross-sections; b. construction materials; c. consequence of failure classification; d. detailed foundation characterization; and e. monitoring and maintenance requirements.	Section B.4.10.6.2
R2-83	Contingency measures or alternatives that may be required in the event of early closure if passive treatment system field trials have not been completed or are shown to be unsuccessful. Details should include: a. identification of alternative treatment methodologies that can be employed at the site with best practicable technologies that is supported by comprehensive technical information; b. a conventional water treatment option within the framework of the water treatment plan for temporary and final closure. This should include the circumstances and triggers under which this treatment option would be developed.	Section B.4.10.7.1
R2-84	Update the CCRP and security estimates based on the Government of Yukon's updated guidance document: Reclamation and Closure Planning for Quartz Mining Projects, Plan Requirements and Closure Costing Guidance (Government of Yukon, 2013).	Section B.4.10.8.1
R2-85	Additional justification and discussion on security estimates based on new information generated by questions throughout this report. Details should include: a. all major mine components; b. all reclamation and closure stages; c. consideration of temporary or early closure;	Section B.4.10.8.2

Request #	Request for Supplementary Information	Response
	d. consideration of accidents and malfunctions, including the implications of structural and non-structural failures of the TMF dam; and e. consideration of effects of the environment.	
R2-86	Location, size, volume, and hydrology of the landfill site	Section B.4.11.1
R2-87	Anticipated volume of landfill space required for different waste streams.	Section B.4.11.2
R2-88	A description of the liner and/or leachate collection system proposed, including details for maintenance, operation, and closure.	Section B.4.11.3
R2-121	Clarification on how the design for the TMF accounts for climate variation in perpetuity, beyond the construction and operation phases of the mine.	Section B.4.12.1
R2-122	After the application of a maximum 25 percent increase in flow to all relevant baseline information, a comprehensive description of resulting changes to the tailings management facility, open pit, water management pond, heap leach facility, and diversion ditches. This should include consideration of project effects, and mitigations.	Section B.4.12.2
R2-123	The data inputs, as requested by ARCADIS and noted above, for the air quality model.	Section B.8.2.1.1
R2-124	Mitigations to reduce or eliminate the frequency and extent of air quality exceedances modeled including evidence for each mitigation's effectiveness.	Section B.8.2.2.1
R2-125	Unclassed air quality model outputs in a standard GIS format.	Section B.8.2.2.2
R2-126	Predicted change in dust composition during construction and operations.	Section B.8.3.1.1
R2-127	Discussion on additional dust sources such as project induced wind-based erosion, blasting, and traffic in relation to dust quantity, including details on the inclusion of these sources in air quality modeling.	Section B.8.3.1.2
R2-128	Water requirements for dust management and dust prevention strategies and details on any water additives.	Section B.8.3.1.3
R2-129	Discuss how the Project affects each of the commercial, recreation, or Aboriginal (CRA) fisheries and the species supporting those fisheries, which includes an understanding of the habitats but also the fish populations utilizing those habitats.	Section B.10.2.1.1
R2-130	Identification of project components likely requiring a paragraph 35(2)(b) Fisheries Act authorization.	Section B.10.2.1.2
R2-131	Demonstrate that proposed charge weights to be used in construction of the access road and infrastructure pads will not cause harm to fish and fish eggs.	Section B.10.3.1.1
R2-132	More information on the fish passage barrier in Taylor Creek, including clarification of its location and documentation that there are no upstream fish. If it is not available, the habitat upstream of the potential barrier in Taylor Creek should be	Section B.10.4.1.1

Request #	Request for Supplementary Information	Response
	included in calculation of habitat losses. This should follow the advice provided in Fisheries and Oceans Canada, Canadian Science Advisory Secretariat (Research Document 2008/026): Protocol for the Protection of Fish Species at Risk in Ontario Great Lakes Area (Fisheries and Oceans Canada, 2008).	
R2-133	Fish presence and habitat suitability maps that include information on freshwater species.	Section B.10.4.1.2
R2-134	A table including information on ephemeral channels and the likelihood of fish species presence during wetted periods.	Section B.10.4.1.3
R2-135	Additional information that allows for quantification of existing habitat value in Casino Creek.	Section B.10.4.1.4
R2-136	Additional quantitative baseline data including fish population and density estimates for all areas that will be impacted by changes in flows (reduced flows, changes in flow due to discharge and timing changes in flows). This should include a description of data quality objectives for both precision and accuracy relative to CPUE abundance estimates and how the data will be used to determine relative number of fish present for future comparisons (e.g. monitoring for change).	Section B.10.4.1.5
R2-137	Rationale and justification for the selection of reference sites and a description for how the data from the reference sites will be used for future comparisons (i.e. monitoring through all project phases).	Section B.10.4.1.6
R2-138	Final reports related to baseline data, if available, of appendices A – E for appendix 10A - Casino Project Fish and Aquatic Resources Baseline Report, November 12, 2013, by Palmer Environmental Consulting Group Inc.	Section B.10.4.2.1
R2-139	Additional information regarding the HEP including: a. methods and data used to calculate habitat gains; b. seasonal use by life stage for Arctic grayling; and c. incorporation of all life stages into the HEP.	Section B.10.5.1.1
R2-140	More information on information used in the PHABSIM model. This should include: a. A comparison of the streamflows from Knight-Piésold and that used in the PHABSIM model including tables and figures to illustrate the comparison; b. Clarity on assumptions and objectives of the modelling process regarding the estimation of impacts on fish habitat (e.g. average conditions, extreme flows, time periods etc.); c. Clarity around the consideration of fish stranding in the assessment (i.e. were extreme low flows considered in the assessment); and d. All sources of data used in the hydrology assessment and a detailed description of methods.	Section B.10.5.1.2
R2-141	An assessment of impacts to fish habitat related to culverted stream crossings on the Freegold Road.	Section B.10.6.1.1
R2-142	For each, if present, of spawning and rearing habitat, details regarding how pier	Section B.10.6.2.1

Request #	Request for Supplementary Information	Response
	construction and hydraulic forces will alter the habitat and over what area.	
R2-143	The rationale for discounting this location as winter habitat, including consideration of juvenile fish species overwintering within substrate.	Section B.10.6.2.2
R2-144	Discussion of possible options for the bridge, including a no-pier option. This discussion should include a rationale detailing the options and alternatives considered if a no-pier option is not possible.	Section B.10.6.2.3
R2-145	A list of crossing details noting crossing properties and type of crossing, index by location as indicated in appendix 10B.	Section B.10.6.3.1
R2-146	A discussion of the potential effects of the construction, operation, and possible decommissioning of project infrastructure in areas with elevated potential for rare plant species. Details should include: a. how the lack of baseline data will be addressed; b. how effects would be detected; and c. what adaptive management measures would be undertaken if effects occur.	Section B.11.2.1.1
R2-147	An analysis of the potential effects of the construction, operation, and possible decommissioning of the airstrip and airstrip access road on proximate vegetation and wetlands, with a focus on downslope wetland impacts due to changes in ground and surface water flows. This analysis should consider all wetland types occurring in the LSA.	Section B.11.2.1.2
R2-148	An analysis of the potential effects to wetlands and suggested mitigation measures related to the construction and use of the airstrip.	Section B.11.2.1.3
R2-149	An assessment of critical habitat, potential project effects, and proposed mitigations to Yukon Podistera (Podistera yukonensis).	Section B.11.2.1.4
R2-150	Initiatives that CMC will lead to monitor and address the issue of potential increased predation, mortality, and disturbance to caribou and Dall's sheep in relation to the Freegold Road.	Section **Error! Reference source not found.**
R2-151	An analysis of how baseline data will be established and how predation mortality will be monitored and addressed.	Section **Error! Reference source not found.**
R2-152	Supporting evidence for the assertion that road design is a sufficient mitigation to the barrier effects of the Freegold Road.	Section **Error! Reference source not found.**
R2-153	A review of available data for population demographics (sex and age ratios related to surveys in the RSA). Use of demographic data for harvest and surveys will provide valuable insight into the sensitivity of regional populations to potential impacts from road maintenance and operations	Section **Error! Reference source not**

Request #	Request for Supplementary Information	Response
		found.
R2-154	A discussion of the proposed Klaza caribou model based on draft components. This should include how the model supports project effects assessment and determination of significance. The review should include available population demographic data from harvest and surveys.	Section **Error! Reference source not found.**
R2-155	A discussion of noise associated with the Project in relation to the habitat suitability model using the most recent reference materials available. This discussion should include consideration of noise from all project activities and baseline conditions (see R2-212, R2-213, R2-314).	Section **Error! Reference source not found.**
R2-156	A discussion of objectives for evaluating model assumptions for caribou disturbance, monitoring movement and potential changes in predation, and setting adaptive management thresholds for actions which may mitigate adverse effects.	Section **Error! Reference source not found.**
R2-157	Discussion on the effects to the Fortymile caribou herd in the event of overlap, including extend, duration, magnitude, and significance. The analysis should consider herd size and demographics.	Section **Error! Reference source not found.**
R2-158	Discuss how the RSF model accounts for variability in caribou distribution based on environmental conditions and among years. This should include consideration of available data on actual caribou distribution from the 1980's – present.	Section **Error! Reference source not found.**
R2-159	Population survey data and demographic models for moose to determine sensitivity to change from potential additional predation or hunting pressure.	Section **Error! Reference source not found.**
R2-160	Moose harvest data by sex, including an estimate of First Nations harvest, as well as a population model and sensitivity analysis.	Section **Error! Reference source not found.**
R2-161	Information on the frequency, extent, and methods for monitoring of the pipeline route including: a. Prior to construction to inform the route, and b. During construction and operations c. Geotechnical and topographical information that will be used to determine which (if any) sections of the pipeline are buried.	Section **Error! Reference source not found.**
R2-162	Initiate additional bear den surveys, utilizing suggestions by Government of Yukon, and indicate when information will be available during the screening process.	Section **Error! Reference source not**

Request #	Request for Supplementary Information	Response
		found.
R2-163	A discussion of how denning may affect or be affected by project activity and suggested mitigations to prevent disturbance.	Section **Error! Reference source not found.**
R2-164	Updated habitat suitability and effectiveness which take into consideration the comments from Yukon government and SLR.	Section **Error! Reference source not found.**
R2-165	Detailed information on how timing of food sources has been incorporated into the models.	Section **Error! Reference source not found.**
R2-166	An updated security areas model using a maximum altitude of 1 900 m and incorporating low intensity disturbance.	Section **Error! Reference source not found.**
R2-167	Additional information on Table 8.1 of the grizzly bear effects assessment, including: a. proportion of males and females harvested; b. a discussion of how the numbers in part a relate to the population estimate; and c. a discussion of the population-level effects of direct mortality.	Section **Error! Reference source not found.**
R2-168	A discussion and analysis of the significance of mortality estimates based on population density estimate of 11 bears/1 000 km² and annual allowable mortality rate of 4 percent.	Section **Error! Reference source not found.**
R2-169	Revised traffic effect analysis, including road kills, using all project traffic not just loaded vehicles.	Section **Error! Reference source not found.**
R2-170	Information on how effects on known sites of collared pika occupancy will be avoided or minimized. This should include mitigation measures to ensure the health of the population.	Section **Error! Reference source not found.**
R2-171	A habitat suitability model and related analyses, which identifies potential denning habitat of wolverines in the local study area and regional study area.	Section **Error! Reference source not found.**

Request #	Request for Supplementary Information	Response
R2-172	A risk assessment for wolverines which considers the habitat suitability model. The assessment should identify potential effects to natal and maternal den sites and proposed measures for avoiding disturbance of females with kits.	Section **Error! Reference source not found.**
R2-173	Detailed information on study methodology for the July, 2014, bat survey.	Section **Error! Reference source not found.**
R2-174	Results and discussion of additional field work needed to determine the presence of little brown myotis and its roosts and hibernacula.	Section **Error! Reference source not found.**
R2-175	Monitoring and mitigation measures that will be undertaken for this species if their presence is determined. This will require more detailed information in the Wildlife Mitigation and Monitoring Plan.	Section **Error! Reference source not found.**
R2-176	Additional baseline information on Dall sheep that will allow for population and demographic monitoring in the future.	Section **Error! Reference source not found.**
R2-177	A discussion of the indirect effects to Dall sheep based on: a. Increased hunter access; b. Disturbance related to land and air traffic; and c. Changes in predator-prey dynamics. d. The discussion should include seasonal variation as well as proposed mitigation and monitoring measures.	Section **Error! Reference source not found.**
R2-178	Rationale on the exclusion of the identified species (rock ptarmigan, white-tailed ptarmigan, and short-eared owl) as key indicators as compared against other species of concern, including available baseline information, or the inclusion of these species as key indicator species (either as a group or individually).	Section **Error! Reference source not found.**
R2-179	Baseline data and assessment of effects in relation to red-necked phalarope.	Section **Error! Reference source not found.**
R2-180	Spatial information on the presence of alpine meadows or alpine open areas.	Section **Error! Reference source not found.**

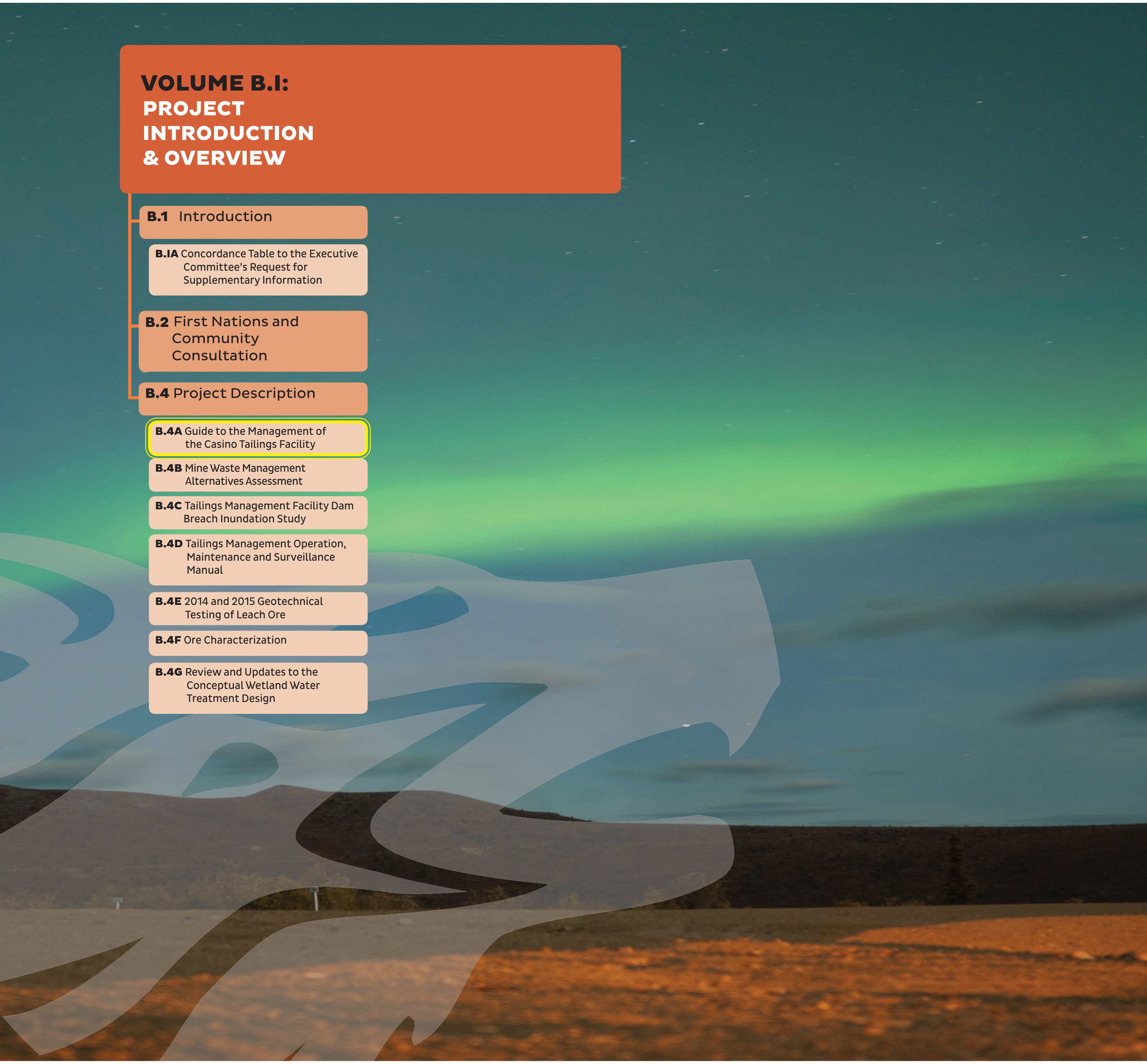
Request #	Request for Supplementary Information	Response
R2-181	Description of how the WMMP will address and protect the identified species (e.g. olive sided fly catcher, rusty blackbird, common nighthawk, short-eared owl, horned grebe, and other human intolerant species of concern.)	Section **Error! Reference source not found.**
R2-182	A description of how the WMMP will address and protect wetland habitats and their occupants.	Section **Error! Reference source not found.**
R2-183	Effects assessment of the TMF wetland on waterfowl. This should include: a. Discussion of pathways by which waterfowl accumulate detrimental levels of metals and negative effects of trace metals, particularly with respect to bioaccumulation; b. Inclusion of other trace metals found in elevated levels according to baseline surveys; and c. Consideration of the availability of open water bodies in the LSA relative to the RSA (i.e. likelihood of waterfowl staging in the project footprint.)	Section **Error! Reference source not found.**
R2-184	Thresholds for trace metal (e.g. selenium, arsenic, lead) concentrations at which waterfowl/TMF wetland monitoring would occur during the construction, operation, and decommissioning phases and a discussion of how this information will be factored into mitigation measures. This should include a discussion of additional deterrence measures that would be utilized if thresholds are crossed and an analysis of their effectiveness.	Section **Error! Reference source not found.**
R2-185	A discussion of amending the Wildlife Mitigation and Monitoring Plan to include a vegetation monitoring and management plan aimed at removing/minimizing plant growth around the TMF and Pit pond.	Section **Error! Reference source not found.**
R2-186	Information on the authority of the Wildlife Working Group (i.e. how are recommendations from the group incorporated into future planning and action?)	Section **Error! Reference source not found.**
R2-187	Details on what triggers will be used, by species, to determine whether to cease or extend monitoring at the 3-5 year mark.	Section **Error! Reference source not found.**
R2-188	Details on if, and how, impacts to species with large ranges will be monitored beyond the 10 km buffer of the project area.	Section **Error! Reference source not found.**

Request #	Request for Supplementary Information	Response
R2-189	Further information on the implementation of employment strategies to mitigate for effects of closure or unplanned closure.	Section B.15.2.1.1
R2-190	Clarification on efforts that will be used to draw employees from unemployed or underemployed populations.	Section B.15.2.1.2
R2-191	Details on implementation of the hiring policy	Section B.14.2.1.1
R2-192	Projected direct Project employment for affected communities based on actual employment information from mines in neighbouring jurisdictions and/or Minto mine. Please indicate if employees are new, existing, or returning residents or from other communities in Yukon.	Section B.14.3.1.1
R2-193	Details on the proposed mitigation strategies (flexible rotations, counselling services, and adaptive management) for the shift structure identified in the proposal.	Section B.14.4.1.1
R2-194	Details on how unscheduled community/cultural events will be accommodated in the shift structure. This should include references to experiences in Yukon and neighbouring jurisdictions.	Section B.14.4.1.2
R2-195	Identify local values within the category of community vitality and wellbeing as informed by communities and First Nations, including communities outside of Carmacks, Pelly Crossing, and Whitehorse where there is potential for significant project effects.	Section B.16.2.1
R2-196	Provide baseline data, and relevant indicators, for identified local values within the category of community vitality and wellbeing.	Section B.16.2.2
R2-197	An assessment of potential effects due to project activities to local values within the category of community vitality and wellbeing, relying where possible on relevant analogs.	Section B.16.2.3
R2-198	A description of input from First Nations including traditional knowledge and how it will inform the plan	Section B.18.2.1
R2-199	A description on how mitigations regarding heritage resources will be implemented throughout the life of the Project	Section B.18.2.2
R2-200	A monitoring and evaluation mechanism.	Section B.18.2.3
R2-201	A comprehensive TLU study including traditional knowledge. The information provided shall cover traditional land use activities identified by First Nations.	Section B.18.3.1
R2-202	An assessment of effects of the Project on TLU.	Section B.18.3.2
R2-203	An assessment of effects of the Project on traditional economies.	Section B.18.3.3

Request #	Request for Supplementary Information	Response
R2-204	A discussion of the potential effects of the Project to commercial, recreational and Aboriginal fisheries (e.g. Arctic grayling and Chinook salmon). This discussion should include: a. a geographic scope that includes areas downstream of Dip Creek up to and including the White River; b. consideration of the changes in rearing, spawning, and overwintering habitat; c. a consideration of the migratory nature of various fish species; and d. potential fish kills and stranding.	Section B.10.6.3.2
R2-205	A description of plant species of traditional, cultural, or economic importance within the Project footprint. Include a description of any efforts to engage First Nations or other land users in identifying plants of concern and any ground studies that sought to identify and map plants of concern. This information shall be provided as part of a Traditional Land Use study as requested in Section 15.1	Section B.18.4.1
R2-206	Provide a description of concerns raised regarding effects to traditional harvest areas and indicate the location of the areas of concern. This information shall be provided as part of a Traditional Land Use study as requested in Section 15.1.	Section B.18.5.1
R2-207	Provide a record of discussions and concerns raised by all affected trapline concession holders. The discussion shall include an assessment of potential impacts and any proposed mitigations for all trapping concessions, focusing on concessions #150 and #408.	Section B.2.2.1.1
R2-208	Provide a record of discussions and concerns raised by all affected outfitting concession holders. The discussion shall include an assessment of potential impacts and any proposed mitigations for all outfitting concessions.	Section B.2.2.1.2
R2-209	A description of any contact or discussions between CMC and mineral rights holders in relation to the road. Also include a description of how many mineral claim holders have been contacted and a summary of the concerns raised.	Section B.2.3.1.1
R2-210	Assessment of effects, and potential mitigations if required, on the Yukon Quest.	Section B.2.4.1.1
R2-211	Clarification of differences between the reference noise levels presented in the original proposal and the Supplementary Information Report.	Section B.9.2.1.1
R2-212	An assessment of effects, and any proposed monitoring and mitigations, due to non-modeled noise, in relation to wildlife, due to: air traffic; blasting; and cycloning.	Section B.9.2.1.2
R2-213	Rationale for a 45 dBA background sound level.	Section B.9.2.1.3
R2-214	Rationale for the use of A-weightings for assessing effects to wildlife and human annoyance (in relation to low frequency sounds), including how the use of A-weightings influence an effects assessment.	Section B.9.2.1.4
R2-215	Discussion on the temporal distribution of noise effects in communities, including Carmacks and Carcross, on a seasonal and diurnal basis	Section B.9.2.1.5

Request #	Request for Supplementary Information	Response
R2-216	Any anticipated effects, proposed mitigations, and monitoring to noise effects in communities including Carmacks and Carcross.	Section B.9.2.1.6
R2-217	Details on evacuation including anticipated timelines and seasonal considerations.	Section B.21.2.1.1
R2-218	Rationale for the two hours, or 682m³, as the minimum capacity for water storage on-site for firefighting capacity.	Section B.21.2.2.1
R2-219	A risk assessment of the transportation route that considers all major water crossings in relation to the transportation of hazardous materials.	Section B.21.2.3.1
R2-220	A human health risk assessment for the Project. Details should include: a. identify hazardous materials present on-site; b. evaluation of toxicity of hazardous materials; c. identify and assess pathways, including consumption of wildlife, fish, and traditional foods; and d. characterize risk to human health.	Section B.21.2.4.1
R2-221	Rationale based on an HHRA for the exclusion of a human health monitoring plan, or, alternatively, details on a human health monitoring plan.	Section B.21.2.4.2
R2-222	Summaries of discussions that support the proposed emergency response plans with emergency service providers, communities, and governments.	Section B.21.2.5.1
R2-223	Details on emergency response for LNG accidents or emergencies in relation to the response team and their equipment including details on training, composition, availability, and location.	Section B.21.2.5.2
R2-224	Please provide a comprehensive emergency response plan that addresses accidents and malfunctions related to major mine infrastructure. This must include consideration of structural and non-structural failure of the TMF dam as informed by the risk assessment and the dam breach and inundation study.	Section B.21.3.1.1

APPENDIX B.4A: Guide to the Management of the Casino Tailings Facility



VOLUME B.I: PROJECT INTRODUCTION & OVERVIEW

CASINO PROJECT

GUIDE TO THE MANAGEMENT OF THE CASINO TAILINGS FACILITY

PRELIMINARY DRAFT

Prepared by:

Casino Mining Corporation

December 2015

Foreword

This Guide to the Management of the Casino Tailings Facility (TMF Guide) is based upon the Mining Association of Canada's (MAC) guidelines for the design & management of tailings facilities. CMC wishes to acknowledge and thank the MAC for use of their guides and their support in our development of project specific guides, consistent with the MAC guidelines.

This document is intended to provide guidance to those responsible for the management and operation of the Casino tailings management facility (TMF) to enable them to meet the objectives and commitments articulated in the Guide to the Management of the Casino Tailings Facility.

Casino is focused on advancing its world-class copper and gold project and the associated tailings management facility (TMF) in the Yukon, through the environmental and socio-economic effects assessment, permitting and licensing process to production, while operating in an environmentally responsible manner. Casino takes a careful, considered and balanced approach that is good for Yukoners and good for business, and aligns with today's responsible mining practices.

Casino will be developed in a manner that respects and protects the environment, while enhancing benefits to Yukon individuals and communities, using sound and proven technologies and territorial, national and international industry best practices. As a proud member of the Mining Association of Canada's Towards Sustainable Mining (TSM), the company is committed to meet or exceed the TSM guiding principles, which include:

- Protecting the health and safety of our employees, contractors and communities;
- Practicing continuous improvement through the application of new technology, innovation and best practices in all facets of our operations; and
- Being responsive to community priorities, needs, and interests through all stages of mineral exploration, and mine development, operations and closure.

These principles are considered vital to Casino's existence, progress, and continued development, and are captured in our Casino Cares initiative and Corporate Social Responsibility Report 2015.

At Casino, we believe that strong collaborative relationships with Yukon communities will create long lasting benefits. We are working to achieve this through open and transparent communication with all interested and affected parties, including the Yukon Government, Yukon First Nation governments, and Yukon communities.

Sincerely,

Casino Mining Corporation

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Glossary

Acceptable risk The level of risk deemed acceptable to the corporate management taking into account government standards and guidelines, corporate policy and business factors.

Accident An unplanned event that causes injury, loss or damage to people, equipment, property or the environment.

As-built drawings Engineering drawings portraying the facility, or components of the facility, as constructed that document actual locations of the components and changes from the original engineering drawings implemented during construction of a facility.

Communities of Interest (COI) All of the individuals and groups who have or believe they have an interest in the management of decisions about operations that may affect them. This includes employees, contractors, Aboriginal or indigenous peoples, mining community members, suppliers, customers, environmental organizations, governments, the financial community and shareholders.

Continual improvement The culture of continual aligned small improvements and standardization, with the overarching aim of compound overall performance improvement.

Emergency A situation that poses an immediate risk to health, life, property, the environment or the integrity of a tailings facility and that requires urgent intervention to prevent a worsening of the situation.

Life cycle The succession of phases, from initial site selection, design and construction, through operations, to decommissioning and closure of a tailings facility, each involving discrete professional disciplines and requiring applied skills, tools and processes.

Risk A potential negative impact, detrimental to operations, a facility, the environment, public health or safety, that may arise from some present process or future event. When evaluating risk, both the potential severity and the consequence of the impact and its probability of occurrence are considered.

Tailings Material remaining after valuable minerals have been extracted from mined ore and that are typically stored or impounded in a managed tailings facility or placed as engineered fill. *See also:* **Tailings facility**

Tailings facility The collective structures, components and equipment pertaining to tailings impoundment and management including, but not limited to, dams and reservoirs, pipelines, spillways, drains, chutes, gates, intake towers, decant structures, tunnels, canals, low-level outlets, water treatment, control and release facilities, monitoring and surveillance installations, mechanical and electrical controls, power supply, and other appurtenances.

1 - INTRODUCTION

The following is derived from *A Guide to Management of Tailings Facilities* (MAC, 2011a).

Tailings facilities are site-specific complex systems that have unique environmental and physical characteristics. They pose a significant business risk that must be effectively managed for the long term. The mining industry has the technology and resources to safely site, design, construct, operate, decommission and close tailings facilities, but there remains a need to continually improve their management in a consistent, safe and environmentally responsible manner through the full life cycle.

One way to do this is to establish a comprehensive tailings management system, one that integrates technical and managerial aspects, and one that individual companies may adapt and implement under often widely ranging conditions. With this approach, the industry can self-regulate, demonstrate due diligence, complement government legislation and regulations, and protect the environment and the public. Perhaps more importantly, such an approach will help companies to integrate environmental and safety considerations in a manner that is consistent with continual improvement in their tailings operations.

A Guide to the Management of Tailings Facilities provides a basis for the development of customized tailings management systems that address the specific needs of individual mining companies and local regulatory and community requirements. The Guide includes:

- a framework for tailings management; and
- sample checklists for implementing the framework through the life cycle of a tailings facility.

The framework offers a foundation for managing tailings in a safe and environmentally responsible manner through the full life cycle of a tailings facility from site selection and design, through construction and operation, to eventual decommissioning and closure.

The tailings management framework is expanded into sample checklists that address the various stages of the life cycle. These checklists provide a basis for developing customized management systems, operating procedures and manuals, exposing gaps within existing procedures, identifying training requirements, communicating with Communities of Interest, obtaining permits, conducting internal audits, and aiding compliance and due diligence, at any stage of the life cycle.

The Guide complements MAC's Towards Sustainable Mining Guiding Principles (MAC, 2004). It is designed to help companies manage their tailings responsibly and safely and to be able to demonstrate this practice to regulators and the public. As well, it will help companies implement due diligence.

The Guide is not a technical manual; technical guidance may be found in other publications. Nor does the Guide replace professional expertise or regulatory requirements. Mining companies should obtain professional and/or expert advice to be sure that each company's specific needs are addressed. Mining companies and tailings facility owners and operators are encouraged to adapt and extend the principles contained in this Guide to meet their own site, operational and community requirements, incorporating appropriate site-specific performance measures.

2 - TAILINGS MANAGEMENT FRAMEWORK

This chapter presents the key elements of the framework to manage the Casino tailings facilities in a safe and environmentally responsible manner. It is the foundation for a management system, which is in development and will be built on by completing the management action checklists in subsequent chapters that address tailings management through the full life cycle. The essentials of this framework are illustrated in Figure 1-1. Casino Mining is developing and putting into effect this management system in the design & approval phase and will continue to develop and implement the management plan through all phases of the project, as appropriate, including closure and the post closure monitoring and maintenance phase.

Policy and Commitment

The Casino Mining tailings management policy includes commitments to:

- implement the principles outlined in this framework consistent with MAC requirements;
- locate, design, construct, operate, decommission and close tailings facilities in a manner such that:
  - All structures are stable;
  - All solids and water are managed within designated areas; and
  - All aspects of tailings management comply with regulatory requirements and conform with sound engineering practice, company standards, the MAC TSM Guiding Principles, this tailings management framework and commitments to Communities of Interest;
- Take responsibility for implementing this framework through the actions of its employees, and consultants;
- Consult with Communities of Interest, taking into account their considerations relating to the tailings facility management; and
- Establish an ongoing program of review and continual improvement to manage health, safety and environmental risks associated with tailings facilities.

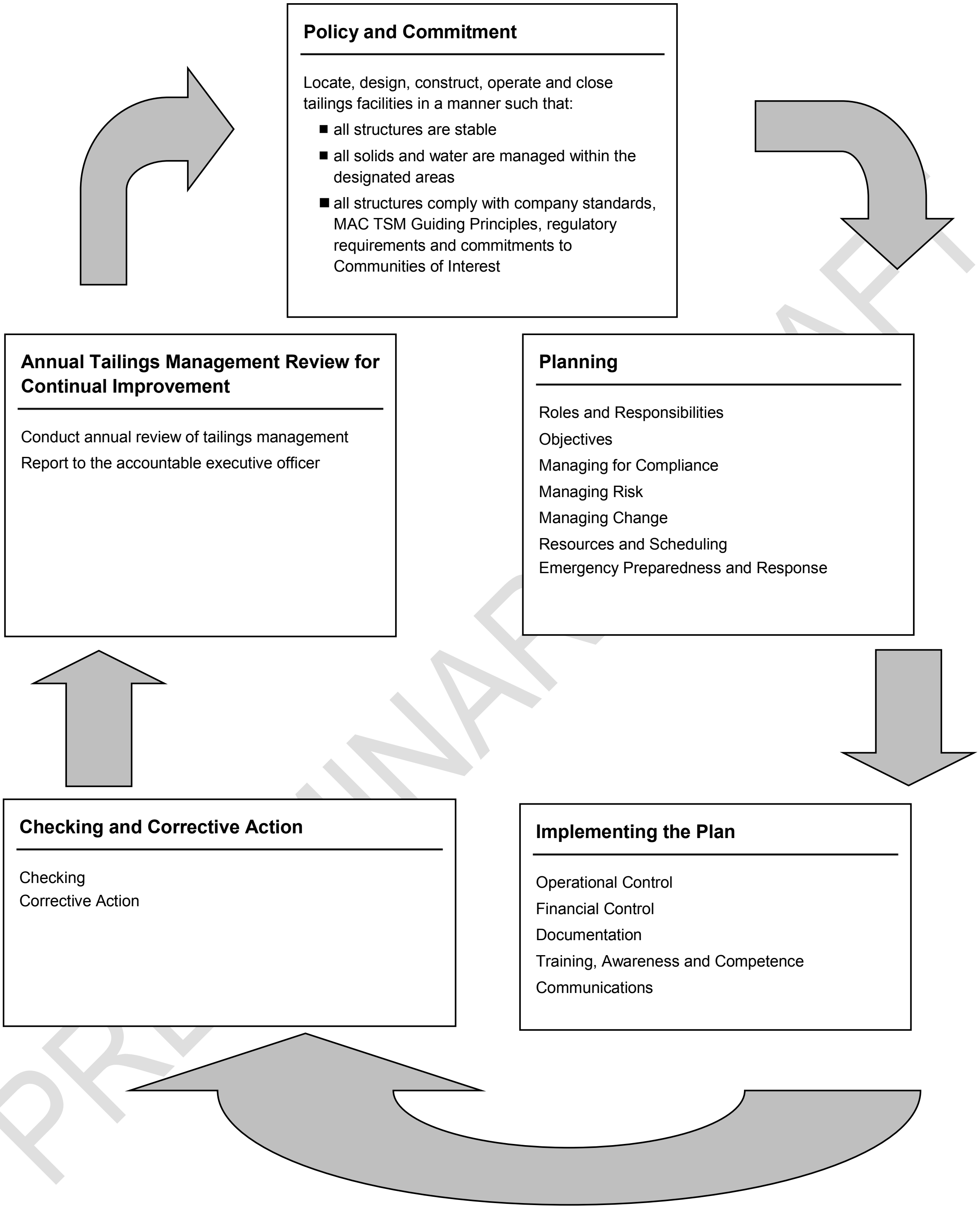


Figure 2-1 Elements of the Tailings Management Framework

2.1. PLANNING

2.1.1. Roles and Responsibilities

The Chief Operating Officer (COO) is accountable for tailings management, with responsibility for putting in place an appropriate management structure and for providing assurance to the corporation and its Communities of Interest that tailings facilities are managed responsibly (Figure 2-2).

The COO has budgetary authority for tailings management facility.

The COO will put in place the necessary organization with clearly defined personnel roles, responsibilities and reporting relationships, supported by job descriptions and organizational charts, limits of accountability and authorities to implement the tailings management framework through all stages in the facility life cycle.

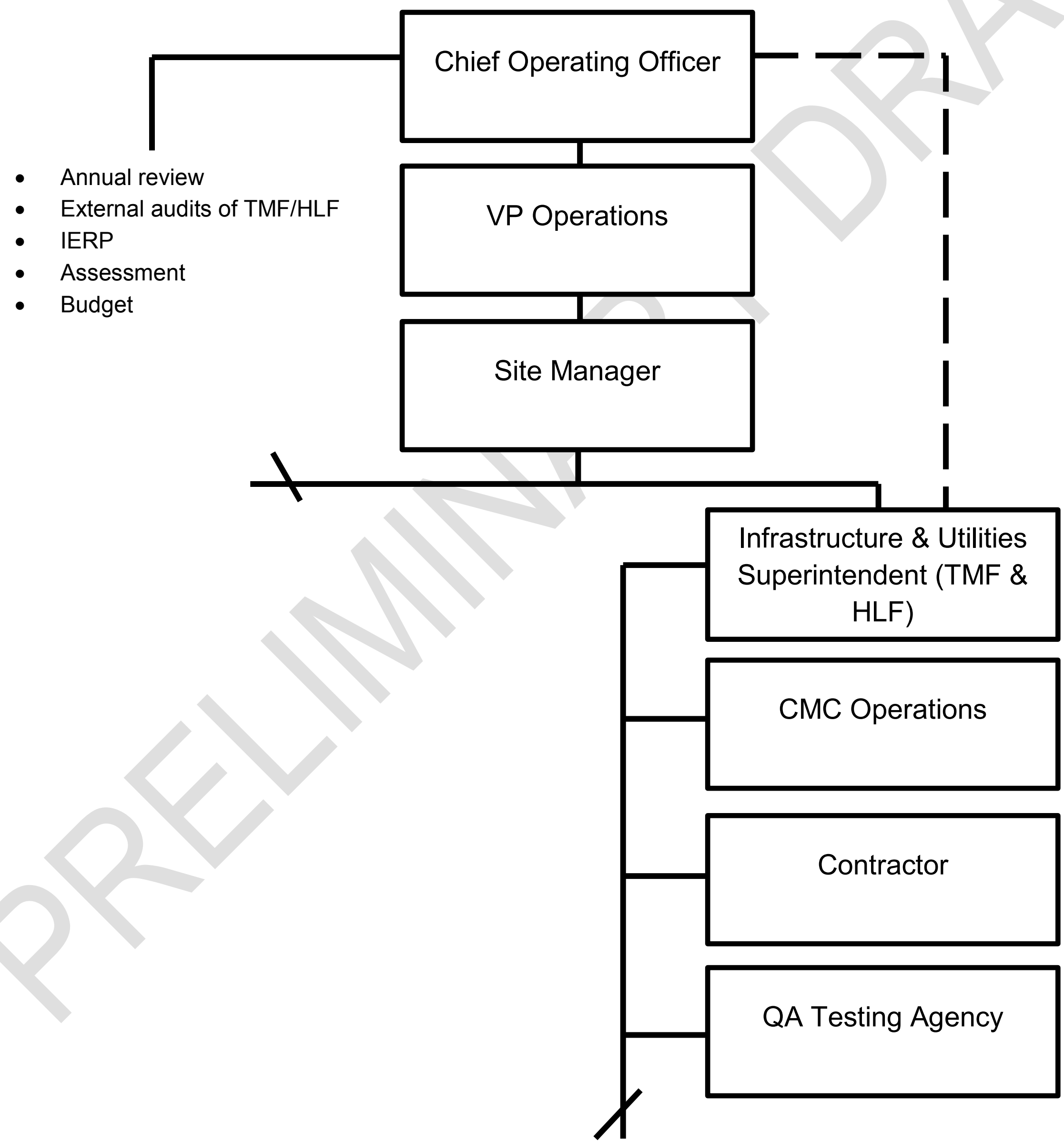


Figure 2-2 Roles and Responsibilities

2.1.2. Objectives

Plan to manage tailings through the full life cycle in conformance with regulatory requirements, company standards, this framework, commitments to Communities of Interest, and sound engineering and environmental practices.

Plan for eventual closure, including:

- protection of public health and safety;
- mitigation of negative environmental impacts; and
- acceptable post-closure use within a feasible technical and economic framework.

Identify and assess significant environmental, health and safety aspects and their associated risks.

Prepare and document tailings facility plans, including descriptions of:

- objectives and performance measures;
- permits and approvals;
- scope and frequency of inspections by the Engineer of Record (EOR);
- scope and frequency of internal audits of the tailings facility;
- scope and frequency of external, independent audits;
- scope and frequency of Independent Engineer Review Panel (IERP) participation in each phase of the tailings facility life cycle and periodic assessments of the facility;
- communication procedures among the team and with management and Communities of Interest;
- site selection and characterization criteria;
- safety, environmental and engineering design criteria;
- construction, operating, decommissioning and closure procedures;
- emergency response plan and training program;
- requirements for documentation, including as-built records;
- maintenance, surveillance, inspection, reporting and review requirements; and
- knowledge and skills (awareness, training and competence) requirements.

Incorporate Communities of Interest considerations in tailings facility planning.

2.1.3. Managing for Compliance

Ensure that:

- applicable legislation, regulations, permits and commitments are identified, documented and understood;
- actions needed to ensure compliance are understood; and
- processes and procedures to ensure measurement and compliance have been established, documented and communicated to all facility employees.

Establish procedures for reporting compliance and non-compliance.

2.1.4. Managing Risk

Casino Mining will conduct risk assessment, define acceptable risk in the context of the facility, and identify and evaluate possible triggers and failure modes. Risk assessment will be carried out in the conceptual design & permitting phase and re-assessed in the basic engineering phase and during the periodic (5 year) assessments carried out with the participation of EOR and the IERP during operations and in post-closure phase.

Plan for risk management to:

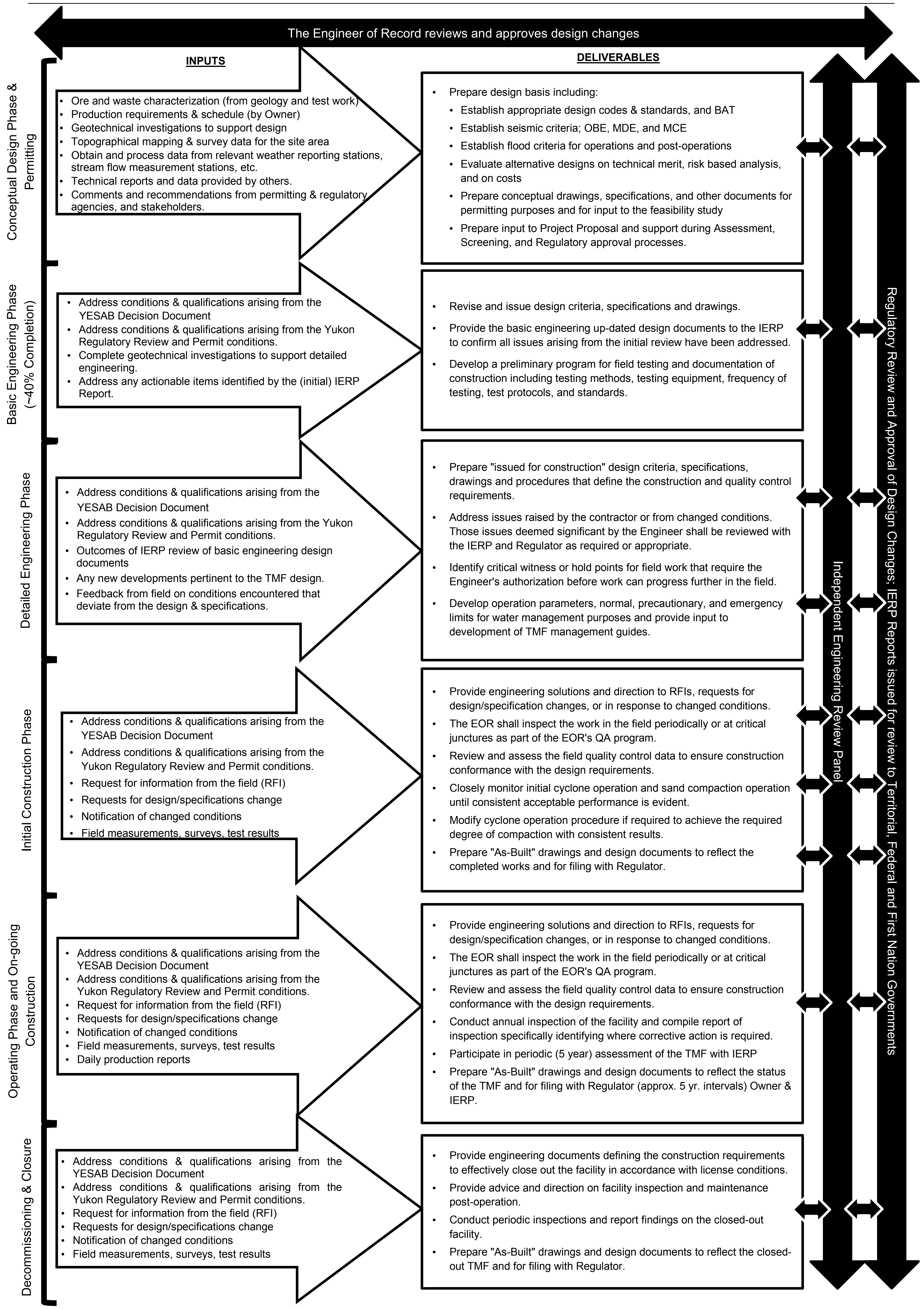
- minimize the likelihood of adverse safety or environmental impacts; and
- detect and respond to potential failures at the facility.

Prepare contingency plans as well as emergency preparedness and response plans.

2.1.5. Managing Change

Prepare and document procedures to ensure that the integrity of both the management system and the approved facility designs and plans is maintained by:

- managing changes in personnel, roles and responsibilities;
- managing changes (through the EOR), including temporary changes, made to approved designs and plans (; and
- responding to changes in regulatory requirements.
- responding to climate change through the re-assessment process during operations and in post-closure period.



QA = Quality Assurance; EOR = Engineer of Record; RFI = Request for Information from the Field; BAT = Best Available Technologies; OBE = Operating Basis Earthquake; MDE = Maximum Design Earthquake; MCE = Maximum Credible Earthquake

Figure 2-3 Inputs, Deliverables and Review of Design Refinements over the Mining Life Cycle

2.1.6. Resources and Scheduling

For effective and efficient implementation of the tailings management system, including eventual decommissioning and closure, identify and secure:

- adequate human and financial resources; and
- a schedule (appropriate to each phase of development).

2.1.7. Emergency Preparedness and Response

Develop and maintain emergency preparedness and response plans to identify possible accident or emergency situations, to respond to emergency situations and to prevent and mitigate on- and off-site environmental and safety impacts associated with emergency situations.

Establish procedures for periodic review, testing and distribution of the emergency preparedness and response plans within the organization and to potentially effected external parties.

Establish emergency notification and reporting protocols, communications requirements and contact particulars within the corporation, with the Regulatory authorities, and with the COI.

2.2. IMPLEMENTING THE PLAN

2.2.1. Operational Control

Assemble a qualified team and assign responsibilities for implementation of the tailings facility.

Select a site, design, construct, operate, decommission and close tailings facilities in compliance with regulatory requirements and in conformance with the approved plans, appropriate engineering and environmental practices, risk management, the MAC TSM Guiding Principles, commitments to Communities of Interest and this tailings management framework.

Evaluate the impact of and document changes made to approved designs, plans and procedures.

Routinely inspect, monitor, test, record, evaluate and report on key characteristics of the tailings facility; including compliance with regulatory requirements and commitments.

Implement and periodically test contingency plans and emergency preparedness and response plans.

2.2.2. Financial Control

Establish a budget and financial controls, obtain budget approval, and track capital and operating costs against the budget.

2.2.3. Documentation

Prepare, maintain, periodically review and revise the documents required to design, construct, operate, decommission and close the tailings facility in accordance with the "change control procedures".

Maintain current versions of all documents at designated, readily accessible locations. Maintain duplicate records in a secure "off-campus" location.

Promptly remove from use and archive obsolete versions of documents.

2.2.4. Training, Awareness and Competence

Employ qualified personnel and contractors.

Provide appropriate training to all personnel, including contractors and suppliers, whose work may significantly affect the tailings facility. Training shall be affected using only approved design documents and procedures. Maintain records of all training, including; name of instructor(s), personnel involved, scope & content of training materials, signed attendance report and record of any comprehension testing.

2.2.5. Communications

Implement documented procedures for communications among tailings operation and related personnel, management and Communities of Interest. Post communications protocols at appropriate locations.

Typical tailings management aspects to be covered in training

- Tailings facility management plans, permits, approvals and commitments
- Detailed description of all facilities and systems, controls systems and operating parameters
- Individual roles, responsibilities and reporting relationships
- The importance of conformance to design, license conditions, operational controls, financial controls and change management procedures
- Water management, including operational limits, precautionary levels, emergency levels and response
- Incident & accident investigation and reporting requirements
- Potential risks and environmental impacts
- Risk management
- Emergency preparedness and response

2.3. CHECKING AND CORRECTIVE ACTION

2.3.1. Checking

In addition to routine monitoring and inspections, conduct periodic inspections and reviews of the tailings facility to:

- evaluate operating and financial performance, compliance with regulatory requirements, and conformance with plans and commitments;
- revisit the facility design, construction, operation and decommissioning and closure plans;
- re-evaluate downstream risks (which may change during the life of the facility);
- up-date the risk assessment on 5 year basis including input from IERP, Regulator, and COI; and
- evaluate need for changes or updates to risk management plans, contingency plans and emergency preparedness and response plans.

Conduct annual internal audit, 3 year external audit and 5 year assessment of the entire tailings management system.

Identify items requiring corrective action.

Document and promptly report to the designated responsible official, observations and recommendations arising from inspections, reviews, audits and assessments.

2.3.2. Corrective Action

Develop and implement action plans to address items that require corrective action as identified during inspections, reviews, audits or assessments and in a manner consistent with "change control procedure".

Document the completion of corrective actions.

2.4. ANNUAL TAILINGS MANAGEMENT REVIEW FOR CONTINUAL IMPROVEMENT

The COO shall conduct an annual review of tailings management to:

- evaluate the performance of the tailings management system, considering inspection results, audit and assessment reports, changing circumstances, monitoring results, spills and other incidents, recommendations, and the commitment to continual improvement;
- evaluate the continuing adequacy of, and need for changes to, policies and objectives for, performance of, and financial resources allocated to the tailings management system; and
- address the need for changes to commitments to Communities of Interest.

The executive officer shall chair the annual review meeting and develop an action plan to address any issues or findings from the review that required corrective action. A complete and accurate record of all design or procedural changes shall be maintained.

3 - MANAGING THROUGH THE LIFE CYCLE OF THE CASINO TAILING FACILITY

Mining companies face the challenge of effectively and efficiently managing tailings facilities through a life cycle from initial site selection and design, through construction and operation, to eventual decommissioning and closure, as illustrated schematically in Figure 3-1.

The Casino tailings management framework presented in the preceding chapter provides the essential elements for managing through the life cycle of the Casino tailings facility. There is an ongoing need for planning the work to be done on the facility, for implementing activities, for checking and for reviewing the facility management. Figure 3-2 illustrates the integration of the tailings management framework with the life cycle of the tailings facility.

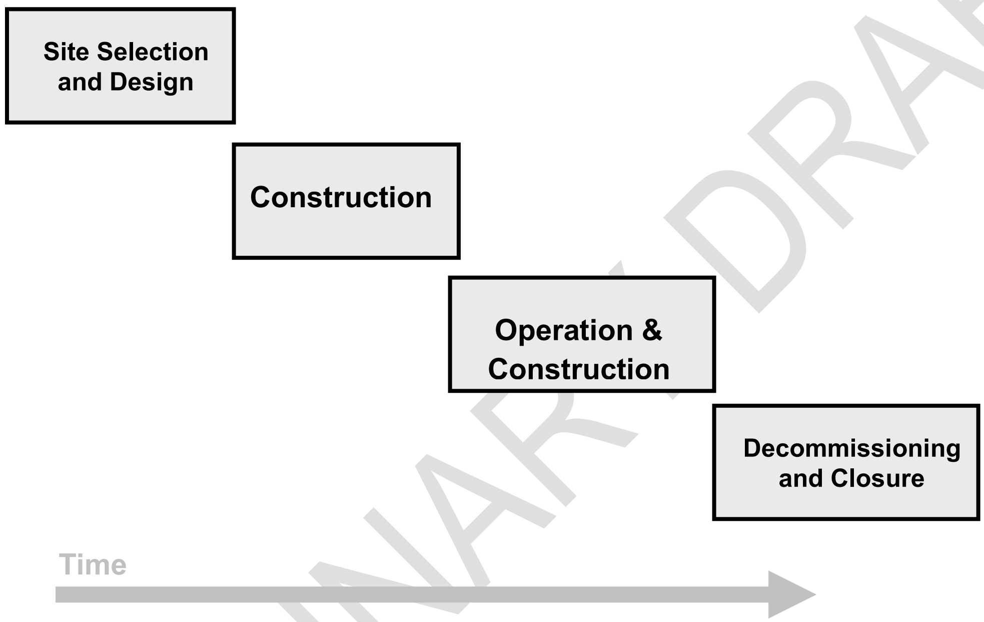


Figure 3-1 Stages in the Life Cycle of a Tailings Facility

At each stage in the tailings facility life cycle, implementation of the management framework requires that actions be planned within the context of policies and commitments, implemented in accordance with plans, checked and corrected, and subjected to management review. Different people will typically take the lead in the management of the tailings facility at different stages of the life cycle:

- site selection and design is managed by the Project Development Team working with the Engineer of Record (EOR) and others;
- facility construction up to the commissioning of a facility will be managed by the EPCM contractor acting as agent for the Owner supported by the EOR ;
- overall responsibility for the TMF safety, environmental compliance, and conformance to the operating license terms and conditions resides with the COO;
- facility operations and continuing construction, on a day to day basis, through the operating life will be managed by General Manager through the TMF Superintendent supported by the EOR as required; and
- decommissioning and closure will be managed by a team comprised of technical specialists and construction management personnel.

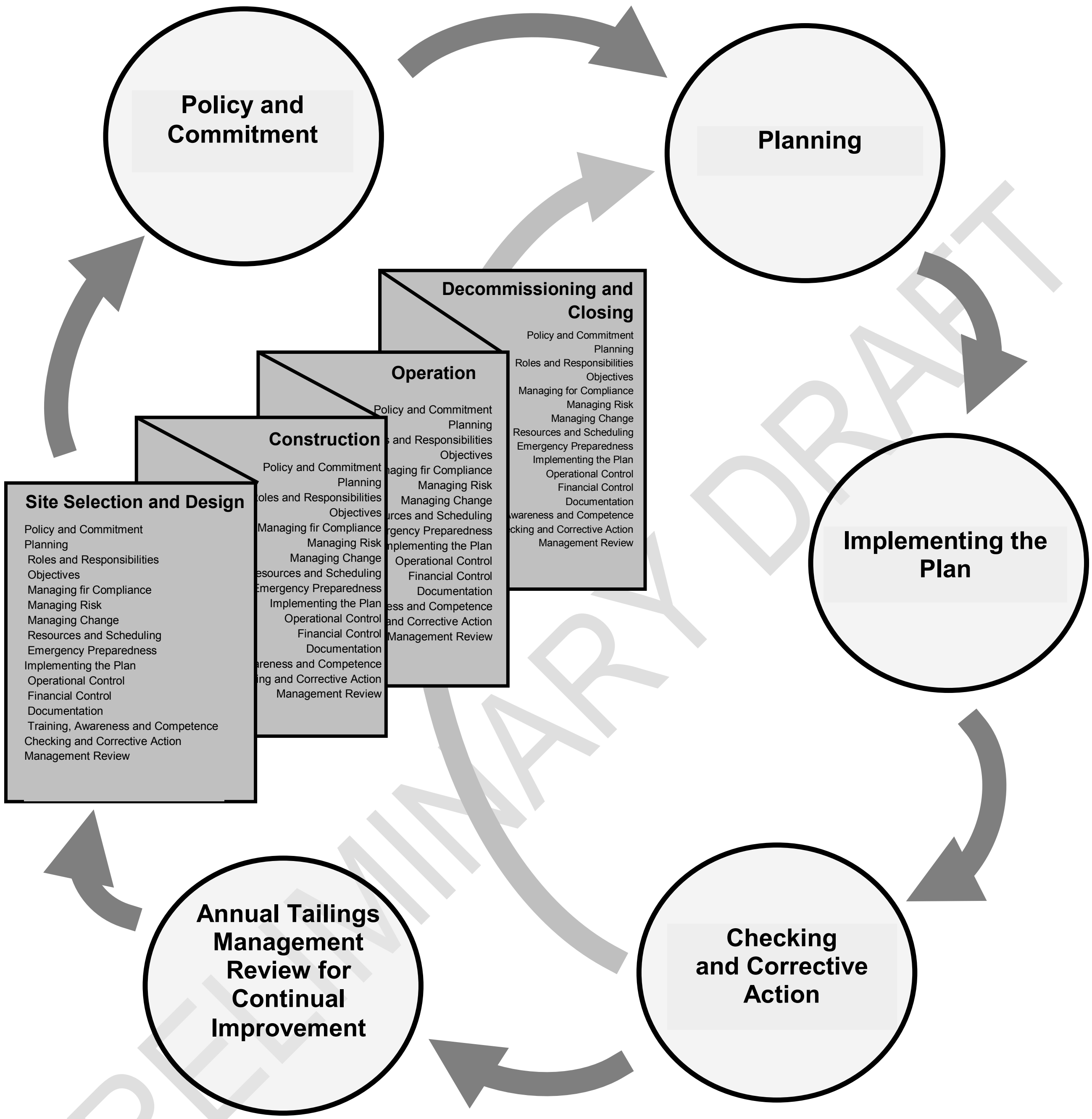


Figure 3-2 Application of the Tailings Management Framework through the Life Cycle

4 - IMPLEMENTING THE TAILINGS MANAGEMENT FRAMEWORK

The tailings management framework has been designed for application through the full life cycle of the tailings facility, beginning at the design stage. Casino Mining has elected to implement the framework at the formative phase of the project development to have continuity of the management philosophy throughout the life cycle of the facility.

Implementing the tailings management framework requires the following:

- confirming and/or customizing the relevant management actions as derived from the tailings management framework;
- assigning responsibility and authority for the management actions to individuals within the organization;
- determining relevant site-specific performance measures as indicators of progress on management actions and objectives, quantified where practicable, to enable tracking of progress;
- identifying a schedule to provide a time frame for completing significant milestones for a management action, which may include specific delivery dates or times, and/or frequency of ongoing or periodic activities such as monitoring and reviews, and providing a clear timeline for key actions; and
- adding references, including technical, managerial and regulatory information relevant to the management action and to the site.

The framework is being developed to meet the specific needs of the Casino tailings facility, company policies and local & federal regulatory requirements and community requirements. It will be implemented through the use of checklists and other forms of documentation that address the various life cycle stages. Preliminary checklists are provided in Sections 5, 6,7 & 8, respectively:

- Checklist for Site Selection and Design of the Casino Tailings Facility;
- Checklist for Construction of the Casino Tailings Facility;
- Checklist for Operating the Casino Tailings Facility; and
- Checklist for Decommissioning and Closing the Casino Tailings Facility.

These checklists provide a basis for developing and monitoring customized, site-specific tailings management systems. Completing the checklists can help identify gaps and/or deficiencies in tailings management.

When fully implemented at the Casino, a management system based on this framework will encourage continual improvement in the safe and environmentally responsible management of the tailings facilities.

5 - CHECKLIST FOR SITE SELECTION AND DESIGN OF THE CASINO TAILINGS FACILITY

Management Action	Responsibility	Performance Measure	Schedule	References
1 POLICY AND COMMITMENT				
Select a site and design a tailings facility in compliance with regulatory requirements and in conformance with sound engineering practice, company standards, the MAC TSM Guiding Principles, the MAC tailings management framework, and commitments to Communities of Interest	COO through Project Mgr., EOR	Compliance with: CDA, Yukon regulations, MAC guidelines	During permitting & design phase	Feasibility study (FS), design documents, permit applications
Ensure that the tailings management framework is implemented through the actions of all employees working at the facility	COO/Proj. Mgr.	Per TMF guidelines & MAC		
Consult with Communities of Interest, taking into account their considerations relating to the tailings facility site selection and design	COO/ Environmental Mgr. (EM)	YESAB assessment & periodic consultations		
Establish an ongoing program of review and continual improvement to manage health, safety and environmental risks associated with tailings facilities	COO/EM	Internal & External reviews (IERP)	Basic, detail eng. phases & construction	
2 PLANNING				
2.1 ROLES AND RESPONSIBILITIES				
Assign overall accountability for tailings management to an executive officer of the company (CEO or COO), with responsibility for putting in place an appropriate management structure and for providing assurance to the corporation and its Communities of Interest that tailings facilities are managed responsibly	COO through Project Mgr.	Feasibility Study estimate & schedule	FS, basic & detailed engineering documents	FS, design documents
Assign responsibility and budget authority for tailings management facility design	COO through Project Mgr.	Feasibility Study estimate & schedule		
Define the roles, responsibilities and reporting relationships for the site selection and design team, supported by job descriptions and organization charts	Project Mgr. & EOR	Compliance with CDA, MAC, environmental objectives	Through basic & detailed design phases	
2.2 OBJECTIVES				
Develop criteria and procedures to ensure that tailings facility site selection and				

Management Action	Responsibility	Performance Measure	Schedule	References
design will:				
• meet regulatory requirements, company policies and standards, sound engineering and environmental practices, and commitments to Communities of Interest	COO through Project Mgr. & Environmental Mgr.	YESAB assessment Decision Body review & approval	Permitting & License application	FS and subsequent design documents
• facilitate eventual decommissioning and closure, including: ○ protection of public health and safety ○ mitigation of negative environmental impacts ○ acceptable post-closure use within a feasible technical and economic framework • incorporate risk assessment and risk management, including contingency plans and emergency preparedness and response plans • provide continued protection of the environment and public health and safety • dnable the specified performance to be achieved	Included in design basis			
Define the interaction and communication procedures among the design team and with management and Communities of Interest	COO/EM	On-going	Throughout life-cycle	Project documentation
Identify requirements for documentation	COO/EOR	Engineering document control procedures/other	Throughout life-cycle	Project documentation control
Identify knowledge and skills (awareness, training and competence) requirements	COO/EOR			
Plan for site selection and design; establish a process of evaluation, including:				
• identification of significant environmental, health and safety aspects and their associated risks •	EM & EOR			
• standards for collection and interpretation of environmental, scientific and engineering data	EM & EOR			
• environmental assessment	EM & consultants	YESAB assessment & Decision Body Reviews		

Management Action	Responsibility	Performance Measure	Schedule	References
2.3 Managing For Compliance				
Compile and maintain a log of all applicable legislation, regulations, permits and commitments	COO/EM		On-going	Project document control procedures
Ensure that the applicable legislation, regulations, permits and commitments are understood	EM & Proj. Mgr.	Compliance with YESAB & Decision Body requirements	On-going	License conditions & qualifications
Ensure that the actions needed to ensure compliance are understood	EM & Proj. Mgr.	Audit compliance against license conditions	On-going	
Establish and document processes and procedures to ensure compliance	EM & Proj. Mgr.	Change control procedure	On-going	
Establish procedures for reporting of compliance and non-compliance	EM & Proj. Mgr.	Reporting per change control procedure	On-going	
Communicate the requirements, processes and procedures to ensure compliance to all employees	EM & Proj. Mgr.	Design change control procedures & documentation	On-going	
2.4 Managing Risk				
Evaluate hazards and prepare risk assessment for the site selection and design	COO through EM, Proj. Mgr. & EOR	Mitigate all significant risks	Complete, subject to review at each development phase	
Develop risk management plans for the site selection and design, including:				
• plans to minimize the likelihood of adverse safety or environmental impacts	As above	IERP review	Detail design phase	
• contingency plans	As above	As above	As above	
• emergency preparedness and response plans	EM	External review	Detail design phase	

Management Action	Responsibility	Performance Measure	Schedule	References
2.5 MANAGING CHANGE				
Prepare and document procedures to ensure that the integrity of the management system and the approved designs and plans is maintained by managing:				
• changes in personnel, roles and responsibilities	COO			
• changes, including temporary changes, made to approved plans and procedures	Proj. Mgr. & EOR	Per change control procedure	As required	
• changes in regulatory requirements	Proj. Mgr. & EOR	Per change control procedure	As required	
2.6 RESOURCES AND SCHEDULING				
Identify budget requirements and secure adequate human and financial resources for site selection and design	COO & Proj. Mgr.			
Develop a schedule for site selection and design	COO	Completed in preliminary design phase	Review & revise at each phase of development	
Identify the resource requirements for construction, operations and eventual decommissioning and closure	COO & Proj. Mgr.			
2.7 EMERGENCY PREPAREDNESS AND RESPONSE				
Develop and maintain emergency preparedness and response plans to identify possible accident or emergency situations, to respond to emergency situations, and to prevent and mitigate on- and off-site environmental and safety impacts associated with emergency situations	COO & EM		Detailed engineering phase	
Establish procedures for periodic review, testing and distribution of the emergency preparedness and response plans within the organization and to potentially affected external parties	COO & EM		Same as above	

3 IMPLEMENTING THE PLAN

3.1 SITE SELECTION AND DESIGN CONTROL				
Assemble a qualified team and assign responsibilities for site selection and design of the tailings facility	COO/Proj. Mgr.	YESAB assessment & Decision Body reviews and approvals	Preliminary engineering through detail engineering phases	License with conditions & qualifications

Management Action	Responsibility	Performance Measure	Schedule	References
Obtain approvals and permits for the site selection and design	COO & EM	As above	As above	As above
In accordance with the objectives:		As above	As above	As above
• select an appropriate site	COO/EM &EOR		completed	
• design the tailings facility	EOR	Comply with CDA, License conditions, MAC guidelines	Preliminary completed, review and revise at each development stage	
• prepare a comprehensive risk assessment	COO & EOR	Compliance with design standards, mitigate all significant risks	As above	
• develop related plans and procedures, including				
○ management system	CMC/EOR		Detail eng. phase	
○ documentation procedures	CMC/EOR		Detail eng. phase	
○ construction procedures	EOR		Detail eng. phase	
○ operation, maintenance and surveillance (OMS) procedures	CMC/EOR		Detail eng. phase	
○ communication procedures	CMC/EOR		Detail eng. phase	
○ knowledge and skills requirements	CMC/EOR		Detail eng. phase	
○ decommissioning and closure plan	CMC/EOR	Per license requirements	Detail eng. phase	
○ risk management plans	CMC/EOR	Per license requirements & MAC	Detail eng. phase	
○ contingency plans	CMC/EM	Per license requirements &	Detail eng. phase	

Management Action	Responsibility	Performance Measure	Schedule	References
		MAC		
○ emergency preparedness and response plans	CMC/EM	Per license requirements & MAC	Detail eng. phase	
Implement management control to:				
• ensure conformance with design objectives and criteria, appropriate engineering and environmental practices, risk management, the MAC TSM Guiding Principles, the MAC tailings management framework, and commitments to Communities of Interest	COO/EM/Proj. Mgr	Code compliance, license requirements, CMC commitments	On-going through all phases of project	
• ensure compliance with legislation, regulations, permits and commitments	As above	As above		
• manage risk	COO	Internal & external audits, periodic assessments		
• manage change	COO/Proj. Mgr.	Per change control procedure		
• identify, evaluate the impact of, and document deviations from approved plans, procedures, schedule and budget	Proj. Mgr./EOR	Change control procedure		
Implement and periodically test contingency plans and emergency preparedness and response plans for site selection and design	COO/EM		Detail eng. phase	
3.2 FINANCIAL CONTROL				
Establish a budget and financial controls	COO		On project release	
Obtain budget approval for the works	Proj. Mgr.		On project release	
Track capital and operating costs against the budget	Proj. Mgr.	Change control	Detail eng. phase	
3.3 DOCUMENTATION				
Prepare, maintain, periodically review and revise the documents required to select a site and design the tailings facility				
Maintain current versions of all documents at designated, readily accessible				

Management Action	Responsibility	Performance Measure	Schedule	References
locations, including:				
• submissions to and from regulatory agencies	COO	Document & Change control	On-going	
• training records	Proj. Mgr./EOR	Document control	On-going	
• quality control reports, photos, videos, etc.	Proj. MGr. / EOR	Document control	On-going	
• monitoring results and analyses	Proj. Mgr./EOR	Change control	On-going	
• unusual or special conditions	Proj. Mgr./EOR	Change control	On-going	
• conditions encountered	Proj. Mgr./EOR	Change control	On-going	
• communications with Communities of Interest	COO/EM	Periodic consultations	On-going	
3.4 Training, Awareness and Competence				
Employ qualified personnel	Proj. Mgr.			
Ensure that all personnel understand:				
• the design intent	EOR	Meet design criteria, code compliance	Through all phases of project	
• the potential health, safety and environmental risks and impacts of the work	EM/EOR	As above	As above	
• appropriate measures to minimize risks and impacts	Proj. Mgr. Mgr./EM/EOR	Internal & external (IERP) reviews	At discrete intervals during project development	
Identify training needs, conduct training as appropriate, and maintain records of all training provided	Proj. Mgr./EOR		Detail design	
3.5 Communications				
Implement documented procedures for communications				
• among tailings personnel	EOR		On-going	
• with management	Proj. Mgr/EOR		On-going	
• with Communities of Interest	COO/EM		On-going	

4 Checking and Corrective Action

Management Action	Responsibility	Performance Measure	Schedule	References
4.1 CHECKING				
Review site selection and design to ensure compliance with regulatory requirements and conformance with policies and commitments	COO/EM/Proj. Mgr.	Compliance with CDA, MAC, License conditions	On-going, includes IERP at distinct stages of project development	
Consider independent review of design	Coo/Proj. Mgr		Early detailed design stage, late design & construction stage and during operations (assessment)	
Document and promptly report to the designated responsible official any observations and recommendations arising from reviews, specifically identifying items requiring corrective action	COO/Proj. Mgr.	Per code & regulation requirements	On-going	
4.2 CORRECTIVE ACTION				
Develop and implement action plans to address items that require corrective action	COO/Proj. Mgr.	Obtain regulatory approval for change/action	Per change control procedure	
Document completion of corrective actions		Notify regulator of completed action	Per change control procedure	

5 ANNUAL TAILINGS MANAGEMENT REVIEW FOR CONTINUAL IMPROVEMENT

Conduct an annual review of tailings management to:				
• evaluate the performance of the tailings management system, considering inspection, audit and assessment reports, changing circumstances, recommendations, and the commitment to continual improvement				
• evaluate the continuing adequacy of, and need for changes to, policies and objectives and performance of the tailings management system				
• address the need for changes to commitments to Communities of Interest				
Report the observations and conclusions of this annual review of tailings management to the accountable executive officer				

6 - CHECKLIST FOR CONSTRUCTION OF THE CASINO TAILINGS FACILITY

Management Action	Responsibility	Performance Measure	Schedule
1 POLICY AND COMMITMENT			
Construct the tailings facility according to the design in a safe and environmentally responsible manner, in compliance with regulatory requirements, and in conformance with sound engineering practice, company standards, the MAC TSM Guiding Principles, the MAC tailings management framework, and commitments to Communities of Interest	COO	Compliance with codes, license & conditions, MAC principles	On-going
Ensure that the tailings management framework is implemented through the actions of all employees working at the facility	COO/Proj. Mgr	Per TMF guidelines	On-going
Consult with Communities of Interest, taking into account their considerations relating to the tailings facility construction	COO/EM	Periodic consultations	On-going
Establish an ongoing program of review and continual improvement to manage health, safety and environmental risks associated with tailings facilities	COO/EM	Internal & External reviews	Detail eng. & construction phase
2 PLANNING			
2.1 ROLES AND RESPONSIBILITIES			
Assign overall accountability for tailings management to an executive officer of the company (CEO or COO), with responsibility for putting in place an appropriate management structure and for providing assurance to the corporation and its Communities of Interest that tailings facilities are managed responsibly	COO		
Assign responsibility and budget authority for tailings management	COO		
Define the roles, responsibilities and reporting relationships for the tailings facility construction, supported by job descriptions and organization charts, and including:			
• project management	Proj. Mgr/EPCM	Project procedures	
• ongoing liaison with the design team regarding found conditions, design changes and site supervision	EPCM/EOR	In accordance with change control process	On-going
• selection of contractors	Proj. Mgr/EPCM	Pre-qualification process	On-going
• quality assurance	EPCM/EOR	Project procedures	On-going
• quality control	contractor	Design documents	On-going
• field testing	Independent test agency	specifications	On-going
• environmental protection	EPCM &	Project standards	On-going

Management Action	Responsibility	Performance Measure	Schedule
	contractors		
• construction supervision, health and safety	EPCM & contractors Pre-qualification process	Project procedures	On-going
• temporary works	EPCM & contractors	Design documents	As required
• instrumentation	EPCM & contractors	Design documents	Per construction schedule
• commissioning	CMC/EPCM	Project procedures	Per construction schedule
• documentation, including changes to design and management	EPCM & contractors	Project procedures	On-going
• communications, both internally and to Communities of Interest	COO/EM	Periodic consultations	On-going
2.2 Objectives			
Develop criteria and procedures to ensure that tailings facility construction will:			
• be in conformance with design	Proj. Mgr./EPCM	Project procedures	Detailed engineering
• meet regulatory requirements, company policies and standards, sound engineering and environmental practices, and commitments to Communities of Interest	COO/Proj. Mgr.	Project procedures & corporate policy	Detailed engineering
• facilitate eventual decommissioning and closure	COO/Proj. Mgr.	Corporate policy & design requirement	Detailed engineering
• provide continued protection of the environment and public health and safety	Proj. Mgr./EPCM	Project procedures	Detailed engineering
• enable the specified performance to be achieved	Proj. Mgr.	Project procedures	Detailed engineering
Define procedures for communication among the construction team and with management and Communities of Interest	COO/EM	Project procedures	Detailed engineering
Identify requirements for documentation	COO	Project procedures	Detailed engineering
Identify knowledge and skills (awareness, training and competence) requirements	COO	Project procedures	Detailed engineering
Prepare detailed plans for construction of the tailings facility to:			
• establish a quality control system for construction	EPCM/EOR	Project procedures	Detailed engineering
• identify and review deviations from design	EPCM/EOR	Project procedures	Detailed engineering
• produce as-built drawings and construction reports	EPCM/EOR	Project procedures	Detailed engineering

Management Action	Responsibility	Performance Measure	Schedule
• ensure availability of suitable quality and quantity of construction materials	EPCM	Project procedures	Detailed engineering
• install instrumentation	EPCM	Design documents	Detailed engineering
• meet environmental objectives	Proj. Mgr./EPCM	Project procedures	Detailed engineering
• obtain all required construction permits	COO/Proj. Mgr.	Project procedures	Detailed engineering
• specify contractor bonding requirements and	Proj. Mgr.	Project procedures	Detailed engineering
• establish contractor tendering procedures	Proj. Mgr./EPCM	Project procedures	Detailed engineering
2.3 MANAGING FOR COMPLIANCE			
Compile and maintain a log of all applicable legislation, regulations, permits and commitments	Proj. Mgr./EPCM	Project procedures	Detailed engineering
Ensure that the applicable legislation, regulations, permits and commitments are understood	Proj. Mgr./EPCM	Project procedures	Detailed engineering
Ensure that the actions needed to ensure compliance are understood	Proj. Mgr./EPCM	Project procedures	Detailed engineering
Establish and document processes and procedures to ensure compliance	Proj. Mgr./EPCM	Project procedures	Detailed engineering
Establish procedures for reporting of compliance and non-compliance	Proj. Mgr./EPCM	Project procedures	Detailed engineering
Communicate the requirements, processes and procedures to ensure compliance to all employees	Proj. Mgr./EPCM	Project procedures	Detailed engineering
2.4 MANAGING RISK			
Prior to the start of construction, prepare a risk assessment for the facility:			
• the risks associated with possible triggers and failure modes for construction	Proj. Mgr./EPCM & EOR	Internal & external reviews	Detailed engineering
• possible impacts on the environment, public health and safety	Proj. Mgr./EPCM	Internal & external reviews	Detailed engineering
• the construction parameters that can affect the triggers and failure modes	Proj. Mgr./EPCM	Internal & external reviews	Detailed engineering
Develop:			
• risk management plans to minimize the likelihood of adverse safety or environmental impacts	COO/Proj. Mgr.	Internal & external reviews	Detailed engineering
• contingency plans	COO/Proj. Mgr.	Internal & external reviews	Detailed engineering
• emergency preparedness and response plans	COO/Proj. Mgr.	Internal & external reviews	Detailed engineering
• that include:			

Management Action	Responsibility	Performance Measure	Schedule
○ control strategies to manage the identified risks and/or reassess the design	COO/Proj. Mgr.	Internal & external reviews (IERP)	Detailed engineering
○ identification of thresholds to trigger implementation of contingency plans and emergency response plans	COO/Proj. Mgr.	Internal & external reviews (IERP)	Detailed engineering
○ communication procedures	COO/EM	Corporate Policy	Detailed engineering
2.5 MANAGING CHANGE			
Prepare and document procedures to ensure that the integrity of both the management system and the approved designs and plans is maintained by managing:			
changes in personnel, roles and responsibilities	COO		Detailed engineering
changes, including temporary changes, made to approved plans and procedures	Proj. Mgr./EOR	Per change control procedure	Detailed engineering
changes in regulatory requirements	Proj. Mgr./EOR	Per change control procedure	Detailed engineering
2.6 RESOURCES AND SCHEDULING			
Identify budget requirements and secure adequate human and financial resources for construction			
Develop a schedule for construction	Proj. Mgr./EPCM	Project procedures	Detailed engineering
Update the resource requirements for operations, decommissioning and closure	Proj. Mgr./EPCM	Project procedures	Detailed engineering
2.7 EMERGENCY PREPAREDNESS AND RESPONSE			
Develop and maintain emergency preparedness and response plans to identify possible accident or emergency situations, to respond to emergency situations, and to prevent and mitigate on- and off-site environmental and safety impacts associated with emergency situations	Proj. Mgr./EPCM	Project procedures	Detailed engineering
Establish procedures for periodic review, testing and distribution of the emergency preparedness and response plans within the organization and to potentially affected external parties	Proj. Mgr./EPCM	Project procedures	Detailed engineering

3 IMPLEMENTING THE PLAN

3.1 CONSTRUCTION CONTROL			
Assemble a qualified team and assign responsibilities for construction of the tailings facility	Proj. Mgr./EPCM	Project procedures	Detailed engineering
Obtain approvals and permits	Proj. Mgr./EM	Project procedures	Detailed engineering
Implement management control to:			

Management Action	Responsibility	Performance Measure	Schedule
• ensure conformance with design and plan specifications, appropriate engineering and environmental practices, risk management, the MAC TSM Guiding Principles, the MAC tailings management framework and commitments to Communities of Interest	Proj. Mgr./EPCM	Project procedures	Detailed engineering
• ensure compliance with legislation, regulations, permits and commitments	Proj. Mgr./EPCM	Project procedures	Detailed engineering
• manage risk	Proj. Mgr./EPCM	Project procedures	Detailed engineering
• manage change	Proj. Mgr./EPCM	**Project procedures**	Detailed engineering
• identify, evaluate the impact of, and document deviations from approved design, plans, procedures, schedule and budget, and to ensure modifications are subjected to appropriate approval processes	Proj. Mgr./EPCM	Project procedures	Detailed engineering
• Monitor and inspect the works to:			
• verify actual field conditions against design assumptions	EPCM/EOR	Project procedures	Detailed engineering
• determine conformance with objectives	EPCM/EOR	Project procedures	Detailed engineering
• assess environmental, health and safety performance of the construction	Proj. Mgr./EPCM	Project procedures	Detailed engineering Detailed engineering
• identify, document and report construction deficiencies, unusual and/or unsafe conditions	Proj. Mgr./EPCM	Project procedures	Detailed engineering
Implement and periodically test contingency plans and emergency preparedness and response plans	Proj. Mgr./EPCM	Project procedures	Detailed engineering
3.2 Financial Control			
Establish a budget and financial controls	Proj. Mgr./EPCM	Project procedures	Detailed engineering
Obtain budget approval for the works	Proj. Mgr./EPCM	Project procedures	Detailed engineering
Track capital and operating costs against the budget	Proj. Mgr./EPCM	Project procedures	Detailed engineering
3.3 Documentation			
Prepare, maintain, periodically review and revise the documents required for construction of the tailings facility	EPCM/EOR	Project procedures	Detailed engineering
Maintain current versions of all documents at designated, readily accessible locations, including:	Proj. Mgr./EPCM	Project procedures	Detailed engineering
• permits, licences and other regulatory requirements	Proj. Mgr./EPCM	Project procedures	Detailed engineering
• submissions to and from regulatory agencies	COO/EM	Project procedures	Detailed engineering
• facility design and plans	Proj. Mgr./EPCM	Project procedures	Detailed engineering
• training records	Proj. Mgr./EPCM	Project procedures	Detailed engineering

Management Action	Responsibility	Performance Measure	Schedule
• quality control reports, construction reports, photos, videos, etc.	Proj. Mgr./EPCM	Project procedures	Detailed engineering
• monitoring results and analyses	Proj. Mgr./EPCM	Project procedures	Detailed engineering
• unusual or special conditions	Proj. Mgr./EPCM	Project procedures	Detailed engineering
• conditions encountered	Proj. Mgr./EPCM	Project procedures	Detailed engineering
• as-built drawings and records	Proj. Mgr./EPCM	Project procedures	**Detailed engineering**
• modifications to the tailings facility design and operating plans	EOR	Project procedures	**Detailed engineering**
• communications with Communities of Interest	COO/EM	Corporate policy	Detailed engineering
Promptly remove from use and archive obsolete versions of documents	EPCM	Project procedures	Detailed engineering
3.4 TRAINING, AWARENESS AND COMPETENCE			
Employ qualified personnel			
Ensure that personnel understand:			
• the design intent	Proj. Mgr./EPCM	Project procedures	Detailed engineering
• the potential health, safety and environmental risks and impacts of the work	Proj. Mgr./EPCM	Project procedures	Detailed engineering
• appropriate measures to minimize risks and impacts	Proj. Mgr./EPCM	Project procedures	Detailed engineering
Identify training needs, conduct training as appropriate, and maintain records of all training provided	Proj. Mgr./EPCM	Project procedures	Detailed engineering
3.5 COMMUNICATIONS			
Implement documented procedures for communications:			
• among tailings personnel	Proj. Mgr.	Project procedures	Detailed engineering
• with management	Proj. Mgr.	Project procedures	Detailed engineering
• with Communities of Interest	COO/EM	Corporate policy	Detailed engineering

4 CHECKING AND CORRECTIVE ACTION

Management Action	Responsibility	Performance Measure	Schedule
4.1 CHECKING			
Inspect, review and audit construction to ensure compliance with regulatory requirements and conformance with design objectives, plans and commitments	COO/Proj. Mgr.	Project procedures	Detailed engineering
Consider independent review of design and construction should problems occur during construction	COO/Proj. Mgr.	Project procedures	Detailed engineering

Management Action	Responsibility	Performance Measure	Schedule
Document and promptly report to the designated responsible official any observations and recommendations arising from reviews, audits and assessments, specifically identifying items requiring corrective action	COO/Proj. Mgr.	Project procedures	Detailed engineering
4.2 Corrective Action			
Develop and implement action plans to address items that require corrective action	COO/Proj. Mgr.	As required	Detailed engineering
Document completion of corrective actions	COO/Proj. Mgr.	As required	Detailed engineering
5 Annual Tailings Management Review for Continual Improvement			
Conduct an annual review of tailings management to:			
evaluate the performance of the tailings management system, considering inspection, audit and assessment reports, changing circumstances, monitoring results, spills and other incidents, recommendations, and the commitment to continual improvement			
evaluate the continuing adequacy of, and need for changes to, policies and objectives and performance of the tailings management system			
address the need for changes to commitments to Communities of Interest			
Report the observations and conclusions of this annual review of tailings management to the accountable executive officer			

7 - CHECKLIST FOR OPERATING THE CASINO TAILINGS FACILITY

Management Action	Responsibility
1 POLICY AND COMMITMENT[1]	
Operate the tailings facility in such a manner that all structures are stable, all solids and water are managed within the designated areas, and all aspects of tailings management are in compliance with regulatory requirements and in conformance with sound engineering practice, company standards, the MAC TSM Guiding Principles, the MAC tailings management framework, and commitments to Communities of Interest[2]	COO
Ensure that the tailings management framework is implemented through the actions of all employees working at the facility	COO
Consult with Communities of Interest, taking into account their considerations relating to the tailings facility management	COO/EM
Establish an ongoing program of review and continual improvement to manage health, safety and environmental risks associated with tailings facilities	COO
2 PLANNING	
2.1 ROLES AND RESPONSIBILITIES	
Assign overall accountability for tailings management to an executive officer of the company (CEO or COO), with responsibility for putting in place an appropriate management structure and for providing assurance to the corporation and its Communities of Interest that tailings facilities are managed responsibly	COO
Assign responsibility and budget authority for tailings management	COO
Define the roles, responsibilities and reporting relationships for the tailings facility operation, supported by job descriptions and organization charts, and including:	
• site management	General Mgr – site (GM)
• operating plans	GM
• operating strategy	GM
• obtaining and maintaining approvals	GM
• operation of the tailings facility, including maintenance and surveillance	GM
• health, safety and environmental protection	GM
• emergency preparedness and response	GM
• continuing expert support	COO

[1] *Additional guidance for implementing the principles of the tailings management framework through the operating stage of the life cycle are provided in MAC's companion guide,* Developing an Operation, Maintenance and Surveillance Manual for Tailings and Water Management Facilities *(MAC, 2011b).*

[2] QML with conditions, Yukon Water Use licence, Final "As-Built" design & construction documents

Management Action	Responsibility
• documentation, including changes to design and management	GM
• communications, both internally and to Communities of Interest on:	COO/EM
• routine performance issues	GM
• emergency preparedness	COO/GM
• regulatory compliance and/or incident reporting	COO/EM
• the closure plan	COO/EM
2.2 *Objectives*	
Develop criteria and procedures to ensure that tailings facility operations will:	
• be in conformance with design	GM
• meet regulatory requirements, company policies and standards, sound engineering and environmental practices, and commitments to Communities of Interest	GM
• integrate preparation for eventual decommissioning and closure into ongoing operations to ensure:	COO/GM
○ protection of public health and safety	COO/GM
○ mitigation of negative environmental impacts	COO/GM
○ acceptable post-closure use within a feasible technical and economic framework	COO
○ provide continued protection of the environment and public health and safety	COO
○ enable the specified performance to be achieved	COO
Define procedures for communication among the operations team and with management and Communities of Interest	COO
Identify requirements for documentation	COO
Identify knowledge and skills (awareness, training and competence) requirements	COO/GM
Plan for operation and review design documents, regulatory requirements, as-built construction drawings, conceptual operating and closure plans, environmental assessment and commitments to Communities of Interest	COO/GM
Prepare, review and update on a regular basis an operation, maintenance and surveillance (OMS) manual for the facility (reference: MAC's companion guide, *Developing an Operation, Maintenance and Surveillance Manual for Tailings and Water Management Facilities),* including:	COO/GM
• tailings deposition plan	GM
• water balance and management plan	GM
• water quality plan	GM/EM
• maintenance plan for mechanical, civil works and electronic devices	GM

Management Action	Responsibility
• contaminant release plan	GM/EM
• environmental control and monitoring plan	GM/EM
• dam stability monitoring plan	GM/EOR
• calibration program for key instrumentation	GM
• emergency preparedness and response plan	COO/GM/EM
• decommissioning and closure plan, including progressive rehabilitation	COO/GM/EM
2.3 MANAGING FOR COMPLIANCE	
Compile and maintain a log of all applicable legislation, regulations, permits and commitments	GM
Ensure that the applicable legislation, regulations, permits and commitments are understood	GM
Ensure that the actions needed to ensure compliance are understood	GM
Establish and document processes and procedures to ensure compliance	GM
Establish procedures for reporting of compliance and non-compliance	COO/GM
Communicate the requirements, processes and procedures to ensure compliance to all employees	COO
2.4 MANAGING RISK	
Prepare and periodically update a comprehensive risk assessment for the facility, to:	
• evaluate the risks associated with possible triggers and failure modes for both the operating and closure stages	COO
• identify possible impacts on the environment, public health and safety	COO/EM
• determine the operating parameters that can have an impact on the triggers and failure modes	COO/EOR
Develop:	
• risk management plans to minimize the likelihood of adverse safety or environmental impacts	COO
• contingency plans	COO/EM
• emergency preparedness and response plans	COO/EM
• that include:	
○ control strategies to manage the identified risks and/or reassess the design	COO
○ identification of thresholds to trigger implementation of contingency plans and emergency response plans	COO
○ communication procedures	COO
2.5 MANAGING CHANGE	
Prepare and document procedures to ensure that the integrity of the management system and of approved designs and plans is maintained by managing:	COO/EOR

Management Action	Responsibility
• changes in personnel, roles and responsibilities	COO/GM
• changes, including temporary changes, made to approved plans and procedures	COO/GM/EOR
• changes in regulatory requirements	COO/GM
2.6 *Resources and Scheduling*	
Identify budget requirements and secure adequate human and financial resources for operating the facility, including	COO
• operations, maintenance and surveillance	GM
• inspection, review, audit and assessment	COO/GM/EM
Develop a schedule for operating the facility	GM
Update on a periodic basis the resource requirements for decommissioning and closure	COO
2.7 *Emergency Preparedness and Response*	
Develop and maintain emergency preparedness and response plans to identify possible accident or emergency situations, to respond to emergency situations and to prevent and mitigate on- and off-site environmental and safety impacts associated with emergency situations	COO/EM
Establish procedures for periodic review, testing and distribution of the emergency preparedness and response plans within the organization and to potentially affected external parties	COO/EM

3 Implementing the Plan

3.1 *Operational Control*	
Assemble a qualified team and assign responsibilities for operating the tailings facility	COO/GM
Obtain approvals and permits	COO/EM
Implement management control to:	
• apply the operation, maintenance and surveillance (OMS) manual for the facility	COO
• ensure conformance with design and plan specifications, appropriate engineering and environmental practices, risk management, the MAC TSM Guiding Principles, the MAC tailings management framework and commitments to Communities of Interest	COO
• ensure compliance with legislation, regulations, permits and commitments	COO
• manage risk	COO
• manage change	COO/EOR
• identify, evaluate the impact of and document deviations from approved plans, procedures, schedule and budget, and to ensure modifications are subjected to appropriate approval processes	COO/EOR
• Implement the operation, maintenance and surveillance (OMS) manual for the facility, including:	COO/GM

Management Action	Responsibility
○ operational procedures and controls addressing:	GM
○ water balance	GM
○ water quality	GM
○ contaminant mass balance	GM
○ groundwater, pore pressure regime and seepage	GM
○ tailings characteristics and deposition	GM
○ physical stability of structures and appurtenances	GM
○ dust	GM
○ environmental impacts	GM
○ site security	GM
○ protection of flora and fauna	GM
○ routine inspection, monitoring, testing, evaluation and reporting of:	GM
○ conformance with operating objectives	GM
○ compliance with requirements and commitments	GM
○ environmental and safety performance	COO/GM
○ deficiencies, unusual and/or unsafe conditions	COO
Implement and periodically test contingency plans and emergency preparedness and response plans	COO/EM
3.2 FINANCIAL CONTROL	
Establish a budget and financial controls	COO/GM
Obtain budget approval for the tailings management	GM
Track capital and operating costs against the budget	GM
3.3 DOCUMENTATION	
Prepare, maintain, periodically review and revise the documents required for operating the tailings facility	GM
Maintain current versions of all documents at designated, readily accessible locations, including:	GM
• permits, licences and other regulatory requirements	GM
• facility design and plans	GM
• submissions to and from regulatory agencies	COO
• the operation, maintenance and surveillance (OMS) manual	GM

Management Action	Responsibility
• training records	GM
• quality control reports, construction and operating reports, photos, videos, etc.	GM
• monitoring results and analyses	GM
• unusual or special conditions	GM/EOR
• conditions encountered	GM/EOR
• as-built drawings and records	GM/EOR
• modifications to the tailings facility design and operating plans	GM/EOR
• communications with Communities of Interest	COO/EM
Promptly remove from use and archive obsolete versions of documents	GM
3.4 TRAINING, AWARENESS AND COMPETENCE	
Employ qualified personnel	GM
Ensure that all personnel understand:	
• the design intent	GM
• operating, maintenance and surveillance (OMS) parameters and procedures	GM
• the potential health, safety and environmental risks and impacts of the work	GM
• appropriate measures to minimize risks and impacts	GM
Identify training needs, conduct training as appropriate and maintain records of all training provided	GM
3.5 COMMUNICATIONS	
Implement documented procedures for communications:	
• among tailings personnel	GM
• with management	GM
• with Communities of Interest	COO/EM

4 CHECKING AND CORRECTIVE ACTION

4.1 CHECKING	
In addition to routine monitoring and inspections, conduct periodic inspection of operations to ensure compliance with regulatory requirements and conformance with design objectives, plans and commitments	COO/GM
Conduct periodic review of the tailings facility to:	
• verify design assumptions against actual conditions and performance	COO

Management Action	Responsibility
• revisit or update the design and/or operating plans	COO
• re-evaluate downstream risks	COO
• update the risk assessment	COO
• evaluate the need for changes or updates to risk management plans, contingency plans, emergency preparedness and response plans, and plans for eventual decommissioning and closure	COO
Conduct periodic audit and assessment of the entire tailings management system	COO
Document and promptly report to the designated responsible official any observations and recommendations arising from reviews, audits and assessments, specifically identifying items requiring corrective action	COO/EM
4.2 Corrective Action	
Develop and implement action plans to address items that require corrective action, including changes to inspection and review programs, as warranted, following changes in design or fundamental operating parameters	COO/GM/EOR
Document completion of corrective actions	GM
5 Annual Tailings Management Review for Continual Improvement	
Conduct an annual review of tailings management to:	
• evaluate the performance of the tailings management system, considering inspection, audit and assessment reports, changing circumstances, monitoring results, spills and other incidents, recommendations and the commitment to continual improvement	COO/GM
• evaluate the continuing adequacy of, and need for changes to, policies and objectives and performance of the tailings management system	GM
• address the need for changes to commitments to Communities of Interest	GM
Report the observations and conclusions of this annual review of tailings management to the accountable executive officer	GM

8 - CHECKLIST FOR DECOMMISSIONING AND CLOSING THE CASINO TAILINGS FACILITY

Management Action	Responsibility
1 POLICY AND COMMITMENT[3,4]	
Decommission and close the tailings facility in a manner such that all remaining structures are stable, all solids and water are managed within the designated areas, and all aspects of tailings management are in compliance with regulatory requirements and in conformance with sound engineering practice, company standards, the MAC TSM Guiding Principles, the MAC tailings management framework and commitments to Communities of Interest	COO
Ensure that the tailings management framework is implemented through the actions of all employees working at the facility	GM
Consult with Communities of Interest, taking into account their considerations relating to the tailings facility decommissioning and closure	COO/EM
Establish an ongoing program of review and continual improvement to manage health, safety and environmental risks associated with tailings facilities	COO
2 PLANNING	
2.1 ROLES AND RESPONSIBILITIES	
Assign overall accountability for tailings management to an executive officer of the company (CEO or COO), with responsibility for putting in place an appropriate management structure and for providing assurance to the corporation and its Communities of Interest that tailings facilities are managed responsibly	COO
Assign responsibility and budget authority for tailings management	GM
Define the roles, responsibilities and reporting relationships for decommissioning and closure of the tailings facility, supported by job descriptions and organization charts, and including:	
• site management	GM
• the closure plan	EM
• obtaining and maintaining approvals	EM
• decommissioning and closure	GM/EM
• long-term care and maintenance	EM
• health, safety and environmental protection	EM
• emergency preparedness and response	COO/EM

3 ***Additional** guidance for implementing the principles of the tailings management framework through the decommissioning and closing stages of the life cycle are provided in MAC's companion guide,* Developing an Operation, Maintenance and Surveillance Manual for Tailings and Water Management Facilities *(MAC, 2011b)*.

4 Closure plan approved by the Regulator, issued for construction design documents, approved post-closure monitoring plan & reporting protocols

Management Action	Responsibility
• documentation, including changes to design and management	COO/EOR
• continuing expert support	COO
• ensuring financial assurance	COO
• communications, both internally and to Communities of Interest on:	COO/EM
○ the closure plan	COO/EM
○ routine performance issues	GM
○ emergency preparedness	GM/EM
○ regulatory compliance and/or incident reporting	COO/EM
2.2 OBJECTIVES	
Develop criteria and procedures to ensure that tailings facility decommissioning and closure will:	
• be in conformance with design	GM
• provide continued protection of the environment and public health and safety	GM
• mitigate negative environmental impacts	GM/EM
• meet regulatory requirements, land use objectives, financial assurance commitments, company policies and standards, sound engineering and environmental practices, and commitments to Communities of Interest	COO
• enable surrender of the land or transfer to non-mining use, consistent with regional land-use objectives or approved uses, or provide for long-term care and maintenance	COO
• ensure long-term stability of tailings, dams, related facilities and structures	COO
Define procedures for communication among the decommissioning and closure team and with management and Communities of Interest	COO/EM
Identify requirements for documentation	COO
Identify knowledge and skills (awareness, training and competence) requirements	COO
Plan for decommissioning and closure and review design documents, regulatory requirements, as-built construction and operating drawings, conceptual decommissioning and closure plans, environmental assessment and commitments to Communities of Interest	COO
Prepare, review and update on a regular basis an operation, maintenance and surveillance (OMS) manual for the facility (reference: MAC's companion guide, Developing an Operation, Maintenance and Surveillance Manual for Tailings and Water Management Facilities), including:	GM
• water balance and management plan	GM
• water quality plan	GM

Management Action	Responsibility
• maintenance plan for mechanical, civil works and electronic devices	GM
• contaminant release plan	GM
• environmental control and monitoring plan	EM
• dam stability monitoring plan	GM
• calibration program for key instrumentation	GM
• emergency preparedness and response plan	COO/EM
• decommissioning and closure plan	COO/EM
• rehabilitation work schedule for facilities no longer required	GM
Revisit the approved decommissioning and closure plan to:	
• identify and assess new environmental concerns that have become apparent since the plan was approved	COO/EM
• identify and assess potential environmental impacts that may be caused by the implementation of closure	COO/EM
• assess alternative technology for closure	COO/EM
Review performance of progressive reclamation to date	COO
2.3 MANAGING FOR COMPLIANCE	
Compile and maintain a log of all applicable legislation, regulations, permits and commitments	GM
Ensure that the applicable legislation, regulations, permits and commitments are understood	GM
Ensure that the actions needed to ensure compliance are understood	GM
Establish and document processes and procedures to ensure compliance	GM
Establish procedures for reporting of compliance and non-compliance	GM
Communicate the requirements, processes and procedures to ensure compliance to all employees	GM
2.4 MANAGING RISK	
Prepare and periodically update a comprehensive risk assessment for decommissioning and closure to:	COO
• evaluate the risks associated with possible triggers and failure modes	COO/EOR
• identify possible impacts on the environment, public health and safety	COO/EM
• determine the parameters that can have an impact on these triggers and failure modes	COO/EOR
Develop:	
• risk management plans to minimize the likelihood of adverse safety or environmental impacts	COO/EM
• contingency plans	COO/EM

Management Action	Responsibility
• emergency preparedness and response plans	COO/EM
• that include:	
○ control strategies to manage the identified risks and/or reassess the design	COO/EOR
○ identification of thresholds to trigger implementation of contingency plans and emergency response plans	COO/EOR
○ communication procedures	COO
2.5 MANAGING CHANGE	
Prepare and document procedures to ensure that the integrity of the management system and of approved designs and plans is maintained, by managing:	COO
• changes in personnel, roles and responsibilities	GM
• changes, including temporary changes, made to approved plans and procedures	GM/EOR
• changes in regulatory requirements	GM/EOR
2.6 RESOURCES AND SCHEDULING	
Identify budget requirements and secure adequate human and financial resources for decommissioning and closure of the facility, including:	COO
• operations, maintenance and surveillance	GM
• inspection, review, audit and assessment	COO/EOR/IERP
• financial assurance	COO
Develop a schedule for decommissioning and closure of the facility	GM
2.7 EMERGENCY PREPAREDNESS AND RESPONSE	
Develop and maintain emergency preparedness and response plans to identify possible accident or emergency situations, to respond to emergency situations and to prevent and mitigate on- and off-site environmental and safety impacts associated with emergency situations	COO/EM
Establish procedures for periodic review, testing and distribution of the emergency preparedness and response plans within the organization and to potentially affected external parties	EM
3 IMPLEMENTING THE PLAN	
3.1 CLOSURE CONTROL	
Assemble a qualified team and assign responsibilities for decommissioning and closing the tailings facility	COO
Obtain approvals and permits	COO/EM
Implement management control to:	
• apply the operation, maintenance and surveillance (OMS) manual for decommissioning and closure of the facility	GM

Management Action	Responsibility
• ensure conformance with design and plan specifications, appropriate engineering and environmental practices, risk management, the MAC TSM Guiding Principles, the MAC tailings management framework, and commitments to Communities of Interest	GM
• ensure compliance with legislation, regulations, permits and commitments	GM
• manage risk	COO/GM
• manage change	GM/EOR
• identify, evaluate the impact of, and document deviations from approved plans, procedures, schedule and budget, and to ensure modifications are subjected to appropriate approval processes	GM/EOR
Implement and periodically test contingency plans and emergency preparedness and response plans	COO/EM
3.2 Financial Control	
Establish a budget and financial controls	COO
Obtain budget approval for the decommissioning and closure	GM
Track capital and operating costs against the budget	GM
Track actual costs and budget updates against the closure financial assurance	GM
3.3 Documentation	
Prepare, maintain and periodically review and revise the documents required for decommissioning and closing the tailings facility	GM/EOR
Maintain current versions of all documents at designated, readily accessible locations, including:	GM
• permits, licences and other regulatory requirements	GM
• decommissioning and closure plans	GM
• submissions to and from regulatory agencies	COO/EM
• the operation, maintenance and surveillance (OMS) manual	GM
• training records	GM
• quality control reports, construction and operating reports, photos, videos, etc	GM
• monitoring results and analyses	GM/EOR
• unusual or special conditions	GM/EOR
• conditions encountered	GM/EOR
• as-built drawings and records	GM/EOR
• progress reports and reviews	GM

Management Action	Responsibility
• modifications to the tailings facility design, operating, decommissioning and closure plans	COO/EOR
• communications with Communities of Interest	COO/EM
Promptly remove from use and archive obsolete versions of documents	GM
3.4 Training, Awareness and Competence	
Employ qualified personnel	COO
Ensure that all personnel understand:	
• the decommissioning and closure design intent	GM
• operating, maintenance and surveillance (OMS) parameters and procedures	GM
• the potential health, safety and environmental risks and impacts of the work	GM
• appropriate measures to minimize risks and impacts	GM
Identify training needs, conduct training as appropriate and maintain records of all training provided	GM
3.5 Communications	
Implement documented procedures for communications:	
• among tailings personnel	GM
• with management	GM
• with Communities of Interest	COO/EM
4 Checking and Corrective Action	
4.1 Checking	
In addition to routine monitoring and inspections, conduct periodic inspection of decommissioning and closure to ensure compliance with regulatory requirements and conformance with design objectives, plans and commitments	COO
Conduct periodic review of the tailings facility to:	
• verify design assumptions against actual conditions and performance	GM
• revisit or update the decommissioning and closing design and/or plans	GM
• re-evaluate downstream risks	COO/EM
• update the risk assessment	COO/EM/EOR
• evaluate the need for changes or updates to risk management plans, contingency plans and emergency preparedness and response plans	COO
Conduct periodic audit and assessment of the entire tailings management system	COO

Management Action	Responsibility
Document and promptly report to the designated responsible official any observations and recommendations arising from reviews, audits and assessments, specifically identifying items requiring corrective action	COO/EM
4.2 CORRECTIVE ACTION	
Develop and implement action plans to address items that require corrective action, including changes to inspection and review programs, as warranted, following changes in design or fundamental operating parameters	COO
Document completion of corrective actions	GM
5 ANNUAL TAILINGS MANAGEMENT REVIEW FOR CONTINUAL IMPROVEMENT	
Conduct an annual review of tailings management to:	COO
• evaluate the performance of the tailings management system, considering inspection, audit and assessment reports, changing circumstances, monitoring results, spills and other incidents, recommendations and the commitment to continual improvement	GM
• evaluate the continuing adequacy of, and need for changes to, policies and objectives and performance of the tailings management system	GM
• address the need for changes to commitments to Communities of Interest	EM
Report the observations and conclusions of this annual review of tailings management to the accountable executive officer	GM

9 - REFERENCES

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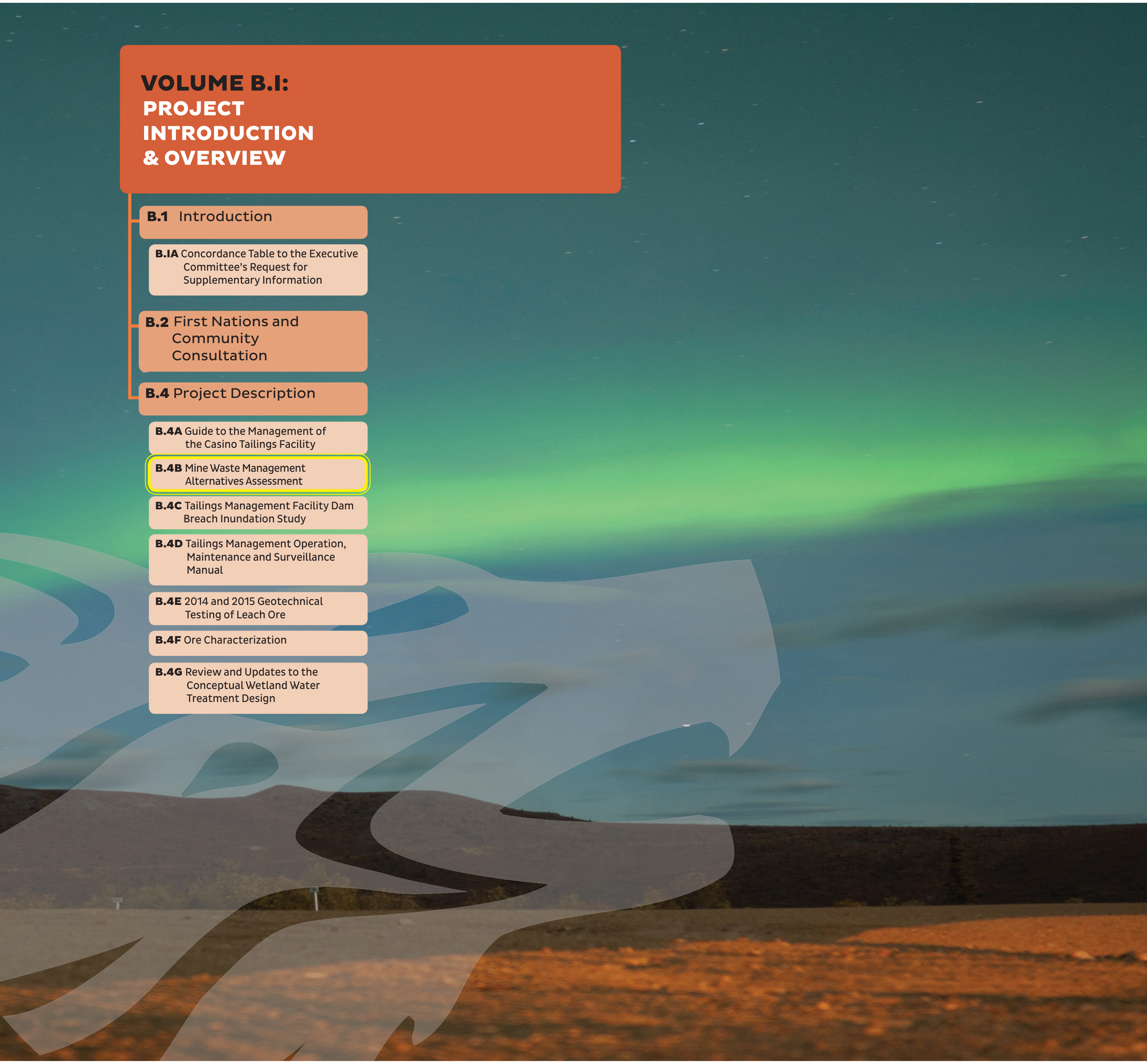
APPENDIX B.4B: Mine Waste Management Alternatives Assessment



VOLUME B.I: PROJECT INTRODUCTION & OVERVIEW

CASINO

CASINO PROJECT

MINE WASTE MANAGEMENT ALTERNATIVES ASSESSMENT

Prepared by:

Casino Mining Corporation

December 2015

Executive Summary

The Casino Project is a proposed copper-gold open pit mine located 150 km northwest of Carmacks and 300 km from Whitehorse. The Project is designed to process approximately 120,000 t/d of copper and gold ore over a 22 year mine life. Processing of the sulphide ore will occur via conventional flotation to produce copper and molybdenum mineral concentrates. Processing of oxide ore is via heap leaching and carbon adsorption technology that will produce gold and silver doré bars.

Mine waste generated at the Project consists of mining waste rock and tailings generated from the flotation process. Mine waste volumes are derived from a feasibility study conducted in 2013, the geochemical characterization of which indicates that of the 956 million tonnes of tailings, approximately 80% is geochemically innocuous non-acid generating (NAG) material, and the remaining 20% is potentially reactive. Additionally, the 658 million tonnes of waste rock and overburden material has also been characterized as potentially reactive.

The assessment of mine waste management for the Casino Project was initiated in 2008, and refinement of the mine waste management strategy has continued through to completion of the Feasibility Study in 2013. This report summarizes the alternatives assessment for mine waste management conducted for the Casino Project, with information derived from a number of previous reports.

The approach used for this alternatives assessment is based on the guidance provided by Environment Canada (2011) for Multiple Accounts Analysis (MAA). The guidance was used as a tool to evaluate a set of options for the management of waste rock and tailings at the Casino Project. The assessment presents all tailings alternatives that have been assessed to date, with an evaluation in accordance with screening criteria applicable to the Casino Project.

The alternatives assessment has two parts: the analysis and selection of the preferred method for managing mine waste; and the analysis and selection of the preferred location for mine waste storage. Both parts of the alternatives assessment evaluate the mine water management options based on technical, environmental, economic, and socio-economic criteria.

The findings of the comparative assessment indicate that the use of cyclone sand for embankment construction is the preferred option. It provides low operational complexity and controllable geotechnical conditions given the project's location and water conditions, with the least environmental disturbance.

The preferred option for location is upper Casino Creek, as it had the highest combined score, when considering technical, environmental, socio-economic and economic factors. The upper Casino Creek option also had the highest score in the environmental and socio-economic accounts and was identified by all sensitivity analyses.

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1 INTRODUCTION

The Casino Project is a proposed copper-gold open pit mine located 150 km northwest of Carmacks and 300 km from Whitehorse. The Project is designed to process approximately 120,000 t/d of copper and gold ore over a 22 year mine life. Processing of the sulphide ore will occur via conventional flotation to produce copper and molybdenum mineral concentrates. Processing of oxide ore is via heap leaching and carbon adsorption technology that will produce gold and silver doré bars. Supplemental freshwater for processing and camp activities will be provided by a pipeline from the Yukon River. Access to the Project is via the 200 km Freegold Road from Carmacks, of which 80 km is a public use highway maintained by the Yukon Government, and the remaining 120 km extension will be a private access road.

Mine waste generated at the Project consists of mining waste rock and tailings generated from the flotation process. Mine waste volumes are derived from a feasibility study conducted in 2013, the geochemical characterization of which indicates that of the 956 million tonnes of tailings, approximately 80% is geochemically innocuous non-acid generating (NAG) material, and the remaining 20% is potentially reactive (PAG). Additionally, the 658 million tonnes of waste rock and overburden material has also been characterized as potentially reactive.

The assessment of mine waste management for the Casino Project was initiated in 2008, and refinement of the mine waste management strategy has continued through to completion of the Feasibility Study in 2013 (M3, 2013). This report summarizes the alternatives assessment for mine waste management conducted for the Casino Project, with information derived from the following documents:

- Knight Piesold Consulting (KP), Casino Copper-Gold Project, Mine Waste Management Assessment, January 18, 2008.
- KP, Casino Copper-Gold Project, Tailings Management Facility Construction Material Alternatives, June 15, 2010.
- KP, Casino Copper-Gold Project, Tailings Management Facility Alternative Assessment, July 20, 2010.
- KP, Casino Copper-Gold Project, Report on Feasibility Design of the Tailings Management Facility, December 20, 2012.
- Lorax Environmental, Casino Waste Rock and Ore Geochemical Static Test Assessment, December 3, 2013.
- Lorax Environmental, Casino Geochemical Source Term Development, December 4, 2013.
- Lorax Environmental, Casino Kinetic Testwork 2014 Update for Ore, Waste Rock and Tailings, December 15, 2014.
- Tailings Management Facility Risk Assessment, provided in Supplementary Information Report to ARR-2, YESAB Project #2014-0002, Section B.4, response to R2-4, December 2015.

The alternatives assessment has two parts: the analysis and selection of the preferred method for managing mine waste; and the analysis and selection of the preferred location for mine waste storage. Both analyses follow the same general framework to arrive at the preferred option, as follows:

- Define criteria used to evaluate options;
- Describe all available options;
- Identify the advantages and disadvantages of each option with respect to key engineering, environmental, socio-economic and economic considerations;
- Conduct a ranking, scaling and weighting evaluation in order to compare the cumulative advantages and disadvantages of each option; and
- Provide a conclusion as to preferred option based on transparent rationale.

The approach for the analysis and selection of the preferred location is based on the guidance provided by Environment Canada (2011) for Multiple Accounts Analysis (MAA), which is used as a tool to evaluate a set of options for the management of waste rock and tailings at the Casino Project. The assessment presents all tailings alternatives that have been assessed to date, with an evaluation in accordance with screening criteria applicable to the Casino Project.

The conclusions and recommendations in the documents listed above were used to direct the further design of the TMF, as provided in the Report on Feasibility Design of the Tailings Management Facility (KP, 2012), which provides site-specific details of the cyclone sand dam option, using updated mine planning and site investigation results. As such, the process design details provided herein should be considered as preliminary details, which were generated for alternatives assessment purposes, and have been superseded by the details in the Report on Feasibility Design of the Tailings Management Facility (KP, 2012).

2 CASINO MINE WASTE

2.1 WASTE PRODUCTION

The proposed components of the project facilities include an open pit up to 600 metres deep containing a mineable reserve of approximately 965 million tonnes (Mt) of mill ore. The deposit will be mined using open pit methods with a nominal mill throughput of approximately 120,000 tonnes/day (tpd) of ore over a 22 year operating life. Approximately 157.5 Mt of additional mined ore will be processed at a Heap Leach Facility (HLF) located south of the open pit. Mine waste includes approximately 956 Mt of tailings and up to 658 Mt potentially reactive waste rock and overburden materials. The waste production and milling schedule is summarized in Table 2-1.

Table 2-1: Casino Mine Waste and Ore Production Schedule

Year of Operations	Mill Ore (kt)	Gold Leach Ore (kt)	Overburden (kt)	All Waste (kt)
-3		5,030	187	2,151
-2		12,676	542	3,644
-1		18,517	959	6,127
1	32,850	16,601	4,087	23,522
2	43,800	14,877	2,230	27,592
3	43,801	11,824	646	32,239
4	43,800	2,087	882	43,368
5	43,799	96	1,188	38,249
6	43,800	8	53	32,749
7	43,800	3,201	408	42,736
8	43,800	7,777	306	46,722
9	43,800	9,407	372	51,153
10	43,799	5,209	180	48,062
11	43,800	11,141	1,537	52,200
12	43,800	387	373	47,913
13	43,800	591	947	48,345
14	43,800	425	593	48,399
15	43,800	79	56	46,962
16	43,800			34,214
17	43,800			30,457
18	43,800			20,758
19	43,800			19,143
20	43,800			14,186
21	43,800			
22	43,800			
23	23,139			
TOTAL	**975,788**	**119,933**	**15,546**	**760,891**

The pre-feasibility assessment (KP, 2008) assumed a total tailings storage of 974 million tonnes with an unquantified volume of potentially reactive waste rock, therefore, an initial assessment was conducted assuming co-disposal of one-third (282 Mt) and two thirds (564 Mt) of produced waste. Subsequent analysis identified that the entire waste rock volume (658 Mt) is potentially reactive. Specifically, the large majority of the NAG waste rock was found to be metal (copper) leaching, and therefore is not suitable for construction material and is required to be disposed of sub-aqueously.

2.2 MINE ROCK GEOCHEMICAL PROPERTIES

Lorax Environmental has conducted an extensive geochemical characterization program which has contributed to the development of waste rock and tailings management planning for the Casino Project. Techniques used to assess metal leaching/acid rock drainage (ML/ARD) potential include static tests which examine the intrinsic ML/ARD potential of a sample, and kinetic tests which expose the material to various weathering conditions. Data gathered as part of the static and kinetic testwork program are presented in:

- Casino Geochemical Static Test Assessment (Lorax, 2013a);
- Kinetic Testwork Update in Support of Casino ML/ARD Assessment (Lorax, 2013b); and
- Casino Kinetic Testwork 2014 Update for Ore, Waste Rock and Tailings (Lorax, 2014).

The Lorax (2013a) study concluded that ML/ARD characteristics varied within the Casino deposit primarily by mineralization zone and to a lesser extent lithologic unit. Trends were not identified based on the alteration zones of the Casino Intrusive Complex. Therefore, the Casino kinetic test program was primarily focused on geochemical characteristics of the mineralization zones (Lorax, 2013b). An overview of ML/ARD properties of the three mineralization zones is provided below. The neutralization potential ratio (NPR) values sited below are defined by the ratio of neutralization potential (calculated from carbonate content) and acid potential (calculated from non-sulphate S content).

Oxide Leach CAP Zone

- The CAP samples (ore and waste) have acidic median paste pH values of 4.7, indicating that the majority of the CAP waste rock will be immediately acid generating when excavated.
- Secondary water soluble sulphate and oxide minerals, rather than sulphide minerals, are the major source of acidity and metal leaching from CAP samples.

Supergene (SUP) Zone (includes Supergene Oxide (SOX) and Supergene Sulphide (SUS))

- The majority of the SUP samples have a NPR < 2.0 (88% SOX and 97% SUS), which implies that waste rock and ore from this mineralization zone is potentially acid generating (PAG).
- Unlike the CAP sample set, some SUP samples still contain carbonate minerals capable of buffering pH; however, the samples also contain sulphide minerals in sufficient quantities to deplete the buffering capacity over time and provide an additional source of metal leaching.

- Similar to the CAP sample set, SUP samples contain oxide minerals as a source of acidity and metal leaching. The SUP samples (ore and waste) have a median paste pH of 6.1.

Hypogene (HYP) Zone

- The majority of the HYP samples (87% ore and 92% waste rock) have been identified as having a NPR < 2, which implies that under advanced weathering conditions waste rock and ore from the HYP zone will produce acidic drainage.
- Ore and waste rock samples from the HYP zone have the highest median carbonate neutralization potential (27 kg CaCO3/t), and highest median paste pH (8.1) of the mineralization zones in the Casino deposit.

Due to the nature of the mineralization at the Casino Project, Lorax recommends that tailings and waste rock produced at the Casino mine be subaqueously disposed of in a tailings management facility (Lorax, 2013c). Sub-aqueous disposal will prevent sulphide oxidation in mine waste and is considered geochemically favorable compared to disposal in an unsaturated environment. Further, Lorax suggests that PAG tailings and pyrite concentrate from the de-sulphidization circuit be deposited into the centre of the impoundment and covered with a layer of depyritized (NAG) tailings at the end of mine life, which will result in saturated source terms for both the PAG and NAG which are predicted to be pH-neutral with relatively low metal concentrations due to the stability of sulphide minerals under saturated conditions (Lorax, 2013c).

These geochemical considerations form the basis of the mine waste management alternatives assessment, discussed further in subsequent sections.

3 ALTERNATIVES ASSESSMENT METHODOLOGY

This report addresses the alternative assessment for mine waste management at the Casino Project through the evaluation of two criteria:

1. The method for managing mine waste through various tailings disposal options; and
2. The identification of a preferred location for the option chosen in 1. above.

The methodology for ranking and weighting the options for 1. and 2. above vary slightly, in that the options for managing mine waste are mainly constrained by the technical considerations available for the specific conditions and disposal criteria (i.e., high throughput milling and mining and high geochemical risk), whereas the options for location are more flexible, and can be considered in the context of environmental, socio-economic and economic factors.

Therefore, a relative ranking of 1 through 4 was given to the mine waste disposal alternatives (Section 4), whereas a 6-point ranking scale is provided for the location alternatives assessments. The location alternatives are further weighted, based on a tiered system of weighting, whereby the main considerations (i.e. technical, environmental, socio-economic, and economic), and the sub-accounts, were weighted relative to one another. This is described further in Sections 3.2 and 3.3.

The collective evaluation is described in Section 5.5, by consideration. The combined numerical evaluation is provided in Appendix A, and sensitivity analysis provided in Section 5.7.

3.1 PARTICIPANTS

The evaluation of mine waste management options was conducted by Knight Piesold (KP), in consultation with Casino Mining Corporation, and the results presented in the following documents:

- Knight Piesold Consulting (KP), Casino Copper-Gold Project, Mine Waste Management Assessment, January 18, 2008.
- KP, Casino Copper-Gold Project, Tailings Management Facility Construction Material Alternatives, June 15, 2010.
- KP, Casino Copper-Gold Project, Tailings Management Facility Alternative Assessment, July 20, 2010.

These documents were summarized and adapted to the alternatives assessment framework, with the results presented in Section 4, below.

The evaluation of location options was conducted largely based on the guidelines provided by Environment Canada (EC - 2011) and includes a relative assessment of positive and negative effects of these options with respect to technical, environmental, socio-economic and project economic accounts. The evaluation was completed by a group of technical experts in May 2013, given existing baseline information and professional judgment of expectations during and after mining. Participant groups included:

- Casino Mining Corporation (CMC);

- Knight Piesold (KP);
- Palmer Environmental Consulting Group Ltd. (PECG);
- Lorax Environmental Services Inc. (Lorax);
- Marsland Environmental Associates (MEA); and
- Brodie Consulting Ltd. (BCL).

Following the guidelines provided by EC, within each of the main considerations (i.e., technical, environmental, socio-economic and economic), the group defined a series of sub-accounts selected as issues that were considered to be of key importance and or of a material effect (positive or negative). Each sub-account was described on the basis of an indicator or a series of indicators. The numerical evaluation was conducted via a ranking-scaling and weighting assessment with both scalars and weights assigned on the basis of a 6-point scale. In this manner, a scale of 6 was applied to the best option for each indicator individually with other options scaled comparatively. Weights were applied to indicators, sub-accounts and accounts such that most important were given a weight of 6 and others weighted by comparison of relative importance.

3.2 RANKING

For the mine waste management options, a relative ranking of 1 through 4 was given, as the options were strongly driven by comparison to each other. For the locations alternatives, ranking involved an assessment of comparing the relative expectations of characteristics of alternatives for each of the issues defined in the assessment. In this manner, the location alternatives were first ranked from best, or most favored, to worst or least favored for that aspect being considered. In order to convey the evaluators' judgment of how much better or how much worse any one alternative was expected to be from the others, a scale was applied. As in the EC guidelines, a 6-point scale was used and modified to be meaningful for each indicator independently. The best alternative was assigned a value of 6 and all others scaled relative to that. It should be noted that while a value of 6 was always applied to the best alternative, there does not need to be a corresponding value of 1, in fact in many cases, alternatives were deemed equal and all assigned values of 6. It should also be noted that a value of 6 for one indicator is unique to that indicator and not necessarily equal in a numerical sense to a value of 6 in any of the other indicators. Ranking and scaling compares alternatives on an indicator by indicator basis. This is distinct from the comparison of indicators to one another which was accomplished via weighting.

Additionally, the sub-accounts within any one main account were weighted relative to one another and the indicators within any one sub-account were weighted relative to one another. The higher the weight of any one indicator, the higher the deemed relative importance of that indicator compared to others in its sub-account. A scale of 1 to 6 was used in this evaluation whereby a value of 6 reflects the view by the evaluators that it was an issue of greatest importance within the evaluation.

3.3 WEIGHTING

The exercise of applying weights to accounts, sub-accounts and indicators instills a level of importance to the issues being considered relative to one another. Just as ranking and scaling was distinctly independent of indicators beyond the immediate one in any single scaling, the process of weighting is distinctly separate from any comparison of one alternative to another.

A tiered system of weighting was conducted whereby the main accounts were weighted relative to one another, the sub-accounts within any one main account were weighted relative to one another and the indicators within any one sub-account were weighted relative to one another. The higher the weight of any one indicator, the higher the deemed relative importance of that indicator compared to others in its sub-account. A scale of 1 to 6 was used in this evaluation whereby a value of 6 reflects the view by the evaluators that it was an issue of greatest importance within the evaluation.

The weights applied to the main accounts were as recommended in the EC guidelines whereby the weight for the technical account was a value of 3, that for the environment account was a 6, that for the socio-economic account was a 3 and the project economic account was a 1.5.

Within each main account, the sub-accounts were weighted relative to one another and within each sub-account the indicators were weighted relative to one another. The resultant weights are summarized in the set of tables below for each main account as assigned by the group of participants.

3.3.1 Technical Account Weights

In review of the weights for the sub-accounts within the technical account, the highest weights and therefore the issues of greatest importance were considered to be the operational management, structural stability and presence of permafrost (Table 3-1). Compared to these issues, dam design details, construction and capacity were deemed of lower importance. This weighting reflects the evaluators' emphasis on the degree of complexity related to the operational management of disposing of tailings and waste rock in the manner proposed, the resultant stability of the facility which in part is influenced by the presence or lack of permafrost in the area. Other issues, while important design considerations were deemed to be less critical to the technical considerations of the TMF facilities.

Though of somewhat lesser weight, the dam characteristics were refined by a number of indicators, more than many of the sub-accounts. Within that sub-account, the issues of dam size and configuration, the total number of dams and the total embankment volume were considered of equal and important weight.

Other sub-accounts were described by only a few indicators. Operational management was described further by the footprint area and the operational ease of managing the tailings and waste rock. Of these, it was considered that the operational management of waste rock given that this involved identifying rock types as PAG or otherwise on an operational scale, scheduling trucks with PAG waste to haul to the TMF facility and sub-aqueous placement of the PAG rock, was considered more important than the disposal of tailings via conventional slurry pipeline.

The construction sub-account considered both geotechnical complexity and scheduling of construction rock as unique indicators. Of these, the geotechnical complexity was deemed of higher importance.

Table 3-1: Technical Account Sub-Account and Indicator Weights

Sub-account	Sub-account Weight	Indicator	Indicator Weight
Dam Design	4	Impoundment storage volume	2
		Dam size and configuration	6
		Number of large dams required	6
		Total embankment volume	6
Operational Management	6	Impoundment footprint	4
		operational ease – tailings	5
		operational ease - waste rock	6
Construction	4	Geotechnical complexity	6
		scheduling (construction)	4
Structural Stability	6	stability considerations operations and long term	6
Permafrost	6	permafrost sensitivity	6
Capacity	3	expansion potential	6

3.3.2 Environmental Account Weights

The sub-account and indicator weights within the environmental account are summarized in Table 3-2.

Within the environmental sub-accounts, those considered to be of highest importance related to the environmental consequence of a dam failure, water management and water quality. These sub-accounts were weighted with values of 6. Compared to those issues, other environmental sub-accounts were given lower values, with fish habitat and closure measures given values of 4, wildlife habitat and flora given values of 3, groundwater effects given a value of 2 and air quality given a value of 1. These sub-account weights reflect the expectations that the project is located in an area where there is not anticipated to be substantial effect on fish habitat, wildlife, flora, groundwater or air quality. Closure, while notably a very important consideration, was in this evaluation uncoupled from the effects on water quality in the closure phase of the mine life. It was considered that the potential long term effects on water quality were one of, if not the most important aspect of closure for this project and therefore weighted at a value below that of water quality.

Indicator weights within those sub-accounts that were described with more than one indicator are relatively straightforward. Within the water management indicators, the catchment area and amount of seepage expected were considered more important indicators than were the complexity of water management systems or the long term requirements related to the management structures in part due to the expectations that water management infrastructure would not be any more complex or onerous than is typical for a mine of this type.

Table 3-2: Environmental Account Sub-Account and Indicator Weights

Sub-account	Sub-account Weight	Indicator	Indicator Weight
Consequence of Dam Failure	6	Potential environmental effect as a consequence of dam failure	6
Water Management (storage & seepage)	6	Catchment area	6
		Degree of TMF seepage expected	6
		Operational water management complexity	4
		Long term maintenance requirements	4
Water Quality	6	Operational water quality (assumes 10% bypass) with respect to MMER at the toe of the dam (ratio of Cu seepage/Cu MMER)	6
		Operational water quality (assumes 10% bypass + discharge if required) with respect to CCME immediately below first tributary (assumed first occurrence of fish) d/s of dam (ratio of Cu seepage/Cu CCME)	6
		Operational water quality (assumes 10% bypass + discharge if required) with respect to CCME 10 km d/s of dam (ratio of Cu seepage/Cu CCME)	4
		Closure water quality (assumes 100% bypass) with respect to CCME at the toe of the dam (ratio of Cu seepage/Cu CCME)	4
		Closure water quality (assumes 100% bypass) with respect to CCME at first tributary (assumed first occurrence of fish) d/s of dam (ratio of Cu seepage/Cu CCME)	6
		Closure water quality (assumes 100% bypass + discharge if required) with respect to CCME 10 km d/s of dam (ratio of Cu seepage/Cu CCME)	6
		Operational water quality at point of spillway discharge (ratio of Cu /Cu CCME)	6
		Closure water quality at point of spillway discharge (ratio of Cu /Cu CCME)	6
Groundwater	2	Potential reduction in groundwater contributions downgradient	3
		Potential impacts to GW quality downgradient	6
Fish Habitat	4	Quality of fish habitat under the footprint of the TMF	2
		Quality of fish habitat at first tributary d/s of the dam during operations	4
		Quality of fish habitat 10 km d/s of the dam during operations	6
		Reduction of flow (Operations to early closure)	3
		Removal of fish habitat by footprint	6
Wildlife Habitat	3	Effect on wildlife habitat in footprint area	6
Flora	3	Effect on flora in footprint area	6
Air Quality	1	Potential for fugitive dust emissions	6
Closure Measures	4	Duration of long term liability	6
		Extent of measures to implement closure	6
		Long term level/intensity of site activity	6

The water quality sub-account was delineated by mining stage (operational and closure stage) and by location of potential effect (toe of the dam, first tributary and 10 km downstream as well as in the TMF pond itself). Within these indicators, all but two were considered to be of high importance and given a weight of 6. The two that were weighted lower (both values of 4) included the operational term at a location 10 km downstream, as during operations the potential effect that far from the facilities was considered to be of a very low probability, and the indicator representing toe seepage on closure, which was expected to be still within the area that would be controlled by closure measures with negligible if any release to the environment if of poor quality.

The indicators representing groundwater were for a reduction in flow (quantity) and potential effects on groundwater quality. Comparing these two indicators, the evaluators' assessed the issue of quality to be of higher importance than quantity in part because there are no immediate users of groundwater in the project area.

Fish habitat was described by a number of indicators that reflect the effects on fish habitat at various locations in a manner similar to what was done for water quality. Specifically this was the area affected by the TMF footprint, at the first tributary downstream and at a location 10 km downstream. In addition the potential for flow reduction and any resulting effect on fish habitat was included. Comparing these indicators against one another, the quality of habitat 10 km downstream of the TMF options was considered the most important indicator, as this is the location where there is likely to be good fish habitat. The other points of reference were assessed as having lower weights. Similarly flow reductions, particularly further downgradient were perceived to be of lesser concern than potential effects on quality.

The sub-account representing closure measures was the only other sub-account within the environmental account that was represented by more than one indicator as in the table above. All three of these indicators were considered equal in weight and high in value and given weights of 6.

3.3.3 Socio-Economic Account Weights

The weights applied to the socio-economic sub-accounts and indicators are summarized in Table 3-3.

The evaluators assigned weights of 6, or those sub-accounts considered to be of highest importance with respect to socio-economic considerations, to issues such as traditional land use, long term care and maintenance, permitting, archaeology, safety, community perception and the future burden on society. By comparison, the issues of noise and aesthetics given the remote location of the project were given values of 1. Similarly issues related to tax contribution and job opportunities, while very important considerations for the project as a whole were considered of lesser importance to the evaluation of TMF alternatives and were also given values of 1.

Only a few of the sub-accounts were described by more than one indicator. Long term care and maintenance for example was defined as considering both winter operating requirements and total effort separately because the project is located in the north and winter can pose challenges that are not present at other times of the year it was given special consideration. Both indicators however were considered of equal, and high importance.

Table 3-3: Socio-Economic Account Sub-Account and Indicator Weights

Sub-account	Sub-account Weight	Indicator	Indicator Weight
Traditional Land Use	6	In immediate area	6
Long Term Care and Maintenance	6	Winter operating requirements	6
		Total effort	6
Permitting	6	Overall project complexity from permitting point of view	6
		Requirement for schedule 2 amendment	6
Archaeology	6	Sites of importance in immediate area	6
Safety	6	Consequence of dam breach (socio-economic impacts)	6
Noise	1	Degree of noise pollution	6
Aesthetics	1	Visibility from frequented areas	6
Tax contribution	1	Anticipated taxes	6
Job opportunities	1	Job/contracting potential	6
		Training/experience opportunities	6
Community perception	6	Community perception	6
Future Burden on Society	6	Future burden on society	6

Permitting was also divided into two indicators; the overall complexity from a permitting perspective as well as the expectations for a Schedule 2 amendment requirement. Again, both indicators were considered to be of equal and high importance and both given weighted values of 6.

Job opportunities were described as both the direct potential for jobs as well as the opportunities for training and experience that otherwise wouldn't be available to people in the area. These indicators, as with the others, were considered to be of high importance and both given values of 6.

3.3.4 Project Economic Account Weights

Weight values for the project economic account were as summarized in Table 3-4.

Table 3-4: Project Economic Account Sub-Account and Indicator Weights

Sub-account	Sub-account Weight	Indicator	Indicator Weight
Government Costs	6	Supporting infrastructure costs	6
Project Costs	6	Initial capital cost (waste and water management costs only)	6
		Sustaining and operating costs	5
		Fish habitat compensation	2
		Closure costs	2
		Post closure costs	2

Both the government costs and the project costs were considered of high importance and given weights of 6. Within the project costs, indicators were developed for different time periods as well as for fish habitat compensation costs. Of these, the initial capital costs were considered the most important indicator followed by the sustaining and operating costs. All other costs; fish habitat compensation, closure and post closure costs, were considered of lower importance in large part because they are typically amounts far less than the capital and sustaining costs. These were all given values of 2 as compared to other project costs.

4 MINE WASTE MANAGEMENT ALTERNATIVES ASSESSMENT

4.1 OBJECTIVES AND ASSUMPTIONS

The objectives of the mine waste and water management strategy at the Casino Project are:

1. Permanent and secure storage of tailings and mine waste
2. Selective placement of waste materials to:
    a. Ensure long term geotechnical stability, incorporating settlement and the minimization of seepage; and
    b. Maximize water quality through the minimization of acid generation potential and metal leaching waste.

A number of assumptions or design bases are defined for assessment of the options associated with the project. Assumptions are typically developed on the basis of the deposit type and size, expected production rates and anticipated environmental management requirements for wastes associated with the deposit. The assumptions used for the development of options for the Casino Project are:

- 157.5 Mt of oxide ore will be processed in a heap leach facility, south of the open pit. The location and operation of the heap leach facility is distinct from the storage of tailings and waste rock and is therefore outside the scope of this evaluation.
- Underground mining methods are not feasible. Mining will be via open pit mining methods. As with the heap leach facility, the open pit was considered outside the scope of the evaluation of waste storage alternatives.
- The candidate waste management facility locations need to be able to store 956 Mt of tailings and 658 Mt of waste rock.
- Geochemical characterization work indicates a large proportion of the waste will be potentially acid generating (PAG). The current assumption is that to align with the industry's best management practices for management of PAG waste this waste will be managed and stored sub-aqueously within a management facility.

4.2 TAILINGS AND MINE WASTE DISPOSAL METHODS

Tailings can be disposed of in a variety of ways, dependent on the geotechnical and chemical properties of the tailings after final processing (Journeaux Assoc., 2012). Typical tailings generated through milled flotation processes may be deposited in one of four ways: as conventional/slurry tailings, thickened tailings, paste tailings or filtered tailings, which have characteristics outlined in Table 4-1 and increase in solids concentration, as shown in Figure 4-1.

Table 4-1: Characteristics of Tailings Deposition Methods (from Taguchi, 2014 and Journeaux Assoc., 2012)

Tailings	Solids Content	Conveyance System	Beach Slope	Disposal Option
Slurry	<45%	Centrifugal pump	0.5% - 2%	Sub-aqueous
				Open Pit
				Natural terrain – dam and dikes built to form perimeter barrier
Thickened	45% - 65%	Centrifugal pump	2% - 6%	Sub-aqueous
				Open Pit
				Natural terrain – dam and dikes built to form perimeter barrier
Paste	65% - 70%	Positive displacement pump	2% - 10%	Sub-aqueous
				Open Pit
				Natural terrain – dam and dikes built to form perimeter barrier
Filtered	80% - 85%	Non-pumpable. Trucked or conveyed	No beaches	Open Pit
				Natural terrain – "dry" stacking and freezing

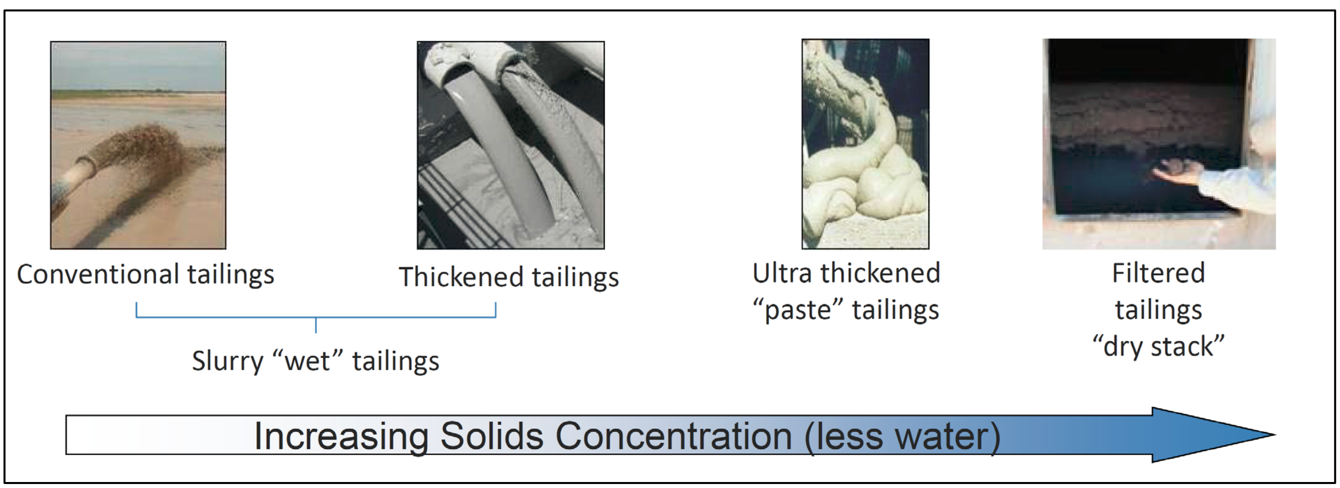


Figure 4-1: Solids Concentration of Typical Tailings Disposal Processes

Tailings slurries and thickened tailings are typically contained in facilities made of dams and dikes placed at points in the natural terrain that constrain the tailings and restrict seepage from the facility (i.e., tailings management facilities (TMFs)). Tailings slurries are best suited to operations where:

- Geochemical issues may arise through oxidation of the tailings and/or waste rock;
- Climatic conditions are extremely wet/seasonally wet; and/or

- Operations are at a larger scale (from Davies, 2015).

Globally, conventional slurry tailings make up the majority of existing TMFs, with approximately the same number of thickened plus surface paste tailings and filtered tailings facilities (Davies, 2011).

Filtered or “dry” tailings are best suited to projects that have one or more of the following attributes (from Davies, 2011):

- Reside in arid regions, where water conservation is crucial (e.g. Western Australia, Southwest United States, much of Africa, many regions of South America, arctic regions of Canada and Russia).
- Have flow sheets where economic recovery (commodity or process agent(s)) is enhanced by tailings filtration.
- Reside in areas where very high seismicity contraindicates some forms of conventional tailings impoundments.
- Reside in cold regions, where water handling is very difficult in winter.
- Have topographic considerations that exclude conventional dam construction and/or viable storage to dam material volume ratios.
- The operating and/or closure liability of a conventional tailings impoundment are in excess of the incremental increase to develop a dry stack.
- Milling rate is generally less than 10,000 tonnes per day.

Waste rock is typically disposed of in either surface dumps (which require soil covers to manage acid rock drainage and metal leaching potential), placement back in an open pit or underground mine, or co-disposed together with tailings in a co-disposal facility. Co-disposal of tailings and waste rock in one integrated disposal facility is used to improve disposal methods in cold regions, and can reduce acid mine drainage, metal leaching, storage facility footprints, increase compaction and facilitate progressive closure (Journeaux Assoc., 2012).

4.3 MANAGEMENT ALTERNATIVES

The selection of alternatives available for mine waste management at the Casino Project must take into consideration the objectives, assumptions, and criteria listed above. Four options for dam construction and/or tailings disposal and management are evaluated:

1. Use of local borrow materials to replace mine waste rock for construction of the tailings embankment;
2. Cyclone sand construction of the tailings embankment;
3. Thickened/paste tailings; and
4. Development of a dewatered tailings (dry stack) facility.

The general advantages and disadvantages to the various disposal options are outlined in Figure 4-2, and assessment of the four options detailed below.

At the wetter end of the density spectrum, tailings slurries are likely the lowest operating costs, but are the least efficient water conservation option, and require containment dams where seepage may be an issue, depending on the impoundment type. Tailings slurries have relatively complex water management. Conversely, at the other end of the density spectrum “dry” stack tailings have the most efficient water conservation, have low seepage losses from the stack, have the potential to be progressively covered and reclaimed, should be a geotechnically stable tailings mass, have minimal containment requirements and have relatively simple water management. However, “dry” stack tailings is limited by the scale of filtration technology (i.e., <10,000 tonnes per day) and has much higher operating costs.

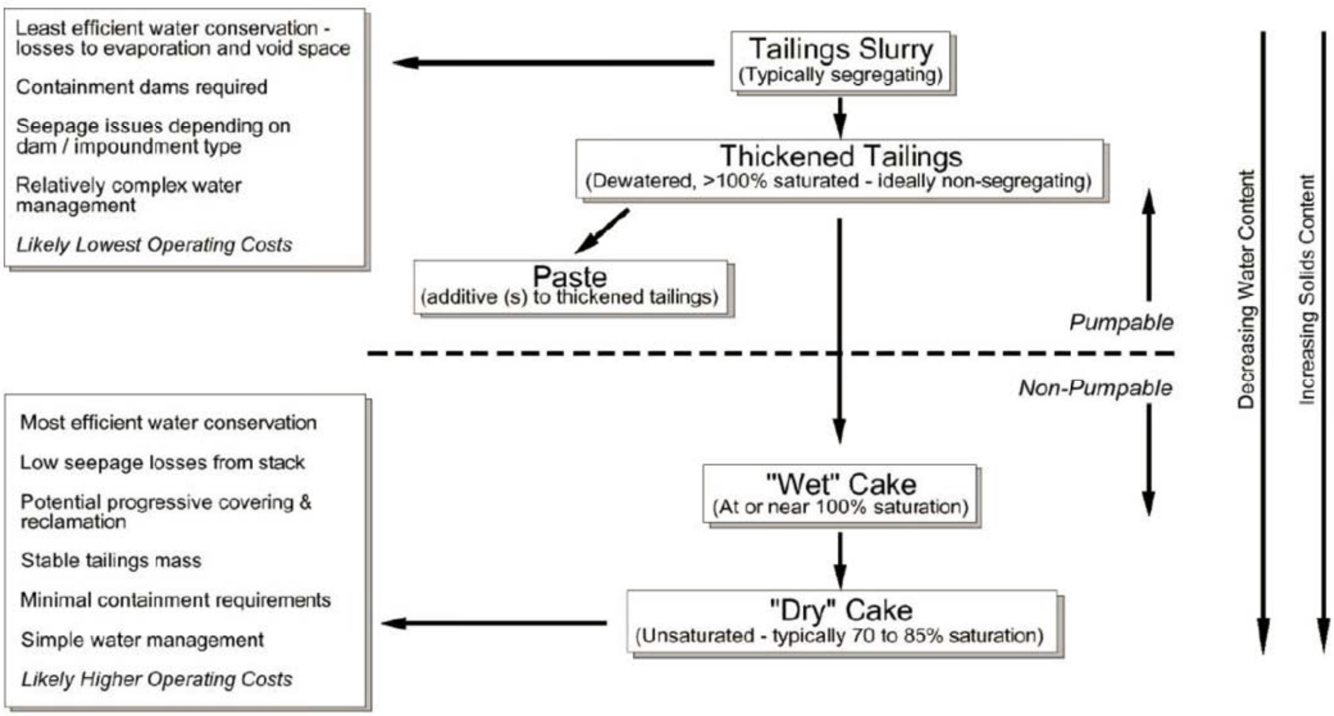


Figure 4-2: Tailings Disposal Options Advantages and Disadvantages (from Davies, 2011)

4.3.1 Local Borrow Materials

The local borrow material option incorporates the construction of a valley-fill dam made from primarily rockfill, with the co-disposal of slurried tailings and waste rock in the resulting impoundment. A schematic arrangement of the TMF for this option is illustrated on Figure 4-3. Suitable waste rock from the Open Pit is assumed to be available to construct the Stage I (starter) dam using NAG material from the oxide cap. Embankment construction to facilitate staged expansion of the TMF will be carried out using suitable rockfill materials sourced from local quarrying.

The embankments will be constructed as water-retaining zoned structures with a low permeability core zone and appropriate filter and transition zones to prevent downstream migration of fines. The core zone will include a seepage cut-off keyed into competent rock in the foundation. Information from previous geotechnical investigations at the site indicates that residual soils in the area may provide suitable low permeability borrow fill for use in construction of the embankment core zone and seepage cut-off.

The embankments are designed as full section embankments, with 2H:1V upstream and downstream slopes. Staged expansions of the embankments will utilize the centreline method of construction. A typical section through the Main Embankment is shown on Figure 4-4. An embankment height of approximately 303 m (elevation 1,008 m) is required at the deepest section for storage of 974.4 million tonnes of tailings (including approximately 49 million tonnes of pyritic tailings) and 837.6 million tonnes of PAG and ML waste rock. The depth-area-capacity (storage) relationship for this facility is given on Figure 4-5.

Tailings slurry will be discharged from the mill circuits at about 55% solids by total mass of slurry. It is assumed that approximately 80% of the tailings will be delivered to the TMF as geochemically innocuous material following pyrite separation. The remaining 20% of the total tailings comprises potentially reactive pyritic tailings discharged by a separate pipeline into a cell contained within the northern end of the TMF, remote from the embankment. Given the elevation difference between the mill and the TMF, the tailings will flow by gravity through a single pipeline, with provision for energy dissipation as required. The slurry is typically discharged through one or several off-takes, from header pipes situated around the periphery of the TMF and its confining embankments. The tailings solids settle out of the slurry and released water accumulates in a surface water (supernatant pond). Clear water from this pond is pumped back to the mill for re-use in the process.

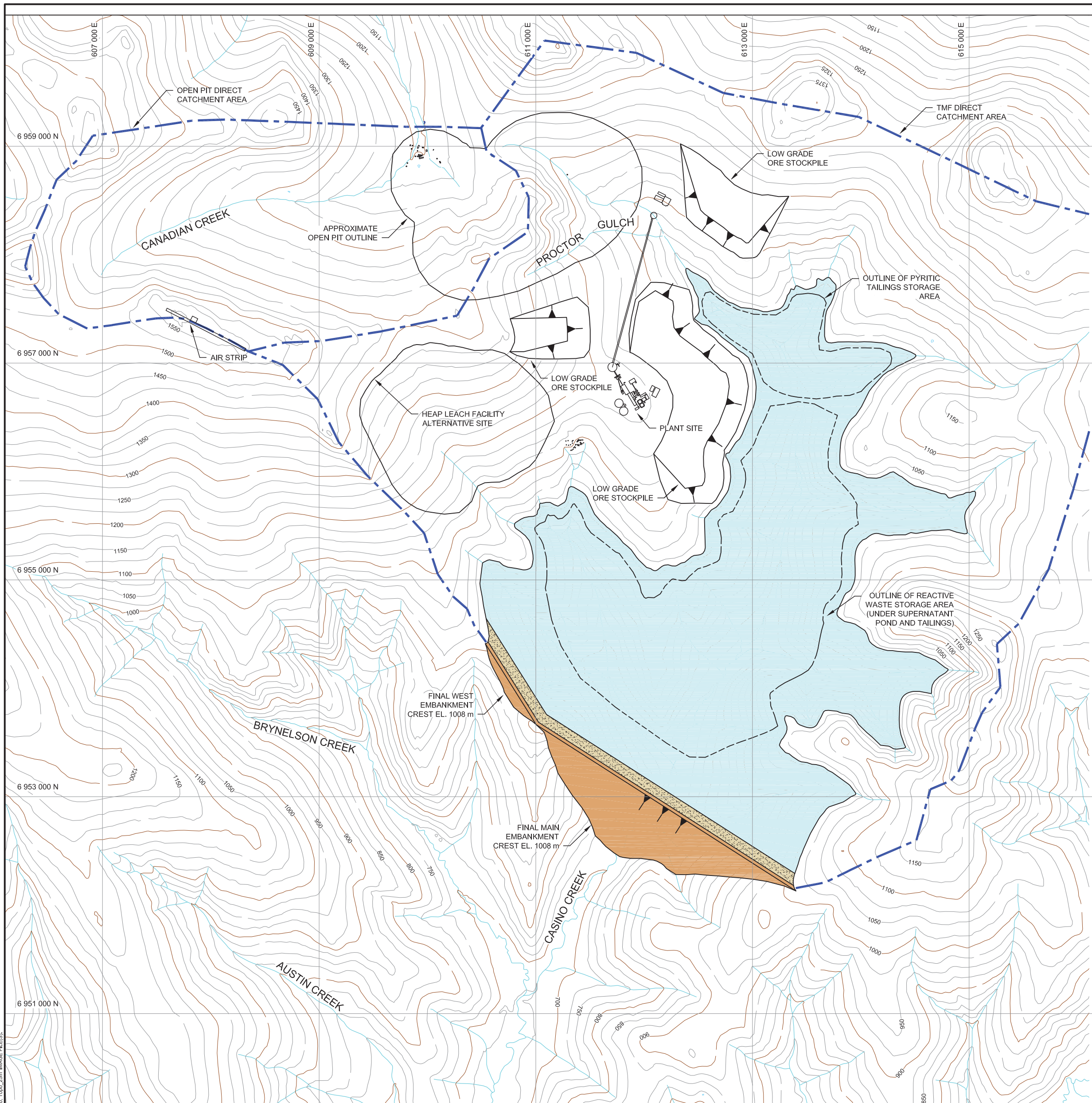
Specific overall features of this TMF option include:

- Two earth-rockfill, zoned embankments, referred to as the Main and West Embankments;
- Tailings distribution system;
- Reclaim water system;
- PAG/ML waste storage area;
- Pyritic tailings storage area;
- Supernatant (surface water) pond, and
- Seepage collection ditches and ponds/sumps.

Key design considerations for the evaluation of use of local borrow materials for dam construction include:

- Availability of borrow materials. The quantity of shell zone material required for the Main and West Embankments (excluding the Stage I dam) is approximately 105 million m^3. For this study, this material is assumed to be sourced from a quarry operation within 5 km of the Main Embankment.

- The geochemical characteristics of rockfill borrow materials would need to be assessed to confirm that they are not potentially acid generating or have metal leaching potential.
- Site investigations and testing will be required to characterize the availability and suitability of potential rockfill quarry locations.
- Any NAG waste rock material determined to have no metal leaching potential can be used to supplement local borrow materials in embankment construction. The unit cost for mine waste rock will likely be less than that associated with rockfill sourced by local quarrying.
- Placement of a buttress against the downstream shell of the Main Embankment may be required to ensure long-term stability and integrity of the TMF due to the height of the final dam (exceeding 300 m). Embankment stability analyses will need to consider the condition of underlying foundation soils and the impact of high confining stresses on the shear strength of the rockfill materials (with consideration of rock type, distribution of rockfill particle sizes, density and durability).



NOTES:

1. COORDINATE GRID IS UTM (WGS84/NAD83) ZONE 7 (m).
2. CONTOUR INTERVAL IS 25 METRES.
3. DIMENSIONS ARE IN METRES UNLESS NOTED.
4. PLANT SITE AND CRUSHER LAYOUT PROVIDED BY M3ENGINEERING AND TECHNOLOGY CORPORATION (APRIL 9, 2008).

SCALE A: 400 200 0 400 800 1200 1600 2000 m

WESTERN COPPER CORPORATION

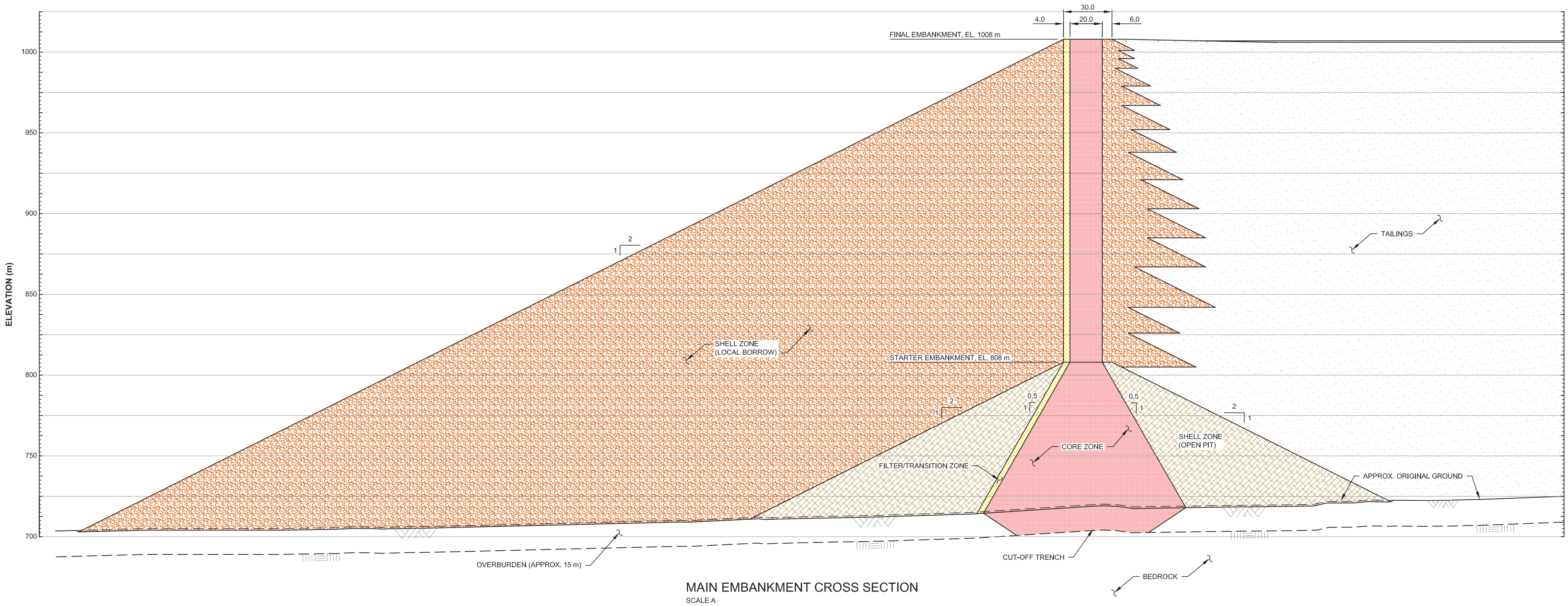
CASINO COPPER-GOLD PROJECT

LOCAL BORROW MATERIALS OPTION GENERAL ARRANGEMENT

Knight Piésold CONSULTING

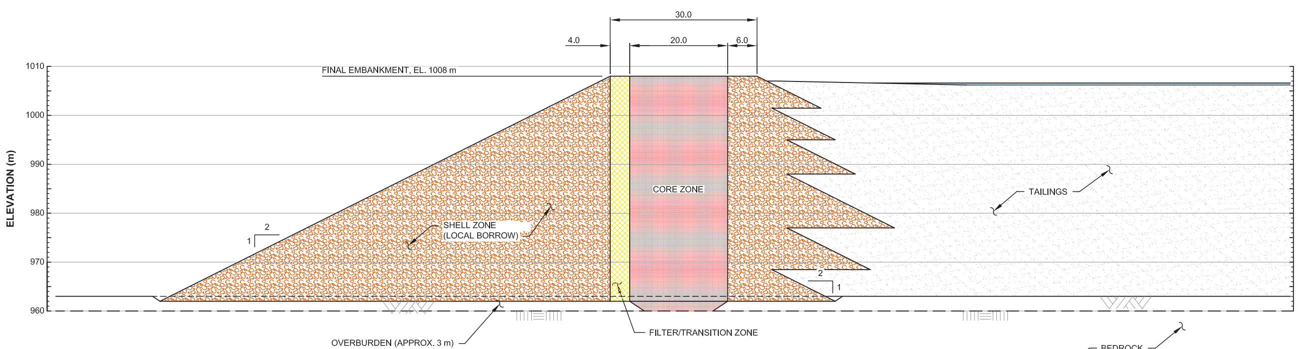
P/A NO.	REF NO.
VA101-325/3	2
Figure 4-3	REV 0

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
0	16APR'10	ISSUED WITH REPORT	AG	SC	GRG	KJB



MAIN EMBANKMENT CROSS SECTION

SCALE A



WEST EMBANKMENT CROSS SECTION

SCALE B

SCALE B 10 5 0 10 20 30 40 50 m

SCALE A 25 12.5 0 25 50 75 100 125 m

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
0	16APR'10	ISSUED WITH REPORT	AG	SC	GRG	KJB

WESTERN COPPER CORPORATION

CASINO COPPER-GOLD PROJECT

LOCAL BORROW MATERIALS OPTION
TYPICAL EMBANKMENT SECTIONS

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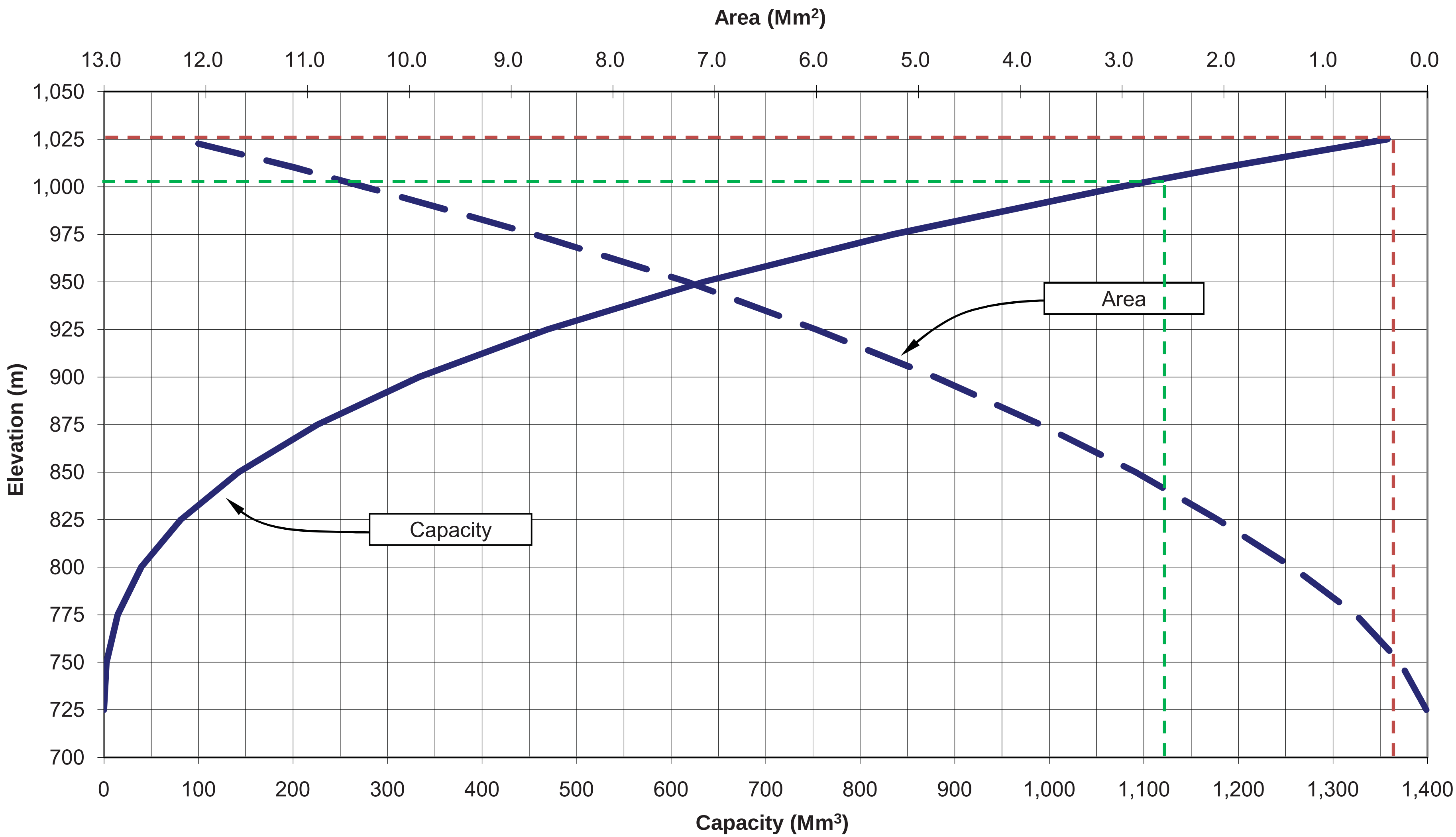
P/A NO. VA101-325/3 | REF NO. 2

Figure 4-4 | REV 0



NOTES:
1. TAILINGS PLUS PAG AND ML WASTE MATERIAL STORAGE VOLUME = 1,119 Mm^3.
2. EXPANDED CASE: TAILINGS PLUS PAG AND ML WASTE MATERIAL STORAGE VOLUME = 1,369.9 Mm^3.

WESTERN COPPER CORPORATION

CASINO COPPER-GOLD PROJECT

LOCAL BORROW MATERIALS OPTION
DEPTH-AREA-CAPACITY RELATIONSHIP

Knight Piésold CONSULTING

PROJECT / ASSIGNMENT NO.	REF NO.
VA101-325/3	2
Figure 4-5	REV. 0

REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D
0	03MAY'10	ISSUED WITH REPORT	AG	GRG	KJB

4.3.2 Cyclone Sand Embankment

This option also requires the construction of a valley-fill dam with an impoundment to store slurried tailings and waste, subaqueously. Embankment construction for this option is assumed to be primarily from cyclone sand material. The sand fraction of the bulk tailings is extracted by cycloning the tailings slurry. The resulting sandy underflow product can be used as a construction material provided that it can be placed, drained and compacted sufficiently to ensure embankment stability and preclude potential for liquefaction during seismic shaking. Suitable waste rock from the Open Pit is assumed to be available to construct the Stage I (starter) dam using NAG material from the oxide cap. Embankment construction to facilitate staged expansion of the TMF will be carried out primarily using cyclone sand material. A general arrangement of the TMF for this design option is illustrated on Figure 4-6.

The particle size distribution of the Casino mill tailings is a key consideration for determining the suitability of the bulk tailings to provide cyclone sand fill material of suitable quality and sufficient quantity. Coarser tailings are preferred, as a higher sand fraction or ‘split’ can be realized. A low percentage of fines is also preferred, in order to promote rapid drainage and to facilitate compaction. Two stage cycloning will be required to achieve the desired sand product (low fines content).

Similar to the TMF option utilizing only local borrow materials, the embankments will be constructed as water-retaining zoned structures with a low permeability core zone, appropriate filter and transition zones to prevent downstream migration of fines, and a seepage cut-off keyed into competent rock in the foundation. Information from previous geotechnical investigations at the site indicates that residual soils in the area may provide suitable low permeability borrow fill for use in construction of the embankment core zone and seepage cut-off. Staged expansions of the embankments will utilize the centreline method of construction with a minimum downstream slope of 3H:1V. A typical section through the Main Embankment is shown on Figure 4-7. An embankment height of approximately 286 metres is required at the deepest section for storage of 956 million tonnes of tailings and 658 million tonnes of potentially reactive waste rock.

Approximately 221 million tonnes of the stored tailings will be utilized as cyclone sand fill for embankment construction. The depth-area-capacity (storage) relationship for this facility is given on Figure 4-8.

Cell construction using narrow sand deposition panels will be required for raising the downstream shell of the embankments. The panel method involves the construction and maintenance of long, narrow cells along the face of the embankment. A schematic of the panel construction sequence is shown on Figure 4-9.

It is estimated that 50% of the NAG tailings can be recovered as cyclone sand when the cyclone station is operating. This amounts to approximately 7.2 to 7.5 million m^3 of cyclone sand fill material produced annually. Any shortfall of embankment fill material would need to be made up with rockfill from Open Pit stripping (if available and geochemically innocuous) and/or suitable fill material from local borrow sources or quarries. Approximately 50% of NAG tailings solids assumed to be produced by cyclone plant as sand fill is suitable for embankment construction (based on expected tailings particle size distribution). Cyclone sand production is assume for average 9 months per year. Cyclone sand production begins at start of Year 1 and plant availability is 90%.

It is assumed that approximately 80% of the tailings will be geochemically innocuous material following pyrite separation. The remaining 20% of the total tailings comprises potentially reactive pyritic tailings discharged by a separate pipeline into a cell contained within the northern end of the TMF, remote from the embankment.

Significant features of the cyclone sand design concept required for the TMF include the following:

- A two stage cyclone sand plant.
- The cyclone sand plant will be located at an elevation such that discharge of sand and combined cyclone overflow can be achieved by gravity. Relocation of the cyclone plant may be required later in the project life.
- The cyclone sand plant will be fed directly from the mill using off-take connections from and to the existing bulk tailings pipelines. This arrangement will maintain the operational ability to bypass the cyclone plant and continue to deposit bulk tailings directly into the TMF when required.
- An additional water inflow of approximately 5,000 m^3/hr is required at the cyclone sand plant during operations. This will be used to reduce the solids content of the primary and secondary cyclone feeds and to fluidize the sand to enhance gravity transport, reduce pipeline pressures and minimize sand pumping costs. Supply of the additional water will come from a dedicated floating reclaim pump-station located within the TMF. A single dedicated pipeline will connect this floating pumpstation to the cyclone sand plant.
- The cyclone underflow (sand fraction) will be pumped as required and discharged by gravity from the cyclone sand plant as a slurry of approximately 55% solids by weight, through one of several steel pipelines laid from the cyclone station. These lines will be laid across a downstream bench below the crest of the TMF confining embankment and extended at intervals down the downstream face for deposition of sand into confining “cells” for use as construction material. The provision of several lines enables the relocation of discharge points, on-going pipeline maintenance and the continuous placement of sand, allowing zones of previously deposited sand material to drain and be compacted by earthmoving equipment.
- The fine cyclone overflow material (fine tailings) will be returned back into the existing bulk tailings discharge pipelines, immediately downstream of the cyclone sand plant, and discharged directly into the TMF from existing off-takes in pipelines laid along the upstream embankment crest and around the periphery of the TMF. Additional pumping will be provided as required.
- Additional solids collection and water recovery measures will be required at the downstream embankment toe. These include sediment collection ponds, drainage recovery pumping and pipeworks systems, plus a seepage recovery pond and pump-back system. These components are required to collect fine sediments and water recovered from the draining sand fill. The sediments will need to be removed by dredging or excavation on at least an annual basis and all

water will be pumped back into the TMF through dedicated pipelines. Back-up pumping and power will be required.

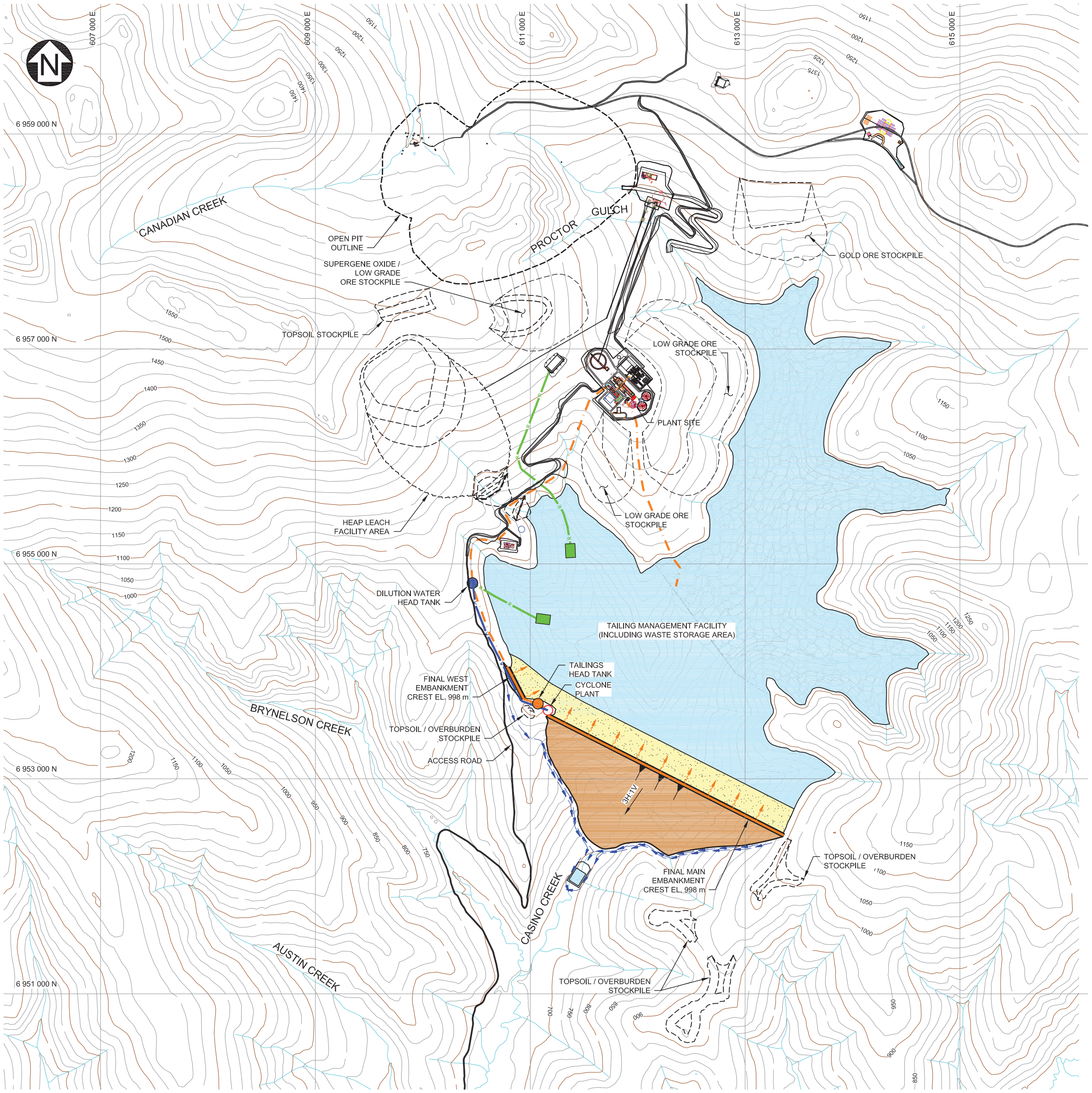
- During the winter months and at other times when the cyclone sand plant is not operating, bulk tailings discharge will be rotated sequentially into the TMF from offtakes in the bulk tailings pipelines.

Key design and operating considerations that need to be included in the evaluation of cyclone sand material for embankment construction include the following:

- Embankment height, stability and seismic resistance. This limits the sand placement options and would likely necessitate construction using sand cells, where additional vibratory compaction would be required to ensure a sufficiently dense, high strength and liquefaction resistant material.
- Cold winter conditions that will reduce the construction period, partly due to the potential for freezing and ice entrainment in the sand fill and partly because of snow drifting in the sand cells.
- Tailings particle size distribution. The tailings grind is fundamental in determining the ‘split’ that can be achieved by cycloning (i.e. the percentage of the tailings stream that can be separated and used as sand fill for construction). Clean sand, with a low fines content, will be required for placement in the sand cells, in order to facilitate rapid drainage and subsequent compaction. It is anticipated that the fines content (% passing a #200 sieve) of the cyclone sand will need to be less than 15%, in order to maximize fill placement rates and to ensure adequate compaction and drainage.
- The availability of cyclone sand needs to be matched with the filling schedule for the TMF, to ensure adequate embankment heights are provided well in advance of the rising tailings surface. The Stage 1 (starter) embankment must be high enough to allow sufficient quantities of sand to be produced and placed to facilitate subsequent embankment raises. A hybrid approach (combination of rockfill and cyclone sand) may be necessary to offset any shortfall of cyclone sand available for construction during the operating life of the TMF. The sequencing of sand cell construction in relation to the requirements for embankment crest raising and the associated rockfill placement schedules will need to be carefully evaluated in subsequent design studies. Similarly, the timing, logistics and operating requirements for pipeline management and relocations will also need to be evaluated for future design studies.
- If a combination of cyclone sand and rockfill is utilised for embankment construction, additional filter and drainage layers will be required at the base of sand zones to prevent the migration of tailings sand into underlying rockfill and to provide drainage for the transport of water released from the sand.
- The possibility of windy conditions at the site must be considered. The problem can be exacerbated during cold winter conditions as a ‘freeze drying’ process tends to destroy capillary tensions in partially saturated sand, making it more susceptible to dusting. This will be a significant environmental consideration. Appropriate provisions will need to be incorporated to

prevent windblown dusting. This will most likely mean that the cyclone sand material will have to be capped with erosion resistant fill material, particularly during the cold winter months, when it may be impractical and/or impossible to continue with active sand placement.

- Only clean (geochemically innocuous) bulk tailings can be cycloned to produce sand fill material for embankment construction. No potentially acid generating or metal leaching materials can be used for embankment construction. Management of the potentially reactive pyritic tailings stream during system maintenance or breakdown needs to be coordinated to ensure that total tailings that include the pyrite stream are not directed to the cyclone sand plant.
- Water management is a major consideration, as protection of downstream fisheries resources is a fundamental requirement. Downstream cyclone water recovery systems will need to include appropriate provisions for containment of fines washed out of the cyclone sand fill, along with additional water collection ponds and water recovery systems. The provision of back-up pumps and a standby power supply must be considered for pump-back systems. The water management aspects of the cyclone sand systems will be major environmental considerations. These will need to be carefully considered to ensure appropriate levels of environmental protection are maintained, both during operations and after closure.
- The requirement for a very large embankment may warrant the installation of multiple or movable sand plants, particularly if the use of cyclone sand as a construction material is to be maximized.
- To accommodate cyclone sand plant maintenance or downtime (primarily during the winter months), valves and pipeworks will need to allow bulk tailings to be delivered directly to the TMF for discharge.
- Placement of a buttress against the downstream shell of the Main Embankment, or an overall flattening of the slope, may be required to ensure long-term stability and integrity of the TMF due to the height of the final dam (280+ metres). Embankment stability analyses will need to consider the condition of underlying foundation soils and the impact of high confining stresses on the shear strength of the cyclone sand material.



LEGEND:

- TAILINGS
- EMBANKMENT (CYCLONE SAND)
- EMBANKMENT (ROCKFILL)
- POND
- TAILINGS PIPELINES
- RECLAIM PIPELINES
- WATER PIPELINES
- TAILINGS HEAD TANK
- DILUTION WATER HEAD TANK
- CYCLONE PLANT
- DIVERSION DITCHES

NOTES:

1. COORDINATE GRID IS UTM (WGS84/NAD83) ZONE 7 (m).
2. CONTOUR INTERVAL IS 25 METRES.
3. DIMENSIONS ARE IN METRES UNLESS NOTED.
4. OPEN PIT AT ITS FINAL OUTLINE AS PROVIDED BY CASINO MINING CORPORATION (NOVEMBER 2012).
5. PLANT SITE AND CRUSHER LAYOUT PROVIDED BY M3 ENGINEERING AND TECHNOLOGY CORPORATION (OCTOBER 4, 2012).
6. ORE AND TOPSOIL STOCKPILES ARE SHOWN AT THEIR MAXIMUM SIZE DURING OPERATIONS.

SCALE A: 400 200 0 400 800 1200 1600 2000 m

CASINO MINING CORPORATION

CASINO COPPER-GOLD PROJECT

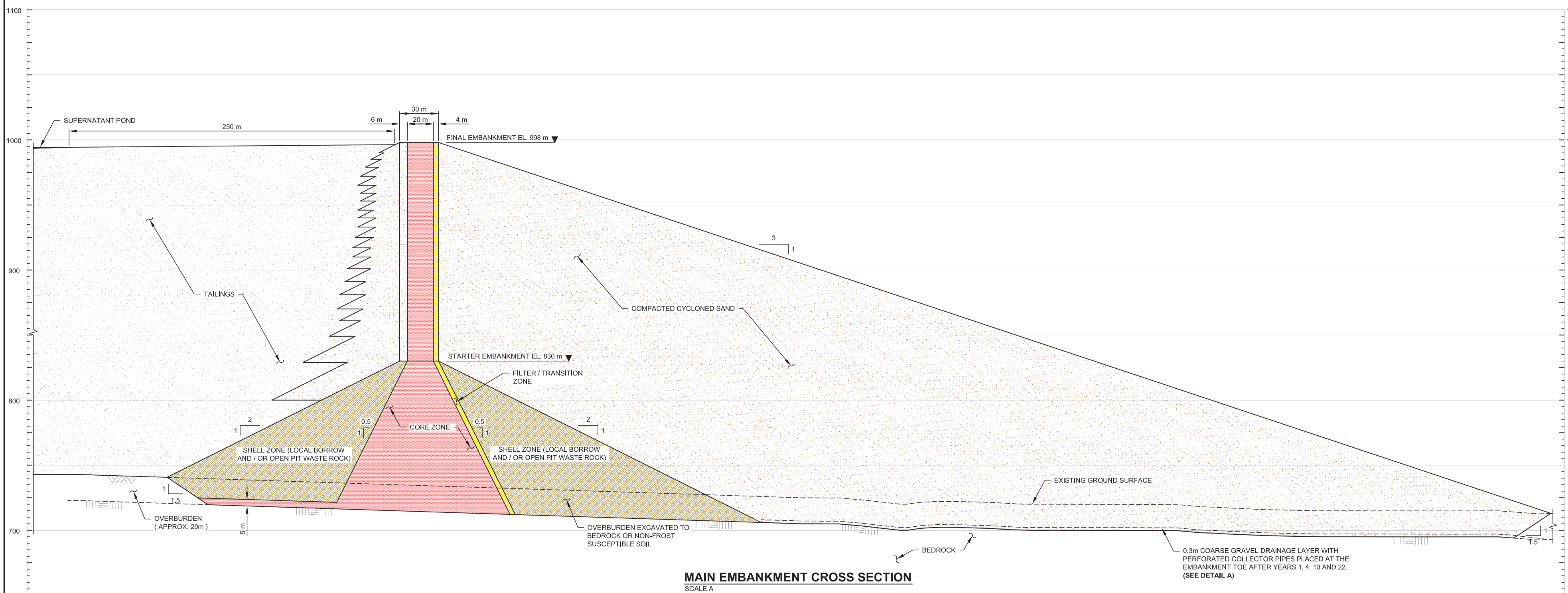
Cyclone Sand Embankment Option
General Arrangement

Knight Piésold CONSULTING

P/A NO.	REF NO.
VA101-325/8	10

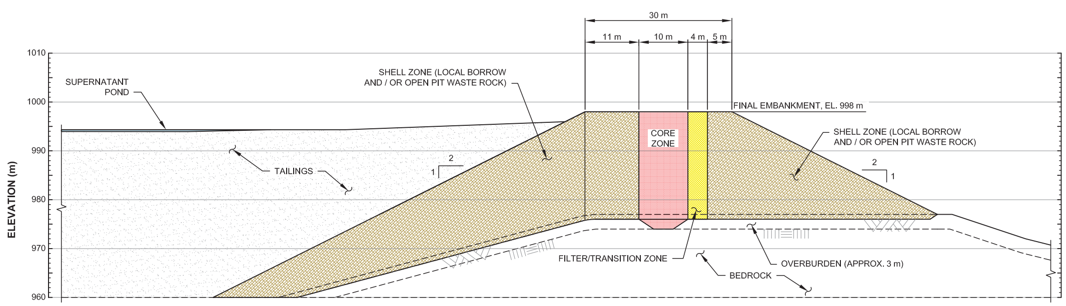
Figure 4-6 — REV 0

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
0	19DEC'12	ISSUED WITH REPORT	SB	DP	LM	KJB



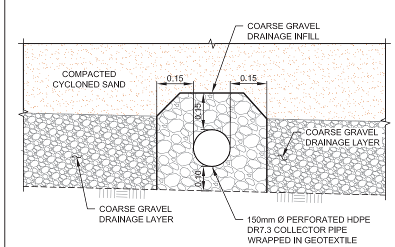
MAIN EMBANKMENT CROSS SECTION

SCALE A



WEST EMBANKMENT CROSS SECTION

SCALE B



A - **DETAIL**

EMBANKMENT DRAINAGE SYSTEM

SCALE C

NOTES:

1. COORDINATE GRID IS UTM (WGS84/NAD83) ZONE 7 (m).
2. DIMENSIONS AND ELEVATIONS ARE IN METRES UNLESS NOTED.
3. GENERALIZED TOPOGRAPHY SHOWN.

SCALE C: 0.2 0.1 0 0.2 0.4 0.6 0.8 1 m

SCALE B: 10 5 0 10 20 30 40 50 m

SCALE A: 30 15 0 50 100 150 m

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
0	19DEC'12	ISSUED WITH REPORT	SB	PP	LM	KJB

CASINO MINING CORPORATION

CASINO COPPER-GOLD PROJECT

Cyclone Sand Embankment Option
Typical Embankment Sections

Knight Piésold CONSULTING

P/A NO.	REF NO.
VA101-325/8	10

Figure 4-7 REV 0

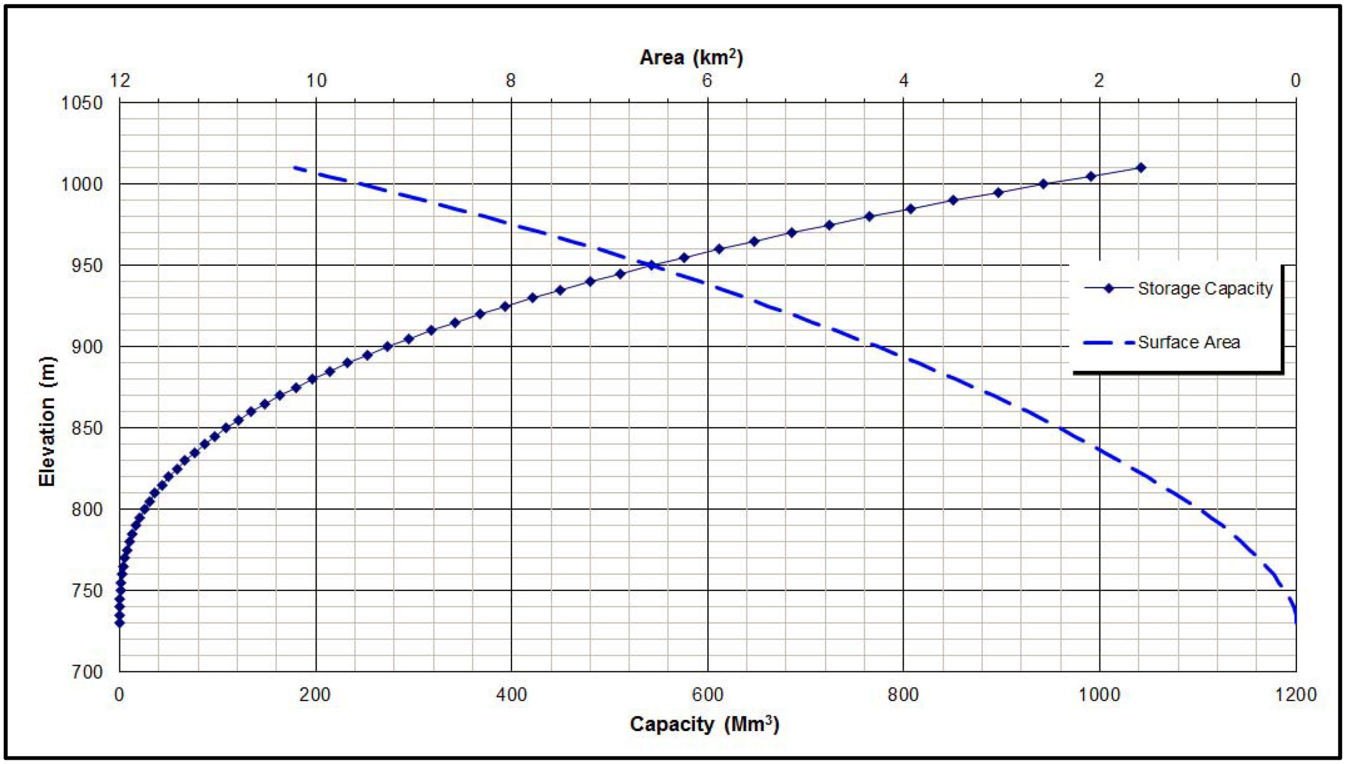


Figure 4-8: Cyclone Sand Embankment Option Depth-Area-Capacity Relationship

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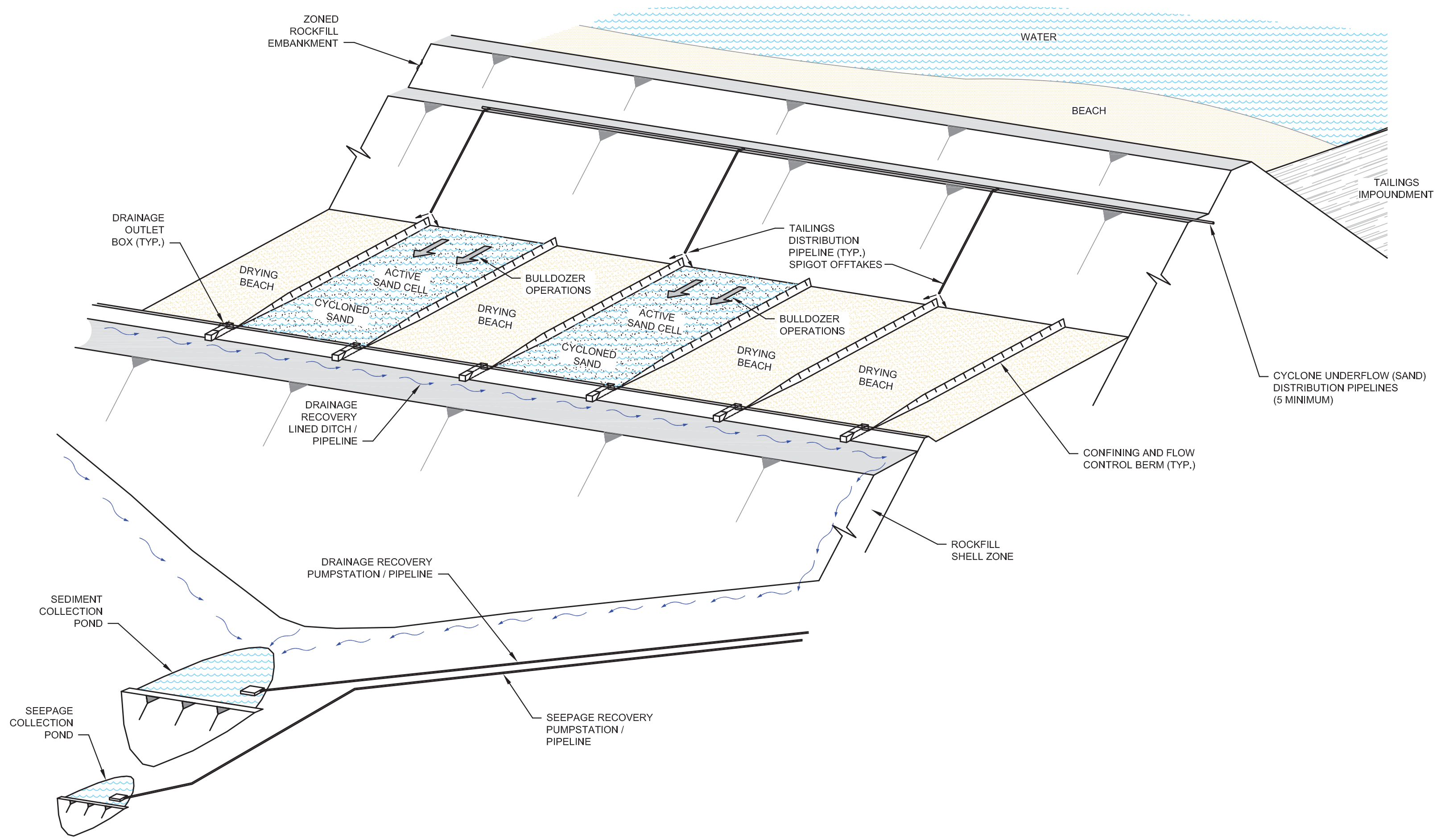

NOTES:

1. SAND CELL PLACEMENT OPERATIONS OCCUR SIMULATANEOUSLY IN TWO OR THREE CELLS.

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REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D

WESTERN COPPER CORPORATION

CASINO COPPER -GOLD PROJECT

CYCLONE SAND DEPOSITION SCHEMATIC

Knight Piésold CONSULTING

P/A NO. VA101-325/3

REF NO. 2

Figure 4-9

REV 0

4.3.3 Thickened/Paste Tailings

Thickened and paste tailings production uses settling, thickening and filtration processes to increase the tailings solids content. The tailings behaviour (rheology) changes with increases in density and viscosity. Commonly cited advantages for surface disposal of tailings as a thickened slurry or paste compared to conventional slurried tailings disposal include the following:

- Decreases the time required for a tailings deposit to achieve its final density and volume;
- Minimizes seepage from the tailings;
- Ease of operations and reduced water storage requirements;
- Reduced storage requirements and dam construction requirements;
- Reduces disturbance areas (facility footprint);
- Improved environmental performance; and
- Ease of reclamation at closure.

The tailings system complexity and working area increases with the need for mechanical equipment and flocculent addition. Paste tailings require positive displacement pumps and high pressure pipelines to deliver tailings to the TMF. An advantage may be the reduced power cost for pumping smaller tailings flows to the TMF and smaller reclaim water volumes from the TMF. However, potential capital cost advantages with smaller diameter tailings and reclaim pipelines may be offset by costs for processing equipment such as thickeners and re-circulation pumps, the need for earlier installation of booster pumps (due to increased tailings viscosity) and the added risk to operations from process upsets or equipment malfunction. Reduced power costs for pumping may be significantly offset by dewatering (e.g. flocculent) costs and higher operating and maintenance costs.

A consistent finding of dewatered tailings studies is that for most operations the production and delivery of thickened, and particularly paste tailings, is a high cost, high maintenance operation. Experience with thickened slurry and paste tailings has demonstrated the importance of a consistent feed and the technical and maintenance problems associated with production and delivery of a consistent tailings product. The demand for dewatering can result in major conflicts with the milling process, while the tailings distribution system can be adversely affected if it is not suitably designed for the specific characteristics and variations of the dewatered tailings stream.

The implementation of a dewatered tailings process, the production, delivery and deposition requirements, and the revised water management systems typically combine to increase operational complexity. The likelihood of periodic upset conditions increases, especially during the commissioning period. With more complex tailings handling and disposal systems, cold weather and darkness, the potential for mill shutdown or spillage may be significantly greater than for conventional slurry tailings disposal.

Thickened and paste tailings still retain considerable moisture after dewatering and deposition. The in situ strength characteristics of these materials are typically very similar to those associated with conventional slurried tailings deposits. Consequently, it often remains necessary to provide a substantial confining embankment to maintain appropriate stability under static and seismic loading conditions. The addition of cement can increase the strength characteristics of paste tailings, but can be very costly.

The use of dewatered tailings is unlikely to change the general design requirements for the TMF at the Casino project. The facility would still need to provide a confining embankment, storage for water management (surplus), accommodate storm water flows, as well as maintaining an appropriate water cover over potentially reactive mine waste materials (to inhibit oxidation) placed into the TMF for co-disposal.

A preliminary assessment has been carried out to examine the impact of dewatered tailings on TMF embankment height and impoundment footprint area, due to the potential increase in average dry density of the stored tailings and the corresponding reduction in stored volume. Information from existing mine operations indicates that an average tailings dry density of approximately 1.6 t/m^3 to 1.8 t/m^3 may be achievable, depending on the physical characteristics of the tailings, the level of dewatering employed (thickened slurry or paste) and site-specific conditions (including placement strategy and climate conditions). The potential decrease in the starter and final embankment heights is only about 6 and 16 metres respectively. The corresponding reduction in the final impoundment footprint size is also minor (less than 10%). This assumes a high average dry density of about 1.8 t/m^3 is achieved and maintained. The potential decrease in embankment height and footprint size will be even smaller if the average dry density is lower.

4.3.4 Dewatered Tailings 'Dry Stack'

This option considers the use of dewatered (filtered) tailings for storage within a "dry stack" facility. A dry stack facility can be used to store the majority of the tailings and would require significantly less material for the confining embankments, compared to disposal by conventional tailings slurry discharge. However, a separate facility is still required to provide subaqueous storage and confinement of potentially reactive waste rock (PAG and ML) and pyritic tailings, and to provide a facility for water management (including recovery to the mill) and contingency storage for those periods when the dry stack facility or dewatering plant is not operational.

Filtered tailings are produced using pressure or vacuum forces in presses, drums or belt filtration units. The tailings are typically dewatered to a moist, cake-like consistency, with water contents sufficiently low to achieve an unsaturated tailings material. The dewatered tailings are transported by conveyors or trucks to a 'dry stack' where they can be compacted in lifts to improve density and stability and enable the ability for machinery to work on the impoundment surface to facilitate on-going expansion.

Pyritic tailings (assumed to be approximately 20% of the total tailings) and all PAG and ML waste rock will be deposited within a Potentially Reactive (PR) waste facility located in the Casino Creek valley south-east from the Open Pit. The dry stack facility accommodating all non-reactive tailings will be located immediately downstream of this impoundment.

A general arrangement of the dry stack facility and adjacent PR waste facility is shown on Figure 4-10.

Specific features of the mine waste facilities are listed below:

- One earth-rockfill, zoned embankment;
- Non-reactive tailings distribution system;
- Pyritic tailings distribution system;
- Dewatered tailings distribution system;
- Reclaim water system;
- Reactive waste storage area;
- Pyritic tailings storage area;
- Supernatant (surface water) pond; and
- Seepage collection ditches and ponds/sumps.

It is assumed that the dry stack tailings facility will accommodate approximately 80% of the total tailings stream. The dewatered tailings will be placed and compacted in conjunction with a perimeter berm constructed from NAG waste rock and/or local borrow materials. Filtered tailings will be produced at a dewatering plant, likely established in the area west of the dry stack facility, where the proposed plant site is currently situated. It is assumed that the dewatered tailings will be delivered to the dry stack either by truck or by conveyor. A typical section through the dry stack facility is shown on Figure 4-11. The depth-capacity (storage) relationship for the dry stack tailings facility is given on Figure 4-12. The final height of the dry stack facility required for storage of 487.2 million m^3 (876.9 million tonnes) of dewatered tailings is approximately 226 metres (Elevation 991 m). This is based on an assumed in situ average tailings dry density of 1.8 tonnes/m^3. It is likely that an underdrain system will be required to ensure drainage and maintain unsaturated conditions within the filtered tailings pile.

The PR waste facility is required for storage of all pyritic tailings (assumed to be 20% of the total tailings stream) and all mine waste rock identified as Potentially Acid Generating (PAG) or with Metal Leaching (ML) potential. Additionally, it is assumed that approximately 5% of the non-reactive tailings will be discharged into this facility. This will be required during periods when the tailings dewatering plant is not operating (e.g. due to maintenance or unscheduled shutdown) or due to unfavourable weather conditions inhibiting tailings placement in the dry stack facility. The confining embankment for the PR waste facility will have a similar design concept to that described for the local borrow embankment option. The facility has been designed to permanently store 97.4 million tonnes of pyritic and bulk tailings (69.6 million m^3 at an assumed average dry density of 1.4 t/m^3) and approximately 658 million tonnes of PAG and ML waste rock which will be stored in the Reactive Waste Storage Area contained within the PR waste facility. The final embankment height is approximately 280 m (Elevation 1,025 m). The depth-area-capacity relationship for the PR waste facility is shown on Figure 4-13.

The overall configuration of the dry stack tailings facility and adjacent PR waste facility has been developed to minimize disturbed area (impoundment footprint), minimize the contributing catchment area (to simplify water management requirements), and to enable the non-reactive tailings dry stack to provide an additional seepage barrier between the PR waste facility and downstream receiving waters.

Embankment slope revegetation and reclamation could occur incrementally during staged expansion of the dry stack facility. Reclamation at closure would consist of revegetating the final surface of the impoundment. Decommissioning of ancillary facilities such as the tailings filtering and dewatering plant would occur at the time other project facilities were dismantled.

Tailings physical characteristics, such as particle size distribution (percent fines), strongly influence the ability to dewater the tailings solids sufficiently for them to be handled and placed in a compacted dry stack. The presence of excessive fines in the tailings may make it impractical to achieve a workable “dry” tailings product.

The storage of dry tailings can be beneficial, but it is not a method that can be applied in all circumstances. Operational problems may occur as a result of filtering equipment breakdown or a failure of filters to achieve performance requirements, resulting in a variable product. The filtering and transport of dry tailings to the storage area can be very costly in comparison to conventional pumping of tailings slurry, particularly if the slurry can flow under gravity, without pumping. Handling and placement of dewatered tailings in the dry stack facility will add to labour and equipment costs. In an environment with a potential water surplus, such as Casino, water management and water balance requirements may be challenging with a dry stack facility.

In the event of a planned (maintenance) or unplanned halt to operations at the dewatering plant or delivery system, it will be necessary to provide an alternative method for tailings discharge to avoid mill shut-down. This can be achieved by installing a backup pipeline system to the PR waste facility.

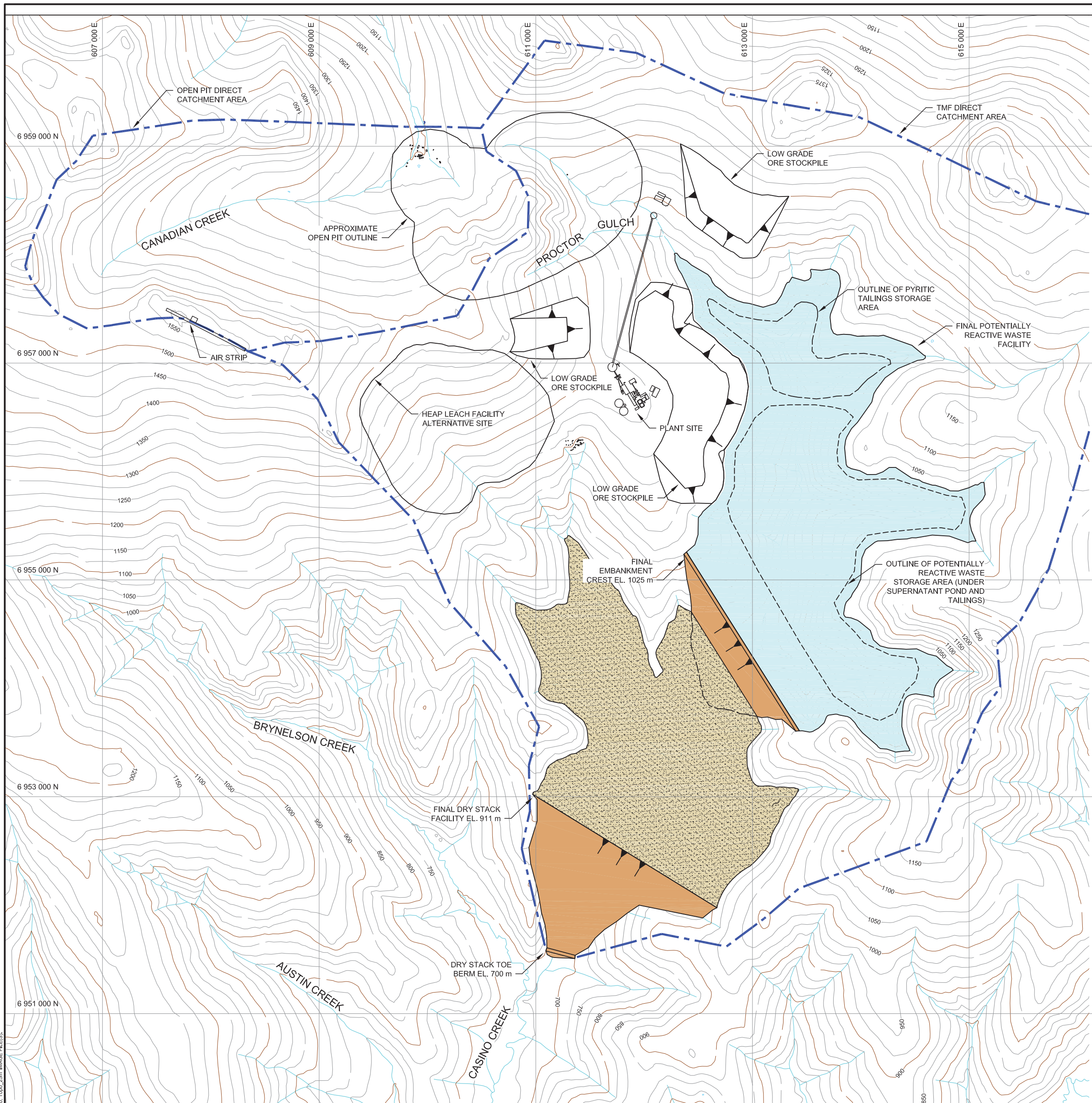
Dry stack tailings facilities by nature are expected to have little seepage, but this may not be the experience in practice. Seepage controls have been required at La Coipa Mine in Chile, the Mineral Hill Mine in Montana and the Raglan Mine in Quebec. At Greens Creek Mine in Alaska, a continuous addition of organic carbon to the tailings is required to assure their long-term chemical stability in order to meet water quality requirements.

The cold climate at the Casino site will present challenges during winter operations, including the need to prevent snow or ice accumulations on the tailings dry stack. Dust emissions from the dewatered tailings surface will be difficult to manage during dry spells, particularly if there is strong wind exposure. Windblown dusting can worsen in winter months, as freeze-drying and other frost processes can loosen the tailings surface. The moderately wet climate may cause problems during the summer months, as excessive moisture addition can result in rapid degradation of trafficability and prevent adequate compaction.

The filtered tailings stack would be susceptible to instability, due to any residual ice lenses or localized liquefaction, if the pile becomes saturated due to rainfall, snow entrainment or percolation from runoff. The risk of embankment stability issues is also high for the PR waste facility due to the need to provide subaqueous storage for the entire impoundment surface, resulting in a water pond immediately upstream of the embankment (no tailings beach).

The above issues will be exacerbated by the need to produce a consistent dewatered tailings product that satisfies performance requirements for a large tonnage, high production rate (100,000 tpd) operation.

The dewatered tailings option incorporates filtered tailings production technologies and delivery systems that are without precedent for the scale of operation anticipated for the Casino project, particularly for the cold winter conditions experienced at the site. Therefore, there are inherent risks in proceeding with this technology for the Casino project, unless appropriate contingency measures are incorporated in the mine waste management plan.



NOTES:

1. COORDINATE GRID IS UTM (WGS84/NAD83) ZONE 7 (m).
2. CONTOUR INTERVAL IS 25 METRES.
3. DIMENSIONS ARE IN METRES UNLESS NOTED.
4. PLANT SITE AND CRUSHER LAYOUT PROVIDED BY M3ENGINEERING AND TECHNOLOGY CORPORATION (APRIL 9, 2008).

SCALE A: 400 200 0 400 800 1200 1600 2000 m

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CASINO COPPER-GOLD PROJECT

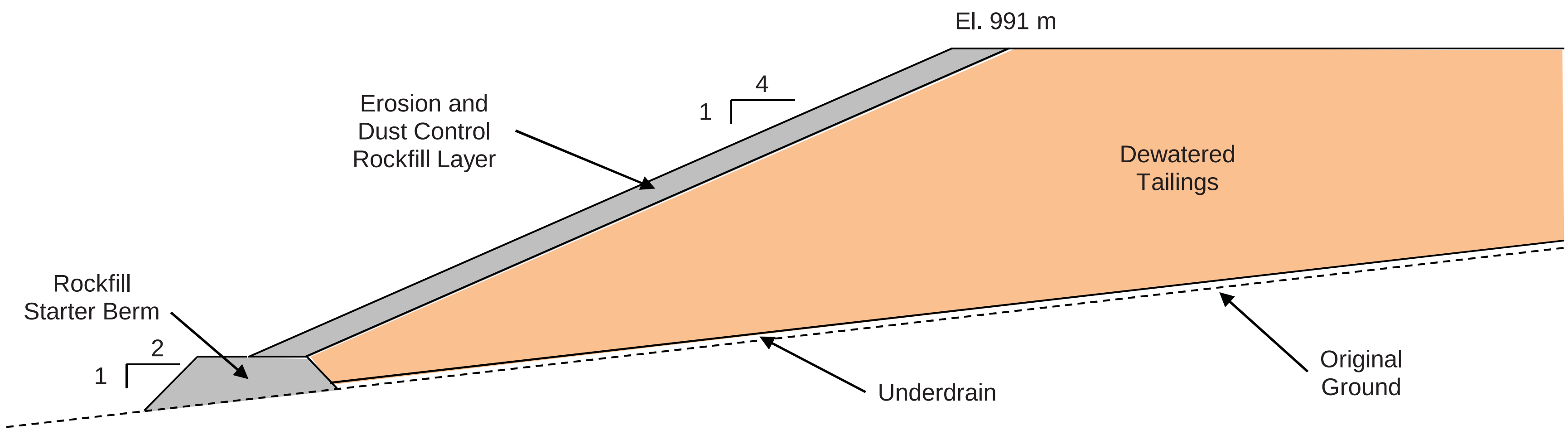
DEWATERED TAILINGS OPTION
GENERAL ARRANGEMENT

Knight Piésold CONSULTING

P/A NO.	REF NO.
VA101-325/3	2

Figure 4-10 — REV 0

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
0	16APR'10	ISSUED WITH REPORT	AG	SC	GRG	KJB



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CASINO COPPER-GOLD PROJECT

DEWATERED TAILINGS OPTION
DRY STACK FACILITY
TYPICAL SECTION

Knight Piésold CONSULTING

P/A NO. VA101-325/3

REF. NO. 2

Figure 4-11

REV 0

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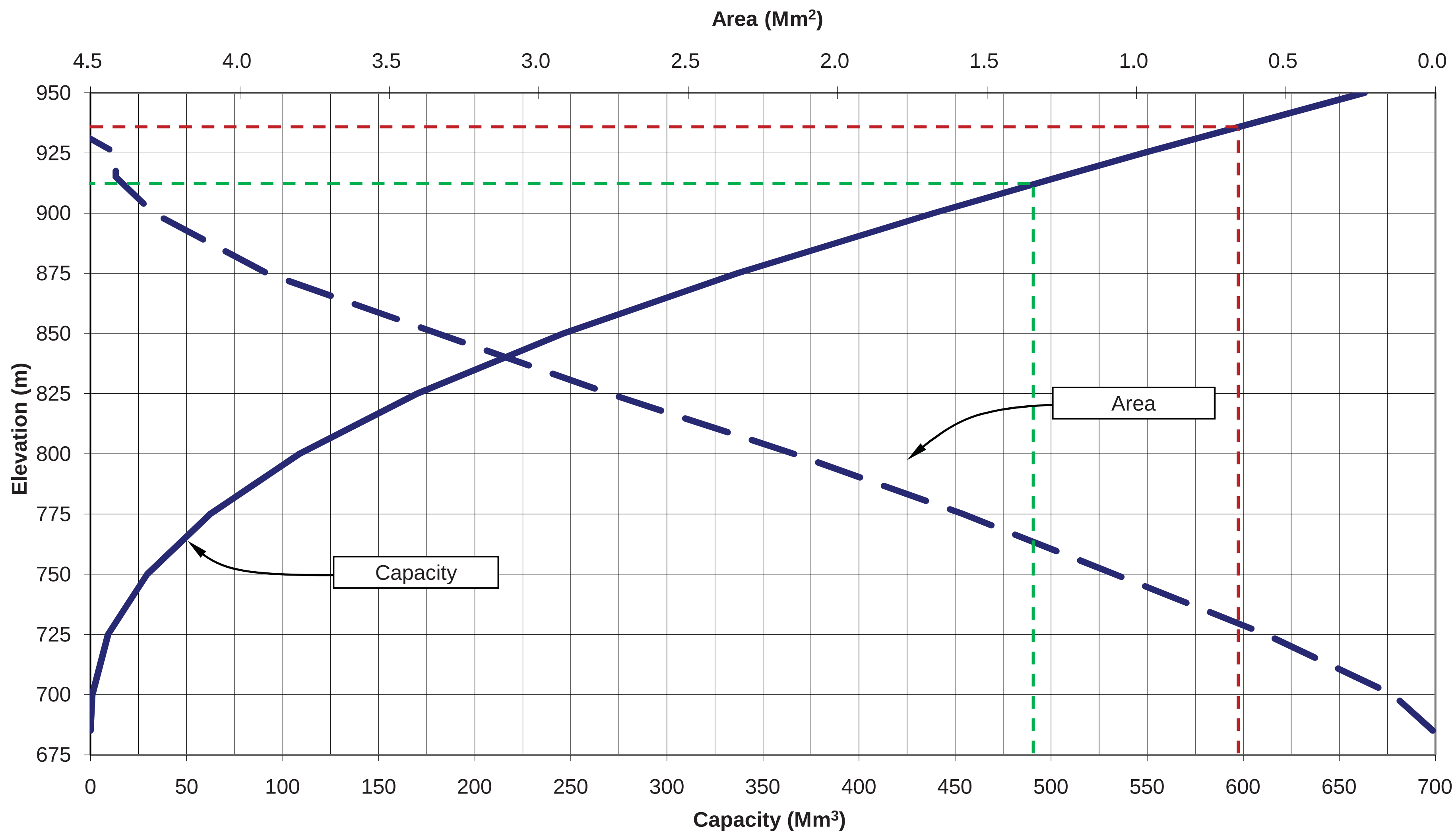


NOTES:

1. TAILINGS STORAGE VOLUME = 487.2 Mm^3.
2. EXPANDED CASE: TAILINGS STORAGE VOLUME = 596.4 Mm^3.

0	03MAY'10	ISSUED WITH REPORT	AG	GRG	KJB
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D

WESTERN COPPER CORPORATION

CASINO COPPER-GOLD PROJECT

DEWATERED TAILINGS OPTION
DRY STACK FACILITY
DEPTH-AREA-CAPACITY RELATIONSHIP

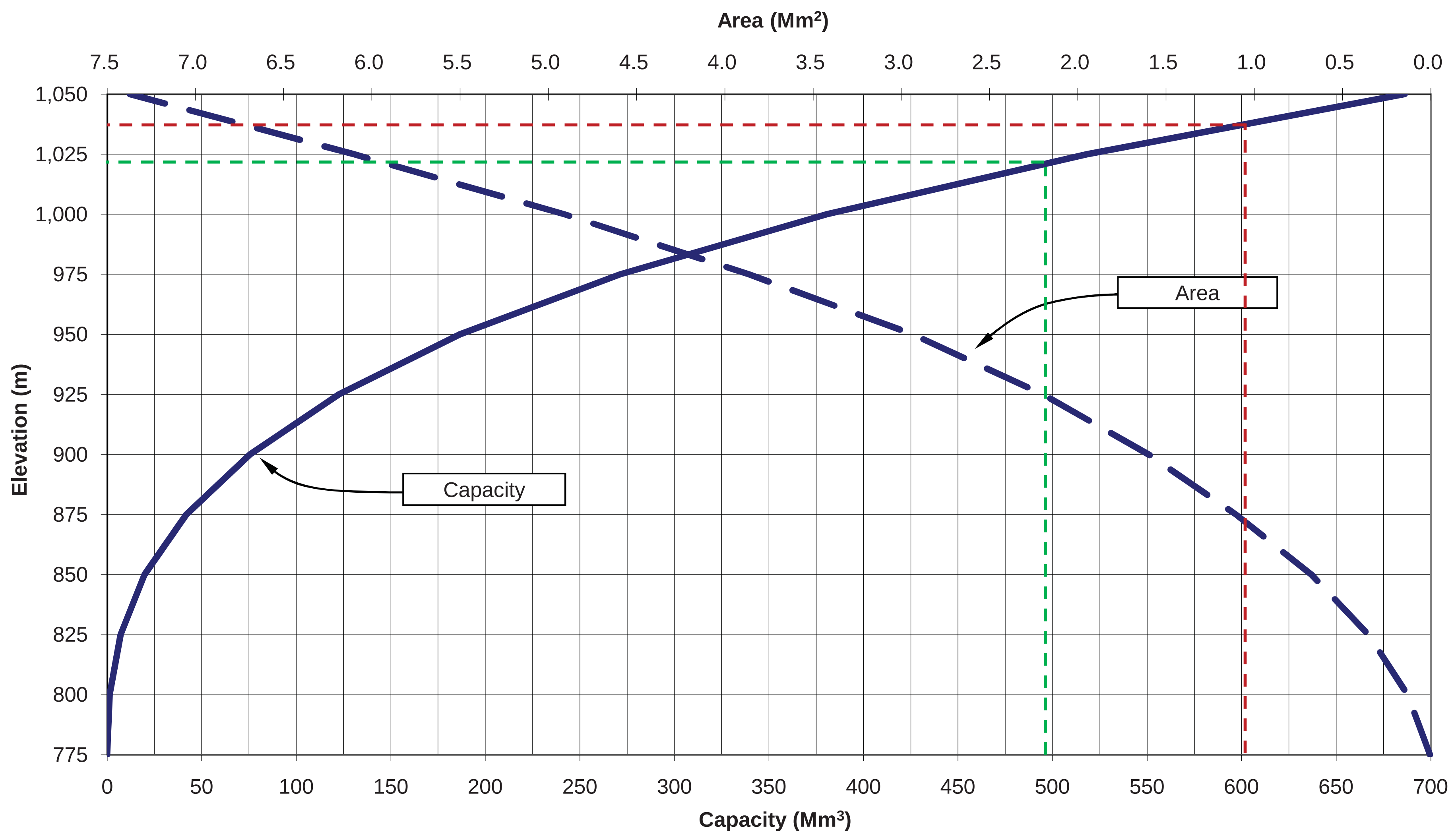
Knight Piésold CONSULTING

PROJECT / ASSIGNMENT NO. VA101-325/3

REF NO. 2

Figure 4-12

REV. 0



NOTES:
1. TAILINGS PLUS PAG AND ML WASTE MATERIAL STORAGE VOLUME = 492.7 Mm^3.
2. EXPANDED CASE: TAILINGS PLUS PAG AND ML WASTE MATERIAL STORAGE VOLUME = 603.9 Mm^3.

WESTERN COPPER CORPORATION

CASINO COPPER-GOLD PROJECT

DEWATERED TAILINGS OPTION
POTENTIALLY REACTIVE WASTE FACILITY
DEPTH-AREA-CAPACITY RELATIONSHIP

Knight Piésold CONSULTING

PROJECT / ASSIGNMENT NO. VA101-325/3 | REF NO. 2

Figure 4-13 | REV. 0

REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D
0	19MAY'10	ISSUED WITH REPORT	AG	GRG	KJB

4.4 MANAGEMENT ALTERNATIVES ASSESSMENT

A comparative scoping level evaluation has been carried out for the four TMF options described above. The potential advantages and short-comings of each TMF option have been examined, including consideration of construction and operating factors for a large scale mine waste management plan in cold climate conditions. The preferred TMF option will be that which is best suited to the site-specific circumstances and requirements. No “one size fits all” solution is available to address every particular and unique environmental, design and operational issue. The chosen option will aim to apply the best available and most appropriate technology, with a commitment to best management practices and cost effectiveness.

Primary design and operating, environmental, and economic considerations for the TMF options are discussed below.

4.4.1 Technical Considerations

Design and operating considerations include adapting to inevitable changes and variability in the mill throughput (production rate and material composition); embankment stability requirements, construction material availability and suitability, TMF seepage control, tailings handling and delivery, pipeline and pumping systems reliability, flexibility and redundancy, tailings deposition and reclaim water management, water management, and closure requirements.

4.4.1.1 Operational Complexity

The water management system for the cycloned sand and dry stack options will be more complex than that required for a conventional tailings management system as utilised for the option using local borrow materials for embankment construction. Two reclaim water systems are required to provide mill process water and feed water for the cycloned sand plant. Also, two mine waste facilities (dry stack and PR waste facility) with very different design and operating requirements are required for the dewatered tailings option.

A TMF that utilises local borrow materials for embankment construction will require a significant quantity of suitable rock/earthfill material that is characterised as non-potentially acid generating and does not exhibit metal leaching potential. Potential locations to source this material are currently not defined.

Placement of embankment fill during the winter months using local borrow (rockfill) materials will be less challenging compared to the other two TMF options. Embankment construction using local borrow materials can be performed year round, although the efficiency of construction operations will likely be less during the winter months. Cyclone sand production and placement may be limited to about 9 months of the year, due to the cold winter climate at the Casino site. Bulk tailings discharge into the TMF will be required during any cessation in cyclone sand production. The availability of cyclone sand for embankment construction is dependent on a number of factors and may not meet embankment construction material requirements at certain times during operations. However, shortfalls in sand production can be balanced with suitable (geochemically innocuous) rockfill from open pit stripping and/or from local borrow sources or quarry.

However, it may be necessary to utilize earth/rockfill materials in the initial years of operations to accommodate any shortfall of cyclone sand availability for construction of staged embankment expansions. Embankment staging, sand cell construction sequencing and integration with rockfill placement schedules (if required) will need to be examined in more detail for future design studies. Suitable earth/rockfill materials may also be required to provide erosion protection and minimise dusting for the cyclone sand embankment, and to satisfy embankment stability requirements. Use of cyclone sand as embankment fill reduces the amount of solids that are stored within the TMF by a volume roughly equivalent to the volume of sand used for construction. This allows for either additional storage capacity or a reduced embankment height.

The potential benefits of thickened tailings (such as smaller tailings facility footprint, lower embankment dam) would be minor, and would likely be outweighed by the higher capital, operating and maintenance costs and increased operational complexity likely to be associated with a dewatered tailings system at this project site.

The dewatered tailings option requires two individually managed facilities, both of which will have their own operating requirements and challenges. The need to operate two facilities will only add to the complexity of the mine waste management plan. All of the design and operating issues identified with the use of local borrow materials for embankment construction will also apply to the PR waste facility.

4.4.1.2 Geotechnical Stability

The static and seismic stability of the confining embankments is an important consideration for each of the TMF options, due to the large dam heights required. The TMF option that utilises local borrow for embankment construction requires a final embankment exceeding 300 m in height. A final embankment height of 286 m is required for the cyclone sand option. Although the dewatered tailings option requires a lower final embankment height (about 280 m), the stability and integrity of the dry stack and PR waste facilities will likely have a higher risk of potential issues associated with embankment stability and integrity.

The use of cyclone sand fill in embankment construction provides a corresponding reduction in impoundment storage requirements, resulting in a reduced embankment height. The final embankment for the cyclone sand option is approximately 18 metres lower than the TMF option using only local borrow (rockfill) materials. This is relatively minor given the large quantity of sand tailings that will be utilised in embankment construction, but is due to the storage characteristics of the TMF in the later years of operations (large storage capacity increase for a small increase in TMF height).

4.4.1.3 Geochemical Characteristics

Tailings and waste rock produced at the Casino mine must be subaqueously disposed of in a tailings management facility. Sub-aqueous disposal will prevent sulphide oxidation in mine waste and is considered geochemically favorable compared to disposal in an unsaturated environment. All four disposal options would require long-term subaqueous disposal of the PAG tailings and waste rock behind a geotechnically sound dam. The cyclone sand option would require a smaller dam as the NAG tailings could be used in the construction of the dam itself, thereby reducing the volume of material required to be stored in the impoundment.

The use of dewatered tailings is unlikely to change the general design requirements for the TMF at the Casino project. The facility would still need to provide a confining embankment, storage for water management (surplus), accommodate storm water flows, as well as maintaining an appropriate water cover over potentially reactive mine waste materials (to inhibit oxidation) placed into the TMF for co-disposal.

A dry stack facility could store the majority of the NAG tailings and would require significantly less material for the confining embankments, compared to disposal by conventional tailings slurry discharge. However, a separate facility is still required to provide subaqueous storage and confinement of potentially reactive waste rock (PAG and ML) and pyritic tailings, and to provide a facility for water management (including recovery to the mill) and contingency storage for those periods when the dry stack facility or dewatering plant is not operational. Pyritic tailings (assumed to be approximately 20% of the total tailings) and all PAG and ML waste rock will be deposited within a Potentially Reactive (PR) waste facility located in the Casino Creek valley south-east from the Open Pit.

4.4.2 Environmental Considerations

Selection of a preferred mine waste management option requires consideration of several environmental factors, including (from Journeaux Assoc., 2012):

- Sub-catchment area;
- Footprint area;
- Potential for generating dust;
- Potential for acid rock drainage and metal leaching;
- Potential for seepage to impact groundwater;
- Potential for geotechnical hazards (includes consideration of foundation conditions, impact of seismicity and height of structure);
- Aquatic habitat loss;
- Visual impact;
- Terrestrial wildlife habitat loss (song birds, water fowl and terrestrial mammals);
- Aquatic wildlife habitat loss (water fowl); and
- Impact on fish and fish habitat.

For the mine waste management options presented in this study, the cyclone sand option has the smallest footprint within the Casino Creek valley. The TMF embankment constructed of local borrow materials will create an impoundment only slightly larger than the cyclone sand option. However, it will also include a large disturbance area outside of the TMF associated with the large borrow area(s) required to provide sufficient rockfill material. The dewatered tailings dry stack facility and adjacent PR waste facility will create the largest disturbance area. The dry stack option also has the largest direct catchment area and will likely have the largest impact on water resources.

Impacts to air quality related to dusting due to construction traffic and windblown sand from the tailings embankments will be higher for the cyclone sand and tailings dry stack facilities. Appropriate provisions to manage dusting will be required for these two options.

4.4.3 Socio-Economic Considerations

Many of the environmental considerations noted above are also socio-economic considerations. Potential environmental effects have a direct impact on local communities and on the lives of those who live in those communities. For example, the TMF footprint area affects use and enjoyment of land during and after operations. Also, the potential for loss of aquatic and terrestrial wildlife affects the way of life for people in local communities.

4.4.4 Economic Considerations

Preliminary order of magnitude initial capital, sustaining capital and operating costs, including costs for material preparation, transport and placement, have been prepared to facilitate a comparative economic assessment of the three TMF options (economic evaluation not conducted for the thickened tailings option). The economic evaluation considers capital and operating costs associated with storage of tailings and waste rock for the full mine life. A summary of the estimated capital and operating costs for the three TMF options is provided in Table 4-2.

Table 4-2: Summary of Initial Capital, Sustaining Capital and Operating Costs (in Million $CAD)

TMF Option	Initial Capital Cost	Sustaining Capital Cost	Operating Cost	Total Cost
Local Borrow	82	1,009	139	1,230
Cyclone Sand	101	597	263	961
Dewatered Tailings	265	1,822	902	2,988

The cycloned sand and dewatered tailings (dry stack) options have larger initial capital costs compared to the option using only local borrow material for embankment construction. The initial capital cost for the cyclone sand option is approximately $20 million more than the local borrow materials option. This is primarily due to the high initial capital costs associated with construction of a cyclone sand plant and associated infrastructure. The initial capital cost for the dewatered tailings option is approximately three times greater than the local borrow materials option and cyclone sand option. High initial capital costs for the dewatered tailings option are associated with the tailings dewatering (filtration) plant, tailings transportation (conveyor/truck delivery system) and provision of a PR waste facility to accommodate subaqueous disposal of PAG and ML waste material and pyritic tailings.

The local borrow materials and dewatered tailings options have significantly larger sustaining capital costs compared to the cyclone sand option. The sustaining capital cost for the cyclone sand option is approximately $410 million less than the local borrow materials option and approximately $1,225 million less than the dry stack option. This is primarily due to the lower unit rate of fill material used for embankment construction. The local borrow materials option has the smallest operating cost of the three options due to lower power requirements.

The use of cyclone sand for TMF embankment construction has the potential to utilize approximately 220 million tonnes of tailings sand which will displace 275 million tonnes of rockfill from within the embankments. The total savings associated with the use of cyclone sand over locally quarried rockfill is in the order of $270 million over the operating life of the facility.

Closure Costs

The local borrow material and cyclone sand dam options would be comparable in terms of closure costs to sustain the water cover in the impoundment, and to provide long-term monitoring and maintenance of the dam. However, the local borrow material would require a larger dam (303 m vs. 286 m) and would require upwards of 105 million m^3 of borrow material. This borrow excavation would require substantial reclamation, thereby increasing the closure costs of the borrow material dam option well above those of the cyclone sand dam option.

The dewatered tailings option would require two dams: one for storage of potentially reactive material 280 m high, and the other for containment of the dry stack tailings, 226 m high. Therefore, the closure costs of the dewatered tailings option would be equal those for the cyclone sand dam option *plus* the costs for closure of the dry stack tailings.

Therefore, the cyclone sand dam option has significantly lower costs for closure than the local borrow material or the dewatered tailings disposal options.

4.5 SELECTION OF MANAGEMENT OPTION

Based on the discussion above, the four options have been ranked with values of 1 through 4, to determine the most appropriate selection. Where there is no difference in the option used, a “-“ symbol is used to signify “equal”.

Option	**Slurried Tailings Borrow Material Dam**	**Slurried Tailings Cyclone Sand Dam**	**Paste Tailings**	**Filtered Tailings (Dry Stack)**
Consideration	**Weighting**			
Technical				
Operational Complexity	4	3	1	1
Geotechnical Stability	4	4	4	1
Geochemical	4	4	4	3

characteristics				
Environmental				
Potential for seepage	2	2	3	3
Area of disturbance	3	4	3	1
Air Quality	4	2	4	2
Visual impact	-	-	-	-
Terrestrial wildlife habitat loss	-	-	-	-
Impact on fish and fish habitat.	-	-	-	-
Economic	2	4	n/a	1
TOTAL	***19***	***23***	***19***	***12***

The dewatered tailings option incorporates filtered tailings production technologies and delivery systems that are without precedent for the scale of operation anticipated for the Casino project, particularly for the cold winter conditions experienced at the site. Therefore, there are inherent risks in proceeding with this technology for the Casino project, unless appropriate contingency measures are incorporated in the mine waste management plan.

The paste tailings option has increased operational complexity, with increased likelihood of periodic upset conditions increases, and more complex tailings handling and disposal systems, the potential for mill shutdown or spillage may be significantly greater than for conventional slurry tailings disposal. Also, the use of dewatered tailings is unlikely to change the general design requirements for the TMF. The facility would still need to provide a confining embankment, storage for water management (surplus), accommodate storm water flows, as well as maintaining an appropriate water cover over potentially reactive mine waste materials (to inhibit oxidation) placed into the TMF for co-disposal.

The option for constructing a dam from local borrow material was ranked equally to the paste tailings options, however, is technically comparable to the cyclone sand dam option. However, preliminary evaluation of borrow availability indicates that to acquire borrow in sufficient quantities to build the embankment entirely of borrow would require excessive disturbance and movement of materials.

Therefore, the comparative assessment indicates that the use of cyclone sand for embankment construction is the preferred option. It provides low operational complexity and controllable geotechnical conditions given the project's location and water conditions, while incurring the least disturbance to the environment.

5 WASTE MANAGEMENT STORAGE SITES

5.1 OBJECTIVES AND ASSUMPTIONS

Following the above determination of preferred mine waste management strategy, a number of TMF locations were evaluated. The evaluation consists of a screening level screening and a detailed evaluation level assessment, detailed below. The development of options initially considered for the project encompasses a larger number of potential waste storage locations than that included the formal evaluation. These locations are termed *potential storage sites* rather than *options*. Those sites that were not excluded at the screening level were developed in greater detailed and termed waste management location options. Both screening level and detailed evaluation results are described herein as:

1. Scoping level identification and screening of potential storage sites; and
2. Detailed development and assessment of selected waste management location options.

5.2 SCOPING LEVEL SCREENING

All potential storage sites are shown on Figure 5-1 and summarized in Table 5-1. The threshold criteria used to scope these sites included the following:

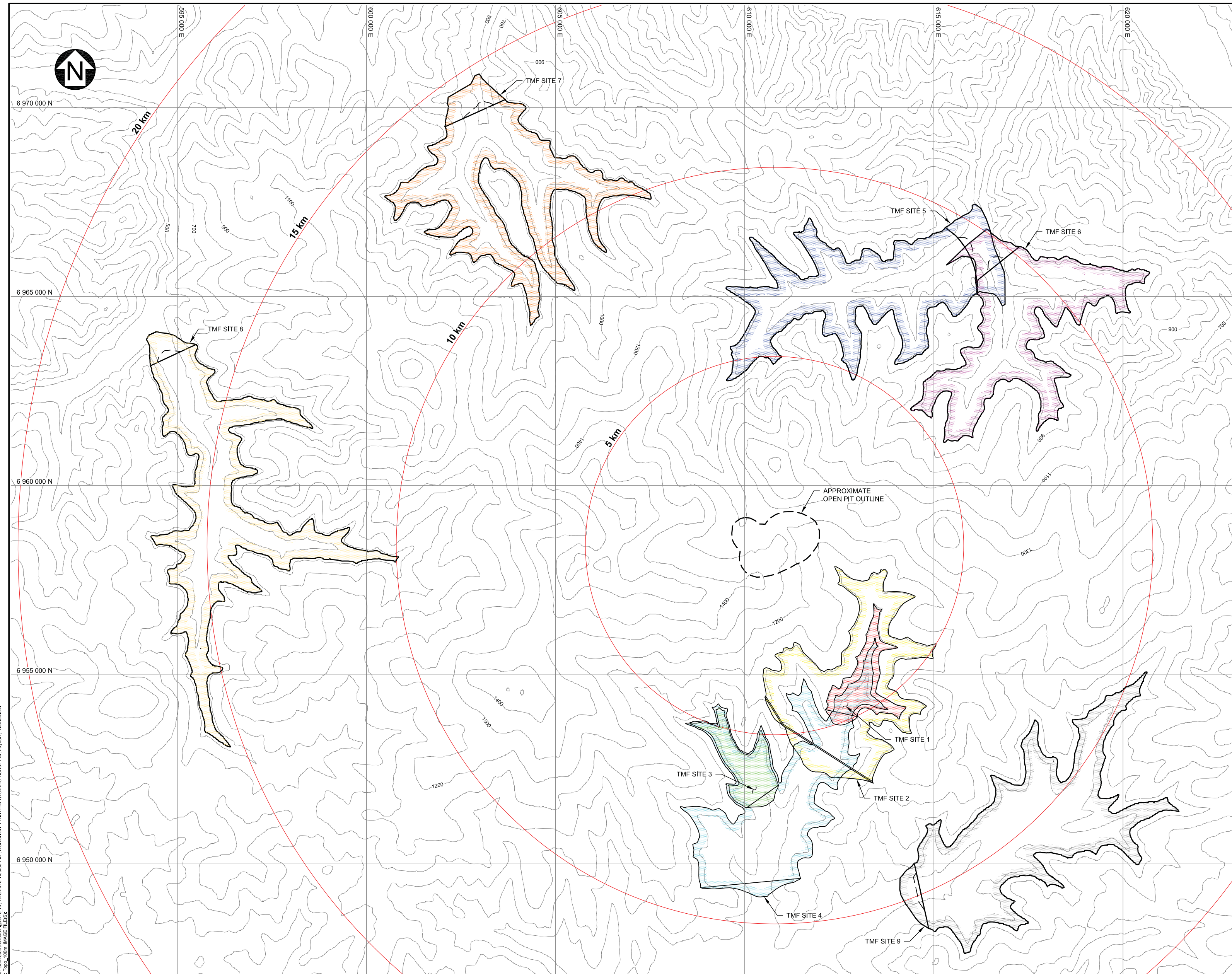
- Sites were within 20 km radial distance from the deposit area;
- Sites would have sufficient capacity (956 Mt of tailings and up to 685 Mt of waste rock); and
- Only considered conventional tailings slurry deposition as anticipated production rates are in excess of what could be managed via dry stack alternatives (as per Section 4 above).

Pre-screening of these potential storage sites was done via a set of specific questions including as summarized in Table 5-2 below.

Table 5-1: Summary of Scoping Level TMF Sites

Site	Construction Approach	Operational Approach	Closure Approach
Site 1	Construction of starter dam, diversions around facility for clean run-off. Insufficient capacity as TMF, possibly useful for scenario with multiple sites	Sub-aqueous deposition of PAG tailings, raises constructed of cyclone sand, overflow to beach, water deficit, so no discharge, capacity insufficient for waste rock storage.	Water cover over PAG tailings, dry cover on beach, waste rock storage elsewhere would require appropriate closure measures.
Site 2	Construction of starter dam, diversions around facility for clean run-off.	Sub-aqueous deposition of PAG tailings, raises constructed of cyclone sand, overflow to beach, sub-aqueous deposition of waste rock, water deficit anticipated, so make-up water likely required.	Dry cover over beach area, water cover over PAG tailings and waste rock.
Site 3	Insufficient capacity as TMF but potential water supply dam or as scenario with multiple dams.		
Site 4	Construction of starter dam, may include significant foundation prep work, diversions around facility for clean run-off.	Sub-aqueous deposition of PAG tailings and waste rock, dam raises use cyclone sand with NAG overflow to beach, water surplus anticipated, so discharge likely required.	Dry cover over beach area, water cover over PAG tailings and waste rock.
Site 5	Construction of starter dam, diversions around facility for clean run-off.		
Site 6			
Site 7			
Site 8			
Site 9			
Multiple Sites[1]	Construction of 3 starter dams in the upper reaches of Casino Creek, Austin Creek and Brynelson Creek with associated water diversions	Storage of tailings in one facility and waste rock in 2 other facilities. Only the tailings facility would have raises constructed by cyclone sand, the other facilities would require rockfill or borrow material	A combination of water and dry covers on 3 facilities.

1. The alternative for more than one facility is included to allow for waste storage in the upper reaches of watersheds to clearly avoid areas frequented by fish, 3 facilities would be required to meet capacity needs.



NOTES:

1. COORDINATE GRID IS UTM (WGS84/NAD83) ZONE 7 (m).
2. CONTOUR INTERVAL IS 100 METRES.
3. DIMENSIONS AND ELEVATIONS ARE IN METRES, UNLESS NOTED OTHERWISE.

SCALE A: 1 0.5 0 1 2 3 4 5 km

WESTERN COPPER CORPORATION

CASINO COPPER-GOLD PROJECT

ALTERNATIVE TAILINGS MANAGEMENT FACILITY SITES

Knight Piésold CONSULTING

P/A NO.	REF NO.
VA101-325/3	VA10-01163

Figure 5-1 | REV 0

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
0	19JUL'10	ISSUED WITH MEMO	AG	NSD	GRG	KJB

Table 5-2: Pre-Screening Assessment

Criteria	Rationale	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Multiple Sites
Would the TMF have sufficient capacity?	It is preferable to have one TMF location except for specific rationale as in the case of our Multiple Sites option	NO	YES	NO	YES	YES	YES	YES	YES	YES	YES
Would the TMF have expansion potential?	In the case of project expansion important to understand if another facility would be required?	NO	YES	NO	YES	YES	YES	YES	YES	YES	NO
Would the TMF avoid sensitive fish habitat?	It is preferable to the extent possible to avoid sensitive fish habitat.	YES	YES	YES	YES	YES	NO	NO	NO	NO	YES
If greater than ~10 km from the deposit, would the TMF provide advantages that do not exist at sites closer to the deposit?	Sites located within 10 km of the deposit are preferable to those at greater distances unless there is a particular advantage with greater distance	-	-	-	-	-	NO	NO	NO	NO	-
Should the site be excluded from further assessment?		YES	NO	YES	NO	NO	YES	YES	YES	YES	NO

5.3 DEVELOPMENT AND ASSESSMENT OF POTENTIAL OPTIONS

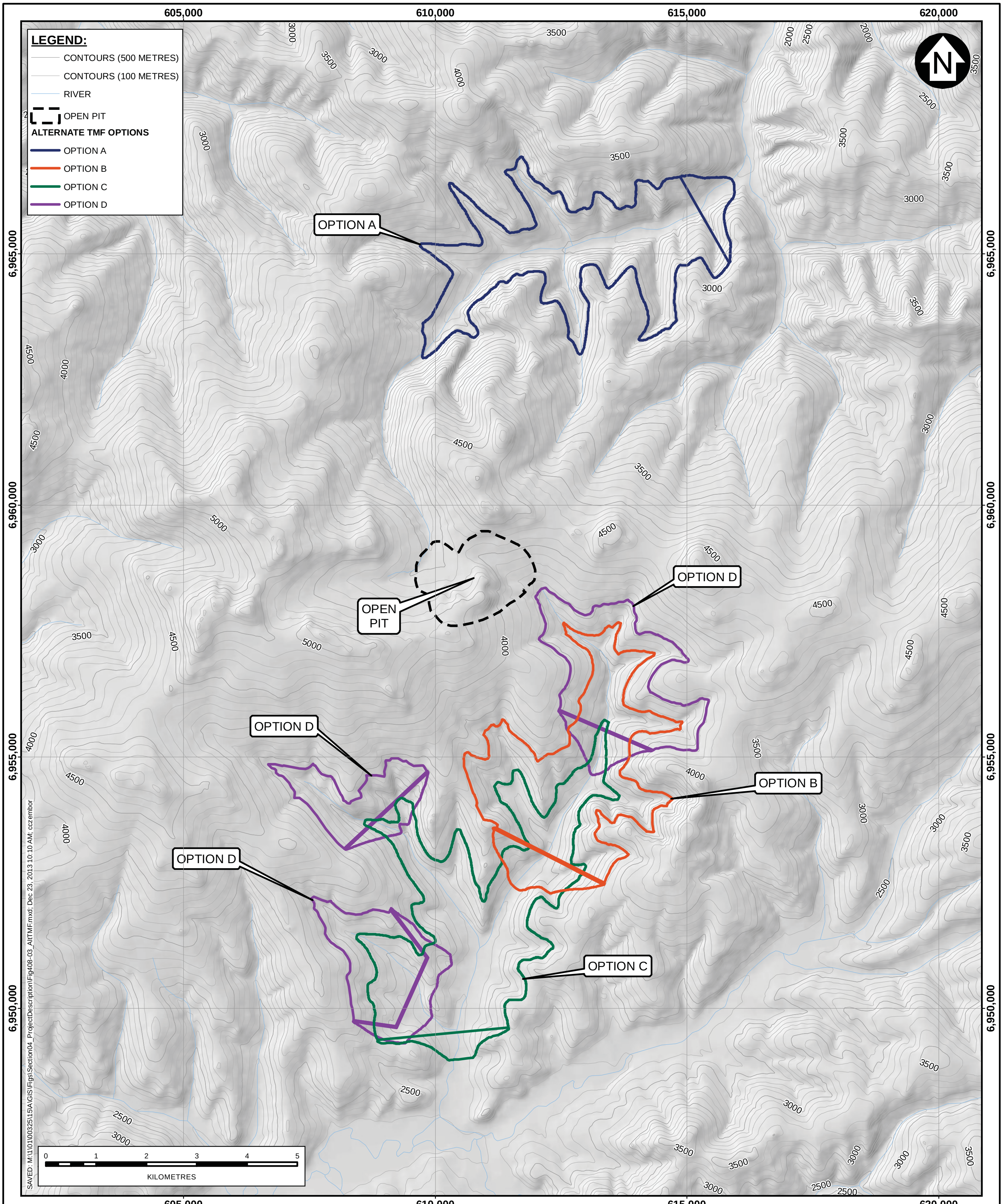
Those sites that were not fatally flawed in the pre-screening evaluation were carried forward into a more detailed assessment. These sites have been structured into the potential Options shown on Figure 2. Potential Options have been given a letter designation so as to differentiate them from the numbered sites from scoping and pre-screening. Labeling starts with the northern-most location and goes southward and include:

- Option A: Canadian Creek location (pre-screening site #5), shown in Figure 5-3. Option A includes a TMF dam located within Canadian Creek just above the confluence with Britannia Creek which drains to the Yukon River located approximately 7 km from the toe of the dam. The facility has capacity to place all tailings and waste rock in a subaqueous environment.

- Option B: Upper Casino Creek (pre-screening site #2) as shown in Figure 5-4. Option B represents the most compact footprint for the overall project. Capacity is sufficient to store all the tailings with underwater disposal of waste rock. Other facilities such as the heap leach facility would drain towards the TMF facility.

- Option C: Lower Casino Creek (pre-screening site #4) shown in Figure 5-5. Option C is located approximately 5 km further downstream from the Option B configuration. This option would provide for sufficient capacity for all tailings and subaqueous disposal of waste rock. As in the Option B configuration, the other facilities such as the heap leach facility would drain towards the Option C impoundment.
- Option D: Option D (pre-screening site “Multiple Sites”) combines a number of sites with the objective of keeping all waste well above any areas frequented by fish. Because of topographic challenges with this approach, three locations are required to provide for the needed capacity (Figure 5-6) located in Upper Casino, Upper Brynelson and Upper Meloy drainages. Option D was developed to clearly avoid areas frequented by fish. In order to accomplish this objective, multiple sites would be required, each located in the upper reaches of three watersheds, namely Casino Creek, Meloy Creek and Brynelson Creek. The non-acid generating tailings would be stored in the Casino Creek facility while waste rock and the potentially acid generating tailings would be stored in the other two facilities.

Table 5-3 provides for some of the engineering characteristics of these potential options.



PREPARED BY:

Knight Piésold
CONSULTING

DESIGNED	CC
DRAWN	CC
CHK'D	CAH
APP'D	KJB
REV	0
DATE	16DEC'13

NOTES:
1. BASE MAP: YUKON GOVERNMENT SHADED RELIEF, EAGLE MAPPING.
2. PROJECTION: NAD 1983 UTM ZONE 7N
3. COORDINATE GRID: METRES

CASINO

CASINO PROJECT

Potential TMF Option Locations

Figure 5-2

REF 1

P/A VA101-325/15

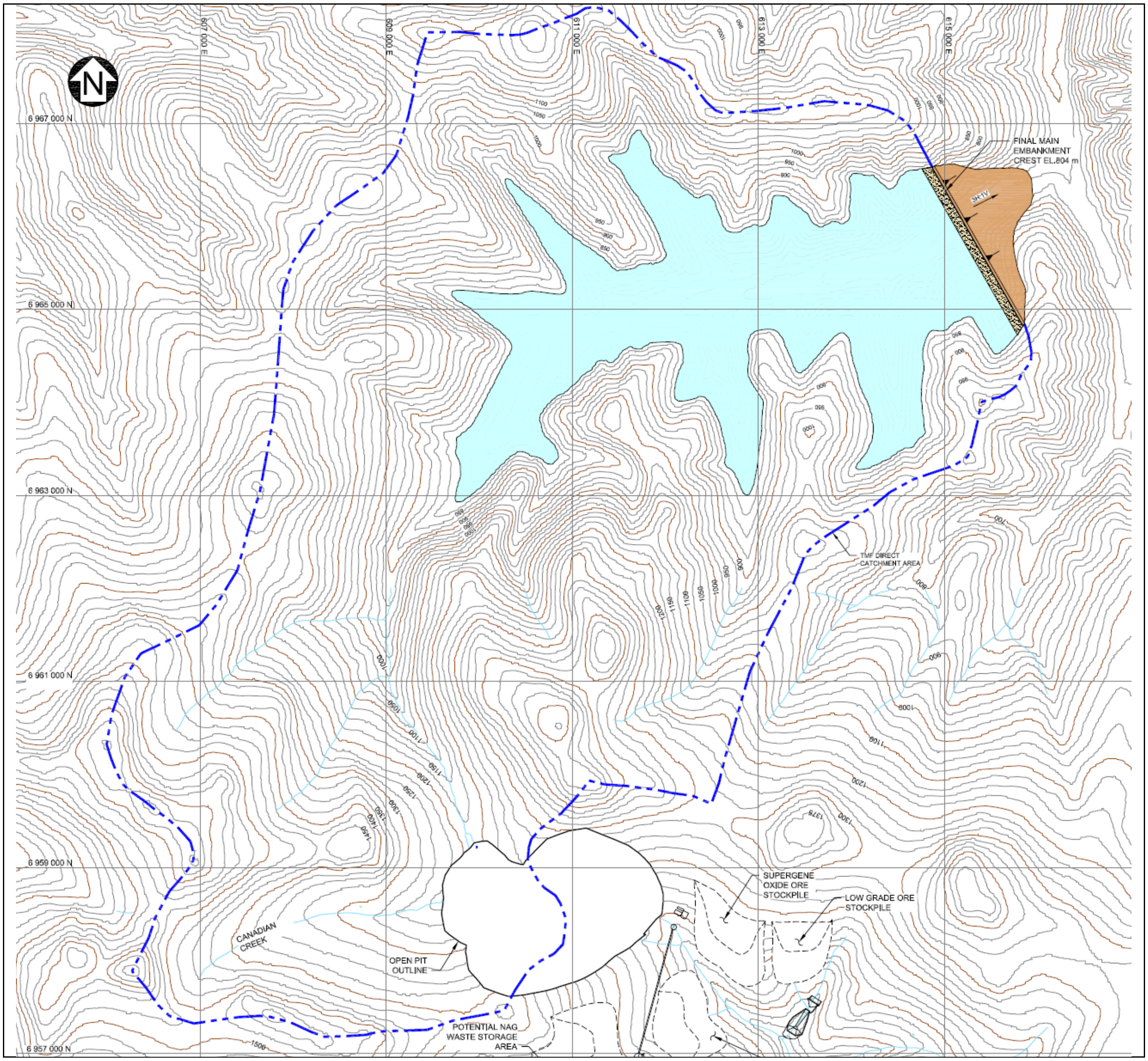


Figure 5-3: Option A: Canadian Creek (Site #5)

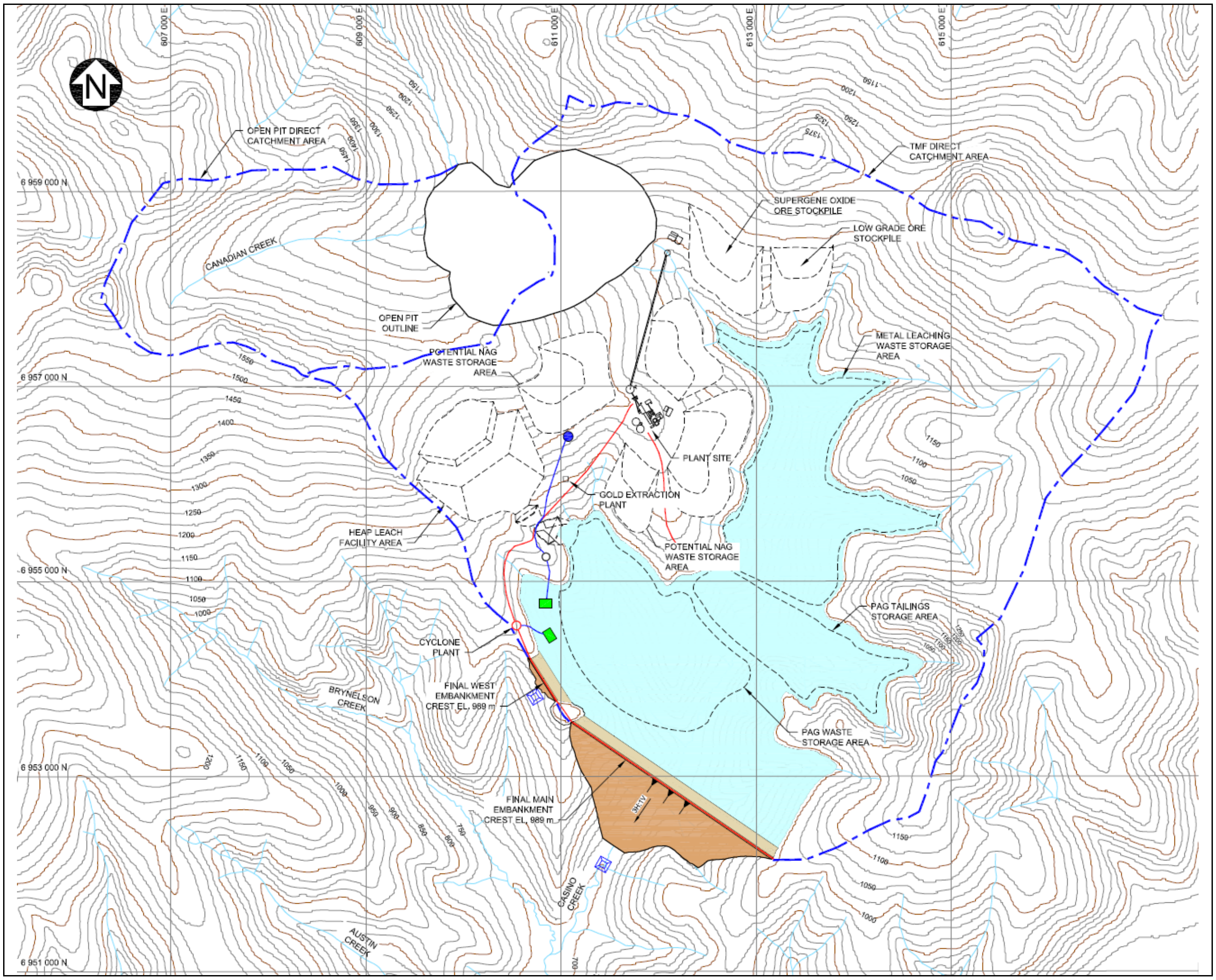


Figure 5-4: Option B: Upper Casino Creek (Site #2)

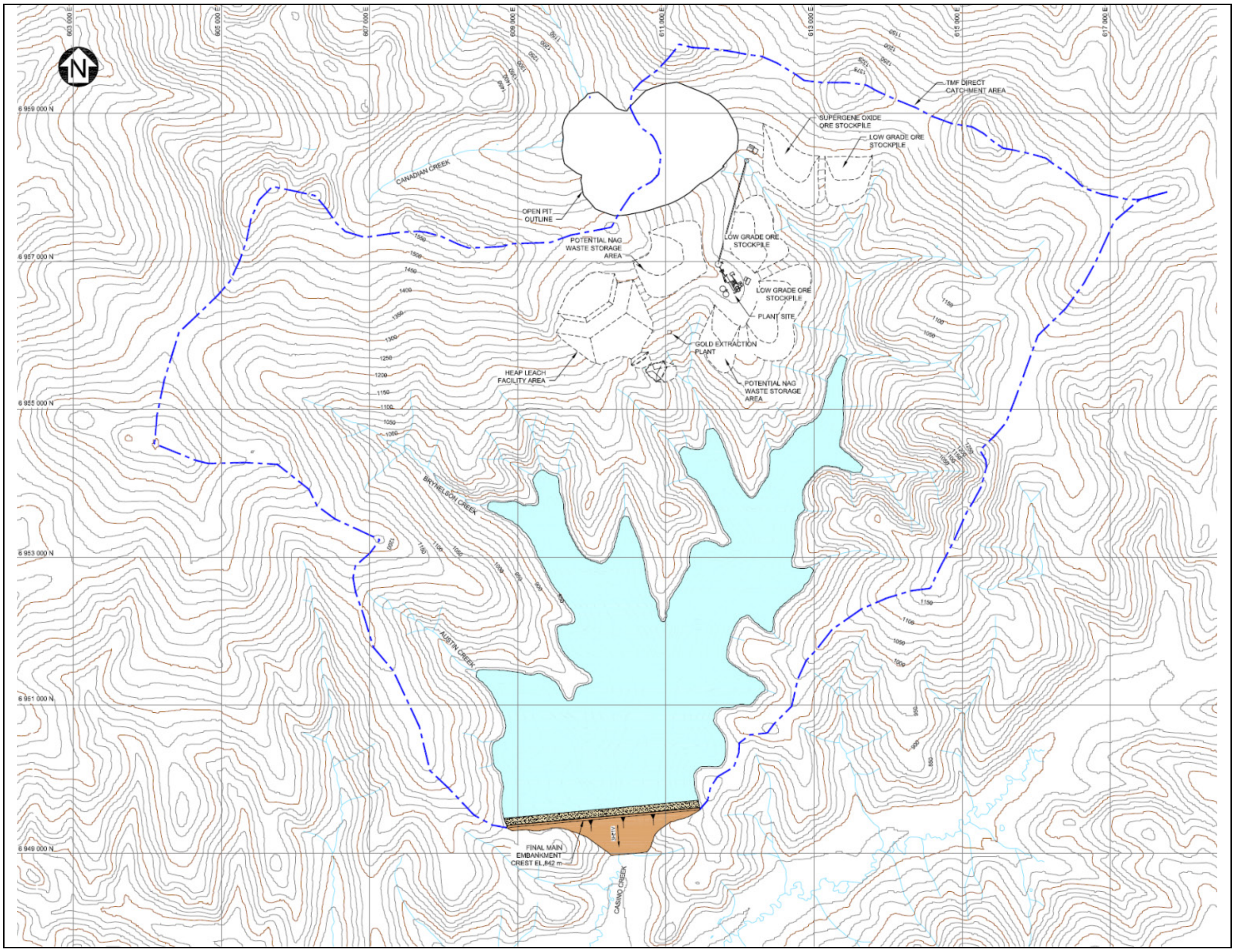


Figure 5-5: Option C: Lower Casino Creek (Site #4)

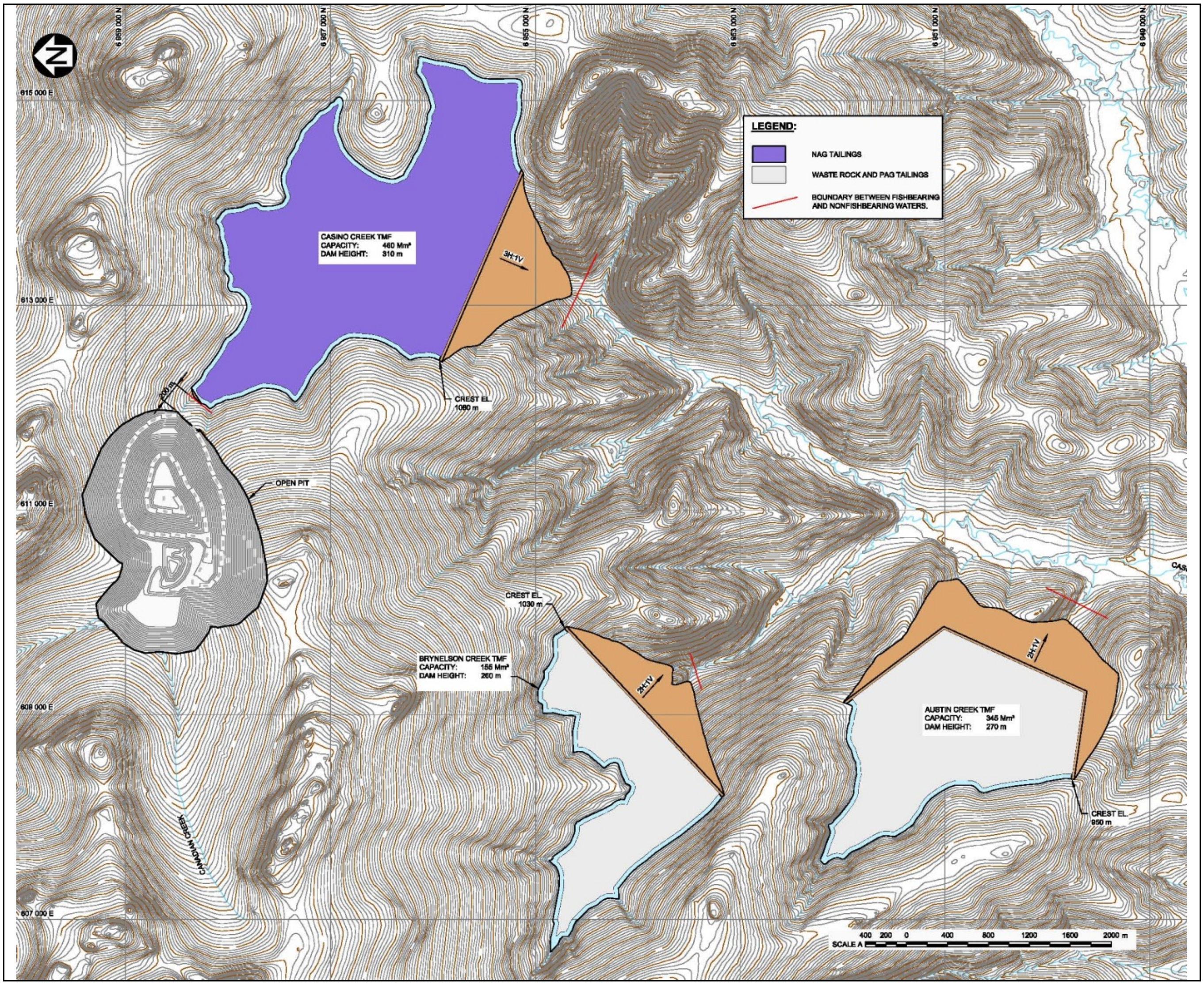


Figure 5-6: Option D: Upper Casino, Brynelson and Meloy Creeks (Site "Multiple Sites")

Table 5-3: Characteristics of Potential Options

Characterization Criteria	Rationale	Option A	Option B	Option C	Option D[1]
Maximum dam height (m)	In general higher dams may be slightly more complex, but all would be designed to meet guidelines provided by the Canadian Dam Association	284	286	192	300/270/260
Embankment volume (Mm^3)	Need to have sufficient cyclone sand for dam raises or borrow source	87	136	48	87/112/57 (256)
Embankment footprint (km^2)	An indication of the size of the facility	0.9	1.4	0.8	0.8/1.0/0.6 (2)
Impoundment storage volume (Mm^3)	An indication of the storage capacity and facility size	939.4	939.4	939.4	460/345/155 (960)
Impoundment footprint (km^2)	A measure of the facility size	10.2	9.8	13.0	5.8/3.1/2.2 (11)
Dam foundation conditions	An indication of potential complexity for foundation preparation work	Moderate to poor	Moderate to poor	Moderate to poor	Moderate to poor
Distance for road/pipeline alignment to dam (km)	Reflection of piping distance, access roads etc.	10	7	13	4.6/5.4/8.8 (18.8)
Catchment area (km^2)	Indication of water management issues	62	37	77	18.3/7.1/17.0 (42)
Total number of watersheds effected	There is a benefit to having all facilities in one single watershed	2	1	1	1
Operational water balance	An indication of whether discharge during operations is anticipated	Water surplus	Water deficit	Water surplus	Water surplus at times
Topography	The general topography consists of well-rounded ridges and hills with deeply incised drainages	Located in the upper reaches of the Britannia drainage, topography generally steep	Located in the upper reaches of Casino drainage, topography generally steep	Located in lower reaches of Casino drainage where valley flattens out.	Located in the upper reaches of three drainages, topography generally steep

Characterization Criteria	Rationale	Option A	Option B	Option C	Option D[1]
Climate	No significant differences in climate are expected for the options being considered other than potentially permafrost expectations (see below)	The climate in the Dawson Range is subarctic. Permafrost is widespread on north-facing slopes, and discontinuous on south-facing slopes. Annual precipitation is 500 mm with average temperatures of -2.7^{o}C			
Permafrost	The area has discontinuous permafrost, in general northern slopes may have greater permafrost	Drainage faces northeast, permafrost on the northern slopes could be greater	Drains to the south, no significant northern slope component	Drains to the south, no significant northern slope component	Three separate facilities, but generally drain to the south
Atmospheric issues	Fugitive dust can be an issue with TMF facilities, since all options consider conventional slurry the effects are considered minimal	No significant dust effects expected other than potentially minor dust from tailings beaches.			
Geochemistry	Waste is expected to be substantially PAG in nature with some NAG or low PAG oxide rock that could have ML issues; rougher tailings expected to be NAG, cleaner tailings expected to be PAG	Waste management includes sub-aqueous disposal of all PAG waste rock and tailings			
Water quality	The ability to meet water quality objectives for any option is a key consideration	Good baseline water quality, significant dilution available downstream	Baseline water quality is poor, little dilution until lower Casino and Dip Creek	Baseline water quality is good, some dilution at Dip Creek	Baseline water quality is mixed, very little dilution until lower Casino and Dip Creek
Vegetation	Vegetation consists of black & white spruce forests with aspen and some lodgepole pine. Black spruce & paper birch on permafrost slopes. Scrub birch and willow form extensive stands in subalpine sections from valley bottoms to well above the tree line	No substantive differences between options expected			
Aquatic life and habitat	The ability to remain protective of aquatic life and habitat is a key consideration for all options	Frequented by fish	Possibly frequented by fish	Frequented by fish	Non-fish bearing

Characterization Criteria	Rationale	Option A	Option B	Option C	Option D[1]
Terrestrial and bird life and habitat	No significant differences expected for the options considered	Characteristic wildlife in the region includes caribou, grizzly and black bear, dall sheep, moose,beaver, fox, wolf, hare, raven, rock and willow ptarmigan, and golden eagle			
Archaeology	Record of archaeological sites considered within the evaluation	None	None	None	None
Mineral/commercial tenures					
First Nations issues		Located within the Selkirk First Nation Traditional Territory			
Perception	The anticipated over-arching perceptions about the options could influence decisions	Concerns about potential effect on the Yukon River	No concerns	Concerns about potential effects on fish	Concerns related to three large dam structures
Previous and existing land use	Will the option have an undue effect on existing or previous land uses in the immediate area	Placer mining activities in the area, exploration activities	Exploration activities, others?		
Aesthetics	Visibility of the site will be limited for any of the options	No aesthetic effect anticipated			
Human safety	Safety always held as paramount concern by mining companies, none of the options are considered 'unsafe'	Dam designed as an extreme classification	Dam designed as an extreme classification	Dam designed as an extreme classification	Three dams designed as having extreme classifications

1. Values provided for Option D are for three individual dams Casino Creek/Meloy Creek/Brynelson Creek respectively with the sum of the three in brackets where appropriate

5.4 EVALUATION OF SELECTED OPTIONS

5.4.1 Technical Considerations

The technical account encompassed those aspects that are commonly included in the engineering assessments completed to select tailings facility locations. The sub-accounts and indicators were selected therefore in an effort to differentiate between the fundamental engineering considerations for the various options (e.g. capacity of the facility) and the geotechnical considerations that may be option-specific (e.g. foundation conditions). Many of the indicators of technical aspects of each option were quantifiable and are described individually in the sections to follow. A summary of the ranking results are provided in Table 5-4, and the ranking and weighting results are provided in Appendix A.

Table 5-4: Technical Considerations Ranking Results

Sub-Accounts	Indicators	Option A	Option B	Option C	Option D
		TIA+WR in Canadian Creek	TIA+WR in Casino Creek (Upper)	TIA+WR in Casino Creek (Lower)	TIA+WR avoiding areas frequented by fish
Dam Design	Impoundment storage volume	6	6	6	6
	Dam size and configuration	4	4	6	1
	Number of large dams required	6	6	6	4
	Total embankment volume	5	4	6	1
Operational Management	Impoundment footprint	5	6	2	4
	Operational ease - tailings	5	6	5	4
	Operational ease - waste rock	4	6	4	3
Construction	Geotechnical complexity	5	6	5	2
	Scheduling (construction)	5	4	6	1
Structural Stability	Stability considerations operations and long term	4	5	6	2
Permafrost	Permafrost sensitivity	6	6	6	6
Capacity	Expansion potential	4	4	6	2

5.4.1.1 Dam Design

The dam design sub-account was evaluated using indicators or measures of the physical nature of the tailings dams associated with each option as described below.

Impoundment storage volume

One of the design aspects for the potential options identified for the project was that each option would be able to store all the tailings and reactive waste rock. While all potential options meet this minimum requirement, there is benefit of having additional volume to accommodate potentially extended mine life, changed volume of waste rock resulting from changing metal prices and cut-off grades etc. Options A, B and C were all designed to have the same storage volume of ~940 Mm^3, while Option D would have a slightly higher cumulative storage volume of 960 Mm^3. This differential however was considered to be inconsequential and all options were considered to be equally ranked (i.e. the same) and given a scalar value of 6, i.e. all options would have the volume to meet the design basis for volume.

Dam size and configuration

The indicator selected to represent the dam size and configuration was dam height. In general, the higher the dam the slightly more complex the design; however dam design for all options would be conducted to meet the guidelines provided by the Canadian Dam Association (CDA) regardless of height. Options A and B which would both be located relatively high in their respective watersheds in tight valleys would have similar dam heights (284 and 287 m respectively). For the same volume, Option C which would be located lower in Casino Valley would be a lower, though longer dam (192 m) while Option D with three dams located high in three of the valleys would require a combined height of 960 m (460, 345 and 155m combined).

Number of large dams required

Typically the number of large dams considered for any one project is limited to the main tailings dam structure, i.e. does not include structures for seepage collection ponds etc. With the increased size of mining operations and the more common management practice of sub-aqueous disposal of waste rock the number of dams considered in feasible options is increasing. However, it remains more desirable not only on a cost basis, but on a technical basis to have only one large engineered structure that will require careful construction and on-going monitoring and maintenance well beyond the mine life. Options A, B and C require only one large dam, while Option D requires 3 large dams to be constructed.

Total embankment volume

The final indicator that used to describe dam characteristics was total embankment volume. This considered the amount of material required to construct the dam(s) in each option. This would consist of rock fill for the starter embankments and cyclone tailings sand for raises of the main dams. In the case of Option D, sufficient cyclone sand would only be available for the main tailings facility dam, and additional rock fill or borrow material would be required for the other two dams. The embankment volumes that would be required for Option A would be 87 Mm^3, for Option B would be 136 Mm^3, for Option C would be 48 Mm^3 and the cumulative volume required for Option D would be 256 Mm^3.

5.4.1.2 Operational Management

The operational management of each facility included in the evaluation was assessed using three indicators; the impoundment footprint, and the operational ease with which tailings and waste rock could be managed.

Impoundment footprint

The footprint of the entire facility each option was quantified by KP in their assessment of options. It was considered that the smaller the footprint of each facility, the better the option with the understanding that minimizing disturbed footprint is generally considered a best management practice in the industry. The areal footprint of the options in consideration did not vary significantly. Option A was calculated to have a footprint size of 10.2 km^2, Option B was 9.8 km^2, Option C was 13.0 km^2, and the combined footprint of the three facilities comprising Option D was 11.1 km^2.

Operational ease (tailings)

One of the fundamental considerations given to waste storage designs, though a difficult one to quantify, is the ease with which the facility can be operated. This encompasses a number of considerations including the distance from the open pit and mill to the waste storage facility, the anticipation of winter conditions, grade (slope) of the pipeline and number of drainages that need to be crossed. In all options considered and with focus on the tailings component of the facility (both storage and construction needs), a few assumptions were made as common to all options including the operation of the mill such that the process will be a flotation process with de-sulphidation and cyclone sand operation for dam construction.

With these aspects considered, Option B which has the smaller dam and would be within the Upper Casino drainage basin was considered the best of the options. Though Option A would be in a different drainage basin, it would not pose significantly greater disturbance along the route from the operations to the storage facility though it would involve some upslope pumping along portions of the line and it would have a slightly higher dam. It was therefore considered to be a scale of 5 by comparison. Option C, with a generally similar location to Option B, but a dam height similar to that in Option A was also given a value of 5. The option with the greater differences would be Option D; however with respect to tailings specifically, the dam that would be constructed of tailings would not differ significantly from the other options. It would however be anticipated to have a higher rate of rise being higher in the watershed and was therefore given a value of 4.

Operational ease (PAG waste rock)

Because the waste management for Casino would integrate both the tailings and the PAG waste rock, the operational ease of management of the waste rock within the TMF options was also considered and done so as a separate indicator. As with the assessment for the tailings operational management, the distance from the pit to the storage facility was a consideration for waste rock management. Another indicator considered was the operational expectations of each option during winter conditions. These considerations are potentially more pertinent to waste rock management than to that of the tailings as the waste rock will be hauled by truck and therefore involve human participation whereas the tailings will be transported by pipeline. Because of this, distance from the pit to the waste storage facility was given significant consideration. Options B and D would be located closest to the pit, while Option A in Canadian Creek and Option C in lower Casino Creek would be further from the pit (by about 8 and 5 km respectively).

In addition to distance for Option D, the fact that 2 of the 3 dams included in this option would be rockfill dams which was considered an added complexity. Waste rock and or borrow material would be required for their construction which would likely pose additional difficulty in order to keep PAG waste rock submerged underwater. The scalar used was again the qualitative range as used for tailings above.

5.4.1.3 Construction

When considering the construction aspects of the options, the main aspect is that of the dam construction itself. This sub-account has been defined further into two main indicators; geotechnical complexity and scheduling of construction materials.

Geotechnical complexity

The geotechnical complexity was evaluated qualitatively and encompassed the considerations of the foundation conditions and placement of the dam within valleys. Unfavorable foundation conditions may include pervious and/or liquefiable soils, presence of permafrost (potentially on northern slopes), highly fractured bedrock etc. and placement of the dam in the headwaters or side valleys were considered more likely to be of higher complexity than at locations in lower reaches of a valley.

While the foundation conditions at all of the locations where dams would be located in the various options considered are not known to the same degree, a professional judgment was made using geological information, aspect (to assess permafrost) and location within the valley. On that basis, Option B was considered to have the most favorable conditions and be the least complex amongst the options. It would drain to the south and therefore would not be anticipated to have permafrost. Options A and C had less information available on which to base an assessment, but have the potential for some permafrost on northern slopes (Option A in particular) and unconsolidated soils (both Options A and C). Option D which would involve 3 dams for consideration, 2 that have relatively little information available related to foundation conditions but all of which would be located in fairly steep valleys.

Scheduling (construction)

Scheduling for construction needs was considered another important indicator of the construction sub-account. Because all options would include demands for rock (starter dam for all options and on-going rock fill for 2 of the 3 dams in Option D) and demands for cyclone sand for the dam raises, this indicator encompassed both tailings and rock needs and the scheduling expectations of those. The success of any of the options in this regard reflected the expectations of how susceptible each of the options would be to scheduling changes. Both the ability to deliver the cyclone sand and rock/quarry material when needed is critical to the design and was assessed on the basis of the size of the dams, fill requirements, and expected rate of rise of the facility.

Based on that perspective, Option C, with the smallest dam and volume needs was considered the best option, Options A and B located at higher elevations in the valley were slightly less desirable with higher volume needs and higher required rates of rise. Option D was considered to be the least favorable option by this measure with a very large volume demand and 3 structures with the expectation that 2 of them would be constructed concurrently.

5.4.1.4 Structural Stability

The stability of the main facilities was another critical sub-account within the technical considerations. Given all the options would be within a very similar area with respect to topography, climate and seismic zones and would all be designed to the appropriate guidelines provided by the Canadian Dam Association, all options would be built to be structurally stable (i.e. there are no stability fatal flaws identified). To differentiate the options in this aspect therefore, a qualitative description of the stability considerations used in design of each of the options was developed.

Stability considerations (operational and long term)

Considerations of structure stability both during operational phase and afterwards was assessed on the basis of the number of dams, the terrain and abutment conditions, expectations of the colluvial aprons and permafrost conditions, dam height and anticipated tailings beach width.

With these considerations in mind, Options A, B and C with only one main dam were assessed to be preferable over Option D with 3 large structures. Further, the lower dam in Option C with the wider tailings beach was considered to be favored over Options A and B, and ground conditions in Option B would be expected to be slightly better than that for Option A. The scalar developed to communicate these considerations was defined in terms of stability concerns that would need to be designed around in each of the options.

5.4.1.5 Permafrost

Permafrost can cause technical challenges in the design of waste storage structures in the north. The Casino project is in an area of discontinuous permafrost and in general the northern slopes are expected to have a greater degree of permafrost. The permafrost sensitivity for each option was evaluated to reflect this aspect of the design of each option considered.

Permafrost sensitivity

Because the northern slopes in the area are expected to have a greater potential for permafrost, aspect was the key consideration in the assessment of permafrost sensitivity. Options B, C and D generally all drain towards the south with very few northern slopes in the design; though with three separate facilities in Option D there is a greater anticipation of sensitivity to permafrost. Option A does include some degree of northern slope exposure, though not to a significant degree within the dam footprint. Given the level of understanding and generally similar nature of each of the options considered, all options were considered equal in terms of permafrost sensitivity and therefore all given a value of 6.

Capacity

The last technical consideration included in the evaluation was that related to capacity of each option and was measured qualitatively on the basis of expansion potential.

Expansion potential

The ability of each option to handle potential expansion was included not only to assess the potential effects of increased production from the project, but also the potential effects of increased volumes of

PAG rock, should it occur. The expansion potential was evaluated qualitatively and considered to be largely dictated by the expected size of the option, the location in which it would be sited and the ability to increase the size of the dam(s) if required.

With the most favorable volume to height relationship, Option C in the Lower Casino location would have the greatest expansion potential, Options A and B would have similar and lower expansion potential by comparison with less favorable volume to height relationships and Option D with three facilities in the upper reaches of 3 drainages would have the least favorable conditions for expansion potential.

5.4.2 Environmental Account

The environmental account encompassed those aspects that are commonly included in the impact assessments completed to support project proposals. The sub-accounts and indicators were selected to differentiate between the potential effects of each option to issues such as water management and quality, fish and wildlife habitat, effects on flora and air quality and closure considerations. A summary of the ranking results are provided in Table 5-5, and the ranking and weighting results are provided in Appendix A.

Table 5-5: Environmental Considerations Ranking Results

Sub-accounts	Indicators	Option A	Option B	Option C	Option D
		TIA+WR in Canadian Creek	TIA+WR in Casino Creek (Upper)	TIA+WR in Casino Creek (Lower)	TIA+WR avoiding areas frequented by fish
Consequence of Dam Failure	Potential environmental effect as a consequence of dam failure	2	6	6	6
Water Management (storage & seepage)	Catchment area	3	6	2	5
	Degree of TIA seepage expected	3	5	6	2
	Operational water management complexity	5	6	4	3
	Long term maintenance requirements	6	6	5	3
Water Quality	Operational water quality at the toe of the dam	6	6	6	2
	Operational water quality immediately below first tributary	4	4	6	2
	Operational water quality 10 km d/s of dam	6	5	4	2
	Closure water quality at the toe of the dam	6	6	6	2
	Closure water quality (assumes 100% bypass) with at first tributary	5	4	6	2

Sub-accounts	Indicators	Option A TIA+WR in Canadian Creek	Option B TIA+WR in Casino Creek (Upper)	Option C TIA+WR in Casino Creek (Lower)	Option D TIA+WR avoiding areas frequented by fish
	Closure water quality 10 km d/s of dam	6	3	3	2
	Operational water quality at point of spillway discharge	5	6	5	6
	Closure water quality at point of spillway discharge	6	3	5	2
Groundwater	Potential reduction in groundwater contributions downgradient	6	6	6	4
	Potential impacts to GW quality downgradient	5	6	6	3
Fish Habitat	Quality of fish habitat under the footrpint of the TIA	4	6	3	6
	Quality of fish habitat at first tributary d/s of the dam during operations	4	6	3	6
	Quality of fish habitat 10 km d/s of the dam during operations	1	6	6	6
	Reduction of flow (Operations to early closure)	5	4	6	4
	Removal of fish habitat by footprint	4	6	3	6
Wildlife Habitat	Effect on wildlife habitat in footprint area	6	6	6	6
Flora	Effect on flora in footprint area	6	6	6	6
Air Quality	Potential for fugitive dust emissions	6	6	6	6
Closure Measures	duration of long term liability	6	6	6	6
	extent of measures to implement closure	4	6	5	4
	long term level/intensity of site activity	6	4	4	4

5.4.2.1 Consequence of Dam Failure

Given the remoteness of the area there was no perceived consequences to humans in the event of a dam failure and as such only environmental consequences were considered, and in particular that related to the fish and wildlife resources down gradient of the dam in each of the options considered.

Potential environmental effect as a consequence of dam failure

The CDA dam classification guidelines include consideration of the receiving environment in the event of a dam failure and were used as a means of evaluating this indicator. Work by Eagen and Greenaway (2011) outlines the criteria considered in the classification of dams as including aspects such as the extent or presence of identified species, habitat use, intensity/degree of change if a failure were to occur, restoration feasibility, duration of impact, and species status in the expected inundation zone that could result in the event of a dam failure. These factors were used to develop a matrix that can be referenced in the classification of a dam (i.e. assignment of a dam class as low, significant, high, very high or extreme) in parallel to geotechnical aspects of dam classification (Eagen and Greenaway, 2011).

The evaluators used that Dam Class matrix to assess the options for Casino and in so doing assigned a Dam Class of “Very High” to the Option A alternative, based on the presence of Arctic grayling downstream in Canadian and Britannia Creeks, and Chinook spawning habitat and Golden Eagle presence on the Yukon River near the mouth of Britannia Creek, approximately 9 km downstream. A Dam Class of “High” was assigned to Options B, C, and each of the TIAs for option D based on the presence of Arctic Grayling in the watersheds associated with Casino Creek.

The Dam Class system uses a 5-point scale and does not require that the ‘best’ option in the evaluation be given a scalar value of 6 as is done in this alternative assessment. Therefore the Dam Class system was used as a basis of evaluation, but re-cast into the scalar system used here as shown below. In short, Options B, C and D were considered equal and more favorable than Option A.

5.4.2.2 Water Management (storage & seepage)

Water management considerations included in the environmental account were represented by four indicators reflecting the physical nature of water management. Water quality related aspects are evaluated separately in subsequent sub-accounts.

Catchment area

The first indicator selected to represent water management was the catchment area which reflects the amount of water that would need to be managed via diversions or captured.

Catchment areas were estimated in units of km^2 and were quantified for the four options. Option A would have a catchment area of 62 km^2, Option B would have a catchment area of 37 km^2, Option C would be 77 km^2 and the combined catchment area of the Option D dams would be 42 km^2.

Degree of TMF seepage expected

Water management of seepage from the TMF is a critical factor in the design and assessment of impacts related to each option. Estimates of the degree of seepage expected from each option were made and considered aspects such as the expected foundation conditions, potential for permafrost and fractures and dam height.

Because Option C would be the lowest dam and would not be expected to have unfavorable foundation conditions, it was considered to be the best option with respect to the degree of expected seepage. Option B which would be located in the upper Casino Creek drainage would be higher than Option C, but is expected to have good foundation conditions. Option A in Canadian Creek would be of similar height to that in Option B, but based on geology was assessed to have less favorable foundation conditions with the expectation of higher amount of seepage likely. Option D, with three dams and points of seepage was considered the least favorable option.

Operational water management complexity

During operations, the management of water in large part depends on whether there will be a water surplus (and therefore discharge) or water deficit (and therefore make-up requirements). An option with a water surplus in this evaluation was considered less attractive from an environmental impact perspective as it implies discharge requirements and more onerous management of diversions etc.

All options considered for Casino are expected to have water surplus situations with the exception of Option B in the Upper Casino location. Option B has assumed a make-up water supply from the Yukon River but would operate as a zero discharge scenario. Option B therefore was considered the best option when considering this indicator. The remaining options were differentiated further based on the expected complexity of diverting excess water, capture of seepage etc. Option A was considered the next most favored option as it is located high in the Canadian Creek watershed and would have less water to manage around the facility than Option C for example located lower in the Casino valley. Option D despite being high in the valleys would require diversion structures and capture facilities associated with all three structures and was considered the least favorable of the options.

Long term maintenance requirements

The previous indicator focused on the operational phase of the project, water management in the closure phase has been evaluated as the long term maintenance requirements of water management structures. This indicator was assessed on the expectations of the degree of maintenance and oversight that would be expected for the water management structures that would be required for each of the options. This considers the frequency of inspections for the dams, the maintenance and number of pumps and ponds that were included in the option and the size of the spillways.

Options A and B in the upper reaches of Canadian and Casino Creeks were evaluated to have a typical degree of maintenance and oversight required for water management structures associated with these facilities. Option C would have a slightly larger spillway and diversion structures to accommodate a higher volume of water being lower in the valley and Option D with three large structures and water management features would be the least favorable of the options with respect to long term maintenance.

5.4.2.3 Water Quality

Water quality was another key sub-account included in the environmental account evaluation. Because processing related activities create a very different water quality than do the long term weathering processes that influence closure, both time frames were considered (i.e. operational and closure) as distinct indicators. In addition, there were four points of reference evaluated; that at the toe of the dam, at the first tributary downstream of the TMF dam, at a location 10 km downstream from the TMF dam and at the spillway in each option.

Water quality predictions to quantify the expectations of concentrations of copper, chosen as an indicator parameter for potential effects from the project, were provided by Marsland Environmental Associates.

Operational water quality (assumes 10% bypass) with respect to MMER at the toe of the dam

Predictions of water quality at the toe of the facility at each of the options assumed 10% bypass in each case and seepage quality represented by 0.54 mg/L copper. The effect therefore was a reflection of the water quality or assimilative capacity of the area immediately below the toe of each facility. The evaluation also considered that for Options A through C would have only one facility while Option D would have three facilities which would all have a seepage contribution. Another difference with Option D as opposed to the others, is that those facilities in which waste rock would be stored without the tailings, there would be no additional alkalinity added through process waters discharged with the tailings. As such, water quality in seepage from the waste rock stored facilities could differ and potentially be higher than for that associated with the tailings. A comparative estimate was made for Option D on a qualitative basis and comparison with predictions for the other options.

Operational water quality (assumes 10% bypass + discharge if required) with respect to CCME immediately below first tributary (assumed first occurrence of fish) downstream of dam

As was done for the above indicator predicting water quality at the toe of the dam, the same exercise was completed for each option at the first tributary below each location; specifically Britannia Creek for Option A, Brynelson Creek for Option B and Dip Creek for Options C and D. A similar scalar to differentiate the options was developed based on predictions provided in Appendix A; specifically that water quality at the first tributary downstream from Option A was predicted to be 0.011 mg/L, for Option B was predicted to be 0.012 mg/L, for Option C was predicted to be 0.0033 mg/L and for Option D was qualitatively evaluated assuming three distinct loads from three facilities, two of which may have worse seepage quality than the main tailings facility.

Operational water quality (assumes 10% bypass + discharge if required) with respect to CCME 10 km downstream of dam

To expand the comparison further, another assessment at a reference point 10 km downstream from each option was also provided. Resultant predictions for Option A, B and C were 0.00089 mg/L, 0.0019 mg/L and 0.0026 mg/L copper respectively. Option D was again only qualitatively assessed and assumed to be the least favored option. The primary difference in these predicted values was in the dilutive capacity of the Yukon River (for Option A) compared to Dip Creek (for Options B, C and D).

Operational water quality at point of spillway discharge

While the previous water quality indicators were intended to assess effects of seepage, the water quality of any surface discharge from the spillway during operations was also assessed. This considered whether or not there would be an anticipated discharge during operations and if so what that water quality would be expected to be. Both Options B and D assumed no discharge during operations and therefore would be the most favored options in this regard. For Option A, the receiving environment would be to the Yukon River with significant dilution and for Option C discharge would be to Dip Creek, with less dilution capacity; however predictions suggest water quality of the ponded water to be well below CCME guidelines. The scalar developed to reflect these differences is below.

Closure water quality (assumes 100% bypass) with respect to CCME at the toe of the dam

As for the operational stage of the operation, predictions were also made at closure at the toe of the dam for each of the options (see Appendix A). For Options A, B and C, the expected concentration of seepage at the toe of the dam is considered to be the same, as the tailings and waste rock management is similar for all these options. Option D, with three dams, two of which would store primarily waste rock was estimated to be less favorable than the other options in which all waste would be stored in one facility.

Closure water quality (assumes 100% bypass) with respect to CCME at first tributary (assumed first occurrence of fish) downstream of dam

On closure at the first tributary downstream of the toe of the dam for each option predicted water quality for Option A was 0.038 mg/L Cu, for Option B was 0.056 mg/L Cu and for Option C was 0.015 mg/L. Option D was qualitatively assessed to be 3 times less favorable to the best option to reflect the three facilities required in this option.

Closure water quality (assumes 100% bypass + discharge if required) with respect to CCME 10 km downstream of dam

At 10 km downstream, predictions were 0.00091, 0.015 and 0.012 mg/L Cu for Options A, B and C. Option D was considered least favorable. Option A is significantly better than Options B, C and D in this indicator due to the dilution capacity in the Yukon River compared to Dip Creek.

Closure water quality at point of spillway discharge

Predictions of water quality on closure in the pond at the point of spillway for each option were prepared as provided in Appendix A. Expectations were that Options A, B and C would produce the copper concentrations of 0.0023, 0.016 and 0.0065 mg/L, while Option D would have three separate facilities that could all discharge a load to the surface water environment and was considered less favorable.

5.4.2.4 Groundwater

The effects on groundwater were assessed and described with respect to an indicator for quantity and an indicator for quality as below.

Potential reduction in groundwater contributions down gradient

The potential reduction in groundwater down gradient of the TMF facility in each option was assessed qualitatively and considered the anticipated permeability and size of each facility. Options A through C were considered equal as there was no reason to assume that Canadian Creek and Casino Creek would have substantially different groundwater regimes. Option D was considered to be less favored as it would have an effect on three drainages.

Potential impacts to GW quality down gradient

The assessment of impacts to groundwater quality was for that potential effect of seepage that does not get captured by the capture systems designed for each facility on the groundwater. It considered the gradient, the higher the gradient the potential for increased seepage and the anticipated bedrock permeability conditions. For this assessment, it was assumed that Canadian Creek may have slightly higher permeability than Casino Creek based on the bedrock geology of schist in the area of Option A. It also considered that the three dams in Option D would all be expected to have higher gradients and therefore possibly higher seepage than those facilities located further down their respective drainages. It was also noted that the waste rock only facilities may have different seepage quality than those that are co-disposed tailings (with process water) and waste rock.

5.4.2.5 Fish Habitat

Fish habitat is another key sub-account within the environmental account. A description of the fish species and stream classification is summarized in Table 5-6. Indicators were developed in a manner that was similar to that for the water quality indicators in the previous sub-section. Specifically this included an assessment of the potential effect to fish habitat quality within the TMF footprint, at the first tributary downstream and at a location 10 km distal. Also considered was an indicator for the reduction of flow and the removal of fish habitat within the footprint of the TMF. Each of these are discussed further below.

Table 5-6: Fish Species and Stream Classification

Option	Creek	Fish Species Downstream (Mapster)	Placer Stream Classification Model (YESAB Geolocator)
A	Canadian Creek	Arctic grayling in Canadian Creek, Britannia Creek, and Chinook salmon in Yukon River, located ~ 8 km downstream	Canadian Creek - salmon proximity 8.9 km; No salmon spawning Britannia Creek - No salmon spawning but Section 2 but salmon proximity (Chinook) ~2.6 km Yukon River - Chinook Salmon spawning
B	Upper Casino Creek	Arctic grayling	Casino Creek - no salmon spawning Dip Creek - No salmon spawning
C	Lower Casino Creek	Arctic grayling	Casino Creek - no salmon spawning Dip Creek - No salmon spawning
D	Casino, Austin & Brynelson Creeks	Non fish bearing Casino headwaters and Austin & Brynelson creeks but Arctic grayling downstream	Casino, Austin & Brynelson Creeks - no salmon spawning Dip Creek - No salmon spawning

Quality of fish habitat under the footprint of the TMF

A qualitative assessment of the quality of the existing fish habitat under the proposed footprint of the TMF in each of the options was also included. The most favorable option in this context would be that with the least favored fish habitat within the footprint area. Options B and D were considered equal in this regard. Option A was given a value of 4 with somewhat higher quality and/or more fish as compared to other options and Option C further downstream in Casino Creek was considered to have the best fish quality.

Quality of fish habitat at first tributary downstream of the dam during operations

Similarly, the quality or number of fish expected at the first tributary downstream of the facility for each option was assessed. The first tributary downstream of Option A is the Britannia Creek, for Option B it would be Brynelson Creek and for Options C and D it would be Dip Creek.

Quality of fish habitat 10 km downstream of the dam during operations

At a location 10 km downstream from the facilities, the comparison was that between the Yukon River (Option A) and Dip Creek (Options B, C and D) and an assessment of the existing quality of fish habitat and number of fish in each respectively. This assessment considered that the quality of fish habitat in the Yukon River far exceeds that of Dip Creek and the scalar values below were developed to reflect that difference.

Reduction of flow (operations to early closure)

A reduction in flow would be expected to potentially have an effect on fish and fish habitat. This was assessed as a specific indicator here and considered the existing flow in receiving environments and the potential to cut off flow. Flow in Britannia and lower reaches of Casino is higher than in Upper Casino, Upper Meloy and Upper Brynelson. Because of these existing respective flows, the reduction in flow for Option A and C would likely have a lesser influence than for Options B and D.

Removal of fish habitat by footprint

The removal of fish habitat as different from the quality of fish habitat affected was assessed on the basis of footprint area. The smallest footprint would be associated with Options B and D followed by Options A and then C.

5.4.2.6 Wildlife Habitat

The assessment of wildlife in part considered the area that would be disturbed and the wildlife use in that area. This has been evaluated in a combined manner via an indicator defined as the effect on wildlife habitat in the footprint area.

Wildlife use in the area of the project includes caribou, grizzly and black bear, dall sheep, moose, beaver, fox, wolf, hare, raven, rock and willow ptarmigan and golden eagle. None of the options would be expected to have a negative effect on any of the species and while the footprint of each would vary slightly, the resultant effect on wildlife was considered to be the same between options and negligible in all cases. All options were therefore given a value of 6.

5.4.2.7 Flora

As with wildlife, the potential effect on flora for the options considered was included as an environmental indicator in the evaluation.

The area around Casino includes vegetation consisting of black and white spruce forest with aspen and some lodgepole pine. Black spruce and paper birch are generally seen on the permafrost slopes. Scrub birch and willow form an extensive stand in subalpine sections from the valley bottoms to well above the tree line. Given all options being considered would be within the same general area, no differences are expected between the options, and as with the wildlife assessment, all options were given a value of 6.

5.4.2.8 Air Quality

Air quality can be a concern at mining operations, particularly with consideration to dust management and was included in the environmental account as a potential for fugitive dust emissions.

Blasting rock and management of tailings include small particulates which can lead to dust emissions that require control. Because all of the options for tailings and waste rock management would include a conventional slurry management of tailings and construction of dam raises by cyclone sand, all options were considered to have a similar potential for dust creation and given a scalar value of 6.

5.4.2.9 Closure Measures

Consideration of closure measures was considered here to be primarily related to long term protection of the environment and therefore included in the environmental account. This evaluation included three indicators in the assessment related to closure; specifically, the duration of the long term liability anticipated, the extent of the measures required to implement closure and the long term level or intensity of activity anticipated to maintain environmental protection through closure. These are discussed individually below.

Duration of long term liability

Closure planning in mining almost universally includes the objective to minimize or limit the duration post closure for which there is a liability to the proponent, regulators and other stakeholders. In practical terms however, there was no significant difference identified in the options being considered with respect to the duration of the long term liability associated with each. Each option will have at least one large dam structure, water diversion infrastructure etc and therefore liabilities associated with these structures for decades post mining. All options therefore were considered to have the same anticipated duration of on-going liability associated with them. All options were given an equal value of 6.

Extent of measures to implement closure

The extent of anticipated measures required for each option in order to successfully implement a protective closure plan was also considered. This included an assessment of the expected complexity of closure and long term management of water for each option. This indicator differs slightly from most others considered in that it in part must consider the closure scenario for the open pit with is integrated into the closure landscape of the TIAs once it has flooded (i.e. drains through the TIAs). For Option A, closure measures would be required to create a drainage system from the open pit into the TMF with drainage routing to Canadian Creek while Options B and C would have an easier spill point from the pit into their respective TMF facilities. As with Option A, Option D with 3 facilities placed high in the valley headwaters would pose difficulty in integrating pit overflow into the TMF system. Because of the integration of pit waters with the TIAs, Options B and C would be preferable to Options A and D. Differentiating Options B and C from one another, Option C has a larger footprint and would require greater water management structures than Option B. Therefore Option B was considered slightly more favorable than Option D.

Long term level/intensity of site activity

The intensity or level of site activity expected through the closure and post closure phase considered the expectations for water collection, pumping requirements and treatment associated with each option. Because all options would include sub-aqueous disposal of PAG rock, the on-going water management and treatment associated with each option is similar. The primary difference anticipated is in the expected receiving environment. In this assessment, Option A was assumed to include a discharge of site waters by gravity to a diffuser in the Yukon River with significant assimilative and dilutive capacity. The remaining Options B, C and D would all include discharge eventually into the Dip Creek system with a lower assimilative and dilutive capacity as compared to the Yukon River and would be expected to have higher number of pumping requirements than the primarily gravity system associated with Option A. A higher degree and intensity of management of the closure water management would therefore be expected.

5.4.3 Socio-economic Account

The third main account included the socio-economic aspects. This included issues that were often more difficult to quantify and dealt with issues such as other land uses, permitting, care and maintenance, perception, safety, job opportunities etc. Each of these are discussed uniquely below and in many cases were not discriminating. A summary of the ranking results are provided in Table 5-7, and the ranking and weighting results are provided in Appendix A.

Table 5-7: Socio-Economic Considerations Ranking Results

Sub-accounts	Indicators	Option A	Option B	Option C	Option D
		TIA+WR in Canadian Creek	TIA+WR in Casino Creek (Upper)	TIA+WR in Casino Creek (Lower)	TIA+WR avoiding areas frequented by fish
Traditional land use	In immediate area	3	6	6	6
Long term care and maintenance	Winter operating requirements	5	6	5	6
	Total effort	6	6	6	6
Permitting	Overall project complexity from permitting point of view	2	6	6	1
	Requirement for schedule 2 amendment	1	6	1	6
Archaeology	Sites of importance in immediate area	6	6	6	6
Safety	Consequence of dam breach (socio-economic impacts)	2	6	6	6
Noise	Degree of noise pollution	6	6	6	6
Aesthetics	Visibility from frequented areas	6	6	6	6
Tax contribution	Anticipated taxes	6	6	6	6
Job opportunities	Job/contracting potential	6	6	6	6
	Training/experience opportunities	6	6	6	6
Community perception	Community perception	2	6	4	1
Future burden on society	Future burden on society	6	6	6	6

5.4.3.1 Traditional Land Use

Traditional land use in this context was meant to consider activities in the immediate area of each of the options related to hunting, gathering, fishing or religious activities.

The evaluation of these options considered differences in land use in the Canadian Creek and Britannia Creek system versus the Casino Drainage. It was assessed that the traditional land usage in the area was limited to the presence of an old fishing village in Britannia and a few artifacts identified in Canadian Creek. Nothing was identified in Casino Creek drainage. Option A was therefore less favorable with respect to this indicator than were Options B, C and D.

5.4.3.2 Long Term Care and Maintenance

The long term care and maintenance sub-account was selected to reflect anticipated closure activities that normally become the burden in part to regulators and other stakeholders distinct from those of an operating mining company. This was assessed in terms of seasonal complexities (winter operating requirements) and total effort.

Winter operating requirements

Winter can pose difficulty with respect to long term care of mine sites with respect to access, ice build-up (glaciation), and equipment operations. The winter operating requirements assessed here reflect the difficulty of options that include a pump back during the winter as opposed to those that do not. Specifically, it was assumed that Options A and C would require winter pump back components which would involve a greater involvement and degree of oversight, maintenance and monitoring than those that do not (Options B and D). Scalar values did not vary significantly however.

Total effort

The assessment of total or overall effort was also included in this sub-account. This considers the expected degree of long term management anticipated with the site in the given options considered and assumed that all options would have a similar degree of long term care and maintenance required and therefore all were given a scalar value equal to 6.

5.4.3.3 Permitting

Two aspects related to permitting were considered in this sub-account. The first was the overall project complexity and the group's expectations related to permitting based on their collective experience elsewhere. The second was the expected requirement for a Schedule 2 Amendment with any of the options considered which was perceived to add a level of difficulty and impact on the project scheduling as a result.

Overall project complexity from a permitting point of view

The overall project complexity from a permitting perspective considered the size of the dams related to each option, the geochemical and geotechnical complexity of each, and the expectations for negative perceptions, if any, related to the receiving environment. In the case of Option A, while the size of the dam and complexity of the system was not significantly different from any of the other options, there was an expectation of negative perception related to the Yukon River being the point of discharge for this option. Options B and C were considered relatively similar with respect to dam precedents and receiving environment. Option D, because it includes 3 large dams was considered less favorable than B or C despite being within the same receiving environment.

Requirement for Schedule 2 amendment

Based on conversations with regulators, it was the understanding of the group completing this evaluation that a Schedule 2 Amendment would be required in areas frequented by fish but could be lifted in areas with poor fish value. As such, Options B and D were considered to have no fish and/or poor fish value and were given a value of 6. Options A and C were considered to have fish of good value and would be subject to a Schedule 2 Amendment. The scalar in this case was simplified whereby Options B and D were given a value of 6 (no amendment required) and Options A and C were given a value of 1 (amendment required).

5.4.3.4 Archaeology

While detailed archaeology in all locations was not completed, an assessment was made based on the existing information and was defined as the presence of sites of importance in the immediate area.

No sites of importance were identified in the Casino Creek drainage and as a result Options B, C and D were all given a value of 6. Some sites of importance however were identified within the Canadian Creek/Britannia Creek system and by comparison Option A was therefore given a value of 2.

5.4.3.5 Safety

Safety on mine sites is always a topic given very high level of scrutiny and attention. Based on feedback from stakeholders, the key safety issue from a socio-economic perspective was the consequence of a dam breach. While the probability of that occurring in any option is considered very low, the consequences could differ option to option.

The consequence was evaluated on the basis of the potential of people, fish, wildlife etc. to exist down gradient of the facility in the drainages considered and the value of habitat that could be affected. This differentiated Option A located in Canadian Creek which eventually feeds into the Yukon River from Options B, C and D located in Casino Creek drainage which feeds into Dip Creek. It was assumed that in this regard, Option A would have a significantly higher consequence than Options B, C or D.

5.4.3.6 Noise

The degree of noise pollution associated with any mining project is a typical aspect of concern and was therefore included in the evaluation.

Given the remoteness of the project and the relative closeness of all options to the open pit, the options considered were all evaluated as equal with respect to degree of noise pollution and were therefore all given a scalar value of 6.

5.4.3.7 Aesthetics

Similarly, aesthetics is an aspect that is considered when developing potential options for waste storage and was included here.

Aesthetics was assessed on the basis of the visibility of each option from areas that were deemed to be frequented by people. Option A situated in the upper reaches of Canadian Creek was not expected to be visible, nor were Options B, C and D located within Casino Creek. As a result, all options were considered equal and given scalar values of 6.

5.4.3.8 Tax Contribution

Tax contribution was another sub-account deemed to be worthy of consideration in the evaluation of options and included in the assessment.

The tax contribution was evaluated on the basis of anticipated taxes, none of the options considered for waste management storage were significantly different with respect to anticipated taxes and therefore all were given a value of 6.

5.4.3.9 Job Opportunities

Job opportunities were considered on the basis of potential for direct jobs but also on the basis of potential training or experience opportunities.

All options were considered to have the same potential for job creation and given values of 6.

All options were considered to have the same expectations for skills required and therefore training and experience opportunities. All options were given a value of 6.

5.4.3.10 Community Perception

Community perception was included in the evaluation and considered as the perception of people in the general vicinity of the project and directly affected by the mine.

Expectations of perception considered the proximity and palatability of discharge locations (e.g. Yukon River versus Dip Creek), the height and number of dams and the potential influence of the option on areas frequented by fish. Based on these considerations, Option B was evaluated as likely being the most favorable of options, followed by Option C and then by Options A and D equally.

5.4.3.11 Future Burden on Society

The future burden on society was included to reflect the expected challenges on closure that would conceivably fall on the local community and society in general.

Anticipated future burden therefore considered differences amongst options such as if any one option would require higher degree of site interaction, be more susceptible to fluctuations in climate, economic or political conditions etc. than the others. Given all options would be located fairly close to the deposit and represent generally similar means of waste handling, storage and closure conditions, the future burden associated with each was considered relatively similar amongst the options and all were given values of 6.

5.4.4 Economic Account

The last main account included was the economic account. It included two sub-accounts, one representing costs that may be attributed to government input and the other relates to the project costs posed to the proponent. A summary of the ranking results are provided in Table 5-8, and the ranking and weighting results are provided in Appendix A.

Table 5-8: Economic Considerations Ranking Results

Sub-accounts	Indicators	Option A	Option B	Option C	Option D
		TIA+WR in Canadian Creek	TIA+WR in Casino Creek (Upper)	TIA+WR in Casino Creek (Lower)	TIA+WR avoiding areas frequented by fish
Government Costs	Supporting infrastructure costs	6	6	6	6
Project Costs	Initial capital cost (waste and water management costs only)	6	4	6	1
	Sustaining and operating costs	4	6	6	1
	Fish habitat compensation	6	6	6	6
	Closure costs	6	6	4	3
	Post closure costs	6	5	4	2

5.4.4.1 Government Costs

Potential government costs considered only those that may relate to development of supporting infrastructure (e.g. roads, power, rail).

Since all options are would be located close to the deposit and require similar infrastructure, all options were considered equal and given a value of 6.

5.4.4.2 Project Costs

Proponent costs have been included to represent itemized costs for construction, operations and closure related timeframes. These are more easily estimated on a quantitative basis and are described in the following sub-sections.

Initial capital cost (waste and water management costs only)

The initial capital costs related to waste and water management were estimated by Knight Piesold with Option A estimated to cost ~$93 million, Option B estimated at $162 million, Option C estimated at $91 million and Option D estimated to be in excess of $300 million. Costs in this indicator were largely related to the construction of the starter dam(s) in each option.

Sustaining and operating costs

Sustaining and operating costs include estimates for the dam raises, disposal of tailings and waste rock, water management etc. These were also estimated by Knight Piesold with Options A through D having estimated amounts of $2.98, $2.77, $2.72 and in excess of $4.00 billion dollars respectively. The scalar range developed to reflect these differences was as follows.

Fish habitat compensation

Fish habitat compensation costs for all options were expected to be similar and on the order of half a million dollars. All options were given a scalar value of 6 to reflect this assessment.

Closure costs

Closure costs for each option were also estimated. These were done on the basis of comparison to the closure cost estimates provided in the pre-feasibility study (PFS) for the project which was a value of approximately $100 million. The scalar developed and relative option value assigned was as below. In the assessment, Options A and B were considered to have closure costs similar to that estimated in the PFS. Because of the positive water balance in Option C there would be additional costs to provide for water diversions through closure and it was therefore evaluated at a higher cost. For Option D, with three large dams, additional costs associated with seepage and water management were also assumed.

Post closure costs

Post closure costs were included to consider the longer term costs for on-going site maintenance and monitoring. Estimates were qualitative and considered the need or potential need for water capture and potentially treatment. As such, it largely reflects anticipated effects of water quality. With discharge assumed to the Yukon River for Option A, this was the favored option in this regard as the high dilution in the Yukon would negate the need for water collection and treatment. Option B was slightly less favored, followed by Option C with a higher amount of water to manage and Options D with three dams and potentially worse seepage quality associated with the two of these being used to store waste rock.

5.5 SELECTION OF PREFERRED LOCATION

The assigned scalar values and weights as described in the preceding sections were used to calculate scores for each indicator, sub-account and account separately and in a combined or overall manner. To accomplish this, the scalar values used to compare alternatives in every indicator were multiplied by the weight for that indicator. The weighted scalar values were then summed within a given sub-account to provide a sub-account score [$=\Sigma S \times W$] and normalized to the original 6-point scale by dividing by the sum of the indicator weights to provide a sub-account merit rating [$=\Sigma S \times W / \Sigma W$]. The result is a normalized value between 1 and 6 for each alternative that provides a comparative measure, i.e. the alternative with the highest value is the most favorable option with respect to the sub-account considered, and the alternative with the lowest value is the least favorable. A similar process of weighting, summation and normalizing is applied to the sub-accounts to obtain account scores and merit ratings for each account considered in the analysis. Finally, the process is repeated again with the accounts to obtain final overall scores and merit ratings for each of the alternatives.

For the Casino project evaluation, the resultant scores were as shown in Table 5-9. The completed ledger is provided in Appendix A.

Table 5-9: TMF Option Combined Ratings

	Option A	Option B	Option C	Option D
	TMF+WR in Canadian Creek	**TMF+WR in Casino Creek (Upper)**	**TMF+WR in Casino Creek (Lower)**	**TMF+WR avoiding areas frequented by fish**
Technical	4.8	5.3	5.5	3.2
Environmental	4.5	5.6	5.2	4.6
Socio-economics	3.8	5.5	4.7	5.4
Project Economics	5.7	5.6	5.8	4.0
Combined Evaluation	4.5	5.5	5.2	4.4

As with the evaluation process itself, these merit ratings are meant to illustrate a relative difference of the options to one another. The yellow highlights indicate the highest scoring option in each of the main accounts as well as the combined evaluation provided in the last row. On review, the preferred or most favored option is Option B which had the highest combined score, as well as the highest score in the environmental and socio-economic account. Option C was given the highest technical rating as well as highest with respect to project economics. These merit ratings are also shown graphically in Figure 5-7.

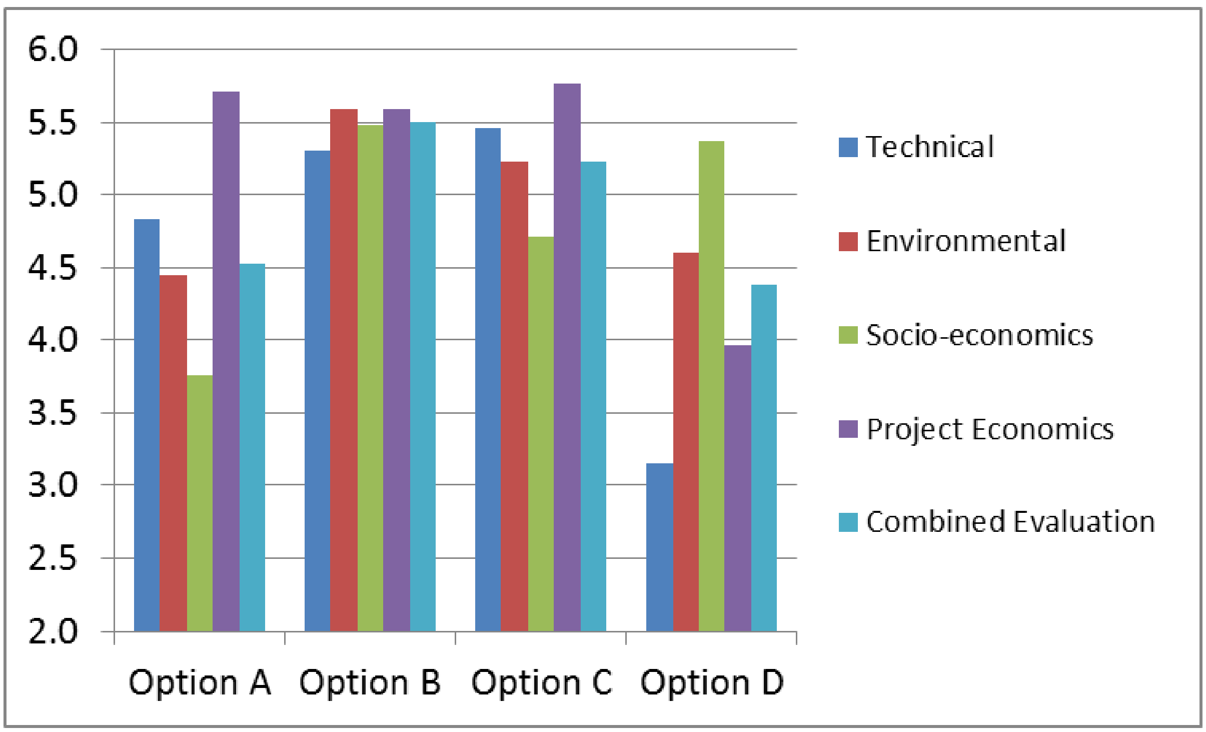


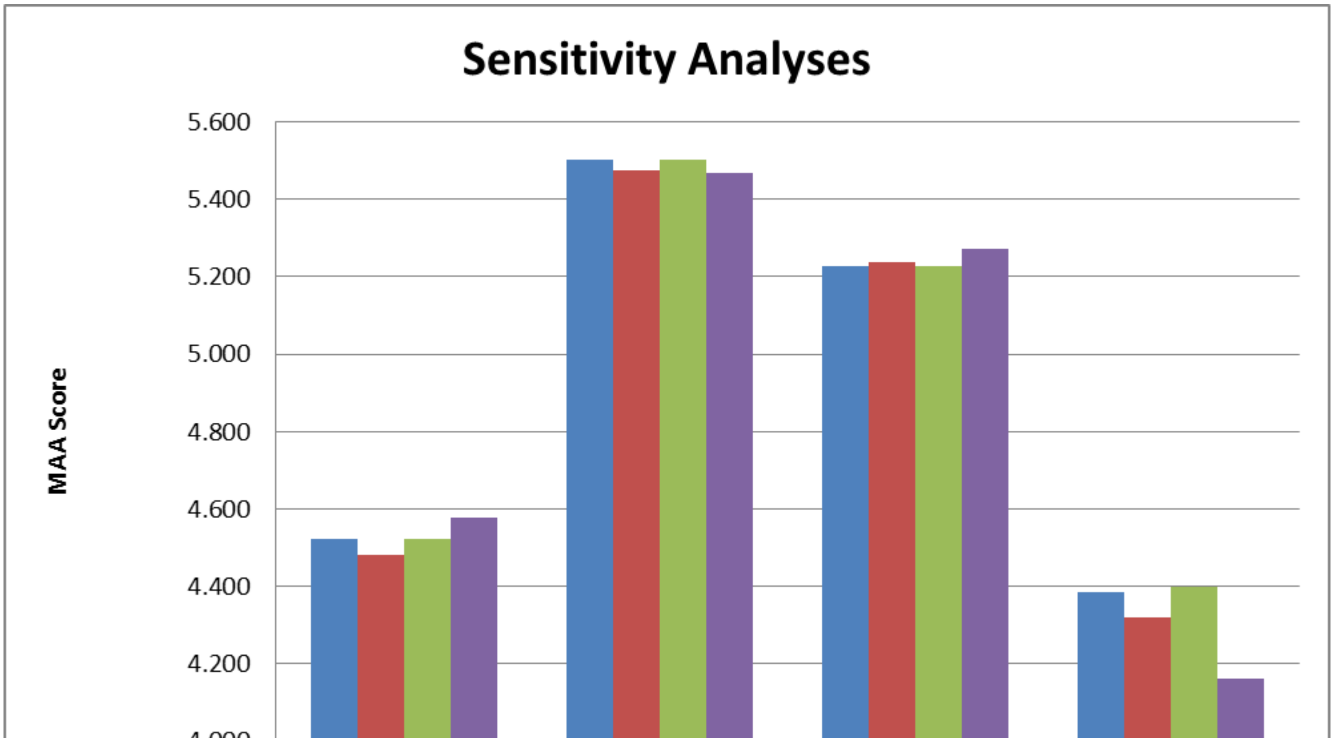
Figure 5-7: Main Account and Combined Evaluation Merit Ratings

5.6 SENSITIVITY ANALYSIS

In addition to the evaluation described above, a set of sensitivity analyses were completed. Three sensitivity analyses were completed as described below:

1. Exclusion of indicators that are non-discriminatory. Those indicators that discriminate amongst alternatives, or provide a mathematical differentiation have a greater influence on the resultant relative merit ratings. Those that are non-discriminating tend to equalize the scores. The evaluation completed here defined an indicator as discriminating if the difference between the weighted scalar (S x W) for the best and worst option in any indicator was more than 30%. Those indicators that were less than 30% different from best to worst were applied a weight of 0.001 and effectively excluded from the numerical calculation.
2. Sensitivity around 'perception' indicators. Based on feedback in presentations on the alternative evaluation process with stakeholders in Whitehorse, it was decided to complete a sensitivity analysis around the indicators related to the complexity of the option from a permitting perspective and the assessment of community perception. During the base case evaluation, the evaluators had assessed the permitting and community perception of three large dams associated with Option D to be negative and given that option a scalar value of 1 in both cases. The feedback at the Whitehorse meetings was that this was perhaps too harsh an assessment and that a sensitivity using a scalar value of 4 for those indicators may be better appropriate. This change is shown as sensitivity run 2.
3. The last sensitivity was to assign a weight to the technical account of higher value, specifically a 6 equal to that of the environmental account.

The results of these sensitivities are shown on Figure 5-8. In every case, Option B resulted in the highest merit rating compared to the other options.



	Option A	Option B	Option C	Option D
Base Case	4.522	5.503	5.228	4.384
Sensitivity Run 1	4.479	5.475	5.236	4.318
Sensitivity Run 2	4.522	5.503	5.228	4.399
Sensitivity Run 3	4.577	5.468	5.271	4.161

Figure 5-8: Results of the Sensitivity Analysis Compared to the Base Case Merit Ratings

6 CONCLUSIONS

The objectives of the mine waste and water management strategy at the Casino Project are to ensure permanent and secure storage of tailings and mine waste and to selectively place waste materials to maximize water quality through the minimization of acid generation potential and metal leaching waste.

Due to the nature of the mineralization at the Casino Project, best available management dictates that potentially reactive tailings and waste rock be subaqueously disposed of in a tailings management facility. Sub-aqueous disposal will prevent sulphide oxidation in mine waste and is considered geochemically favorable compared to disposal in an unsaturated environment. These geochemical considerations form the basis of the mine waste management alternatives assessment.

Four methods of tailings disposal was considered: slurried tailings in a local borrow material constructed valley-fill dam; slurried tailings in a cyclone sand constructed valley-fill dam; thickened tailings and paste tailings, which would also require a storage dam; or “dry” stack, or filtered tailings for disposal of NAG tailings, and an embankment dam for the PAG tailings and waste rock.

The comparative assessment indicates that the use of cyclone sand for embankment construction is the preferred option. It provides low operational complexity and controllable geotechnical conditions given the project’s location and water conditions, while incurring the least disturbance to the environment.

A subsequent analysis of various locations for the cyclone sand embankment and impoundment was conducted following Environment Canada Multiple Accounts Analysis guidelines (EC, 2011). A scoping level screening assessment considered 10 location options, and excluded 6 options from further analysis as they did not meet the basic requirements for the waste management facility. Of the four remaining options, an evaluation by a group of technical experts was conducted in May 2013 incorporating thorough consideration of technical, environmental, socio-economic and economic considerations. A further sensitivity analysis was conducted to verify the results.

The location alternatives assessment indicated that the preferred or most favored option is the Upper Casino Creek option (Option B) which had the highest combined score, as well as the highest score in the environmental and socio-economic account. The sensitivity analysis indicated that in every case, that option (Option B) resulted in the highest merit rating compared to the other options.

Therefore, the mine waste management disposal option selected is slurried tailings co-disposed with waste rock in an impoundment formed by a cyclone sand dam in upper Casino Creek.

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APPENDIX A ALTERNATIVES ANALYSIS RANKING AND WEIGHTING RESULTS

LOCATION ALTERNATIVE ASSESSMENT LEDGER

ACCOUNTS	W	SUB-ACCOUNTS	W	INDICATORS	W	Option A	Option B	Option C	Option D		Discrimination Values (based on a difference of 30%)	
						TIA+WR in Canadian Creek	TIA+WR in Casino Creek (Upper)	TIA+WR in Casino Creek (Lower)	TIA+WR avoiding areas frequented by fish			
Technical	3	Dam Design	4	Impoundment storage volume	2	6	6	6	6		0	ND
				Dam size and configuration	6	4	4	6	1		30	D
				Number of large dams required	6	6	6	6	4		12	D
				Total embankment volume	6	5	4	6	1		30	D
				Sub-account merit score (Σ{SxW})		102	96	120	48			
				Sub-account merit rating (Σ{SxW}/ΣW)		5.1	4.8	6.0	2.4			
		Operational Management	6	Impoundment footprint	4	5	6	2	4		16	D
				operational ease - tailings	5	5	6	5	4		10	D
				operational ease - waste rock	6	4	6	4	3		18	D
				Sub-account merit score (Σ{SxW})		69	90	57	54			
				Sub-account merit rating (Σ{SxW}/ΣW)		4.6	6.0	3.8	3.6			
		Construction	4	Geotechnical complexity	6	5	6	5	2		24	D
				scheduling (construction)	4	5	4	6	1		20	D
				Sub-account merit score (Σ{SxW})		50	52	54	16			
				Sub-account merit rating (Σ{SxW}/ΣW)		5.0	5.2	5.4	1.6			
		Structural Stability	6	stability considerations operations and long term	6	4	5	6	2		24	D
				Sub-account merit score (Σ{SxW})		24	30	36	12			
				Sub-account merit rating (Σ{SxW}/ΣW)		4.0	5.0	6.0	2.0			

LOCATION ALTERNATIVE ASSESSMENT LEDGER

ACCOUNTS	W	SUB-ACCOUNTS	W	INDICATORS	W	Option A	Option B	Option C	Option D	Discrimination Values (based on a difference of 30%)	
		Permafrost	6	permafrost sensitivity	6	6	6	6	6	0	ND
				Sub-account merit score (Σ{SxW})		36	36	36	36		
				Sub-account merit rating (Σ{SxW}/ΣW)		6.0	6.0	6.0	6.0		
		Capacity	3	expansion potential	6	4	4	6	2	24	D
				Sub-account merit score (Σ{SxW})		24	24	36	12		
				Sub-account merit rating (Σ{SxW}/ΣW)		4.0	4.0	6.0	2.0		
		Account merit score (Σ{SxW})				140	154	158	92		
		Account merit rating (Σ{SxW}/ΣW)				4.8	5.3	5.5	3.2		

LOCATION ALTERNATIVE ASSESSMENT LEDGER

ACCOUNTS	W	SUB-ACCOUNTS	W	INDICATORS	W	Option A	Option B	Option C	Option D	Discrimination Values (based on a difference of 30%)	
Environmental	6	Consequence of Dam Failure	6	Potential environmental effect as a consequence of dam failure	6	2	6	6	6	24	D
				Sub-account merit score (Σ{SxW})		12	36	36	36		
				Sub-account merit rating (Σ{SxW}/ΣW)		2.0	6.0	6.0	6.0		
		Water Management (storage & seepage)	6	Catchment area	6	3	6	2	5	24	D
				Degree of TIA seepage expected	6	3	5	6	2	24	D
				Operational water management complexity	4	5	6	4	3	12	D
				Long term maintenance requirements	4	6	6	5	3	12	D
				Sub-account merit score (Σ{SxW})		80	114	84	66		
				Sub-account merit rating (Σ{SxW}/ΣW)		4.0	5.7	4.2	3.3		
		Water Quality	6	Operational water quality (assumes 10% bypass) with respect to MMER at the toe of the dam (ratio of Cu seepage/Cu MMER)	6	6	6	6	2	24	D
				Operational water quality (assumes 10% bypass + discharge if required) with respect to CCME immediately below first	6	4	4	6	2	24	D
				Operational water quality (assumes 10% bypass + discharge if required) with respect to CCME 10 km d/s of dam (ratio	4	6	5	4	2	16	D
				Closure water quality (assumes 100% bypass) with respect to CCME at the toe of the dam (ratio of Cu seepage/Cu CCME)	4	6	6	6	2	16	D
				Closure water quality (assumes 100% bypass) with respect to CCME at first tributary (assumed first occurrence of fish)	6	5	4	6	2	24	D
				Closure water quality (assumes 100% bypass + discharge if required) with respect to CCME 10 km d/s of dam (ratio	6	6	3	3	2	24	D
				Operational water quality at point of spillway discharge (ratio of Cu /Cu CCME)	6	5	6	5	6	6	ND
				Closure water quality at point of spillway discharge (ratio of Cu /Cu CCME)	6	6	3	5	2	24	D
				Sub-account merit score (Σ{SxW})		240	200	226	112		
				Sub-account merit rating (Σ{SxW}/ΣW)		5.5	4.5	5.1	2.5		

LOCATION ALTERNATIVE ASSESSMENT LEDGER

ACCOUNTS	W	SUB-ACCOUNTS	W	INDICATORS	W	Option A	Option B	Option C	Option D	Discrimination Values (based on a difference of 30%)	
		Groundwater	2	Potential reduction in groundwater contributions downgradient	3	6	6	6	4	6	ND
				Potential impacts to GW quality downgradient	6	5	6	6	3	18	D
				Sub-account merit score (Σ{SxW})		48	54	54	30		
				Sub-account merit rating (Σ{SxW}/ΣW)		5.3	6.0	6.0	3.3		
		Fish Habitat	4	Quality of fish habitat under the footrpint of the TIA	2	4	6	3	6	6	ND
				Quality of fish habitat at first tributary d/s of the dam during operations	4	4	6	3	6	12	D
				Quality of fish habitat 10 km d/s of the dam during operations	6	1	6	6	6	30	D
				Reduction of flow (Operations to early closure)	3	5	4	6	4	6	ND
				Removal of fish habitat by footprint	6	4	6	3	6	18	D
				Sub-account merit score (Σ{SxW})		69	120	90	120		
				Sub-account merit rating (Σ{SxW}/ΣW)		3.3	5.7	4.3	5.7		
		Wildlife Habitat	3	Effect on wildlife habitat in footprint area	6	6	6	6	6	0	ND
				Sub-account merit score (Σ{SxW})		36	36	36	36		
				Sub-account merit rating (Σ{SxW}/ΣW)		6.0	6.0	6.0	6.0		
		Flora	3	Effect on flora in footprint area	6	6	6	6	6	0	ND
				Sub-account merit score (Σ{SxW})		36	36	36	36		
				Sub-account merit rating (Σ{SxW}/ΣW)		6.0	6.0	6.0	6.0		
		Air Quality	1	Potential for fugitive dust emissions	6	6	6	6	6	0	ND

LOCATION ALTERNATIVE ASSESSMENT LEDGER

ACCOUNTS	W	SUB-ACCOUNTS	W	INDICATORS	W	Option A	Option B	Option C	Option D	Discrimination Values (based on a difference of 30%)	
				Sub-account merit score (Σ{SxW})		36	36	36	36		
				Sub-account merit rating (Σ{SxW}/ΣW)		6.0	6.0	6.0	6.0		
		Closure Measures	4	duration of long term liability	6	6	6	6	6	0	ND
				extent of measures to implement closure	6	4	6	5	4	12	D
				long term level/intensity of site activity	6	6	4	4	4	12	D
				Sub-account merit score (Σ{SxW})		96	96	90	84		
				Sub-account merit rating (Σ{SxW}/ΣW)		5.3	5.3	5.0	4.7		
		Account merit score (Σ{SxW})				156	196	183	161		
		Account merit rating (Σ{SxW}/ΣW)				4.5	5.6	5.2	4.6		

LOCATION ALTERNATIVE ASSESSMENT LEDGER

ACCOUNTS	W	SUB-ACCOUNTS	W	INDICATORS	W	Option A	Option B	Option C	Option D	Discrimination Values (based on a difference of 30%)	
Socio-economics	3	Traditional Land Use	6	in immediate area	6	3	6	6	6	18	D
				Sub-account merit score (Σ{SxW})		18	36	36	36		
				Sub-account merit rating (Σ{SxW}/ΣW)		3.0	6.0	6.0	6.0		
		Long Term Care and Maintenance	6	winter operating requirements	6	5	6	5	6	6	ND
				total effort	6	6	6	6	6	0	ND
				Sub-account merit score (Σ{SxW})		66	72	66	72		
				Sub-account merit rating (Σ{SxW}/ΣW)		5.5	6.0	5.5	6.0		
		Permitting	6	Overall project complexity from permitting point of view	6	2	6	6	1	30	D
				Requirement for schedule 2 amendment	6	1	6	1	6	30	D
				Sub-account merit score (Σ{SxW})		6	36	6	36		
				Sub-account merit rating (Σ{SxW}/ΣW)		1.0	6.0	1.0	6.0		
		Archaeology	6	sites of importance in immediate area	6	6	6	6	6	0	ND
				Sub-account merit score (Σ{SxW})		36	36	36	36		
				Sub-account merit rating (Σ{SxW}/ΣW)		6.0	6.0	6.0	6.0		
		Safety	6	Consequence of dam breach (socio-economic impacts)	6	2	6	6	6	24	D
				Sub-account merit score (Σ{SxW})		12	36	36	36		
				Sub-account merit rating (Σ{SxW}/ΣW)		2.0	6.0	6.0	6.0		
		Noise	1	Degree of noise pollution	6	6	6	6	6	0	ND
				Sub-account merit score (Σ{SxW})		36	36	36	36		
				Sub-account merit rating (Σ{SxW}/ΣW)		6.0	6.0	6.0	6.0		

LOCATION ALTERNATIVE ASSESSMENT LEDGER

ACCOUNTS	W	SUB-ACCOUNTS	W	INDICATORS	W	Option A	Option B	Option C	Option D	Discrimination Values (based on a difference of 30%)	
		Aesthetics	1	Visibility from frequented areas	6	6	6	6	6	0	ND
				Sub-account merit score (Σ{SxW})		36	36	36	36		
				Sub-account merit rating (Σ{SxW}/ΣW)		6.0	6.0	6.0	6.0		
		Tax contribution	1	Anticipated taxes	6	6	6	6	6	0	ND
				Sub-account merit score (Σ{SxW})		36	36	36	36		
				Sub-account merit rating (Σ{SxW}/ΣW)		6.0	6.0	6.0	6.0		
		Job opportunities	1	Job/contracting potential	6	6	6	6	6	0	ND
				Training/experience opportunities	6	6	6	6	6	0	ND
				Sub-account merit score (Σ{SxW})		72	72	72	72		
				Sub-account merit rating (Σ{SxW}/ΣW)		6.0	6.0	6.0	6.0		
		Community perception	6	Community perception	6	2	6	4	1	30	D
				Sub-account merit score (Σ{SxW})		12	36	24	6		
				Sub-account merit rating (Σ{SxW}/ΣW)		2.0	6.0	4.0	1.0		
		Future Burden on Society	6	Future burden on society	6	6	6	6	6	0	ND
				Sub-account merit score (Σ{SxW})		36	36	36	36		
				Sub-account merit rating (Σ{SxW}/ΣW)		6.0	6.0	6.0	6.0		
		Account merit score (Σ{SxW})				173	252	217	247		
		Account merit rating (Σ{SxW}/ΣW)				3.8	5.5	4.7	5.4		

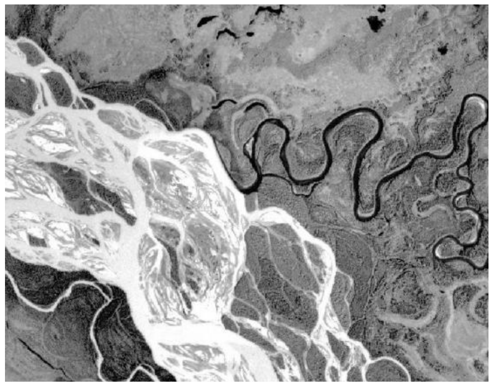
LOCATION ALTERNATIVE ASSESSMENT LEDGER

ACCOUNTS	W	SUB-ACCOUNTS	W	INDICATORS	W	Option A	Option B	Option C	Option D	Discrimination Values (based on a difference of 30%)	
Project Economics	1.5	Government Costs	6	Supporting infrastructure costs	6	6	6	6	6	0	ND
				Sub-account merit score (Σ{SxW})		36	36	36	36		
				Sub-account merit rating (Σ{SxW}/ΣW)		6.0	6.0	6.0	6.0		
		Project Costs	6	Initial capital cost (waste and water management costs only)	6	6	4	6	1	30	D
				Sustaining and operating costs	5	4	6	6	1	25	D
				Fish habitat compensation	2	6	6	6	6	0	ND
				Closure costs	2	6	6	4	3	6	ND
				Post closure costs	2	6	5	4	2	8	ND
				Sub-account merit score (Σ{SxW})		92	88	94	33		
				Sub-account merit rating (Σ{SxW}/ΣW)		5.4	5.2	5.5	1.9		
		Account merit score (Σ{SxW})				68	67	69	48		
		Account merit rating (Σ{SxW}/ΣW)				5.7	5.6	5.8	4.0		
Combined Evaluation		Overall merit score (Σ{SxW})				61	74	71	59		
Combined Evaluation		Overall merit rating (Σ{SxW}/ΣW)				4.5	5.5	5.2	4.4		

APPENDIX B.4C: Tailings Management Facility Dam Breach Inundation Study

VOLUME B.I: PROJECT INTRODUCTION & OVERVIEW

CASINO MINING CORPORATION
CASINO PROJECT


TMF DAM BREACH INUNDATION STUDY

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VA101-325/20-2
Rev 0
September 21, 2015

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ISO 14001 - EMS 550121
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CASINO MINING CORPORATION
CASINO PROJECT

TAILINGS MANAGEMENT FACILITY DAM BREACH INUNDATION STUDY
VA101-325/20-2

Rev	Description	Date
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EXECUTIVE SUMMARY

The Casino Tailings Management Facility (TMF) has been designed to permanently store all tailings and potentially reactive mine waste rock and overburden materials from the Casino Project. The embankments have been designed in accordance with the Canadian Dam Association "Dam Safety Guidelines" (CDA 2007a; 2013). Accordingly, the facility was designed with capacity to contain the inflow design flood (IDF) and to withstand the maximum design earthquake (MDE). The likelihood of occurrence of a TMF breach has been minimized to the maximum practical extent during the planning and design of the facility.

The potential consequences of a tailings dam breach demonstrated through dam breach modelling specifically ignore the likelihood of occurrence. The modelled dam failures are hypothetical and should not occur if the TMF is designed, constructed and operated following standard engineering practices. However, it is prudent to understand the potential consequences of failure, and the results of this study can be used to aid in the development of emergency planning.

The dam breach inundation study for the Casino Project was structured to estimate the potential inundation limits that would result from a hypothetical dam breach during the last year of operations (ultimate arrangement). The potential inundation and consequences of a breach at any time during operations are expected to be less than those presented in this study. The quantitative assessment of the potential consequences of a flood from a TMF dam breach requires an estimate of the volume of water and tailings released in the breach, peak outflow discharge, physical characteristics of the breach (height, width, and side slopes), and an estimate of how quickly the breach would occur. These characteristics were estimated using empirical methods, and applied to develop dam breach hydrographs for sunny day and flood induced failure scenarios. Flow hydrographs were also developed to estimate the flooding from naturally occurring floods without a dam breach, which were used to establish incremental impacts. These breach hydrographs and natural flood hydrographs were then routed downstream using a one dimensional hydrodynamic model to predict the extent of flooding downstream from the TMF location to the confluence of the White and Yukon Rivers.

Floods caused by either a TMF dam breach or a natural probable maximum flood (PMF) would cause severe flooding and erosion in the Casino and Dip Creek channels and floodplains. A cabin on the northwest hill slope above Casino Creek identified by the Yukon Wildland Fire Management Operations is above the modelled inundation area for all modelled scenarios and would not be impacted. The proposed air strip located along Dip Creek is also above the modelled inundation area in all modelled cases. The road connecting the airstrip to the mine crosses Dip Creek just upstream of the air strip, and this bridge crossing is expected to be washed out by the flood wave in either breach scenario and during a naturally occurring PMF flood without a dam breach. No other known existing or proposed settlements or infrastructure are predicted to incur damage during a breach or a PMF flood.

Floods caused by a TMF dam breach or a natural flood without a dam breach would also cause flooding and erosion to the Klotassin River, Donjek River and White River channels and floodplains. No existing or proposed settlements or infrastructure in or near the inundated area are known at the time of this study. The results indicate that the incremental impacts of a dam breach flood wave are reduced in the downstream direction and are diminished to about 1 m above the natural water surface by the confluence of the White and Yukon Rivers.

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ABBREVIATIONS

Casino	the Casino Project
CDA	Canadian Dam Association
CMC	Casino Mining Corporation
EL	elevation
IDF	Inflow Design Flood
KP	Knight Piésold Ltd.
LiDAR	Light Detection and Ranging
m	metres
MAD	Mean Annual Discharge
MMWL	maximum modelled water level
MPWL	maximum possible water level
Mm^3	million cubic metres
Mt	million tonnes
m^3/s	cubic metres per second
NAG	non-acid generating
NOWL	normal operating water level
NTS	National Topographic System
PAG	potentially acid generating
PMF	probable maximum flood
PMP	probable maximum precipitation
t/m^3	tonnes per cubic metre
TPD	tonnes per day
TMF	Tailings Management Facility
YESAB	Yukon Environmental and Socio-Economic Assessment Board

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1 – INTRODUCTION

1.1 PROJECT LOCATION

The Casino Project (Casino) is an open pit copper-gold-molybdenum mine in Yukon proposed by the Casino Mining Corporation (CMC). The deposit will be mined using open pit methods with a nominal mill throughput of approximately 125,000 tonnes/day (tpd) of ore over a 22 year operating life. The project is located in the Dawson Range Mountains of the Klondike Plateau approximately 300 km northwest of Whitehorse, Yukon, Canada, as shown on Figure 1.1. The Tailings Management Facility (TMF) and the TMF Main Embankment are located within the Casino Creek valley. The characteristic terrain features consist of smooth, rolling topography, with moderate to deeply incised valleys. Major drainage channels extend below 1,000 m elevation. Most of the terrain lies between 1,000 m and 1,500 m elevation.

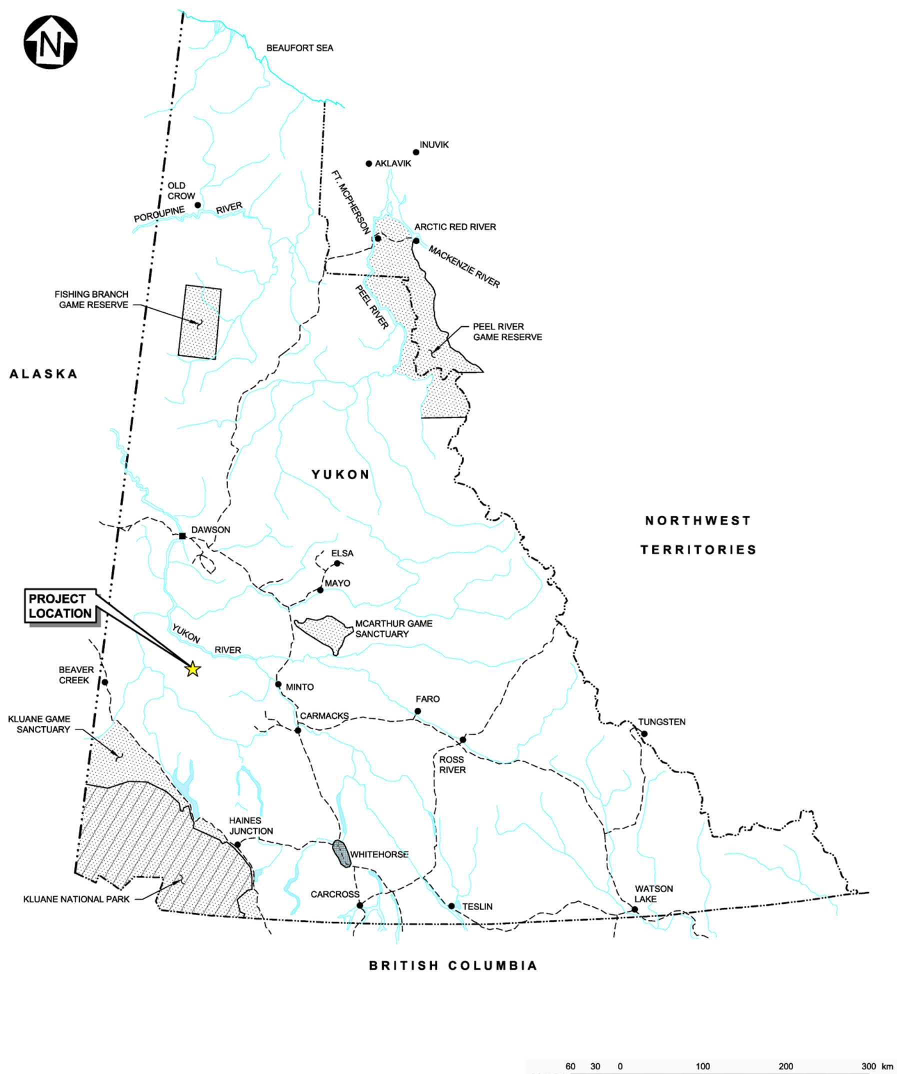


Figure 1.1 Project Location

1.2 PURPOSE OF STUDY

The tailings dams at Casino are designed in accordance with Canadian Dam Association (CDA) "Dam Safety Guidelines" (CDA 2007a; 2013), which also provides guidelines in evaluating the classification of dams in terms of the consequence of failure. The stability of the TMF dams was evaluated during the design stages for a range of loading conditions and a failure of the dams is not likely to occur. The dam breach and inundation study for the Casino TMF was completed for hypothetical failures under extreme and highly unlikely events. The results of the analysis do not reflect upon the structural integrity or safety of the dams.

The dam breach and inundation study for the Casino TMF was completed following CDA guidelines (CDA 2007a; 2013). The study was undertaken to provide a preliminary understanding of the potential consequences of a tailings dam failure and was structured to estimate the potential inundation limits that would result from a dam breach during the last year of operations (ultimate arrangement). The potential inundation and consequences of a breach at any time during operations are expected to be less than those presented in this study.

1.3 SCOPE OF WORK

In accordance with the CDA Guidelines (CDA 2007a; 2007b), the dam breach evaluation addresses two initial hydrologic conditions:

- Sunny day failure – a sudden dam failure that occurs during normal operations, which may be caused by internal erosion, piping, earthquakes, mis-operation leading to overtopping, or another event.
- Flood induced or rainy day failure – a dam failure resulting from a natural flood of a magnitude that is greater than what the dam can safely pass.

The scope of work for this study includes:

- Determination of the critical dam location to be considered in the dam breach analysis. For the proposed breach scenarios, a cross section of the TMF embankment is provided.
- Determination of the dam breach parameters for the critical location during the sunny day and flood induced failure scenarios.
- Determination of peak discharges for the sunny day and flood induced scenarios for the critical breach location.
- Flood routing and inundation mapping for the sunny day and flood induced scenarios for areas downstream of the TMF.

1.4 LIMITATIONS

The potential consequences of a tailings dam breach demonstrated through dam breach modelling specifically ignore the likelihood of occurrence. The modelled dam failures are hypothetical and should not occur for TMFs that are designed, constructed and operated following standard engineering practices throughout the life of mine.

There are limitations in accurately modelling the effects of a tailings outflow because the science of predicting tailings dam breaches is relatively new. The CDA issued a Technical Bulletin "Application of Dam Safety Guidelines to Mining Dams" in 2014; however, this document does not prescribe procedures for conducting dam breach analyses, and is limited to identifying "some specific issues that should be considered during the design and safety evaluation of mining dams" (CDA 2014). Further, the guidelines for dam breach analyses were developed for water retaining dams, and as such, are not fully applicable for tailings dams. There is no definitive "state of practice" for such analyses, and as such tailings are commonly modelled as an equivalent volume of water. This methodology provides a conservative "worst case" estimate of peak discharge, runout distance, and flood inundation levels.

Further limitations for dam breach modelling, downstream flood wave routing and inundation mapping stem from the quality of topographic and bathymetric data available for the downstream drainage network. Bathymetric data often does not exist even for major river channels, while detailed topographic information is typically available only close to the project area. Further downstream, modelling is done using publically available topographic data, which for the Yukon is represented by National Topographic System (NTS) maps with 30 m contour spacing provided by Natural Resource Canada. Such contour spacing does not enable detailed delineation of river channels and associated floodplains and restricts the accuracy of inundation maps. Numerous uncertainties are, therefore, inherent in dam breach modelling and inundation mapping and the flood inundation limits produced from such modelling should be regarded as approximate.

1.5 REFERENCE REPORTS

Information available in the following Knight Piésold (KP) subject matter reports was used to prepare this study:

- Casino Copper-Gold Project, Report on Feasibility Design of the Tailings Management Facility, VA101-325/8-10, December 20, 2012.
- Casino Copper-Gold Project, Baseline Climate Report, VA101-325/14-7, June 14, 2013.
- Casino Copper-Gold Project, Baseline Hydrology Report, VA101-325/14-5, October 10, 2013.
- Casino Copper-Gold Project, Updated YESAB Water balance to Include Climate Variability, VA14-01240, December 16, 2014.

2 – PROJECT SETTING

2.1 TAILINGS FACILITY OVERVIEW

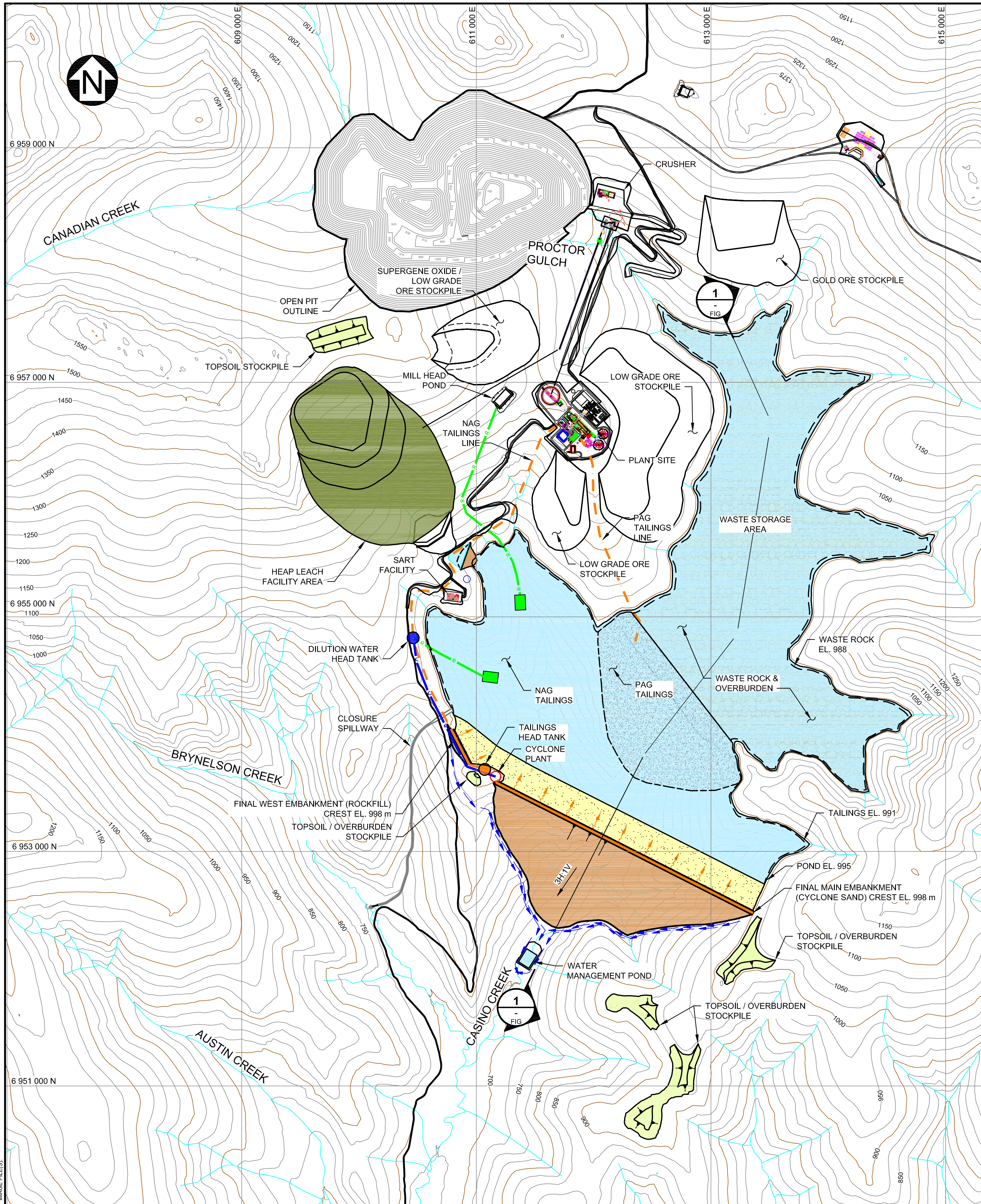
The Casino TMF has been designed to permanently store all tailings and potentially reactive mine waste rock and overburden materials from the Casino Project. The embankments that confine the TMF are the Main Embankment to the south and the West Saddle Embankment to the west. The embankments have been designed in accordance with the CDA "Dam Safety Guidelines" (CDA 2007a; 2013). The details of the TMF design are provided in the Report on Feasibility Design of the Tailings Management Facility (KP 2012), and the sections relevant for this study are revisited in this report. The feasibility design report contains the design criteria for the TMF and ancillary facilities.

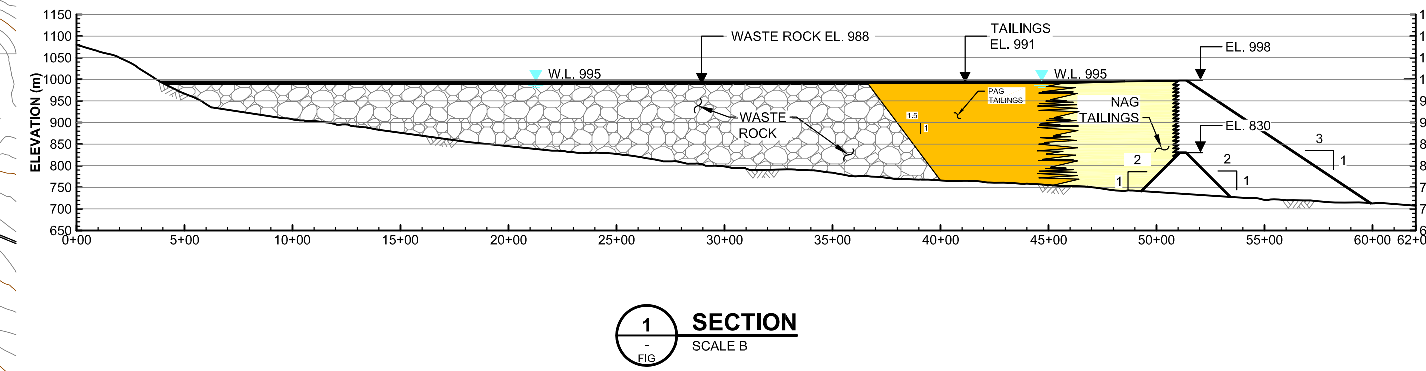
Mining of the open pit will yield approximately 965 million tonnes of ore and the mill will operate at a nominal mill throughput of approximately 125,000 tonnes per day over the 22 year operating life of the mine. The TMF has been sized to provide sufficient capacity to store approximately 956 million tonnes of tailings (including cyclone sand tailings used as embankment fill) and up to 658 million tonnes of potentially reactive waste rock and overburden materials. Approximately 80% of the total tailings will be geochemically innocuous NAG material, following the removal of the pyrite component. These tailings will be used for the production of 221 Mt of cyclone sand (the coarse fraction of the tailings) for construction of the Main Embankment. Approximately 20% of the milled tailings will consist of PAG material and will be deposited in a separate central region of the TMF. In addition to tailings, 658 million tonnes of potentially reactive waste rock will also be stored subaqueously within the proposed TMF in the Waste Storage Area (WSA) located in the upper (northern) region of the TMF basin. Deposition of PAG and potentially reactive waste rock in the central and upstream TMF area will keep these materials remote from the confining embankments, minimize the impact of seepage from these materials, and ensure that they remain in a subaqueous state. The ultimate general arrangement of the TMF is shown on Figure 2.1.

The TMF Main Embankment is designed as a cyclone sand dam. The embankment shell zones for the Main Embankment Starter dam will be constructed with random fill comprising suitable rockfill from local borrow sources and available non-reactive waste rock material from pre-production stripping. The TMF embankments will be constructed as water-retaining zoned structures with a low permeability core zone and appropriate filter and transition zones to prevent downstream migration of fines. The core zone will include a seepage cut-off into competent rock in the foundation. Each stage of the TMF development is sized to store tailings based on the mine production schedule, together with potentially reactive waste rock from the open pit and a supernatant water pond. Additional capacity is provided for storm water storage for the inflow design flood event and an allowance of two additional metres of embankment freeboard for wave run-up protection.

Ongoing Main Embankment stages will be centreline raises with a low permeability core zone and adjacent downstream filter and transition zones. An extensive tailings beach will be developed between the supernatant pond and the embankment to provide a stable upstream construction surface for the centreline embankment raises. The upstream and downstream shell zones will be constructed from compacted cyclone sand with a 3H:1V downstream slope. The ultimate dam will be approximately 286 m high. The final crest width will be 30 m and the crest length will be 2,500 m at EL. 998 m.

The West Saddle Embankment will be constructed at the south-western corner of the TMF and is required at the start of operations to provide a pipeline corridor at a suitable grade for tailings delivery to the cyclone sand plant and TMF. The embankment will comprise an earthfill-rockfill dam, constructed from local borrow materials to a maximum height of approximately 21 metres.





1 - FIG **SECTION**
SCALE B

NOTES:

1. COORDINATE GRID IS IN METERS, COORDINATE SYSTEM: NAD 1983 UTM ZONE 7N.
2. CONTOUR INTERVAL IS 25 METRES.
3. DIMENSIONS ARE IN METRES UNLESS NOTED.
4. OPEN PIT AS PROVIDED BY CASINO MINING CORPORATION (NOVEMBER 2012).
5. PLANT SITE AND CRUSHER LAYOUT PROVIDED BY M3 ENGINEERING AND TECHNOLOGY CORPORATION (OCTOBER 4, 2012).
6. ORE AND TOPSOIL STOCKPILES ARE SHOWN AT THEIR MAXIMUM SIZE DURING OPERATIONS.

LEGEND:

- TOPSOIL / OVERBURDEN
- TAILINGS
- EMBANKMENT (CYCLONE SAND)
- EMBANKMENT (ROCKFILL)
- POND
- TAILINGS PIPELINES
- RECLAIM PIPELINES
- WATER PIPELINES
- TAILINGS HEAD TANK
- DILUTION WATER HEAD TANK
- CYCLONE PLANT
- DIVERSION DITCHES

SCALE B: 350 175 0 350 700 1050 1400 1750 m
SCALE A: 400 200 0 400 800 1200 1600 2000 m

CASINO MINING CORPORATION

CASINO COPPER-GOLD PROJECT

TAILINGS MANAGEMENT FACILITY GENERAL ARRANGEMENT FINAL (YEAR 22)

Knight Piésold CONSULTING

P/A NO.	REF NO.
VA101-325/20	2

FIGURE 2.1 REV 0

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	REVIEWED
0	16SEP'15	ISSUED WITH REPORT	SB	PP	KJB

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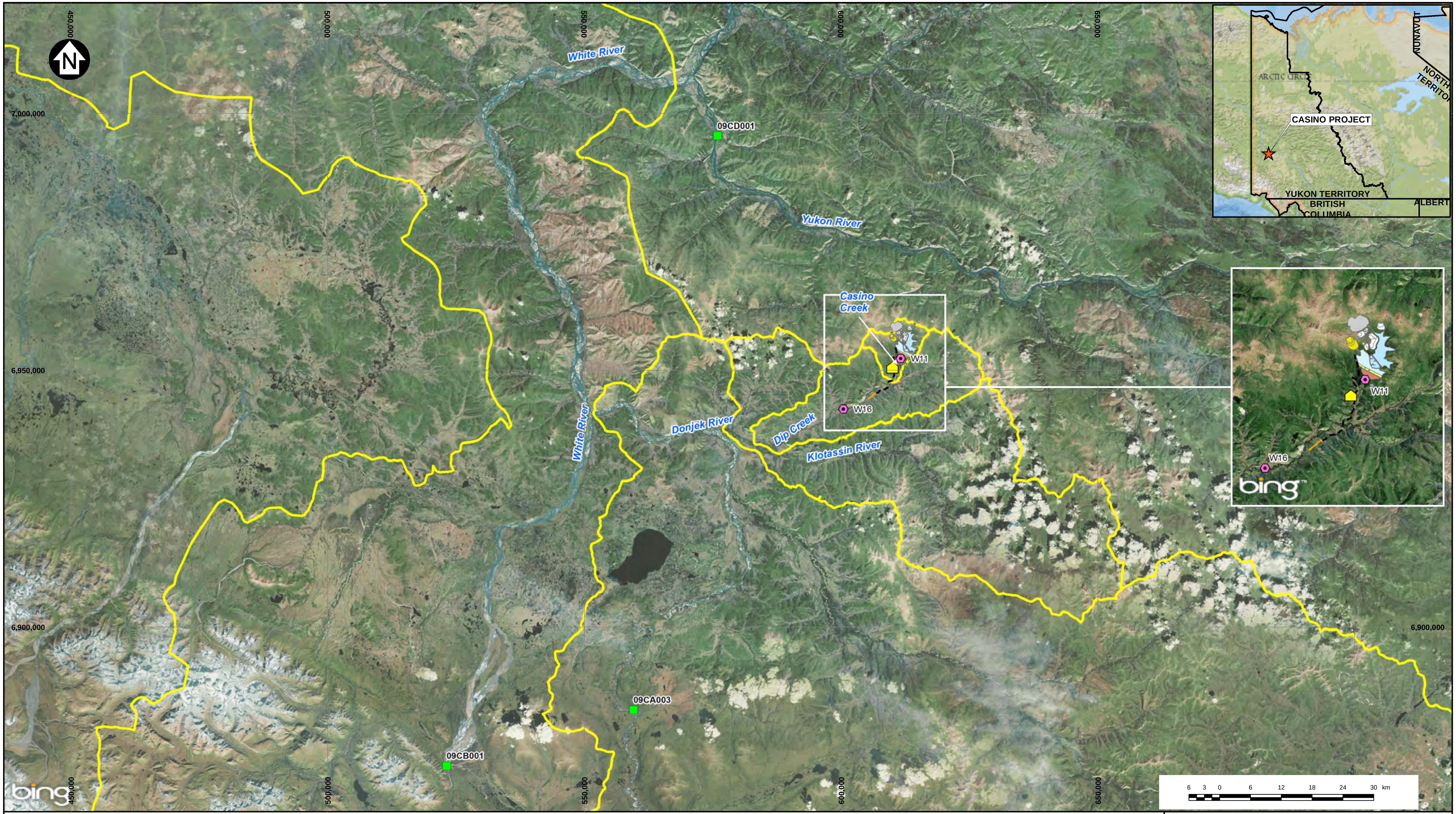
XREF FILE(S): IMAGE FILE(S):

2.2 DOWNSTREAM DRAINAGE NETWORK

Casino is located in the Dawson Mountain Range of the Klondike Plateau, approximately 300 km northwest of Whitehorse, Yukon Territory, Canada. The Project is located within the Boreal Cordillera ecozone, which comprises much of the southern Yukon and a large portion of northern British Columbia, and is more specifically located within the Dawson Range ecoregion (Natural Resources Canada 1993). The Boreal Cordillera ecozone is characterized by the presence of several mountain ranges, including the Dawson Range, that trend in the north-westerly direction and include extensive plateau regions. The plateaus consist of flat or gently rolling terrain separated by broad valleys and lowlands. The climate is characterized by long, cold, dry winters and short, warm, wet summers, with conditions varying according to altitude and aspect. Average annual precipitation is generally quite low, with values in the range of 300 mm to 450 mm (Smith, Meikle, & Roots, 2004).

Casino is situated on the drainage divide between the Casino Creek and Britannia Creek watersheds, with the TMF located in the upper portion of the Casino Creek watershed. Casino Creek drains southwest, eventually flowing into the White River, which is a tributary of the Yukon River, while Britannia Creek drains north directly to the Yukon River. The drainage network downstream of the TMF is shown on Figure 2.2 along with the drainage areas at points of interest.

Casino Creek is a small creek with plane bed morphology (Montgomery and Buffington 1997), cobble substrate and densely vegetated overbanks as shown on Figure 2.3. Casino Creek drains south to Dip Creek, a mid-sized creek with primarily pool-riffle morphology (Montgomery and Buffington 1997), gravel substrate and densely vegetated overbanks as shown on Figure 2.4. Dip Creek flows into the Klotassin River, which according to publically available aerial imagery, is a small meandering river with a high degree of sinuosity as shown on Figure 2.5. The Klotassin River confluence with the Donjek River is a short distance downstream of its confluence with Dip Creek. The Donjek River is a medium to large braided river as shown on Figure 2.5, which flows into the White River, a medium to large braided river as shown on Figure 2.6. Roughly 110 km downstream from the confluence with the Donjek River, the White River flows into the Yukon River.



LEGEND:

- HYDROLOGY STATION
- CABIN
- WATER SURVEY OF CANADA STREAMFLOW STATION
- CATCHMENT BOUNDARY

PROPOSED MINE FACILITIES

- AIRSTRIP ACCESS ROAD
- TAILINGS BEACH
- EMBANKMENT
- HEAP LEACH FACILITY
- OPEN PIT
- POND
- PAG TAILINGS
- AIRSTRIP

River	Drainage Area (km^2)
Casino River at the mouth	82
Dip Creek at the mouth	567
Klotassin River at the mouth	2,373
Donjek River at the mouth	26,360
White River at the mouth	47,644

NOTES:

1. BASE MAP: ESRI ARCGIS ONLINE BING MAPS.
2. COORDINATE GRID IS IN METRES/DEGREES. COORDINATE SYSTEM: NAD 1983 UTM ZONE 7N.
3. THIS FIGURE IS PRODUCED AT A NOMINAL SCALE OF 1:700,000 FOR 11x17 (TABLOID) PAPER. ACTUAL SCALE MAY DIFFER ACCORDING TO CHANGES IN PRINTER SETTINGS OR PRINTED PAPER SIZE.

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	REVIEWED
0	16SEP'15	ISSUED WITH REPORT	ACA	AMD	VM

CASINO MINING CORPORATION

CASINO COPPER-GOLD PROJECT

DRAINAGE NETWORK DOWNSTREAM OF THE CASINO TMF

Knight Piésold CONSULTING

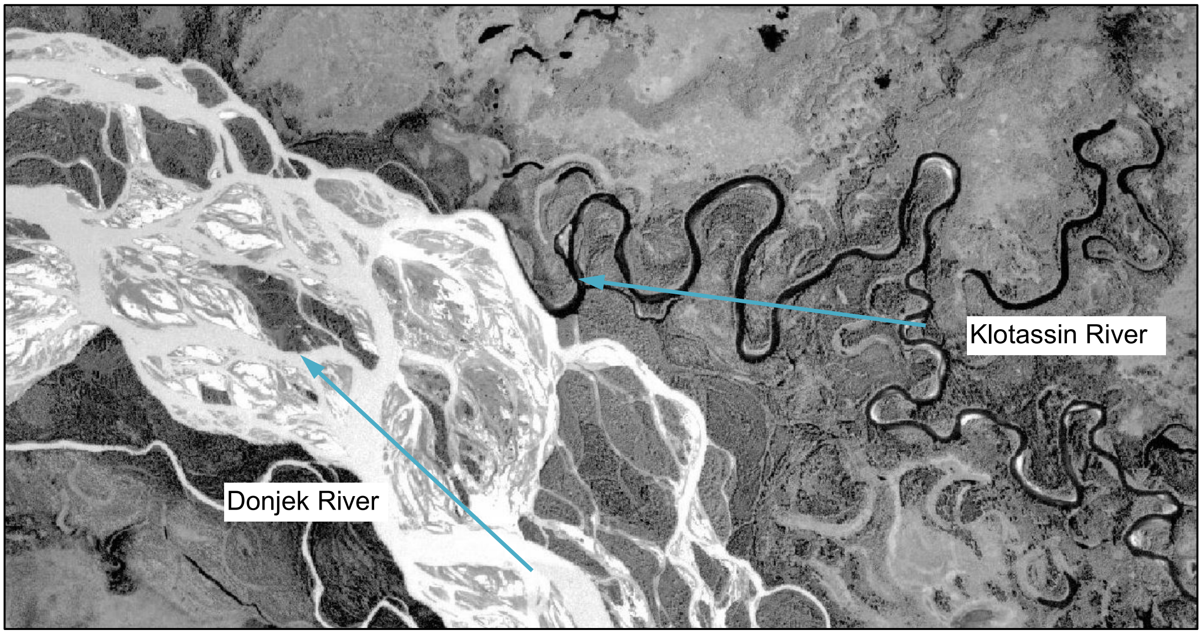
P/A NO.	REF NO.
VA101-325/20	2

FIGURE 2.2 REV 0

SAVED: M:\1\01\00325\20\A\GIS\Figs\Report2_TMF Breach and Innundation Study\Fig2-2_DrainageNetwork_r0.mxd; Sep 16, 2015 4:32 PM; lkrauszova

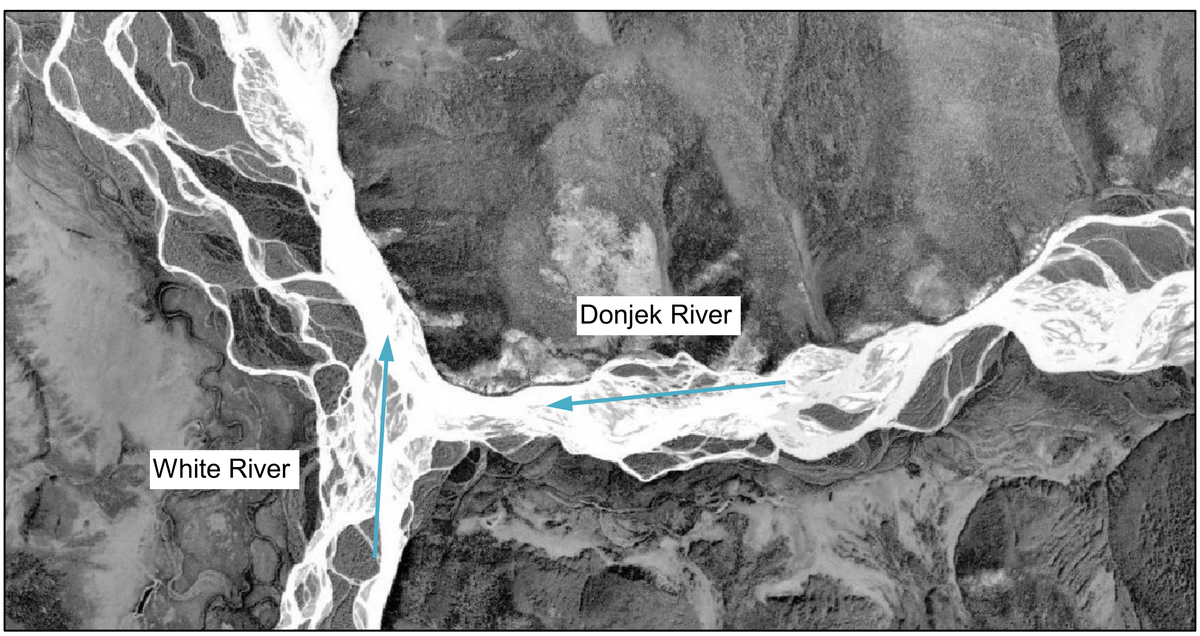
Figure 2.3 Casino Creek below Proposed TMF at Hydrology Station W11

Figure 2.4 Dip Creek below Confluence with Casino Creek at Hydrology Station W16



NOTES:
1. Aerial photo source: GeoYukon (Yukon Government, 2015).

Figure 2.5 Klotassin River and Donjek River Confluence



NOTES:
1. Aerial photo source: GeoYukon (Yukon Government, 2015).

Figure 2.6 Donjek River and White River Confluence

3 – TMF BREACH SCENARIOS

3.1 GENERAL

Breaching through the deepest section of the TMF Main Embankment was considered in this study, as this would result in the largest release of the impounded tailings and water. The ultimate Main Embankment will be approximately 286 m high. The final crest will be 30 m wide and 2,500 m long at EL. 998 m, as shown on Figure 2.1. The deepest section of the Main Embankment is situated on Casino Creek. A breach through the Main Embankment would result in a discharge into Casino Creek, and subsequently to Dip Creek, Klotassin River, Donjek River, and White River, reaching the confluence with the Yukon River. Breaching through the West Saddle Embankment was not considered, because the dam is of a much lesser height (21 m) and would result in a release of a smaller impoundment volume that would discharge to Brynelson Creek and then into Casino Creek about 1,500 m downstream of the Main Embankment.

The dam breach scenarios are conducted for two initial hydrologic conditions, as outlined in the CDA Guidelines (CDA 2007a, 2007b):

- Sunny day failure – a sudden dam failure that occurs during normal operations, which may be caused by internal erosion, piping, earthquakes, mis-operation leading to overtopping, or another event.
- Flood induced or rainy day failure – a dam failure resulting from a natural flood of a magnitude that is greater than what the dam can safely pass.

In a sunny day scenario, the TMF is assumed to be full to the normal operating level, while in a flood induced scenario the TMF is full to the crest of the embankment before it overtops. The types of discharge mechanisms that occur in a dam breach event are discussed in Section 3.2. The TMF layout, storage volumes and water elevations are reviewed in Section 3.3. The basic assumptions for the sunny day and flood induced scenarios are described in Section 3.4.1, while the hydrology for the site and for the downstream drainage network is reviewed in Sections 3.4.2 and 3.4.3, respectively.

3.2 CONCEPTUAL DISCHARGE MECHANISMS IN A DAM BREACH EVENT

There are two conceptual discharge mechanisms that typically occur following a dam breach (Martin et al. 2015):

- Initial Flood Wave, and
- Flow of Liquefied Tailings.

These mechanisms are distinctly different in the type of consequence they pose in terms of life safety and environmental impacts, but would occur in sequence following a catastrophic failure of a TMF dam. The purpose of dam safety measures during design, operation, and closure of the TMF is to prevent release of containment, thereby reducing risk associated with each consequence to the maximum practical extent. These failure mechanisms are discussed below, implicitly ignoring the likelihood of occurrence.

The ***initial flood wave*** would occur immediately following a failure of containment. The free water within the TMF supernatant pond would start to discharge and mobilize both tailings from the impoundment and construction material from the TMF dam along the way. Failure of an earthen dam typically occurs over a matter of minutes to hours with a flood wave rising as the breach develops, peaking at some point during discharge, and then receding as the flood wave subsides. The flood wave would propagate downstream causing significant erosion and inundating the downstream receiving environment. The extents of inundation are largely driven by the size of the impoundment, rate of breach development and the peak discharge, and topography of the downstream drainage network. The flood wave carries fine tailings and dam construction materials, as well as sediment scoured along the way. Depending on the volume discharged and the peak flow magnitude, the consequences of this initial flood wave could carry downstream for tens or hundreds of kilometers.

This failure mechanism is the focus of the dam breach analyses and inundation study presented in this report as it poses the most severe consequences to life safety and physical damage in the downstream environment. This initial flood wave is typically modelled as water, or a Newtonian fluid, which is a conservative, but not an uncommon approach. Modelling of non-Newtonian fluids requires knowledge of the rheology (viscosity and yield stress) for the sediment laden flow. The rheology of the flow is unknown, and furthermore, a non-Newtonian fluid option is not available for most flood routing software. It should be noted however, that research conducted for the same hypothetical breach using water vs. a non-Newtonian fluid has shown that the differences in peak discharge at various points downstream are within 5%, while the differences in depth are on the order of 10% (Bernedo et al. 2011).

The *flow of liquefied tailings* would occur following the initial flood wave, as a portion of the tailings mass would be expected to undergo static liquefaction from the change in confinement following the dam breach. Tailings that are not mobilized with the initial flood wave may slump through the breach in a paste-like fashion until the tailings mass stabilizes downstream. This process cannot be modelled as water, as the viscosity and yield stress of liquefied tailings play a much more significant role, with the tailings behaving like Bingham plastic fluid (Jeyapalan et al. 1983; Seddon 2010; Kulesza 2011). The inundation extent from tailings slumping would be less than from the initial flood wave, as more solids would deposit in the first few kilometers from the breach location.

Conceptually, the slumped tailings mass would appear like a cone of depression in the TMF with a similar cone of deposition downstream of the breach, similar to a debris flow or alluvial fan appearance. The deposition of the tailings material that discharges through this process largely depends on the downstream topography and stream/valley slopes, with the liquefied tailings materials stabilizing at slopes of 1˚ to 4˚ (Lucia et al. 1981; Blight and Fourie 2003).

3.3 TMF LAYOUT FOR DAM BREACH ANALYSIS

The ultimate arrangement of the proposed TMF was considered in the dam breach analysis. This arrangement represents the mine stage with the most tailings stored and the highest possible water level before a spillway is constructed. A full storage breach during this period would likely cause the greatest inundation.

The available storage created in the TMF includes storage of tailings, waste rock, embankment cyclone sand and water. The mass of waste storage in the facility is shown in Table 3.1, while normal and maximum water levels and water volumes for the ultimate arrangement at the end of Year 22 are shown in Table 3.2.

Table 3.1 Ultimate Arrangement Storage Capacity

Dam	Crest Elevation (m)	Waste Storage (Mt)		
		Waste Rock	Tailings	Cyclone Sand
Main Embankment	998.0	658	734	221

NOTES:
1. Waste storage as presented in KP 2012.

Table 3.2 Ultimate Arrangement Water Levels and Volumes

Dam	Normal Operating Water Level (NOWL)		Maximum Modelled Water Level (MMWL)		Maximum Possible Water Level (MPWL)	
	EL. (m)	Pond Volume (Mm^3)	EL. (m)	Pond Volume (Mm^3)	EL. (m)	Pond Volume (Mm^3)
Main Embankment	993.4	23	994.3	31	998.0	65

The normal operating water level (NOWL) was estimated from the depth area capacity (DAC) relationship using the mean simulated pond volume at the end of year 22 (KP 2014). Similarly, the maximum modelled water level (MMWL) was estimated from the DAC using the maximum simulated pond volume at the end of year 22 (KP 2014). The maximum possible water level (MPWL) is defined by the crest elevation of the dam. Freeboard available for stormwater storage and wave run up for the ultimate TMF arrangement is 6.6 m above NOWL and 5.7 m above MMWL, respectively.

3.4 SITE HYDROLOGY

3.4.1 Assumptions for Dam Breach Scenarios

The sunny day and the flood induced scenarios evaluate the consequence of dam breach events under different flow conditions, and therefore result in different outflow hydrographs. The basic assumptions for sunny day and flood induced scenarios are described in Sections 3.4.1.1 and 3.4.1.2, respectively.

3.4.1.1 Sunny Day Failure

The TMF dam was assumed to fail suddenly during normal operations for the sunny day scenario. The Dam Safety Guidelines (CDA 2007b) indicate the impoundment water levels and downstream tributary flow conditions used for such assessments should be those most probable to occur coincident with the breach event. Mean normal reservoir levels (discussed in Section 3.3) are typically combined with flows equivalent to the Mean Annual Discharge (MAD) in the inundation analysis.

The following conditions are modelled for this scenario:

- The TMF is assumed to have a normal operating water level as presented in Table 3.2 resulting in a pond volume of 23 Mm^3, and

- All downstream creeks and rivers are assumed to be flowing at MAD.

3.4.1.2 Flood Induced Failure

The PMF resulting from a 24-hour PMP event combined with snowmelt from a 1:100 snowpack was chosen for modelling the flood induced scenario and it was assumed the TMF would fail. A PMF caused by a PMP is defined as the theoretical maximum flood that could plausibly occur in a particular location at a particular time of year in a design watershed (WMO 2009). Similarly, a PMP is the theoretical maximum precipitation for a given duration meteorologically possible for a design watershed area or a given storm area at a particular geographic location at a certain time of year (WMO 2009), with no allowance made for long-term climatic trends.

In order for the PMF event to cause the TMF dam to overtop during the peak of the PMF event, the initial water level of the TMF pond was artificially raised from the MMWL by 3.1 m to an elevation of 997.4 m. This represents an additional 28 Mm^3 of water in the TMF pond. Given the mean annual precipitation of 460 mm (KP 2013a), mean annual evapotranspiration of 390 mm (KP 2014), and a drainage area of 39 km^2, it would take over 13 years for the TMF pond to reach this level from the NOWL and over 10 years from the MMWL. This is not a realistic scenario, because the spillway will be built at the end of operations, which will control the water level below the dam crest. Overtopping is therefore a very unlikely failure scenario.

The Dam Safety Guidelines (CDA 2007b) indicate the impoundment water levels and the downstream tributary flow conditions used for such assessments should be those most probable to occur coincident with the breach event. The PMP rain event was assumed to be centered on the TMF watershed in Casino Creek. The PMP rain event was scaled for the downstream watersheds and sub-watersheds in Casino Creek and Dip Creek using a methodology further discussed in Section 3.4.3. Klotassin River, Donjek River and White River were assumed to be flowing at 1:200 year flood conditions.

The following assumptions are made ror this scenario:

- The TMF is assumed to have a water level at the start of the PMF event such that the PMF event causes the dam to overtop at the peak of the event resulting in a pond volume of 65 Mm^3.
- Concurrent PMF events occur in Casino Creek and Dip Creek, while 1:200 year floods occur in the larger downstream rivers (further discussed in Section 3.4.3).

3.4.2 Mean Annual Flows for Sunny Day Failure Scenario

The tributary flows that are commonly used in these studies for the sunny day failure scenario are equivalent to MAD (CDA 2007b). Such flows are typically contained within the stream channel and do not cause flooding. These flows were estimated from the *Baseline Hydrology Report* (KP 2013b) and regional WSC stations (09CA003 - Donjek River below Kluane River and 09CB001 - White River at Kilometre 1,881.6 Alaska Highway). The downstream drainage network was discussed in more detail in Section 2.2 and is shown on Figure 2.2.

3.4.3 PMF Hydrograph Development for Flood Induced Failure Scenario

The PMF for the project area was developed by reviewing rain driven PMF events occurring during the summer or autumn, and a rain-on-snow driven PMF event occurring in the spring following CDA guidelines (CDA 2007c). The governing PMF for the project area is a combination of the 24-hour

PMP of 159 mm and a 1:100 year return period snowpack of 256 mm of which 156 mm is expected to melt during the PMP (KP 2012). A PMF hydrograph for the TMF watershed was developed using HydroCAD-10 Stormwater Modelling Software (HydroCAD) by HydroCAD Software Solutions LLC. The TMF watershed PMF hydrograph was used as the TMF inflow hydrograph for the flood induced failure scenario.

3.4.3.1 Concurrent Discharge in Other Tributaries for Flood Induced Failure Scenario

Given the proximity of Casino Creek and Dip Creek to the Casino TMF, a PMF event over the TMF watershed would likely correspond to similarly large events over these neighbouring watersheds. Hydrometeorological Report No. 57 published by the U.S. National Weather Service (Hansen et al., 1994) was used to estimate the scaling factor that needs to be applied to the rain event portion of the PMF to determine the rainfall magnitude in the adjacent catchments.,The relationships between the PMP depth to watershed area for orographic subregions in Southern BC, Washington, Oregon and Idaho are presented in this publication. Unfortunately, a similar report for the project area is unavailable, and so the relationships presented in the Hydrometeorilogical Report No. 57 were used in this study. The snowmelt portion of the PMF is the larger driving factor and was not scaled as less local differences would be expected for snow accumulation. Different sub-watersheds were scaled based on their contributing size and proximity to the TMF using the relationship presented in Hansen et al. (1994). A PMP rainstorm event in the TMF watershed would correspond to a PMP event in the remaining Casino Creek catchment, 95% of a PMP event in the upper Dip Creek watershed and 90% in the lower Dip Creek watershed. The hydrographs for each watershed were developed in HydroCAD and these hydrographs were used as inputs for the flood induced failure scenario.

The 1:200 year flood events were assumed to occur in the remaining larger downstream watersheds concurrently with the PMF in Casino Creek. This assumption was based on the relative size of the watersheds of Klotassin, Donjek and White Rivers in comparison to Casino Creek. The 1:200 year flood events at the mouth of Donjek and White Rivers were scaled from predicted 1:200 year floods at the Water Survey of Canada (WSC) stations for each river (09CA003 on the Donjek River and 09CB001 on the White River). The locations of these WSC stations are shown on Figure 2.2. The 1:200 year floods were calculated using the annual maximum daily discharge values and Environment Canada's CFA flood frequency software. The flood estimates for the WSC stations were scaled by drainage area to the mouth of each river. The 1:200 year flood on the Klotassin River was estimated from the 1:200 year flood estimate at the Casino hydrology station W16 located on lower Dip Creek (KP 2013b) using the same drainage area scaling method.

4 – DAM BREACH CHARACTERISTICS AND MODEL DEVELOPMENT

4.1 GENERAL

Quantitative assessment of the potential consequences of a flood from a TMF dam breach requires an estimate of the volume of water and tailings released in the breach, peak outflow discharge, physical characteristics of the breach (height, width, and side slopes), and an estimate of how quickly the breach would occur (time of failure). These characteristics are used to develop a dam breach hydrograph, which is subsequently routed through the downstream drainage network to produce inundation extents of the flood. The approach used to develop these estimates is described in the following sections.

4.2 DAM BREACH CHARACTERISTICS

4.2.1 Volume of Mobilized Tailings

The total outflow volume released in each breach scenario was estimated as the sum of the volume of free water available in the supernatant pond at the time of the breach, the mobilized tailings volume that includes tailings solids and interstitial water, and the volume of mobilized embankment material. The TMF and the TMF embankment were described in Section 2.1, while the TMF storage capacity for each failure scenario was described in Section 3.3.

The volume of free water for each modelled scenario includes the operating pond volume and any concurrent storm water inflow, as applicable based on the failure scenario. The mobilized tailings and embankment volume was estimated as a function of the volume of free water available in the supernatant pond for each breach scenario. Conceptually this means that a larger pond will mobilize more tailings and embankment material than a smaller pond. The tailings deposit and the embankment at the time of breach are described by mass of solids in the deposit, density of the solids, and average dry density of the deposit and of the compacted embankment material.

The potential mass of mobilized tailings and embankment construction material were estimated as a function of the free water volume assuming instantaneous mixing at 65% solids content by mass. The assumption of 65% solids is based on the “flowability” of slurry and is considered a conservative upper limit to a Newtonian-like fluid behavior. The estimated solids content of the breach outflow has a lower solids content of approximately 53% due to the presence of interstitial water in the tailings mass. The estimated breach outflow volumes for each scenario are summarized in Table 4.1.

A common assumption in dam breach analysis is to breach the dam down to its foundation, which is a reasonable assumption for water retaining dams. Due to the size of the embankment, and in order to develop the breach parameters and peak outflows consistent with guidelines (discussed further in Sections 4.2.2 and 4.2.3), the amount of construction material that would be removed from the dam embankment exceeds the amount of the released tailings material, as shown in Table 4.1. Considering the geometry of the embankment with a flat downstream slope of 3H:1V combined with the tailings beach on the upstream side, it is possible that the breach would not develop all the way to the bottom of the embankment as there is a limited amount of free water available to erode through and move the solids. It is not possible to predict with confidence the depth of the breach that may develop in a failure scenario; however, the total amount of solids moved by free water based on 65% mixing of solids is considered reasonable. In cases where the breach does not develop down to the embankment foundation, the ratio of solids from the embankment and from stored tailings would be different than shown in Table 4.1, but the total outflow volume that is routed through the downstream drainage network would remain the same.

Table 4.1 Estimated Volume in the Breach Outflow by Initial Flood Wave

Breach Scenario	Volume of Free Water(1)	Volume of Mobilized Embankment Material(2)	Volume of Mobilized Tailings(3)	Total Outflow Volume
Sunny Day	23 Mm^3	26 Mm^3	4 Mm^3	52 Mm^3
Flood Induced	74 Mm^3	48 Mm^3	42 Mm^3	165 Mm^3

NOTES:
1. The volume of free water includes pond volume and concurrent storm water inflow.
2. The volume of mobilized embankment material is based on breach parameters used to develop breach hydrographs.
3. The volume of mobilized tailings is the remaining volume to reach the total breach volume.
4. Percent of tailings volume released is based on a total tailings volume of 524 Mm^3.

4.2.2 Development of Dam Breach Parameters

Several available empirical relationships were used to estimate the physical characteristics of the breach (average width and side slopes), and the time of failure equivalent to the time for full breach development. These empirical relationships were developed for water retaining dams, and as such, may not describe the process of a tailings dam failure the best. The main difference is that in TMFs, a large tailings beach is typically developed against the dam, and the breaching process through the dam would have to involve breaching through the tailings solids stored in the facility as well, which is not taken into consideration.

Several references were used to calculate the range for various breach parameters, including: Macdonald and Langridge-Monopolis (1984), Froehlich (1995a, 1995b), and Von Thun and Gillette (1990). Walder and O'Connor (1997) indicate that the down-cutting rate for embankments is on the order of 10 m/hour to 100 m/hour. At a high 100 m/hour, the time to breach the Casino Main Embankment down to the foundation would be on the order of 3 hours.

The calculated failure times and average breach widths are subject to uncertainty and result in a wide range of predicted values. Typically, predictions of breach width have an uncertainty of about ±1/3 order of magnitude, while predictions of failure time have uncertainties approaching ±1 order of magnitude (Wahl, 2004). The adopted ranges for each parameter are shown in Table 4.2.

Table 4.2 Estimates of Dam Breach Parameters

Breach Scenario	Average Width	Side Slope	Time of Failure
Sunny Day	15 – 700 m	0.25 to 1.4	0.2 – 3.9 hours
Flood Induced	35 – 700 m	0.25 to 1.4	0.4 – 4.4 hours

4.2.3 Peak Outflow Discharge

The peak outflow during each breach scenario was estimated to provide a target value for development of the dam breach hydrographs for that scenario. The CDA's *Technical Bulletin: Inundation, Consequences and Classification for Dam Safety* (2007b) recommends Chapter 2 of Federal Energy Regulatory Commission's (FERC) *Engineering Guidelines for the Evaluation of Hydropower Projects* (1993) to be used for estimating the embankment dam breach parameters including the peak discharge. The dam breach guidelines are based on the work of Fread (1981) and Macdonald and Langridge-Monopolis (1984), and are summarized in the Dam Safety Guidelines of the Washington State Department of Ecology (1992, 2007). In order to estimate the peak outflow (Fread 1981) based on the Washington State Guidelines, the following parameters need to be calculated (using relationships of Macdonald and Langridge-Monopolis 1984):

- The breach formation factor that depends on the volume of the breach outflow and the height of the breach (assumed through the deepest section of the embankment)
- The volume of material eroded from the dam in the breach that depends on the breach formation factor
- Width of the breach that depends on the eroded dam volume, upstream and downstream dam slopes, breach side slopes, dam height and width of the dam crest, and
- Breach formation time that depends on the eroded dam volume.

Sensitivity analysis was conducted using other empirical relationships that consider the peak outflow as a function of volume of the breach outflow and height of the breach, in addition to the peak flow estimates using Fread's (1981) relationship. The empirical relationships are based on studies of dam failures and were developed for water retaining dams, except for Rico (2007), which also included tailings dam breaches. The following references were used to establish the range of calculated discharges: Macdonald and Langridge-Monopolis (1984), Costa (1985), Walder and O'Connor (1997), Rico et al. (2007), and Pierce et al. (2010). Of all these estimates, Fread's relationship was among the highest peak outflows for both sunny and rainy day scenarios.

The calculated discharges from each empirical relationship were considered and a range for peak outflows was adopted using the minimum and maximum values determined by the empirical equations. Predictions of peak outflow typically have uncertainties of about ±0.5 to ±1 order of magnitude (Wahl, 2004). The peak outflow range for each scenario is shown in Table 4.3.

Table 4.3 Peak Outflow Discharge Estimates

Breach Scenario	Outflow Volume	Height of Breach	Peak Outflow	
			Minimum	Maximum
Sunny Day	52 Mm^3	286 m	14,000 m^3/s	25,000 m^3/s
Flood Induced	165 Mm^3	286. m	22,000 m^3/s	52,000 m^3/s

A dam breach hydrograph was developed for each failure scenario conservatively using the maximum values presented in Table 4.3 (further discussed in Section 4.3), as the higher peak outflows would cause larger impacts.

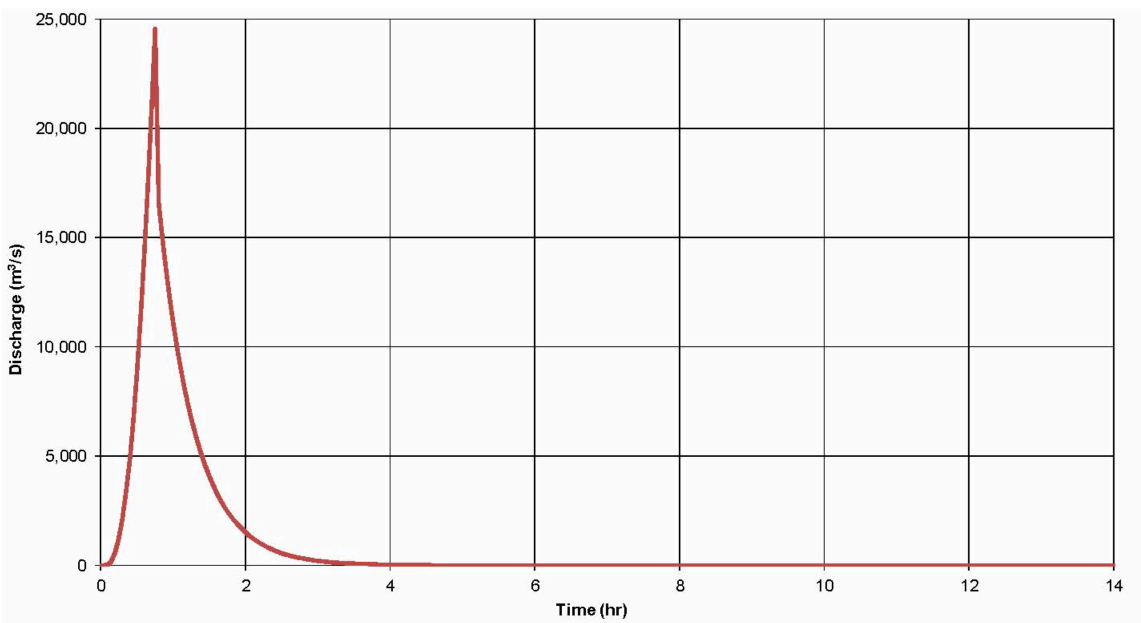
4.3 DAM BREACH HYDROGRAPHS

4.3.1 Sunny Day Failure Scenario

The sunny day failure scenario was modelled as a sudden breach during normal operations. The time of formation, side slopes and average breach width were selected from within the values as outlined in Table 4.2 to develop a maximum peak discharge within a range shown in Table 4.3. Figure 4.1 shows the outflow hydrograph for the sunny day failure scenario that was developed by using the breach parameters shown in Table 4.4. In this case, the breach event begins at 0 hours and the peak discharge occurs at approximately 0.75 hours. The outflow hydrographs contain the stored water volume, the volume of released tailings (solids and interstitial water) and the eroded embankment material.

Table 4.4 Sunny Day Dam Breach Parameters

Breach Scenario	Average Width	Side Slope	Time of Failure
Sunny Day	185 m	0.7	3.3 hours



NOTES:
1. The sunny day breach begins at time 0 hours.

Figure 4.1 Sunny Day Breach Hydrograph

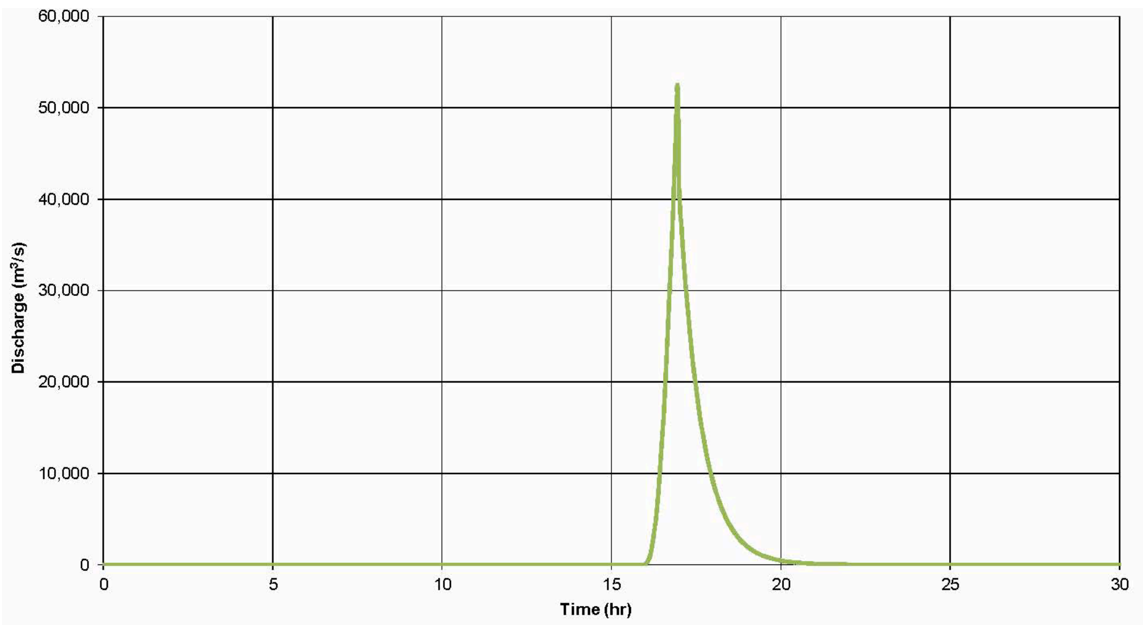
4.3.2 Flood Induced Failure Scenario

The CDA guidelines (2007b) suggest that causes of earth dam failures include overtopping and seepage, piping and internal erosion, embankment instability and slides. Overtopping is a common mechanism for failure during a flood induced breach. The TMF has the capacity to contain the IDF under normal operating conditions, as mentioned in Section 3.4.1. The initial pond level for this study, however, was raised from operational limits in order to cause the dam to overtop during the 24-hour PMF.

The time of formation, side slopes and average breach width were selected from within the range of values shown in Table 4.2 to develop a peak discharge within the range of calculated values presented in Table 4.3. Figure 4.2 shows the outflow hydrograph for a flood induced failure that was developed by using the breach parameters shown in Table 4.5. The rain event starts at 0 hours and the peak of the PMF occurs approximately 16 hours later, which is coincidental with the breach initiation. The peak discharge due to the breach occurs at approximately 17 hours from the beginning of the rain event.

Table 4.5 Flood Induced Dam Breach Parameters

Breach Scenario	Average Width	Side Slope	Time of Failure
Flood Induced	370 m	1.4	4 hours



NOTES:
1. The rain event begins at time 0 hours; the breach begins at time 16 hours.

Figure 4.2 Flood Induced Breach Hydrograph

4.4 FLOOD ROUTING MODEL DEVELOPMENT

4.4.1 General

A one-dimensional hydrodynamic model, HEC-RAS, was used to determine the areas that could be inundated due to a flood wave propagation resulting from a TMF dam breach. HEC-RAS is a flood routing model developed by the U.S. Army Corps of Engineers. It is capable of simulating unsteady one-dimensional flow through a channel network.

4.4.2 Elevation Data

The topographic data in the inundation area was used to develop elevation inputs for the HEC-RAS model. The available data sources are as follows:

- Light Detection and Ranging (LiDAR) topographic mapping for the area of the TMF with 5 m contours. The vertical accuracy of this mapping is expected to be within 1 m of the true ground elevation. LiDAR data covered the area of the TMF, the Casino Creek watershed, and approximately 12 km of Dip Creek below the Casino Creek confluence.
- Additional National Topographic System (NTS) topographic mapping for the area to the west and north of the LiDAR extent, for flood wave routing to the confluence of the White and Yukon Rivers.

Existing 5 m LiDAR contours were combined with 30 m NTS mapping data in ArcGIS to define the extent of the modelled area. This wide range of resolutions between various topographic data used in the model is not unusual for such a large scale inundation analysis, and using publically available topographic mapping is a common practice for such studies. The accuracy of the modelled inundation areas varies through the study area as a result, with greater accuracy expected for the area that had LiDAR coverage.

4.4.3 Cross Section Development

Cross sections were established or “cut” from the topographic information at approximately 250 m intervals along the flood path from Casino Creek just below the TMF to the mouth of the White River. Additional cross sections were cut, as required, to adequately capture hydraulic features like changes in valley width or channel slope, and for tributaries upstream of their confluences with the flood path. The locations of the cross sections used for the HEC-RAS model are shown on Figure 4.3. Specific cross sections have been highlighted on this figure, which represent locations for which detailed model results are presented in later sections of this report.

Additional cross sections were then interpolated between the primary cross sections in order to enhance the numerical stability of the model. The final spacing between primary and interpolated cross sections was approximately 10 m in Casino and Dip Creeks and 20 m in Klotassin, Donjek and White Rivers.

4.4.4 Boundary Conditions

Boundary conditions are used in HEC-RAS to represent the effect that the areas outside of the model limits have on the upstream and downstream ends of the modelled reach. The boundary condition and major assumptions associated with the Casino dam breach model include the following:

- The upstream boundary of Casino Creek was set to the dam breach outflow hydrographs shown in Section 4.3.
- Within Casino Creek and Dip Creek, lateral inflow hydrographs were added to represent incremental PMF inflows and MAD for the flood induced and the sunny day failure scenarios, respectively. The locations of these inflow points are shown on Figure 4.3.
- The upstream boundaries of Klotassin River, Donjek River and White River were set to the 1:200 year flood and the MAD for the flood induced and sunny day failure scenarios, respectively. The locations of these inflow points are shown on Figure 4.3.

- The downstream boundary in the White River was set to represent the normal depth of flow that would occur under these high flow conditions. The normal depth was determined in the model by using the channel slope at the downstream end of the model.

4.4.5 Channel Roughness and Model Calibration

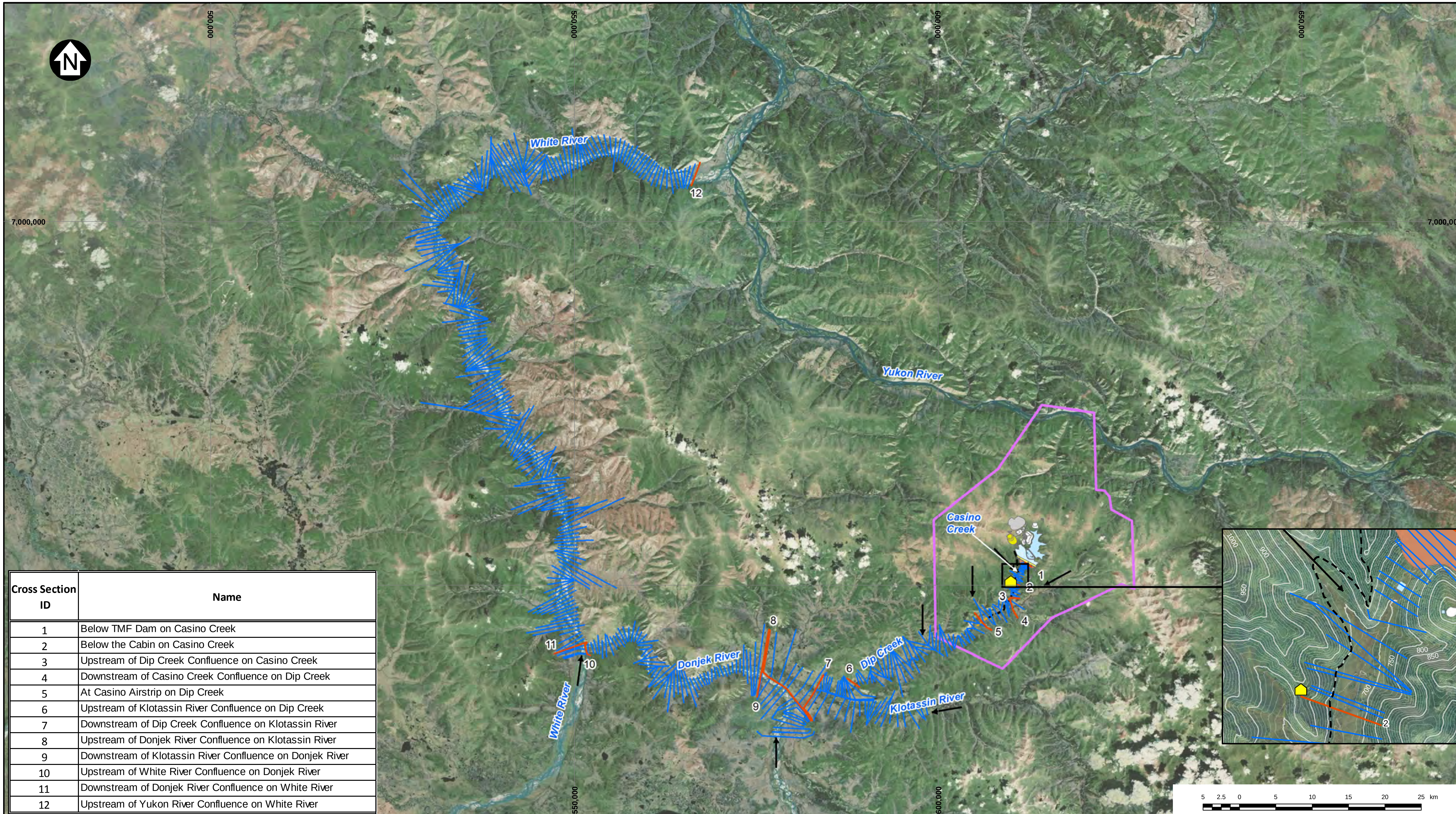
Measured water levels for various discharge rates are required at a streamflow gauging station located within the modelling extent to calibrate a hydrodynamic model. Such data are not available for this study, but even if they were available, the data would cover only the range of flows recorded at the station that would be far below the extreme flood flows expected due to a dam breach or a PMF event. The model could not be calibrated for the extreme flood flows for that reason.

Considering the lack of calibration, which is commonly achieved through the roughness coefficient adjustment, the channel and overbank roughness values were estimated from site and aerial photographs and typical channel and floodplain values (Chow, 1959). Manning's n value of 0.09 was used for Casino Creek and Dip Creek, 0.075 for Klotassin River, 0.04 for Donjek River and White River, and 0.1 for overbanks throughout the model. The high Manning's n values are conservative and were used to account for increased resistance to flow expected during the flood wave passage as a result of erosional processes and transport of debris (logs, boulders, sediment). Higher Manning's n values result in larger depths.

4.4.6 Dam Breach Assumptions and Model Limitations

The volume of mobilized tailings and construction material was added to the volume of water exiting the TMF during the failure, with the assumption that the solids would get suspended and transported with the flood wave, as discussed in Sections 3.2 and 4.2. The rheological parameters (viscosity and yield stress) were not taken into account and the flood wave was modelled as water, which is a conservative assumption, as it is expected that fluids with higher viscosity would propagate less vigorously and decay faster than water. Furthermore, it is expected that some of the sediment released from the TMF would settle along the way, reducing the wave volume, and therefore, the modelled inundation areas are likely overestimated.

Another physical feature that was not modelled, but would likely take place during extreme flooding caused by a dam failure, is the erosion of the natural terrain along the flood path, and transport of the eroded material, boulders and large woody debris. It is not possible to predict where and how much erosion would occur. Extensive erosion would dissipate some of the energy and have an impact on flood wave attenuation, water depths and water velocities.



Cross Section ID	Name
1	Below TMF Dam on Casino Creek
2	Below the Cabin on Casino Creek
3	Upstream of Dip Creek Confluence on Casino Creek
4	Downstream of Casino Creek Confluence on Dip Creek
5	At Casino Airstrip on Dip Creek
6	Upstream of Klotassin River Confluence on Dip Creek
7	Downstream of Dip Creek Confluence on Klotassin River
8	Upstream of Donjek River Confluence on Klotassin River
9	Downstream of Klotassin River Confluence on Donjek River
10	Upstream of White River Confluence on Donjek River
11	Downstream of Donjek River Confluence on White River
12	Upstream of Yukon River Confluence on White River

LEGEND:

- CABIN
- HEC-RAS CROSS SECTION
- SELECTED CROSS SECTION FOR MODEL RESULTS
- 5 M LIDAR EXTENT
- INFLOW NODE LOCATION

PROPOSED MINE FACILITIES

- AIRSTRIP ACCESS ROAD
- TAILINGS BEACH
- EMBANKMENT
- HEAP LEACH FACILITY
- OPEN PIT
- POND
- PAG TAILINGS
- AIRSTRIP

NOTES:

1. BASE MAP: ESRI ARCGIS ONLINE BING MAPS.

2. COORDINATE GRID IS IN METRES/DEGREES.
COORDINATE SYSTEM: NAD 1983 UTM ZONE 7N.

3. THIS FIGURE IS PRODUCED AT A NOMINAL SCALE OF 1:500,000 FOR 11x17 (TABLOID) PAPER. ACTUAL SCALE MAY DIFFER ACCORDING TO CHANGES IN PRINTER SETTINGS OR PRINTED PAPER SIZE.

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EXTENT OF HEC-RAS MODEL

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FIGURE 4.3 | REV 0

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5 – MODELLING RESULTS AND INUNDATION MAPPING

5.1 GENERAL

The outflow hydrographs generated due to hypothetical dam breaches were routed downstream using a one dimensional hydrodynamic model, HEC-RAS. The model was also used to predict the extent of natural flooding coincidental with a PMF centered over the TMF area, but without the mine and the TMF in place. This is referred to as a "natural PMF/200 year flood". The flood induced breach scenario is compared to this base case natural flood in order to evaluate the incremental flooding due to the dam breach. The base case for the sunny day scenario has the MAD in all creeks and rivers.

The modelling results are considered more accurate in the mine area, Casino Creek and approximately 12 km of Dip Creek downstream from the Casino Creek confluence where LiDAR mapping was available. The elevation data is based on 5 m contours in these areas, while farther downstream the information is based on NTS mapping with 30 m contours. The floodplain area of Donjek River and White River is quite flat and wide, and hence, the model results that show the maximum water surface elevation in this area are considered approximate. The elevation data resolution in this area is inadequate to delineate the actual river channels and determine the water depths accurately, and the results represent an estimate of what the inundation would look like.

The inundation maps resulting from the sunny day and flood induced breach scenarios are shown in Section 5.2 and 5.3, respectively. Relevant discharge hydrographs and figures showing change in depth with time for various cross sections of interest downstream of the TMF are also presented in these sections. The cross section locations are shown in Figure 4.3. Arrival of the flood wave, time to peak, and other flow characteristics are summarized for these cross section locations in tables for each modelled scenario.

5.2 SUNNY DAY SCENARIO

Modelling of the sunny day failure scenario was undertaken to estimate the impacts of failure should a sudden breach develop in the TMF during normal operations. The specific conditions assumed in developing the sunny day breach are discussed in Sections 3 and 4.

Following the completion of the sunny day dam breach simulation, the maximum water surface elevations modelled in HEC-RAS were used in modeling software GeoHECRAS to prepare inundation maps for the impacted areas. The sunny day inundation maps are presented and discussed in Section 5.2.2.

5.2.1 Flood Wave Characteristics

The modelled dam breach flood wave arrival times and times to the peak discharges relative to the initiation of breaching for the sunny day breach are summarized in Table 5.1 and shown on Figures 5.1 and 5.2 for various cross section locations (as indicated on Figure 4.3) for a sunny day breach. The distances indicated in Table 5.1 are measured relative to the TMF Main Dam and are based on the modelled flow path.

Figures 5.1 and 5.2 illustrate the modelled variation in discharge and change of maximum cross sectional water depth with time at various cross section locations in the model. The flood wave is shown along with the MAD for comparison. The maximum cross sectional water depth is dependent on the cross sectional shape, and is deeper in the narrower “canyon-like” sections, than at various wider cross sections. The reported flow depth is based on the maximum modelled water elevation and the assumed channel invert.

The flood wave attenuation can be described by examining the flood wave arrival time, time to peak, and peak discharge. The peak discharge is reduced along with the speed of the wave as the flood wave moves downstream and into larger river channels, which lengthens the arrival time and the time to peak.

The flood wave arrival time at the mouth of Casino Creek is approximately 0.7 hours after the onset of the breach event, while the peak discharge occurs approximately 0.8 hours after the onset of the breach event (0.1 hours after the flood wave arrives). The maximum flow depth at the mouth of Casino Creek is estimated to be 10 m for a peak discharge of 20,400 m^3/s.

The flood wave arrival time at the mouth of Dip Creek is approximately 4.2 hours after the onset of the breach event while the peak discharge occurs at approximately 4.7 hours (0.5 hours after the flood wave arrives). The maximum flow depth at the mouth of Dip Creek is estimated to be 6 m for a peak discharge of 5,300 m^3/s.

The flood wave arrives at the mouth of the Klotassin River at approximately 7.7 hours after the onset of the breach event while the peak discharge occurs at approximately 8.8 hours (1.1 hours after the flood wave arrives). The peak discharge at the mouth of the Klotassin River is 3,300 m^3/s with a corresponding maximum flow depth of 1 m.

The flood wave continues downstream to the mouth of the Donjek River and arrives approximately 11.8 hours after the onset of the breach event while the peak discharge occurs at approximately 14.0 hours (2.2 hours after the flood wave arrives). The peak discharge at the mouth of the Donjek River is 2,900 m^3/s with a corresponding maximum flow depth of 3 m.

The flood wave arrives at the end of the model, the mouth of the White River, approximately 32.2 hours after the onset of the breach event and the peak discharge occurs at approximately 35.7 hours (3.5 hours after the wave arrives). The peak discharge due to the sunny day breach is estimated at 2,300 m^3/s, while the incremental peak discharge between the MAD and the breach is 1,400 m^3/s, which corresponds to an incremental maximum flow depth of less than 1 m. The MAD for the White River at the mouth is estimated at 900 m^3/s, while the mean annual flood is estimated at 2,400 m^3/s. Given the river channels can typically contain the mean annual flood within their banks, the sunny day breach flood wave is assumed to be contained within the natural river channel at the mouth of the White River.

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TABLE 5.1

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SUMMARY OF FLOOD WAVE CHARACTERISTICS FOR ULTIMATE ARRANGEMENT
SUNNY DAY BREACH

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Cross Section Number	Cross Section Description	Distance Downstream from Breach Location	Flood Wave Arrival Time	Time to Peak	Mean Annual Discharge - No Breach		Sunny Day Breach		Incremental	
					Maximum Flow Depth	Maximum Cross Sectional Discharge	Maximum Flow Depth	Maximum Cross Sectional Discharge	Change in Maximum Flow Depth	Change in Maximum Cross Sectional Discharge
		(km)	(hr)	(hr)	(m)	(m^3/s)	(m)	(m^3/s)	(m)	(m^3/s)
1	Below TMF Dam on Casino Creek	0.1	0.2	0.7	0.2	0.1	15	22,400	15	22,400
2	Cross Section below the Cabin on Casino Creek	3.4	0.5	0.8	0.5	1.6	15	19,500	15	19,498
3	Upstream of Dip Creek Confluence on Casino Creek	5.4	0.7	0.8	0.3	1.6	10	20,400	10	20,398
4	Downstream of Casino Creek Confluence on Dip Creek	6.0	0.8	0.8	0.3	2.7	8	18,100	8	18,097
5	At Casino Airstrip on Dip Creek	11.3	1.3	1.5	0.4	3.1	9	11,700	9	11,697
6	Upstream of Klotassin River Confluence on Dip Creek	32.7	4.2	4.7	0.7	4.7	6	5,300	5	5,295
7	Downstream of Dip Creek Confluence on Klotassin River	39.4	5.5	7.0	0.5	73	4	3,800	4	3,727
8	Upstream of Donjek River Confluence on Klotassin River	47.2	7.7	8.8	0.2	73	1	3,300	1	3,227
9	Downstream of Klotassin River Confluence on Donjek River	47.4	7.7	8.8	0.5	497	2	3,600	2	3,103
10	Upstream of White River Confluence on Donjek River	77.2	11.8	14.0	1.0	497	3	2,900	2	2,403
11	Downstream of Donjek River Confluence on White River	77.5	12.0	14.2	1.4	742	3	3,100	2	2,358
12	Upstream of Yukon River Confluence on White River	186.2	32.2	35.7	0.9	898	2	2,300	1	1,402

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NOTES:

1. ALL PRESENTED INFORMATION BASED ON 10 MINUTE RESULT OUTPUT FROM MODEL. THIS OUTPUT RESOLUTION MAY NOT CAPTURE THE ABSOLUTE MAXIMUM VALUES.
2. TIMES ARE ROUNDED TO THE NEAREST 0.1 HOUR.
3. BREACH INITIATES AT 0 HOURS.
4. ARRIVAL TIME IS RELATIVE TO THE ONSET OF THE BREACH.
5. TIME TO PEAK IS THE TIME OF MAXIMUM DISCHARGE RELATIVE TO THE BREACH INITIATION.
6. MAXIMUM FLOW DEPTH IS BASED ON THE MAXIMUM MODELLED WATER ELEVATION AND THE ASSUMED CHANNEL INVERT.
7. MAXIMUM FLOW DEPTH VALUES ROUNDED TO THE NEAREST METRE FOR THE BREACH SCENARIO AND NEAREST DECIMAL METRE FOR THE MAD SCENARIO.
8. MAXIMUM CROSS SECTIONAL DISCHARGE ROUNDED TO THE NEAREST 100 m^3/s FOR THE BREACH SCENARIO AND THE NEAREST 0.1 m^3/s AND 1 m^3/s FOR THE MAD SCENARIO.

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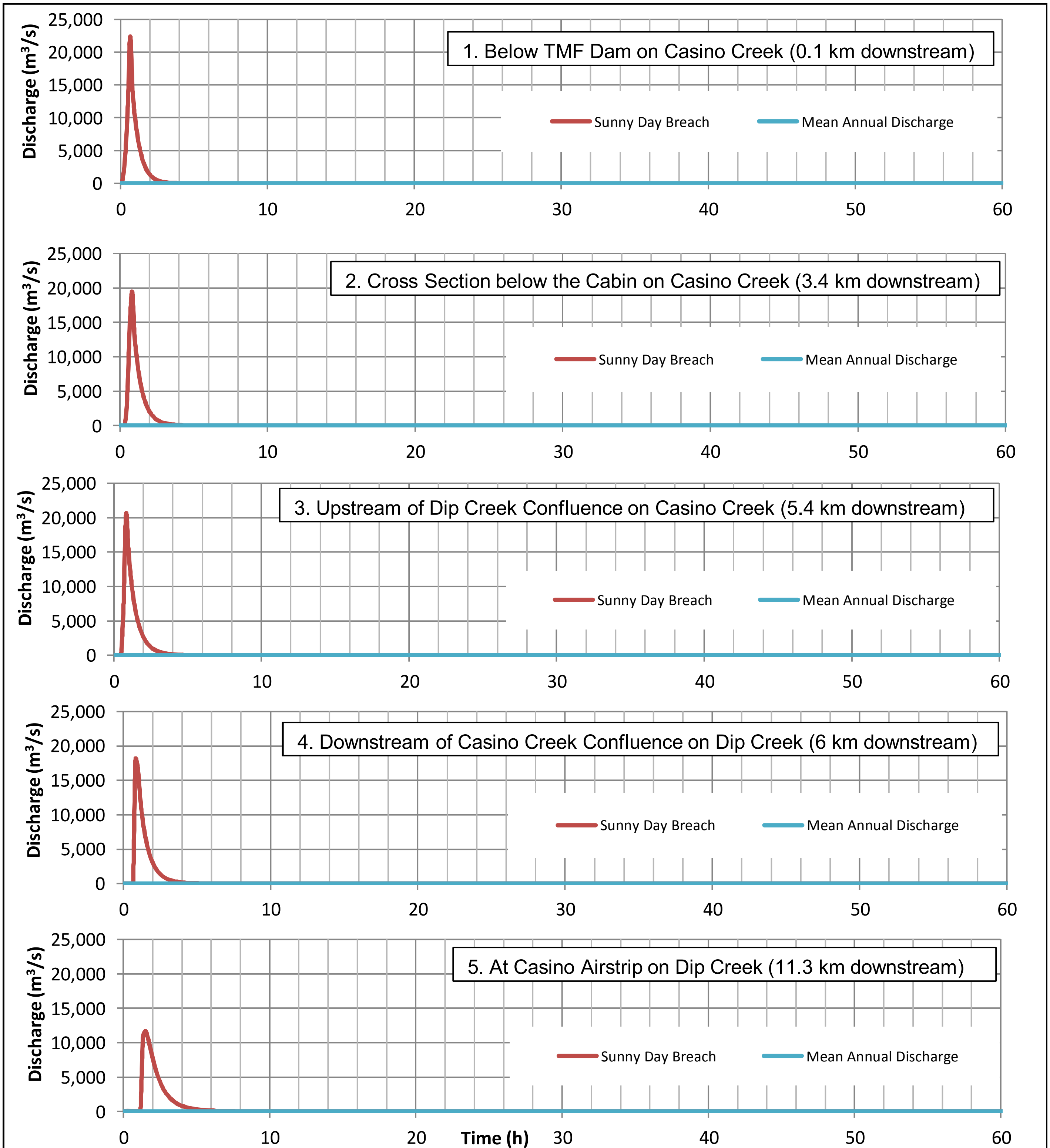

NOTES:

1. TIME 0 HOURS STARTS AT THE BEGINNING OF THE BREACH EVENT.
2. HYDROGRAPHS BASED ON 10 MINUTE MODEL OUTPUTS.

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HYDROGRAPHS DOWNSTREAM OF TMF MAIN DAM
SUNNY DAY BREACH SCENARIO
PAGE 1 OF 3

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REF. NO. 2

FIGURE 5.1a

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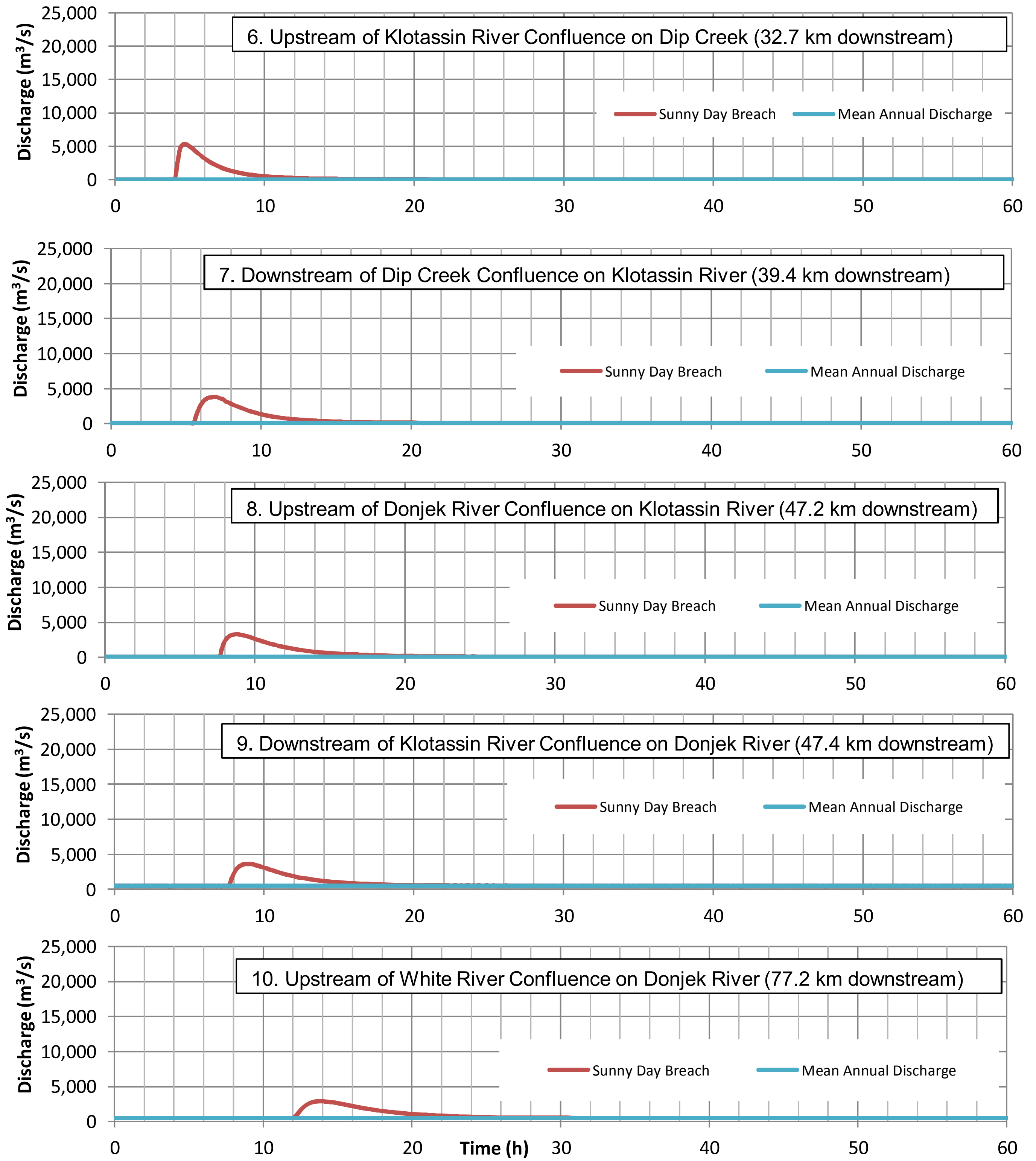

NOTES:
1. TIME 0 HOURS STARTS AT THE BEGINNING OF THE BREACH EVENT.
2. HYDROGRAPHS BASED ON 10 MINUTE MODEL OUTPUTS.

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HYDROGRAPHS DOWNSTREAM OF TMF MAIN DAM
SUNNY DAY BREACH SCENARIO
PAGE 2 OF 3

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P/A NO. VA101-325/20

REF. NO. 2

FIGURE 5.1b

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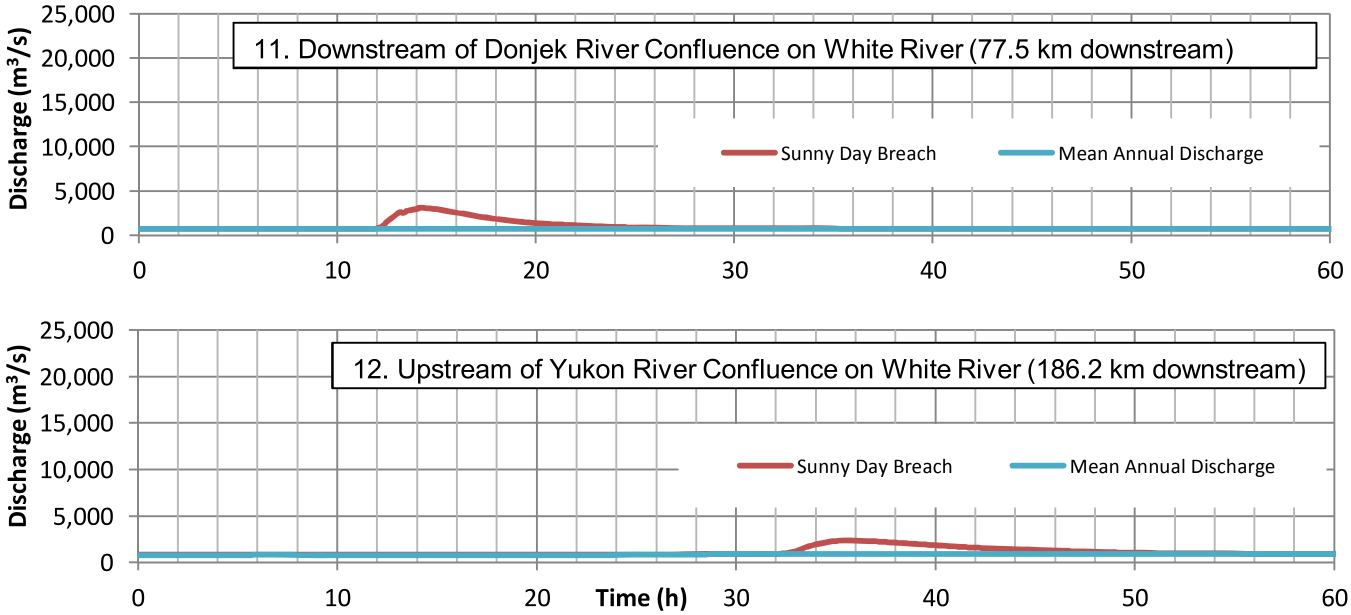

NOTES:

1. TIME 0 HOURS STARTS AT THE BEGINNING OF THE BREACH EVENT.
2. HYDROGRAPHS BASED ON 10 MINUTE MODEL OUTPUTS.

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HYDROGRAPHS DOWNSTREAM OF TMF MAIN DAM
SUNNY DAY BREACH SCENARIO
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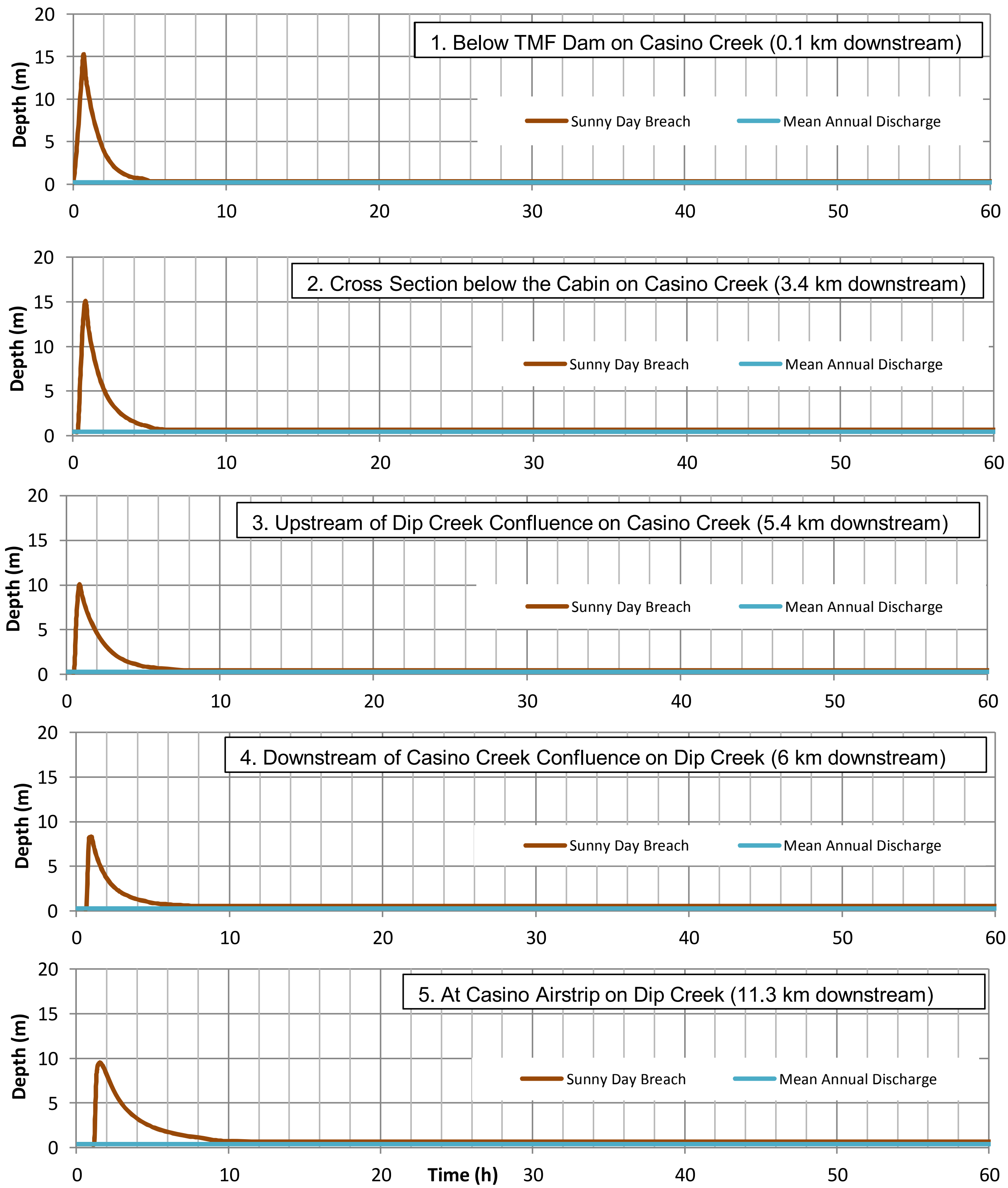
FIGURE 5.1c REV 0



NOTES:

1. TIME 0 HOURS STARTS AT THE BEGINNING OF THE BREACH EVENT.
2. DEPTH IS DEPTH OF WATER FROM THE RIVER CHANNEL INVERT; A DEPTH OF 0 m INDICATES THE RIVER CHANNEL IS DRY.
3. GRAPHS BASED ON 10 MINUTE MODEL OUTPUTS.

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WATER DEPTH DOWNSTREAM OF TMF MAIN DAM
SUNNY DAY BREACH SCENARIO
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FIGURE 5.2a

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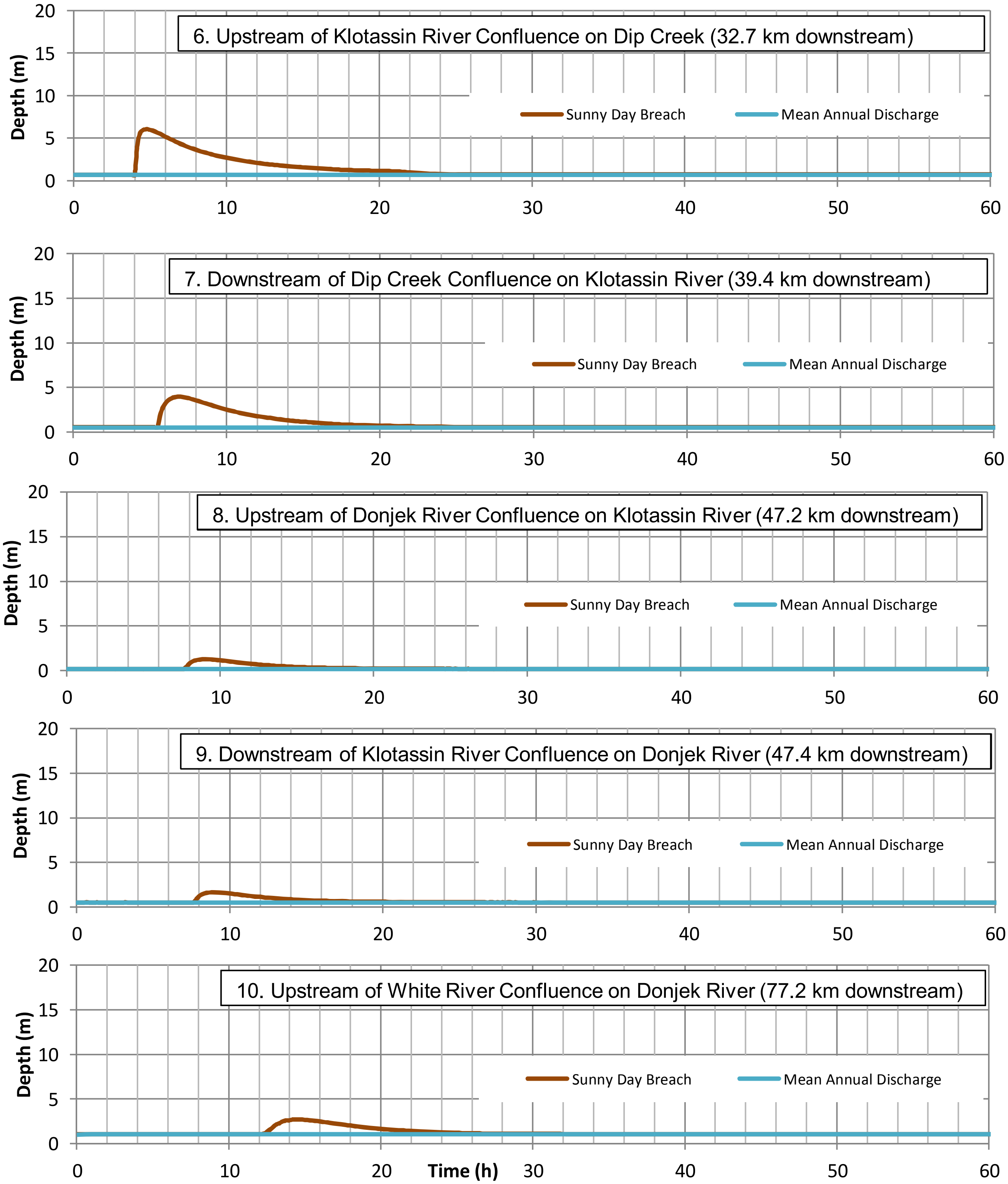

NOTES:

1. TIME 0 HOURS STARTS AT THE BEGINNING OF THE BREACH EVENT.
2. DEPTH IS DEPTH OF WATER FROM THE RIVER CHANNEL INVERT; A DEPTH OF 0 m INDICATES THE RIVER CHANNEL IS DRY.
3. GRAPHS BASED ON 10 MINUTE MODEL OUTPUTS.

REV	DATE	DESCRIPTION	PREP'D	REV'D
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CASINO COPPER-GOLD PROJECT

WATER DEPTH DOWNSTREAM OF TMF MAIN DAM
SUNNY DAY BREACH SCENARIO
PAGE 2 OF 3

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P/A NO.	REF. NO.
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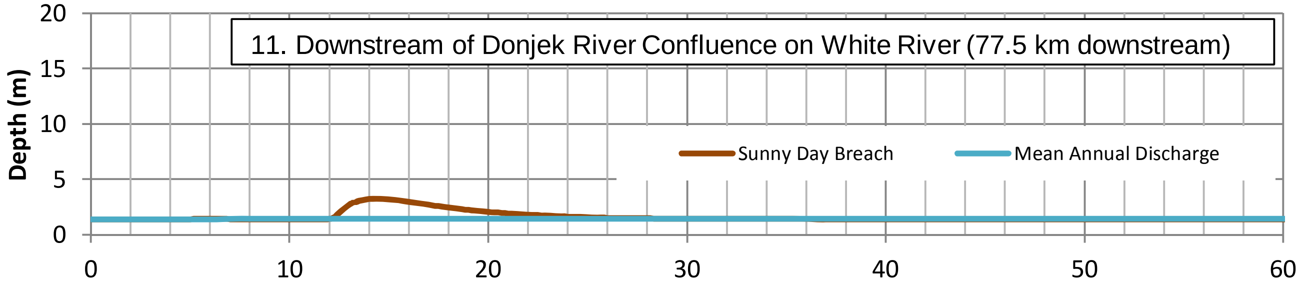
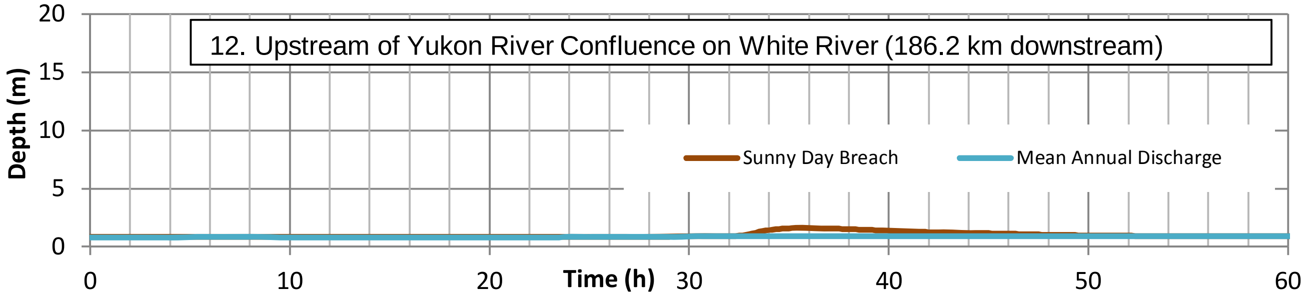
FIGURE 5.2b	REV 0





NOTES:

1. TIME 0 HOURS STARTS AT THE BEGINNING OF THE BREACH EVENT.
2. DEPTH IS DEPTH OF WATER FROM THE RIVER CHANNEL INVERT; A DEPTH OF 0 m INDICATES THE RIVER CHANNEL IS DRY.
3. GRAPHS BASED ON 10 MINUTE MODEL OUTPUTS.

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CASINO COPPER-GOLD PROJECT

WATER DEPTH DOWNSTREAM OF TMF MAIN DAM
SUNNY DAY BREACH SCENARIO
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FIGURE 5.2c

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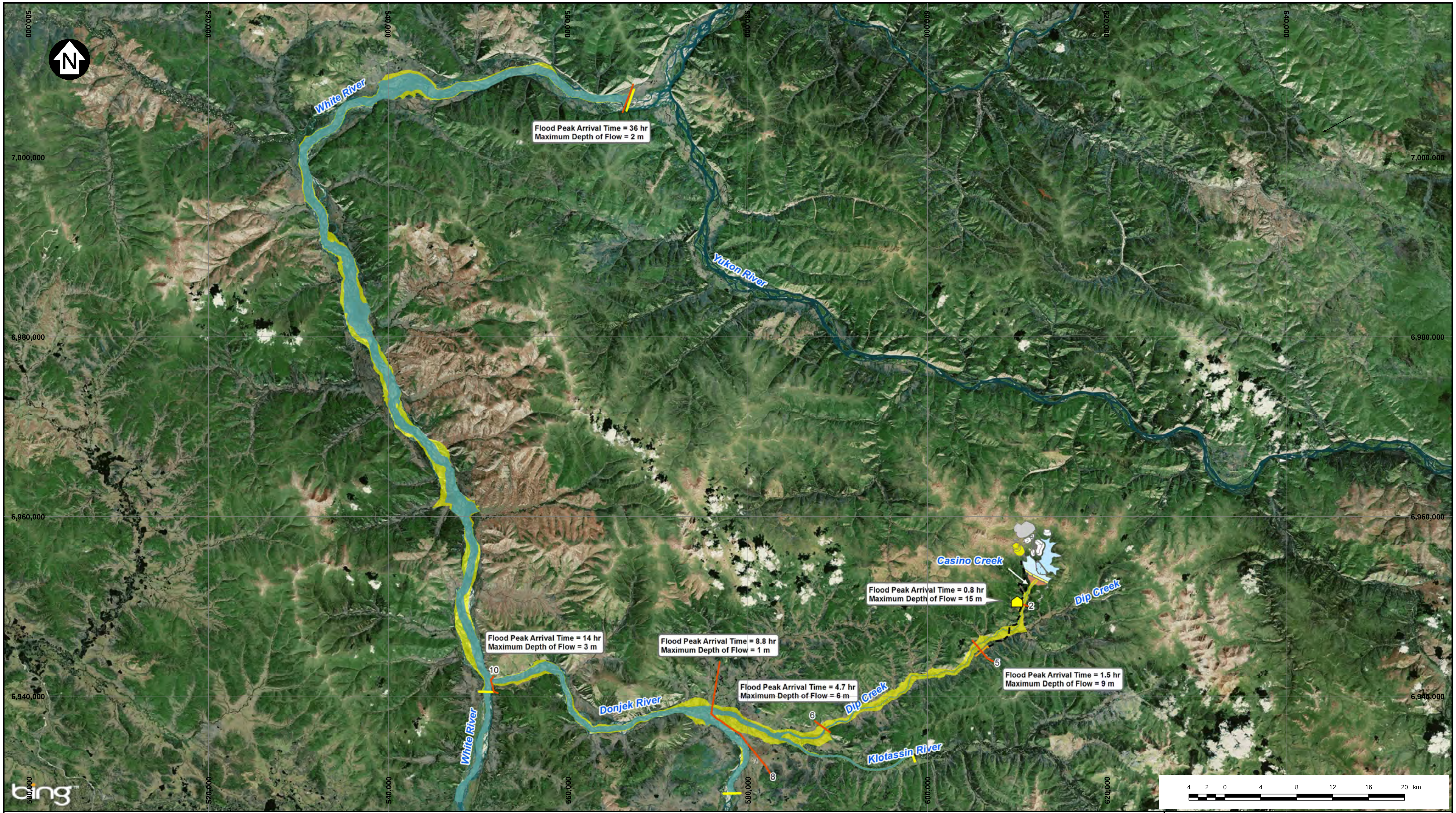
5.2.2 Sunny Day Breach Inundation Maps

The final inundation maps for the sunny day dam breach scenario are shown on Figure 5.3. The maps were prepared using 1:400,000 scale, and ESRI ArcGIS online Bing Maps Aerial imagery. The inundation maps show the peak water surface elevations resulting from a sunny day scenario with a hypothetical dam breach in the ultimate Main Embankment of the TMF. The extent of flooding due to the breach scenario is shown in yellow, while MAD conditions are shown in blue. The yellow shading is equivalent to the incremental flooding as this represents the difference in water surface elevation between MAD conditions and the sunny day dam breach scenario.



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LEGEND:

- CABIN
- EXTENT OF MODEL
- CROSS SECTION
- SUNNY DAY BREACH WATER LEVEL
- MEAN ANNUAL DISCHARGE WATER LEVEL

PROPOSED MINE FACILITIES

- AIRSTRIP ACCESS ROAD
- TAILINGS BEACH
- EMBANKMENT
- HEAP LEACH FACILITY
- OPEN PIT
- POND
- PAG TAILINGS
- AIRSTRIP

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	REVIEWED
0	16SEP'15	ISSUED FOR INFORMATION	ACA	AMD	VM

NOTES:

1. BASE MAP: ESRI ARCGIS ONLINE BING MAPS.
2. COORDINATE GRID IS IN METRES/DEGREES. COORDINATE SYSTEM: NAD 1983 UTM ZONE 7N.
3. THIS FIGURE IS PRODUCED AT A NOMINAL SCALE OF 1:400,000 FOR 11x17 (TABLOID) PAPER. ACTUAL SCALE MAY DIFFER ACCORDING TO CHANGES IN PRINTER SETTINGS OR PRINTED PAPER SIZE.
4. FLOOD PEAK ARRIVAL TIME IS RELATIVE TO THE BREACH INITIATION.
5. MAXIMUM DEPTH OF FLOW IS BASED ON THE MAXIMUM MODELLED WATER ELEVATION AND THE ASSUMED CHANNEL INVERT.

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INUNDATION MAP - SUNNY DAY BREACH

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P/A NO. VA101-325/20

REF NO. 2

FIGURE 5.3

REV 0

5.3 FLOOD INDUCED SCENARIO

Modelling of flood induced failure scenario was undertaken to estimate the incremental impacts of failure should the TMF overtop during extreme flood conditions. The effects of the dam breach are combined with occurrence of a PMF in the project area and high flood conditions in large rivers farther downstream in this scenario. The specific conditions assumed in developing the flood induced breach are discussed in Sections 3 and 4.

Following the completion of the dam breach simulations, the maximum water surface elevations modelled in HEC-RAS were used in GeoHECRAS to prepare inundation maps for the impacted areas. The flood induced inundation maps are presented and discussed in Section 5.3.2.

5.3.1 Flood Wave Characteristics

The flood induced scenario begins at the start of the rain event. The scenario has been developed such that an overtopping breach is initiated at the peak of the TMF inflow hydrograph. The TMF begins filling at the beginning of the rain event, with water reaching the dam crest 16 hours after the rain event started, at which time the breach is initiated.

Figures 5.4 and 5.5 illustrate the modelled variation in discharge and change of maximum water depth with time at various cross section locations (as indicated on Figure 4.3) for a flood induced breach. The flood wave is shown along with the natural PMF/200 year flood without a dam breach, for comparison. The maximum cross sectional water depth is dependent on the cross sectional shape, and is deeper in the narrower “canyon-like” sections, than at various wider cross sections. The reported flow depth is based on the maximum modelled water elevation and the assumed channel invert.

Table 5.2 summarizes the modelled dam breach flood wave arrival time and time to the peak discharges relative to the initiation of breaching for the flood induced breach. Also presented are the maximum flow depths and discharges for the peak conditions as well as maximum flow depths and discharges under natural PMF/200 year flood conditions without a dam breach for comparison. The cross section locations chosen for this summary are presented in Figure 4.3.

The flood wave attenuation can be described by examining the flood wave arrival time, time to peak and peak discharge. The peak discharge will be reduced along with the speed of the wave as the flood wave moves downstream and into larger river channels, which will lengthen the arrival time and the time to peak. The dam breach flood wave attenuation in the Klotassin River, Donjek River and White River appears relatively small when the peak discharge of the flood wave is considered only. It should be noted however, that these large river systems are adding large flood volumes at their confluences, so the comparison of the incremental discharge better demonstrates how the peak flood wave is attenuating as it moves downstream.

The flood wave arrival time at the mouth of Casino Creek is approximately 0.8 hours after the onset of the breach event and the peak discharge at the mouth of Casino Creek occurs approximately 1.0 hour after the onset of the breach event (0.2 hours after the flood wave arrives). The maximum flow depth at the mouth of Casino Creek is estimated to be 13 m for a peak discharge of 42,800 m^3/s. The incremental maximum flow depth between the natural PMF flood and the flood induced breach is 11 m which corresponds to an incremental discharge of 42,370 m^3/s.

The flood wave arrival time at the mouth of Dip Creek is approximately 3.0 hours after the onset of the breach event while the peak discharge occurs at approximately 3.5 hours (0.5 hours after the flood wave arrives). The maximum flow depth at the mouth of Dip Creek is estimated to be 9 m for a peak discharge of 20,800 m^3/s. The incremental maximum flow depth between the natural PMF flood and the flood induced breach is 5 m which corresponds to an incremental discharge of 18,920 m^3/s.

The flood wave arrives at the mouth of the Klotassin River approximately 5.0 hours after the onset of the breach event while the peak discharge occurs at approximately 6.5 hours (1.5 hours after the flood wave arrives). The peak discharge at the mouth of the Klotassin River is 14,600 m^3/s with a corresponding maximum flow depth of 5 m. The incremental maximum flow depth between the natural PMF/200 year flood and the flood induced dam breach is 3 m which corresponds to an incremental discharge of 12,100 m^3/s.

The flood wave continues downstream to the mouth of the Donjek River and arrives approximately 7.3 hours after the onset of the breach event while the peak discharge occurs at approximately 10 hours (2.7 hours after the flood wave arrives). The peak discharge at the mouth of the Donjek River is 14,700 m^3/s with a corresponding maximum flow depth of 7 m. The incremental maximum flow depth between the natural PMF/200 year flood and the flood induced dam breach is 2 m which corresponds to an incremental peak discharge of 9,040 m^3/s.

The flood wave arrives at the end of the model, the mouth of the White River, approximately 18.3 hours after the onset of the breach event and the peak discharges occurs at approximately 24.0 hours (5.7 hours after the wave arrives). The maximum flow depth at the mouth of the White River is about 5 m with a peak discharge estimated at 14,600 m^3/s. The incremental maximum flow depth between the natural PMF/200 year flood and the flood induced dam breach is approximately 1 m, which corresponds to an incremental peak discharge of 5,800 m^3/s. The 1:200 year Yukon River flood equivalent to 5,700 m^3/s is estimated from the WSC station Yukon River above the White River. Addition of this discharge at the confluence of the White and Yukon Rivers would further attenuate the peak of the dam breach flood wave.

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TABLE 5.2

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SUMMARY OF FLOOD WAVE CHARACTERISTICS FOR ULTIMATE ARRANGEMENT
FLOOD INDUCED BREACH

Print Sep/16/15 9:01:44

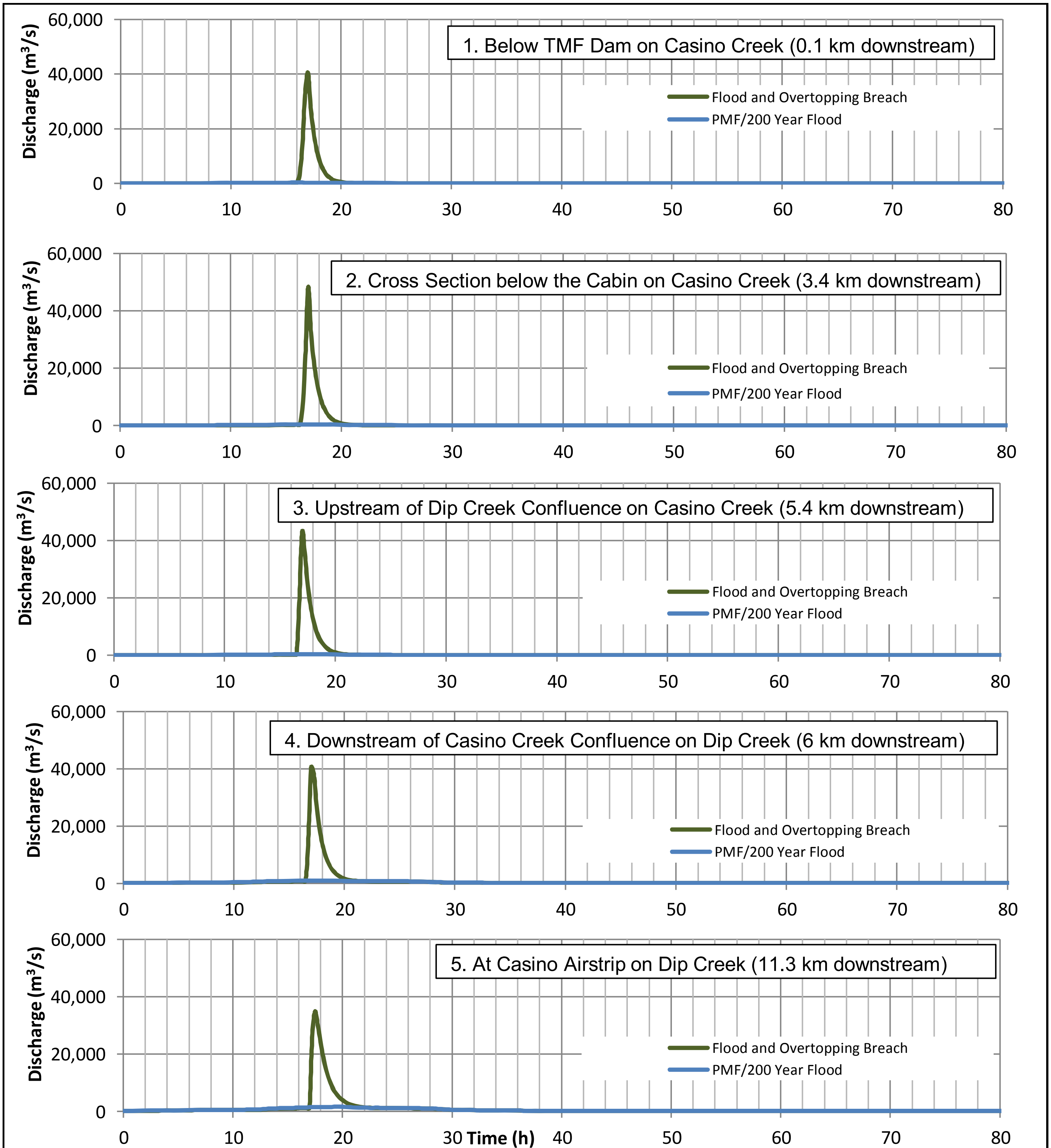
Cross Section Number	Cross Section Description	Distance Downstream from Breach Location	Flood Wave Arrival Time		Time to Peak		PMF/200 Year Flood - No Breach		Flood Induced Breach		Incremental	
			Relative to Start of Rain Event	Relative to Breach Initiation	Relative to Start of Rain Event	Relative to Breach Initiation	Maximum Flow Depth	Maximum Cross Sectional Discharge	Maximum Flow Depth	Maximum Cross Sectional Discharge	Change in Maximum Flow Depth	Change in Maximum Cross Sectional Discharge
		(km)	(hr)	(hr)	(hr)	(hr)	(m)	(m^3/s)	(m)	(m^3/s)	(m)	(m^3/s)
1	Below TMF Dam on Casino Creek	0.1	16.3	0.3	17.0	1.0	1	230	20	40,500	19	40,270
2	Cross Section below the Cabin on Casino Creek	3.4	16.5	0.5	17.0	1.0	2	410	22	48,300	20	47,890
3	Upstream of Dip Creek Confluence on Casino Creek	5.4	16.8	0.8	17.0	1.0	2	430	13	42,800	11	42,370
4	Downstream of Casino Creek Confluence on Dip Creek	6.0	17.0	1.0	17.0	1.0	2	1,100	12	40,400	10	39,300
5	At Casino Airstrip on Dip Creek	11.3	17.3	1.3	17.5	1.5	4	1,540	15	34,900	11	33,360
6	Upstream of Klotassin River Confluence on Dip Creek	32.7	19.0	3.0	19.5	3.5	4	1,880	9	20,800	5	18,920
7	Downstream of Dip Creek Confluence on Klotassin River	39.4	19.8	3.8	21.0	5.0	3	2,620	8	16,500	5	13,880
8	Upstream of Donjek River Confluence on Klotassin River	47.2	21.0	5.0	22.5	6.5	2	2,500	5	14,600	3	12,100
9	Downstream of Klotassin River Confluence on Donjek River	47.4	21.0	5.0	22.5	6.5	2	5,750	5	17,100	3	11,350
10	Upstream of White River Confluence on Donjek River	77.2	23.3	7.3	26.0	10.0	5	5,660	7	14,700	2	9,040
11	Downstream of Donjek River Confluence on White River	77.5	23.5	7.5	26.3	10.3	5	7,620	8	16,600	3	8,980
12	Upstream of Yukon River Confluence on White River	186.2	34.3	18.3	40.0	24.0	4	8,800	5	14,600	1	5,800

M:\1\01\00325\20\A\Data\Task 0700 - Dam Breach\[Outflow Hydrographs and Data 20150608_REV0 edits.xlsx]NOWL TIMING

NOTES:

1. ALL PRESENTED INFORMATION BASED ON 10 MINUTE RESULT OUTPUT FROM MODEL. THIS OUTPUT RESOLUTION MAY NOT CAPTURE THE ABSOLUTE MAXIMUM VALUES.
2. TIMES ARE ROUNDED TO THE NEAREST 0.1 HOUR.
3. PMF RAIN EVENT BEGINS AT 0 HOURS, BREACH INITIATES AT 16 HOURS.
4. ARRIVAL TIME IS RELATIVE TO THE ONSET OF PMF RAIN EVENT.
5. TIME TO PEAK IS THE TIME OF MAXIMUM DISCHARGE RELATIVE TO THE BREACH INITIATION.
6. MAXIMUM CROSS-SECTIONAL FLOW DEPTH IS BASED ON THE MAXIMUM MODELLED WATER ELEVATION AND THE ASSUMED CHANNEL INVERT.
7. MAXIMUM CROSS-SECTIONAL FLOW DEPTH VALUES ROUNDED TO THE NEAREST METRE.
8. MAXIMUM CROSS SECTIONAL DISCHARGE ROUNDED TO THE NEAREST 100 m^3/s FOR THE BREACH SCENARIO AND THE NEAREST 10 m^3/s FOR THE FLOOD SCENARIO.

REV	DATE	DESCRIPTION	PREP'D	REV'D
0	16SEP'15	ISSUED WITH REPORT VA101-325/20-2	ACA	VM



NOTES:

1. TIME 0 HOURS STARTS AT THE ONSET OF THE PMF RAIN EVENT.
2. HYDROGRAPHS BASED ON 15 MINUTE MODEL OUTPUTS.

0	16SEP'15	ISSUED WITH REPORT	ACA	VM
REV	DATE	DESCRIPTION	PREP'D	RVW'D

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HYDROGRAPHS DOWNSTREAM OF TMF MAIN DAM
FLOOD INDUCED BREACH SCENARIO
PAGE 1 OF 3

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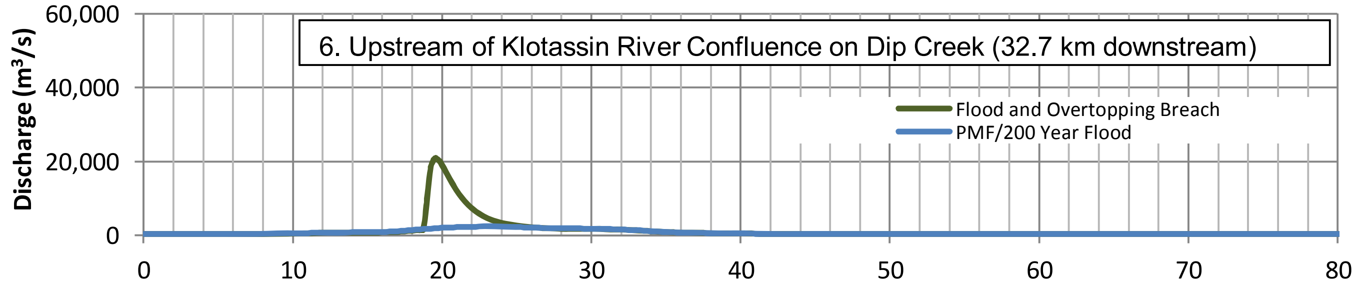
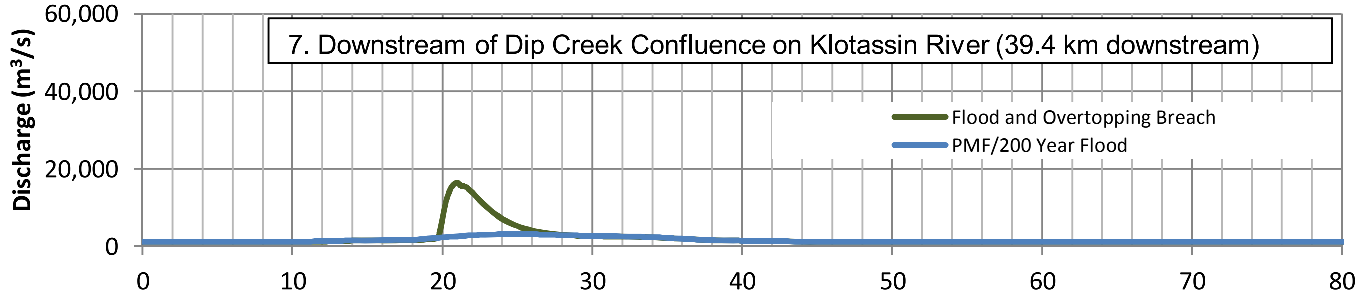
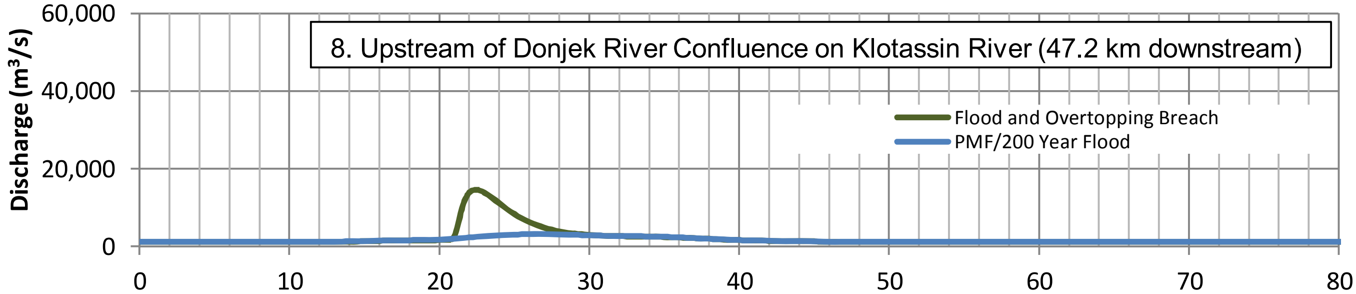
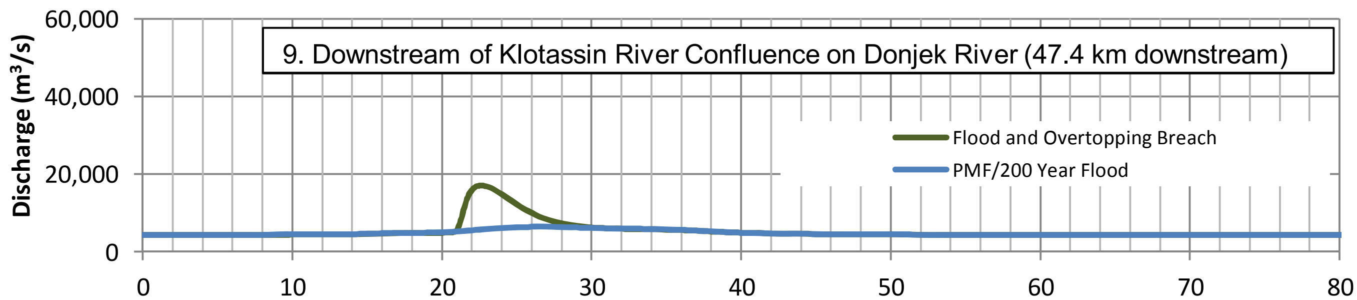
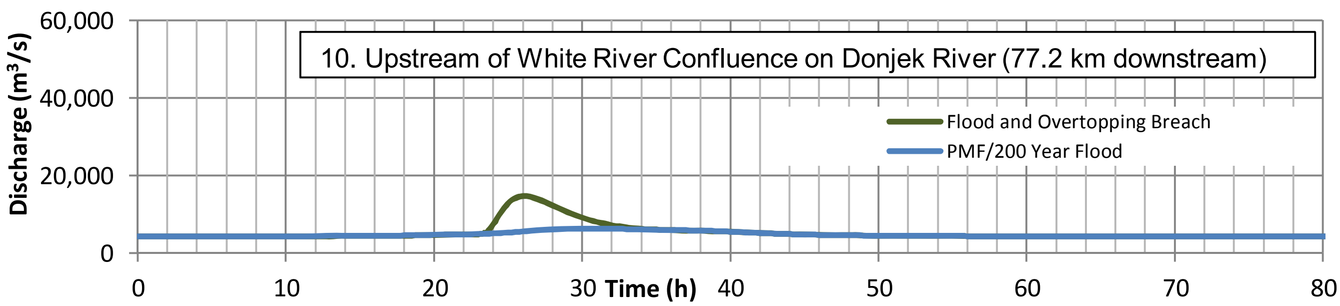
P/A NO.	REF. NO.	
VA101-325/20	2	
FIGURE 5.4a		REV 0











NOTES:
1. TIME 0 HOURS STARTS AT THE ONSET OF THE PMF RAIN EVENT.
2. HYDROGRAPHS BASED ON 15 MINUTE MODEL OUTPUTS.

REV	DATE	DESCRIPTION	PREP'D	REV'D
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CASINO COPPER-GOLD PROJECT

HYDROGRAPHS DOWNSTREAM OF TMF MAIN DAM
FLOOD INDUCED BREACH SCENARIO
PAGE 2 OF 3

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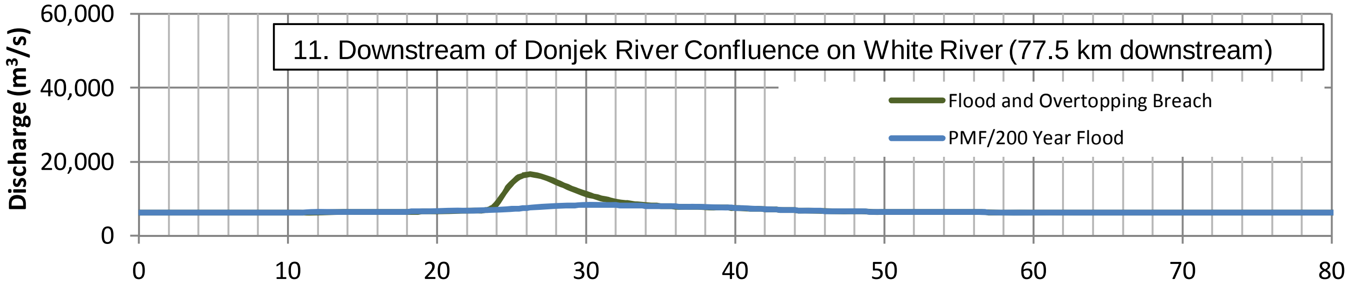
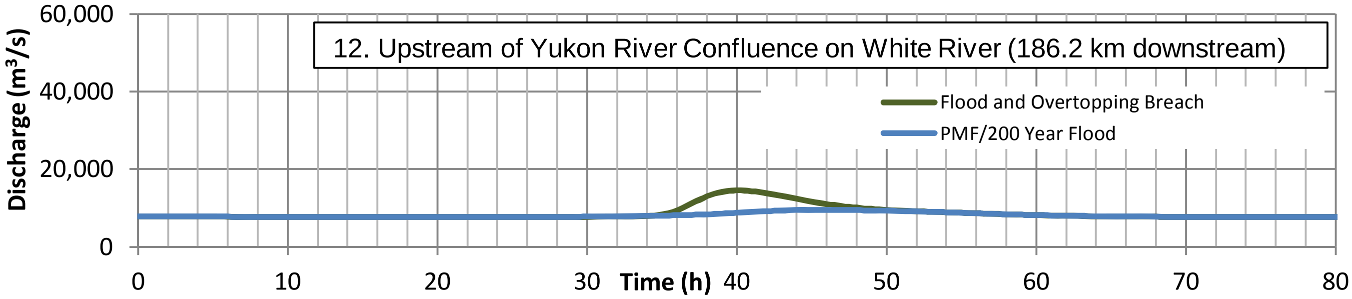
P/A NO.	REF. NO.
VA101-325/20	2

FIGURE 5.4b REV 0





NOTES:
1. TIME 0 HOURS STARTS AT THE ONSET OF THE PMF RAIN EVENT.
2. HYDROGRAPHS BASED ON 15 MINUTE MODEL OUTPUTS.

REV	DATE	DESCRIPTION	PREP'D	REV'D
0	16SEP'15	ISSUED WITH REPORT	ACA	VM

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CASINO COPPER-GOLD PROJECT

HYDROGRAPHS DOWNSTREAM OF TMF MAIN DAM FLOOD INDUCED BREACH SCENARIO PAGE 3 OF 3

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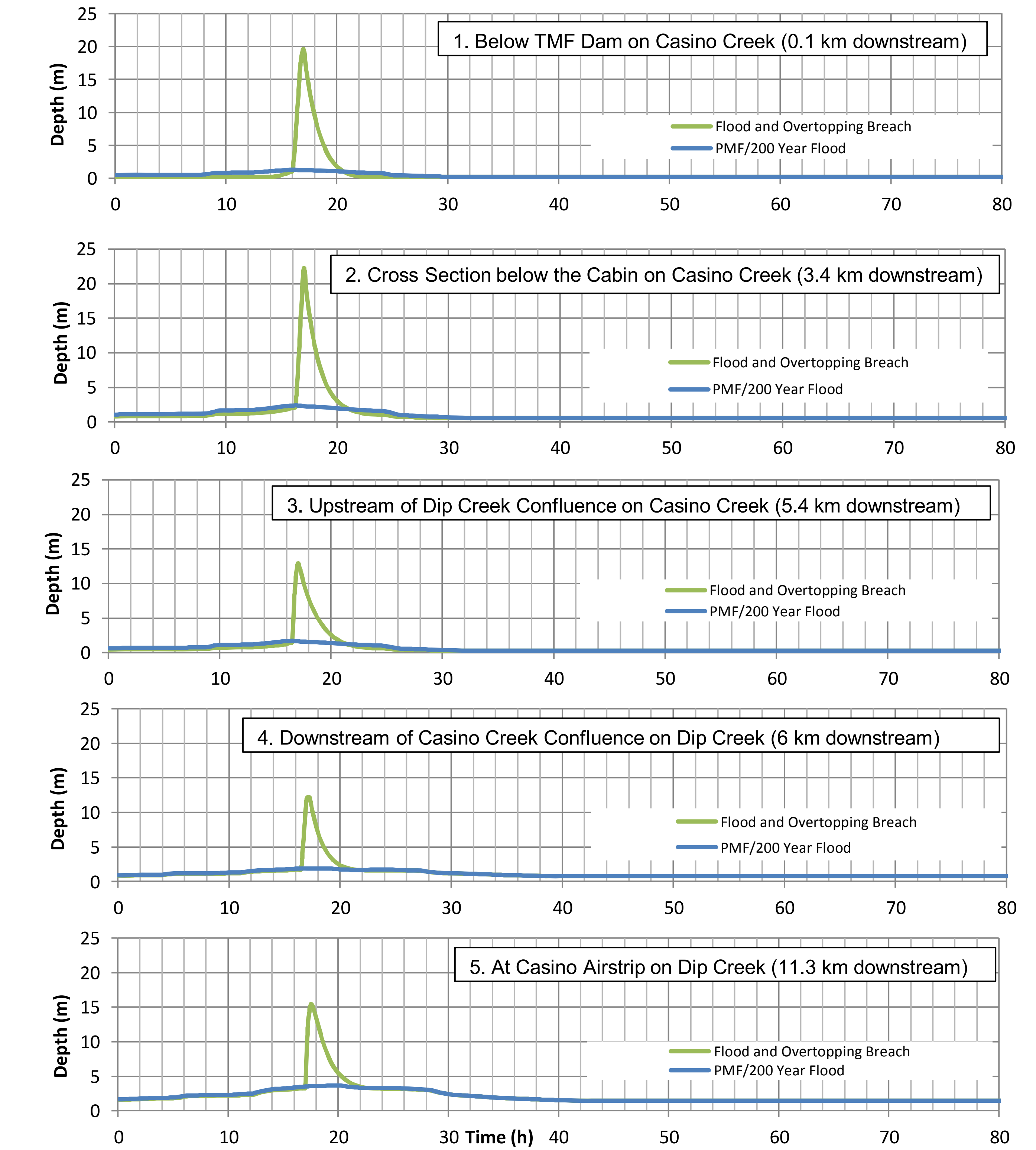
REF. NO. 2

FIGURE 5.4c

REV 0



NOTES:

1. TIME 0 HOURS STARTS AT THE ONSET OF THE PMF RAIN EVENT.
2. DEPTH IS DEPTH OF WATER FROM THE RIVER CHANNEL INVERT; A DEPTH OF 0 m INDICATES THE RIVER CHANNEL IS DRY.
3. GRAPHS BASED ON 15 MINUTE MODEL OUTPUTS.

REV	DATE	DESCRIPTION	PREP'D	REV'D
0	16SEP'15	ISSUED WITH REPORT	ACA	VM

CASINO MINING CORPORATION

CASINO COPPER-GOLD PROJECT

WATER DEPTH DOWNSTREAM OF TMF MAIN DAM
FLOOD INDUCED BREACH SCENARIO
PAGE 1 OF 3

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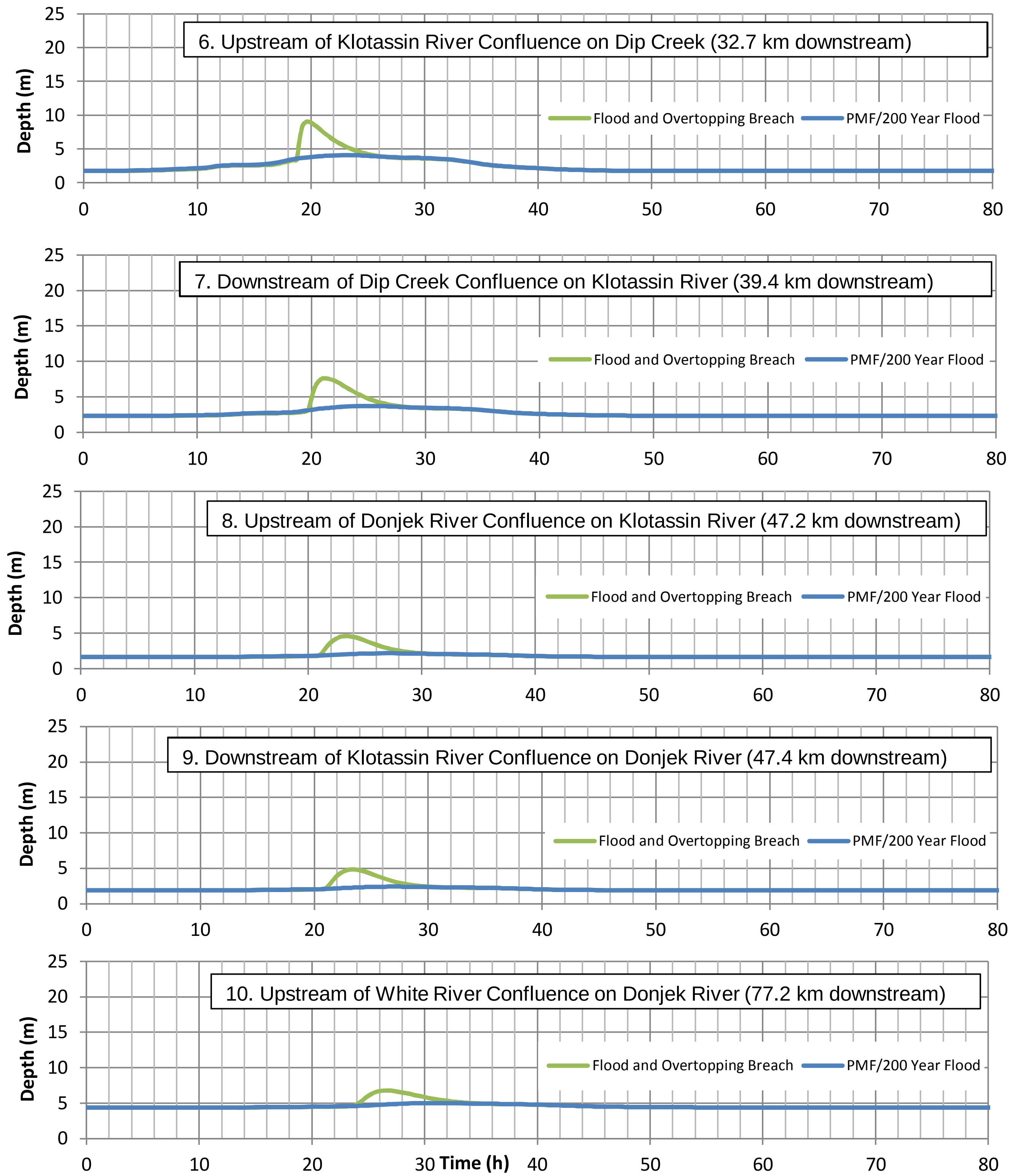
P/A NO.	REF. NO.	
VA101-325/20	2	
FIGURE 5.5a		REV 0



NOTES:
1. TIME 0 HOURS STARTS AT THE ONSET OF THE PMF RAIN EVENT.
2. DEPTH IS DEPTH OF WATER FROM THE RIVER CHANNEL INVERT; A DEPTH OF 0 m INDICATES THE RIVER CHANNEL IS DRY.
3. GRAPHS BASED ON 15 MINUTE MODEL OUTPUTS.

REV	DATE	DESCRIPTION	PREP'D	REV'D
0	16SEP'15	ISSUED WITH REPORT	ACA	VM

CASINO MINING CORPORATION

CASINO COPPER-GOLD PROJECT

WATER DEPTH DOWNSTREAM OF TMF MAIN DAM
FLOOD INDUCED BREACH SCENARIO
PAGE 2 OF 3

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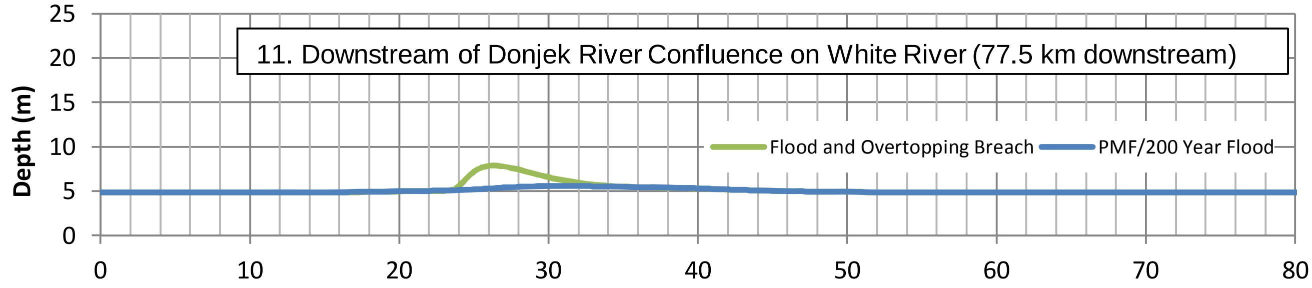
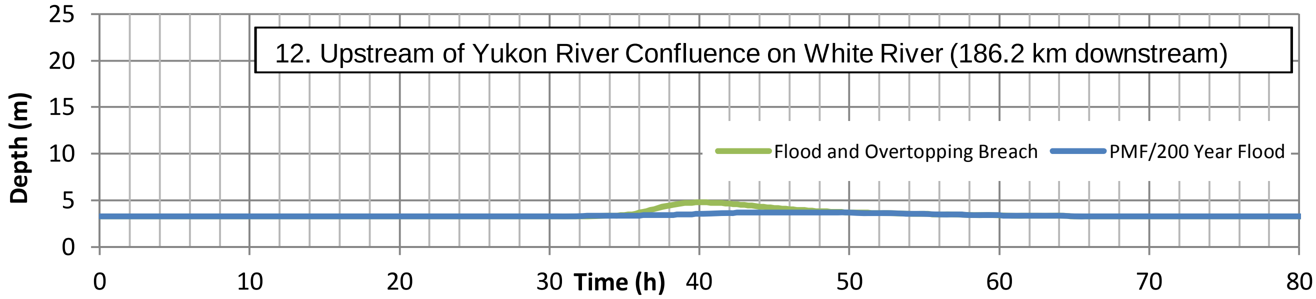
P/A NO.	REF. NO.	
VA101-325/20	2	
FIGURE 5.5b		REV 0





NOTES:

1. TIME 0 HOURS STARTS AT THE ONSET OF THE PMF RAIN EVENT.
2. DEPTH IS DEPTH OF WATER FROM THE RIVER CHANNEL INVERT; A DEPTH OF 0 m INDICATES THE RIVER CHANNEL IS DRY.
3. GRAPHS BASED ON 15 MINUTE MODEL OUTPUTS.

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REV	DATE	DESCRIPTION	PREP'D	REV'D

CASINO MINING CORPORATION

CASINO COPPER-GOLD PROJECT

WATER DEPTH DOWNSTREAM OF TMF MAIN DAM
FLOOD INDUCED BREACH SCENARIO
PAGE 3 OF 3

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P/A NO. VA101-325/20	REF. NO. 2	
FIGURE 5.5c		REV 0

5.3.2 Flood Induced Breach Inundation Maps

The final inundation maps for the flood induced dam breach scenario are shown on Figure 5.6. The maps were prepared using 1:400,000 scale and ESRI ArcGIS online Bing Maps Aerial imagery. The inundation maps show the peak water surface elevations resulting from a flood induced scenario with a hypothetical dam breach for the ultimate arrangement of the TMF. The extent of flooding due to the breach scenario is shown in light green, while natural PMF/200 year flood conditions without a dam breach are shown in blue on top of the green layer. The light green shading is equivalent to the incremental flooding as this represents the difference in water surface elevation between the natural PMF/200 year flood conditions and the flood induced breach scenario.

LEGEND:

- CABIN
- EXTENT OF MODEL
- CROSS SECTION
- FLOOD AND OVERTOPPING BREACH WATER LEVEL
- PMF/200 YEAR FLOOD WATER LEVEL

PROPOSED MINE FACILITIES

- AIRSTRIP ACCESS ROAD
- TAILINGS BEACH
- EMBANKMENT
- HEAP LEACH FACILITY
- OPEN PIT
- POND
- PAG TAILINGS
- AIRSTRIP

NOTES:

1. BASE MAP: ESRI ARCGIS ONLINE BING MAPS.
2. COORDINATE GRID IS IN METRES/DEGREES. COORDINATE SYSTEM: NAD 1983 UTM ZONE 7N.
3. THIS FIGURE IS PRODUCED AT A NOMINAL SCALE OF 1:400,000 FOR 11x17 (TABLOID) PAPER. ACTUAL SCALE MAY DIFFER ACCORDING TO CHANGES IN PRINTER SETTINGS OR PRINTED PAPER SIZE.
4. FLOOD PEAK ARRIVAL TIME IS RELATIVE TO THE BREACH INITIATION.
5. MAXIMUM DEPTH OF FLOW IS BASED ON THE MAXIMUM MODELLED WATER ELEVATION AND THE ASSUMED CHANNEL INVERT.

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	REVIEWED
0	16SEP'15	ISSUED FOR INFORMATION	ACA	AMD	VM

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CASINO COPPER-GOLD PROJECT

INUNDATION MAP - FLOOD INDUCED BREACH

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P/A NO. VA101-325/20 | REF NO. 2

FIGURE 5.6 | REV 0

SAVED: M:\1\01\00325\20\A\GIS\Figs\Report2_TMF Breach and Inundation Study\Fig5-6_InundationMap_RainyDay_r0.mxd; Sep 18, 2015 2:09 PM; kkrauszova

5.4 CONSEQUENCES FOR THE CASINO CREEK AND DIP CREEK FLOODPLAINS

A breach in the TMF ultimate arrangement occurring concurrently with the natural PMF/200 year flood (flood induced breach scenario) would lead to increased flooding and larger inundation limits than a sunny day breach scenario within Casino Creek and Dip Creek catchments. The flood wave would be deeper and wider during the flood induced breach; however, the incremental flooded area is larger for the sunny day breach. The flood wave arrival time and time to peak relative to the time of breach are similar for both scenarios.

A TMF breach and a PMF flood are expected to cause severe flooding and erosion to the Casino and Dip Creek channels and floodplains. A cabin on the northwest hill slope above Casino Creek has been identified in the previous emergency planning map from the Yukon Wildland Fire Management Operations. This map places the cabin roughly 100 m above the creek channel and above the modelled inundation area. The proposed air strip is located on a hillslope along Dip Creek and is also above the modelled inundation area. The road connecting the airstrip to the mine crosses Dip Creek few kilometers upstream of the air strip, and this bridge crossing is expected to be washed out by the flood wave in either breach scenario, as well as during the natural PMF flood. No other known existing or proposed settlements or infrastructure are predicted to incur damage during a breach or a natural PMF flood.

5.5 CONSEQUENCES FOR THE KLOTASSIN RIVER FLOODPLAIN

A breach in the TMF ultimate arrangement occurring concurrently with the natural PMF/200 year flood (flood induced breach scenario) would lead to increased flooding and larger inundation limits than a sunny day breach scenario within the lower Klotassin River. The flood wave would be deeper and wider during the flood induced breach; however, the incremental flooded area is larger for the sunny day breach. The flood wave arrival time and time to peak relative to the time of breach were faster for the flood induced scenario as the larger wave is arriving roughly 2.8 hours sooner than the smaller wave from the sunny day breach.

A TMF breach and a natural PMF/200 year flood would both likely cause severe flooding and erosion to the Klotassin River channel and floodplain. No existing or proposed settlements or infrastructure in or near the inundated area are known at the time of this study.

5.6 CONSEQUENCES FOR THE DONJEK RIVER AND WHITE RIVER FLOODPLAINS

A breach in the TMF ultimate arrangement occurring concurrently with the PMF/200 year flood (flood induced breach scenario) would lead to increased flooding and larger inundation limits than a sunny day breach scenario within the lower Donjek and White Rivers. The flood wave would be deeper and wider during the flood induced breach; however, the incremental flooded area is somewhat larger for the sunny day breach. The flood wave arrival time and time to peak relative to the time of breach were faster for the flood induced scenario as the larger wave arrives roughly 4.0 hours sooner at the mouth of the Donjek River, and about 12 hours sooner at the mouth of the White River than the smaller wave from the sunny day breach.

A TMF breach and a natural PMF/200 year flood would both cause flooding and erosion in the Donjek River and White River channels and floodplains. No existing or proposed settlements or infrastructure in or near the inundated area are known at the time of this study.

6 – SENSITIVITY ANALYSIS

6.1 GENERAL

There are numerous uncertainties inherent in tailings dam breach modelling and routing of extreme floods caused by a dam failure. A literature review of past tailings dam failures reveals that a large range is evident in all dam breach parameters, including the outflow volume, the peak discharge, the formation time, the final breach dimensions and shape, and consequently, selecting these parameters requires considerable judgement. The findings from this and other studies suggest that varying the roughness parameter for the downstream drainage network, which is typically done when conducting sensitivity analysis, would result in a lesser effect than varying any of the dam breach parameters that would cause a larger change in the outflow volume.

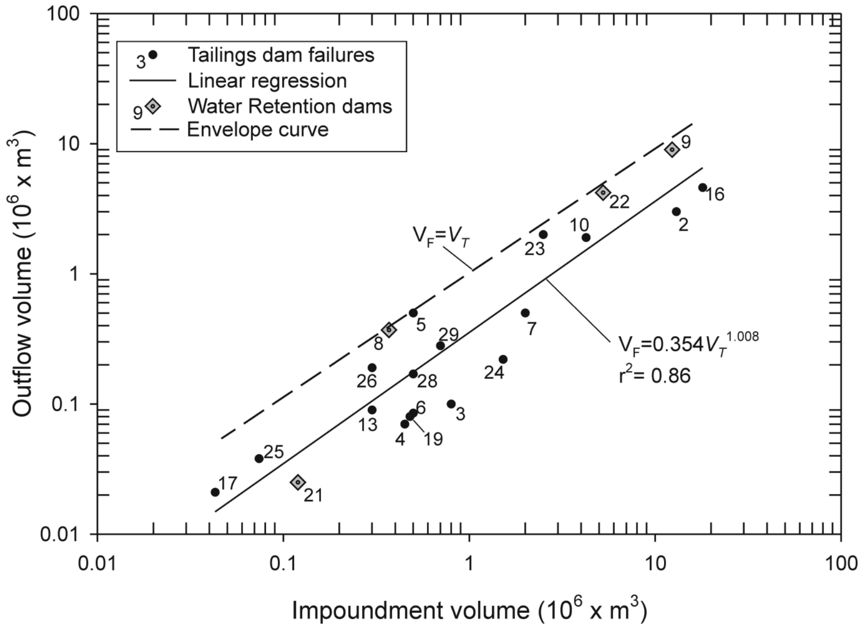
Consequently, the sensitivity tests selected for this study were conducted to determine the effects of outflow volumes on the maximum water surface elevations downstream of the dam. The sensitivity analysis was completed for the sunny day and flood induced dam breach scenarios. This sensitivity analysis was done in addition to testing the range of breach parameters and peak discharges that were discussed in Section 4.

6.2 METHODOLOGY

The outflow volume and peak discharge were calculated based on empirical relationships presented in Rico et al. *Flood from Tailings Dam Failures* (2007) for both sunny day and flood induced failure scenarios. This paper compiles available information on 29 historic tailings dam failures to establish simple correlations between available geometric parameters and hydraulic characteristics of tailings dam breach floods. Because the relationships in this paper are primarily based on past tailings dam failures, these relationships seem to be more frequently used by the mining industry.

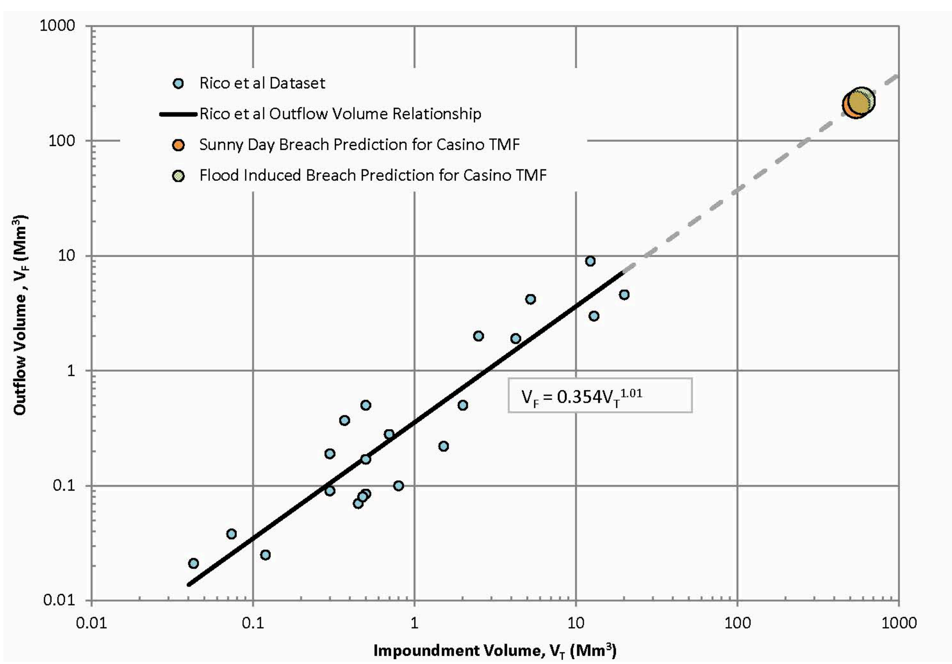
The largest tailings storage facility in the Rico et al. dataset is Los Frailes in Spain which had an impounded volume of 15 - 20 Mm^3 and an outflow volume of 4.6 Mm^3. The largest outflow volume within the dataset is Cities Service in the USA which had an impounded volume of 12.3 Mm^3 and an outflow volume of 9 Mm^3. The tallest dam from this data set was 66 m high at Phelps-Dodge in the USA. These facilities are considerably smaller and some of the relationships that are based on these past failures have to be extrapolated beyond the range for which they were developed.

Figure 6.1 presents the relationship used to develop an estimate of the volume of tailings released (reproduced from Rico et al., 2007) based on the total volume stored (tailings and water), without directly considering the breach size. There is considerable scatter evident in these data, likely due to various factors including the volume of stored water, the type and volume of stored tailings, the dam height and construction method, the type and size of failure, and the failure trigger. The impoundment volume of the dataset is at least an order of magnitude smaller than that proposed for Casino, and hence, the proposed relationship needs to be extrapolated beyond what was presented in Rico et al. (2007), so that it can be applied for this study. This extrapolated relationship is presented on Figure 6.2.



NOTES:
1. FIGURE FROM RICO ET AL. 2007.

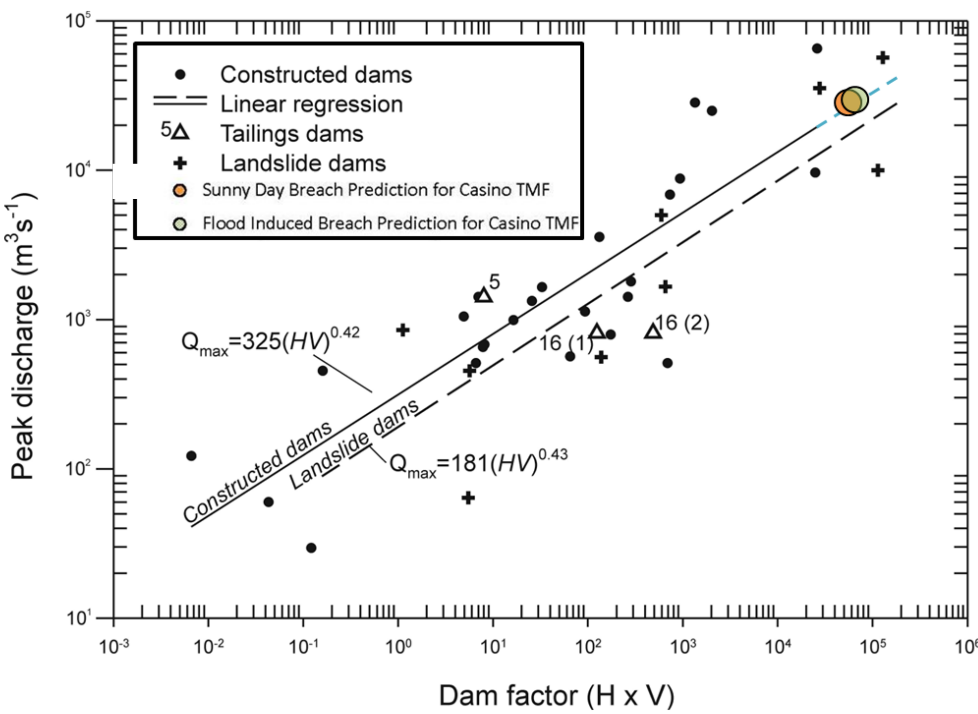
Figure 6.1 Relationship between Tailings Outflow Volume and Impoundment Volume at the Time of the Incident



NOTES:
1. DATA FROM RICO ET AL. 2007.

Figure 6.2 Extrapolated Rico et al. (2007) Relationship between Tailings Outflow Volume and Impoundment Volume

Rico et al. (2007) also proposes a relationship between the dam factor (height x volume) and peak discharge using three cases from the study dataset of tailings dams and a number of constructed water retaining dams or landslide breaches (dataset from Costa 1988). This relationship is presented on Figure 6.3. Peak discharge values for Casino Project are estimated for a sunny day and flood induced breach scenarios based on the extrapolated relationship superimposed on Figure 6.3.



NOTES:
1. FIGURE FROM RICO ET AL. 2007, WITH ADDITIONAL CASINO DATA POINTS PLOTTED.

Figure 6.3 Relationship between Dam Factor and Peak Discharge

The Rico et al. (2007) relationships result in outflow volumes and peak discharges summarized in Table 6.1. The values used in this study (as discussed in Section 4.2.1) based on instantaneous mixing of solids with available free water are presented for comparison.

Table 6.1 Dam Breach Parameter Sensitivity

Breach Scenario	Outflow Volume		Peak Discharge	
	Methodology Based on Rico et al. (2007)	Methodology Based on Available Water	Methodology Based on Rico et al. (2007)	Methodology Based on Available Water
Sunny Day	206 Mm^3	52 Mm^3	31,400 m^3/s	25,000 m^3/s
Flood Induced	223 Mm^3	165 Mm^3	32,600 m^3/s	52,000 m^3/s

The outflow volumes based on Rico et al. (2007) relationships are very similar for the sunny day and flood induced breach scenarios as this study does not explicitly consider the available water to move the sediment (tailings and embankment construction material). Similarly, the peak discharge values are comparable between sunny day and flood induced breach scenarios, as the dam factors for both scenarios are comparable. This similarity in outflow volume and peak discharge represents one of the drawbacks of this methodology as a flood induced scenario coincident with a large flood event and a full TMF pond would be able to move more material than under typical sunny day flow conditions with a much smaller pond.

Another drawback of this methodology is the applicability of the outflow volume relationship. Considering that the relationship is being extrapolated beyond the dataset, it may no longer be valid. A solids content of 70% would be needed in the mobilized sunny day breach volume predicted by the Rico et al. (2007) methodology, assuming the normal operating water level in the TMF. The high solids content would cause the outflow flood wave to deviate from a water-like behaviour, and behave more like a liquefied tailings slump. This would result in a shorter runout distance and a smaller inundation extent, as the solids would deposit near the dam without a sufficient amount of water to carry them farther downstream.

6.3 SENSITIVITY RESULTS

Temporarily setting aside the flaws in this methodology and continuing to conservatively assume that the outflow behaves like water, the Rico et al. (2007) relationship predicts larger outflow volumes than the methodology presented in Section 4.2.1, while the peak discharges are in between those presented in Section 4.2.3. Dam breach hydrographs were developed using the methodology presented in Section 4.2.4 using typical breach characteristics. These larger flood waves were routed through the model to test the sensitivity of the results to outflow volume and peak discharge. Comparisons of sunny day breach hydrographs and water depths are presented on Figures 6.4 and 6.5, while comparison of flood induced breach hydrographs and water depths are presented on Figures 6.6 and 6.7 for selected cross sections.

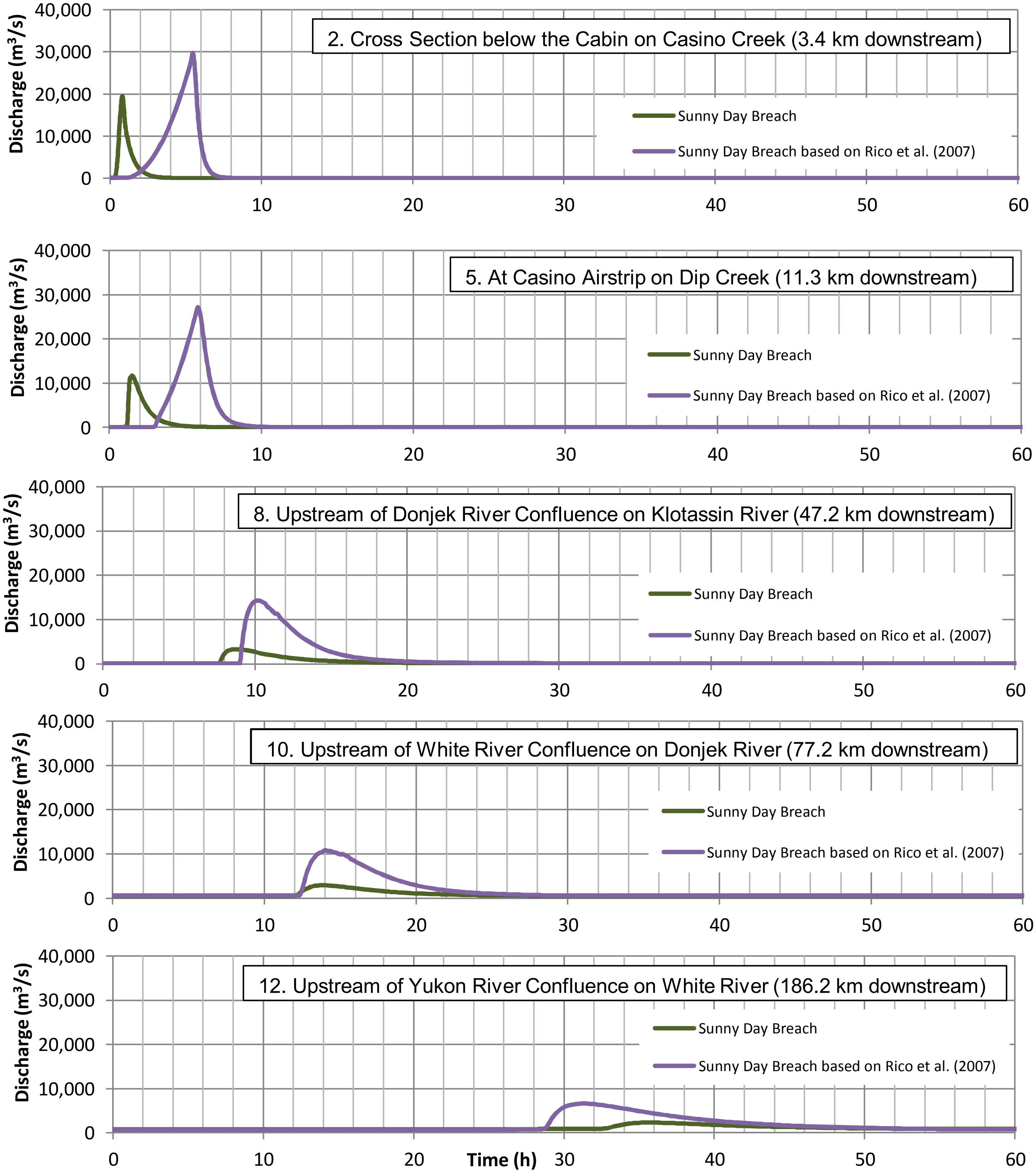
The hydrographs from the Rico et al. (2007) sunny day breach show a higher initial flood wave that takes longer to peak, but moves somewhat faster than the results presented in Section 5.2. The Rico et al. (2007) flood wave arrives at the end of the model 4 hours earlier and peaks 4 hours earlier than the presented results. As the Rico et al. (2007) sunny day breach has a larger volume and initial peak discharge, the flood wave has not attenuated as much at the end of the model, at the mouth of the White River. The peak discharge and the maximum water depth for the Rico et al. (2007) sunny day breach are 4,300 m^3/s larger and 1 m deeper than the results presented in Section 5.2.

The hydrographs from the Rico et al. (2007) flood induced breach show a smaller initial flood wave that takes longer to peak and moves slower than the results presented in Section 5.3. Although the Rico et al. (2007) flood wave initially has a lower peak discharge, the attenuation of the larger volume is slower. At the end of the model, the flood wave arrives and peaks 2 hours later. The peak discharge and the maximum water depth for the Rico et al. (2007) flood induced breach is 1,900 m^3/s larger and less than 0.5 m deeper than the results presented in Section 5.3.

In both cases, the Rico et al. breaches created somewhat larger flood waves at the end of the model. A comparison of inundation maps is presented on Figure 6.8 and Figure 6.9 for the sunny day and flood induced breach scenarios, respectively. When compared to the results presented in Section 5,

Figure 6.8 shows a larger inundation for the Rico et al. (2007) sunny day breach, while Figure 6.9 shows a very similar inundation for the flood induced breach. The inundation extent of the sunny day breach based on Rico et al. (2007) relationships is within the flood induced inundation extents presented in Section 5.3.

This sensitivity analysis shows that the results are sensitive to the breach outflow volume and peak discharge. Given the shortcomings in applying the Rico et al. (2007) relationships for the Casino TMF discussed in Section 6.2, the results and inundation maps presented in Section 5 are considered to be more representative of the hypothetical breach results for the sunny day and flood induced scenarios.



NOTES:
1. TIME 0 HOURS STARTS AT THE ONSET OF THE BREACH.
2. HYDROGRAPHS BASED ON 10 MINUTE MODEL OUTPUTS.

REV	DATE	DESCRIPTION	PREP'D	RVW'D
0	16SEP'15	ISSUED WITH REPORT	ACA	VM

CASINO MINING CORPORATION

CASINO COPPER-GOLD PROJECT

HYDROGRAPHS DOWNSTREAM OF TMF MAIN DAM SUNNY DAY BREACH SCENARIO SENSITIVITY

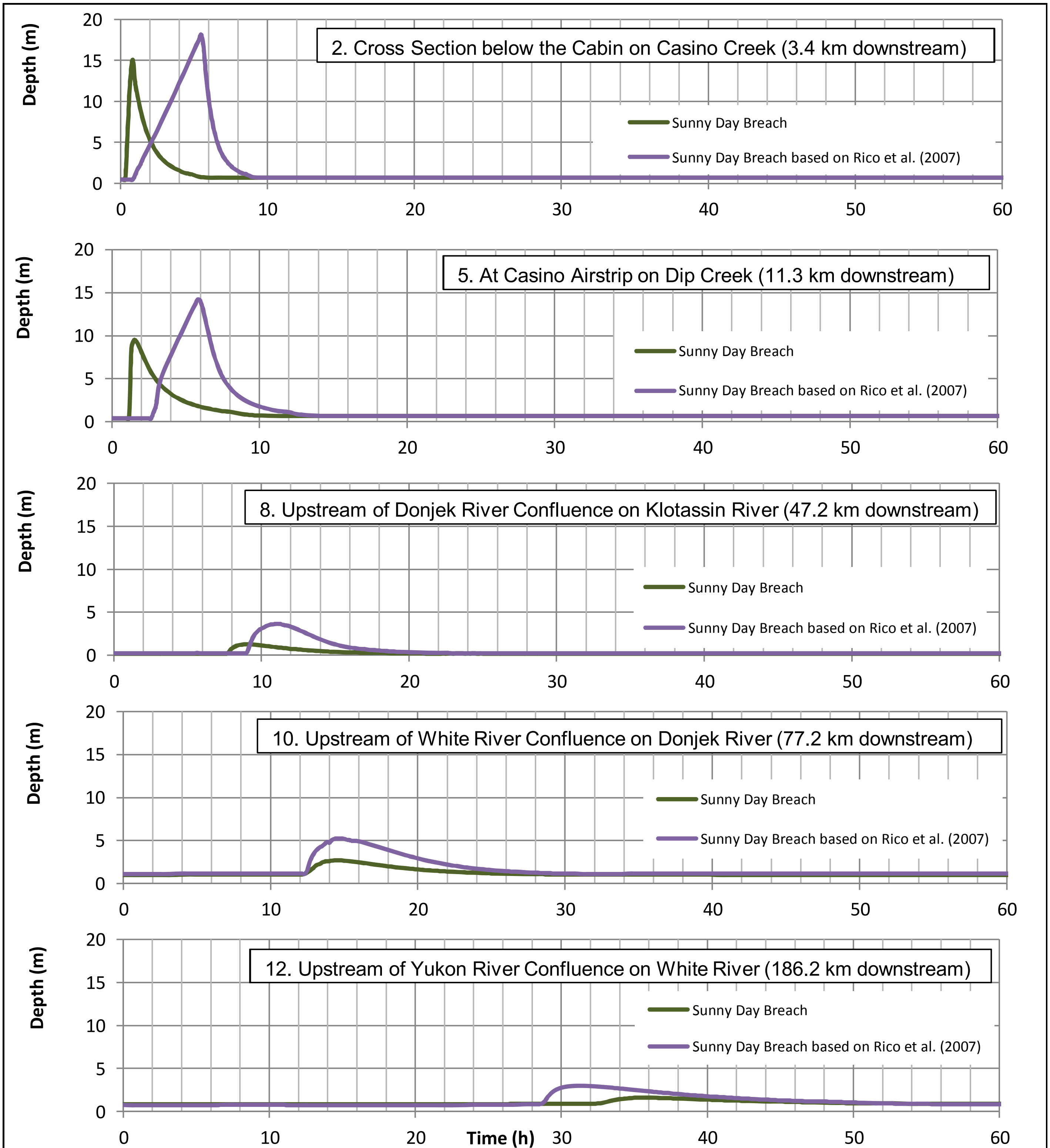
Knight Piésold CONSULTING

P/A NO. VA101-325/20

REF. NO. 2

FIGURE 6.4

REV 0



NOTES:

1. TIME 0 HOURS STARTS AT THE ONSET OF THE BREACH.
2. DEPTH IS DEPTH OF WATER FROM THE RIVER CHANNEL INVERT; A DEPTH OF 0 m INDICATES THE RIVER CHANNEL IS DRY.
3. GRAPHS BASED ON 10 MINUTE MODEL OUTPUTS.

REV	DATE	DESCRIPTION	PREP'D	RVW'D
0	16SEP'15	ISSUED WITH REPORT	ACA	VM

CASINO MINING CORPORATION

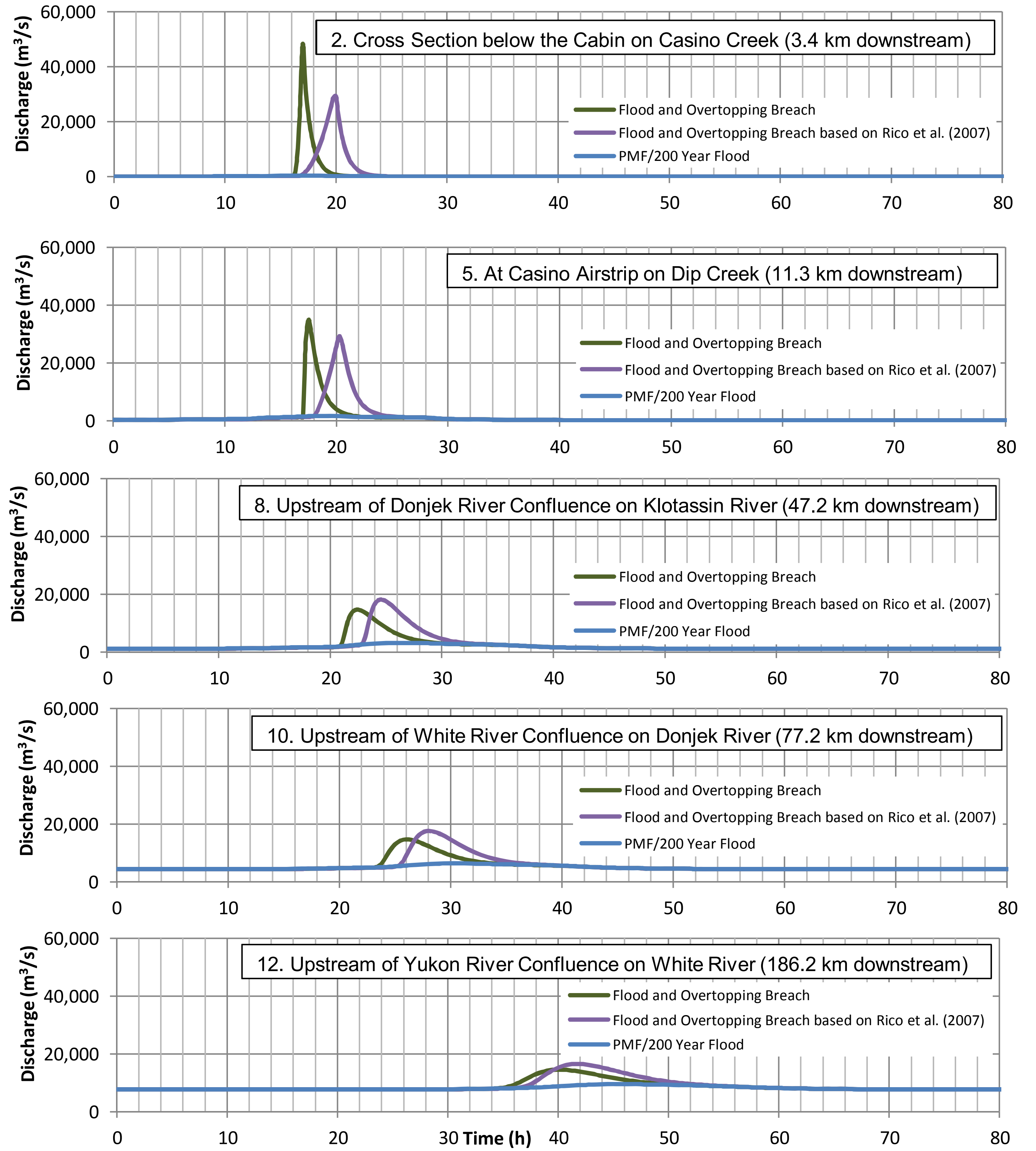
CASINO COPPER-GOLD PROJECT

WATER DEPTH DOWNSTREAM OF TMF MAIN DAM
SUNNY DAY BREACH SCENARIO SENSTIVITY

Knight Piésold CONSULTING

P/A NO.	REF. NO.
VA101-325/20	2

FIGURE 6.5 REV 0



NOTES:

1. TIME 0 HOURS STARTS AT THE ONSET OF THE PMF RAIN EVENT.
2. HYDROGRAPHS BASED ON 15 MINUTE MODEL OUTPUTS.

CASINO MINING CORPORATION

CASINO COPPER-GOLD PROJECT

HYDROGRAPHS DOWNSTREAM OF TMF MAIN DAM FLOOD INDUCED BREACH SCENARIO SENSITIVITY

Knight Piésold CONSULTING

P/A NO.	REF. NO.
VA101-325/20	2

FIGURE 6.6 REV 0

REV	DATE	DESCRIPTION	PREP'D	RVW'D
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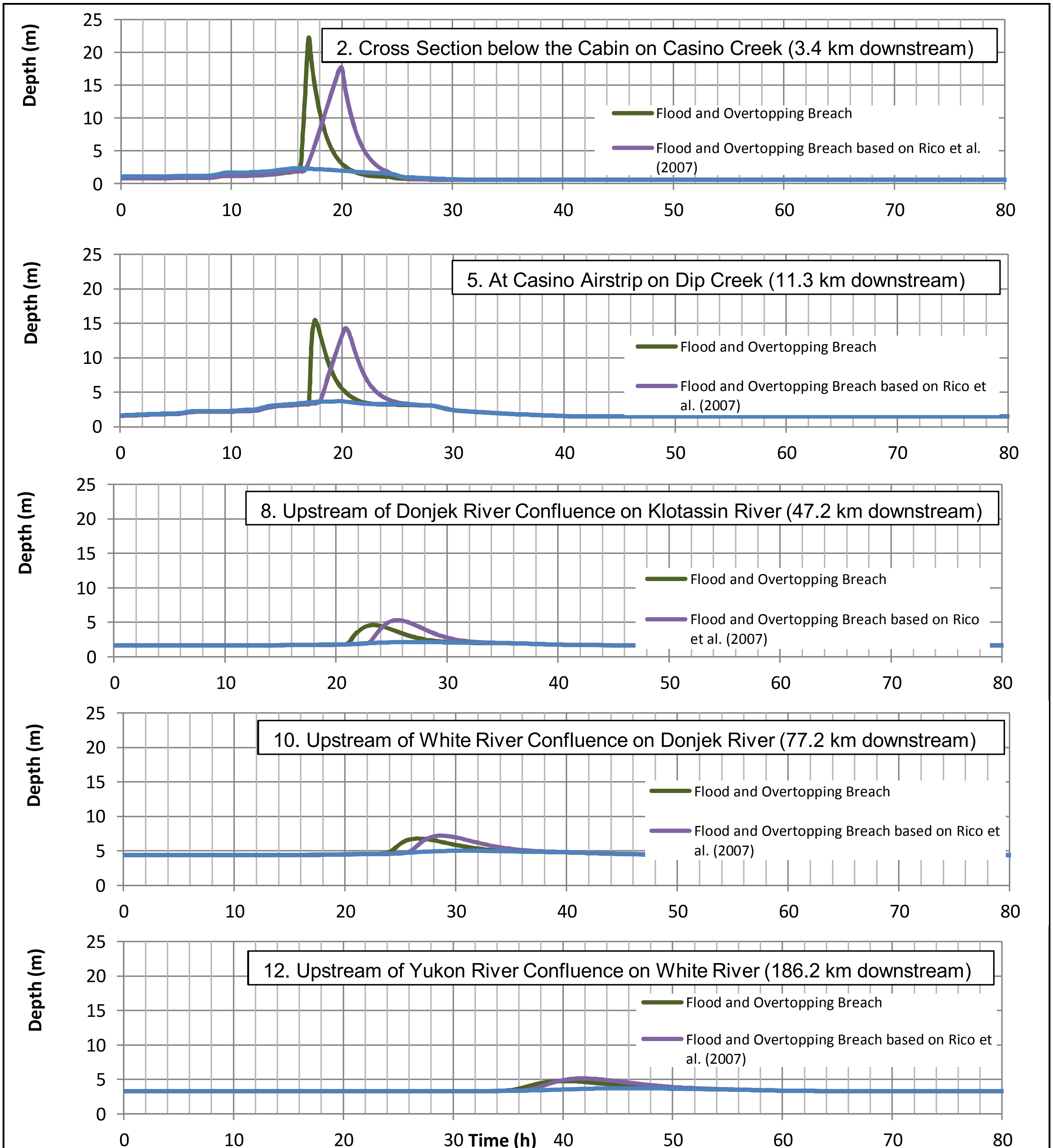


NOTES:

1. TIME 0 HOURS STARTS AT THE ONSET OF THE PMF RAIN EVENT.
2. DEPTH IS DEPTH OF WATER FROM THE RIVER CHANNEL INVERT; A DEPTH OF 0 m INDICATES THE RIVER CHANNEL IS DRY.
3. GRAPHS BASED ON 15 MINUTE MODEL OUTPUTS.

REV	DATE	DESCRIPTION	PREP'D	RVW'D
0	16SEP'15	ISSUED WITH REPORT	ACA	VM

CASINO MINING CORPORATION

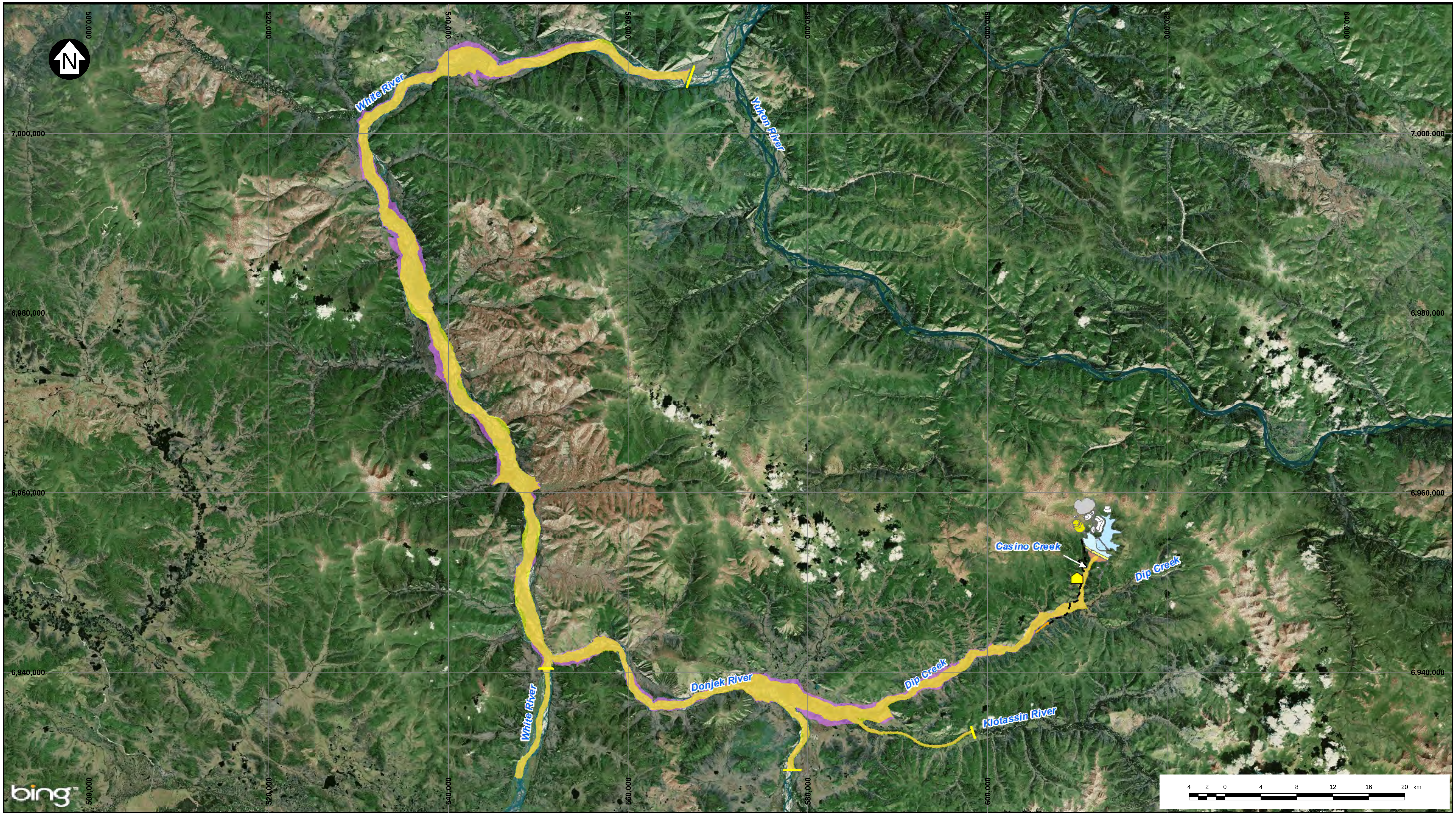
CASINO COPPER-GOLD PROJECT

WATER DEPTH DOWNSTREAM OF TMF MAIN DAM FLOOD INDUCED BREACH SCENARIO SENSTIVITY

Knight Piésold CONSULTING

P/A NO.	REF. NO.
VA101-325/20	2

FIGURE 6.7 REV 0



LEGEND:

- CABIN
- EXTENT OF MODEL
- CROSS SECTION
- SUNNY DAY BREACH WATER LEVEL
- RICO ET AL. (2007) SUNNY DAY BREACH WATER LEVEL

PROPOSED MINE FACILITIES

- AIRSTRIP ACCESS ROAD
- TAILINGS BEACH
- EMBANKMENT
- HEAP LEACH FACILITY
- OPEN PIT
- POND
- PAG TAILINGS
- AIRSTRIP

NOTES:

1. BASE MAP: ESRI ARCGIS ONLINE BING MAPS.
2. COORDINATE GRID IS IN METRES/DEGREES. COORDINATE SYSTEM: NAD 1983 UTM ZONE 7N.
3. THIS FIGURE IS PRODUCED AT A NOMINAL SCALE OF 1:400,000 FOR 11x17 (TABLOID) PAPER. ACTUAL SCALE MAY DIFFER ACCORDING TO CHANGES IN PRINTER SETTINGS OR PRINTED PAPER SIZE.

0	16SEP'15	ISSUED FOR INFORMATION	ACA	AMD	VM
REV	DATE	DESCRIPTION	DESIGNED	DRAWN	REVIEWED

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CASINO COPPER-GOLD PROJECT

INUNDATION MAP - SUNNY DAY BREACH SENSITIVITY SCENARIO

Knight Piésold CONSULTING

P/A NO.	REF NO.	
VA101-325/20	2	
FIGURE 6.8		REV 0

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LEGEND:

- CABIN
- EXTENT OF MODEL
- CROSS SECTION
- FLOOD AND OVERTOPPING BREACH WATER LEVEL
- RICO ET AL. (2007) FLOOD AND OVERTOPPING BREACH WATER LEVEL

PROPOSED MINE FACILITIES

- AIRSTRIP ACCESS ROAD
- TAILINGS BEACH
- EMBANKMENT
- HEAP LEACH FACILITY
- OPEN PIT
- POND
- PAG TAILINGS
- AIRSTRIP

NOTES:

1. BASE MAP: ESRI ARCGIS ONLINE BING MAPS.
2. COORDINATE GRID IS IN METRES/DEGREES. COORDINATE SYSTEM: NAD 1983 UTM ZONE 7N.
3. THIS FIGURE IS PRODUCED AT A NOMINAL SCALE OF 1:400,000 FOR 11x17 (TABLOID) PAPER. ACTUAL SCALE MAY DIFFER ACCORDING TO CHANGES IN PRINTER SETTINGS OR PRINTED PAPER SIZE.

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	REVIEWED
0	16SEP'15	ISSUED FOR INFORMATION	ACA	AMD	VM

CASINO MINING CORPORATION

CASINO COPPER-GOLD PROJECT

INUNDATION MAP - FLOOD INDUCED BREACH SENSITIVITY SCENARIO

Knight Piésold CONSULTING

P/A NO.	REF NO.	REV
VA101-325/20	2	0

FIGURE 6.9

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7 – CONCLUSIONS

7.1 LIKELIHOOD OF OCCURRENCE

The Casino TMF is designed to permanently store all tailings and potentially reactive mine waste rock and overburden materials in a safe and environmentally secure manner. The embankments have been designed in accordance with the CDA Guidelines (CDA 2007a; 2013). The likelihood of occurrence of a TMF breach has been minimized to the maximum practical extent during the planning and design of the facility.

The potential consequences of a tailings dam breach demonstrated through dam breach modelling specifically ignore the likelihood of occurrence. The modelled dam failures are hypothetical and should not occur for TMFs designed, constructed and operated following standard engineering practices.

7.2 CONSEQUENCES OF FAILURE

The dam breach inundation study for the Casino Project was conducted to provide an understanding of the potential consequences of a tailings dam failure. This study examined two initial hydrologic conditions in accordance with the CDA Guidelines (CDA 2007a; 2013) - sunny day breach and flood induced breach. The study has been structured to estimate the potential inundation limits resulting from a hypothetical dam breach during the last year of operations (ultimate arrangement). The limits of potential consequences due to a failure at any time during operations are expected to be below the range shown for these failure scenarios.

A TMF breach and natural PMF flood would likely cause severe flooding and erosion in the Casino and Dip Creek channels and floodplains. A cabin on the northwest hill slope above Casino Creek has been identified in an emergency planning map from the Yukon Wildland Fire Management Operations. This map places the cabin roughly 100 m above the creek channel and above the modelled inundation area. The proposed air strip is located in Dip Creek and is also above the modelled inundation area. The road connecting the airstrip to the mine crosses Dip Creek upstream of the air strip, and this bridge crossing is expected to be washed out by the flood wave in either breach scenario and during a PMF flood. No other known existing or proposed settlements or infrastructure are predicted to incur damage during a breach or a PMF flood.

A TMF dam breach and a natural PMF/200 year flood without a dam breach would likely cause considerable flooding and erosion to the Klotassin River, Donjek River and White River channels and floodplains. The results indicate that the incremental impacts of a dam breach flood wave are reduced in the downstream direction and are diminished to about 1 m above the natural water surface by the confluence of the White and Yukon Rivers. No existing or proposed settlements or infrastructure in or near the inundated area are known at the time of this study.

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9 – CERTIFICATION

This report was prepared and reviewed by the undersigned.

Prepared: ______________________________

A. C. S. AKKERMAN # 40280

Anna Akkerman, P.Eng.
Project Engineer

Reviewed: ______________________________

Violeta Martin, Ph.D., P.Eng.
Senior Hydrotechnical Engineer

Reviewed: ______________________________

Les Galbraith, P.Eng.
Specialist Engineer | Associate

Approval that this document adheres to Knight Piésold Quality Systems:

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Whitehorse, YT Y1A 3T8
P: (867) 393-4882 • F: (867) 393-4883

MEMO

Date: October 7, 2015

To: Mary Mioska, Senior Environmental Manager

Re: Effects of Casino Tailings Management Facility Dam Breach on Terrestrial Wildlife

Casino Mining Corporation (CMC) is proposing to develop the Casino Project located in central Yukon. Part of the project plan is to construct a tailings management facility (TMF) for subaqueous storage of tailing materials. CMC requested that EDI Environmental Dynamics Inc. (EDI) provide a qualitative assessment of potential effects to the terrestrial environment from a scenario where the proposed TMF dam embankment breached. The qualitative assessment of the potential effects of a Casino TMF dam breach on terrestrial wildlife is provided below, using the sunny day scenario described in the Dam Breach Inundation Study (KP 2015). A sunny day scenario was chosen to be evaluated because the incremental effect on terrestrial wildlife is greater than the incremental effect during the rainy-day event.

Dam Breach Interaction

A TMF dam breach would affect terrestrial wildlife that occupy the inundation area at the time of a dam breach. A dam breach would affect primarily the riparian, lowland and wetland habitats adjacent the Casino Creek, Dip Creek, Klotassin River, Donjek River and White River. The most affected area would be within the Casino Creek, Dip Creek and Klotassin River valleys as the peak discharge would far exceed the volume of natural flood events. The Donjek and White rivers would be less affected because the inundated area would be within the range of natural flooding, and thus within the regularly disturbed area.

Species most likely to be affected by a dam breach include those common to the area, summarized in the Wildlife Baseline Report Version 2 (Appendix A.12B) and the Bird Baseline Report (Appendix 12B) of the Project Proposal. The species with the greatest potential to occur within the inundation area include moose, black and grizzly bear, lynx, coyote, red fox, wolverine, porcupine, small mustelids, aquatic mammals, small mammals, amphibians, passerine birds and waterfowl, and any terrestrial mammals that use low elevation habitat. Animals that use high elevation habitats are unlikely to be affected by a dam breach; for example, caribou, thinhorn sheep, cliff nesting raptors and pika primarily occupy higher elevations that are outside of the area that could be inundated by the initial flood wave. Species used as key indicators in the Project Proposal to assess potential Project effects and their potential interactions with a dam breach are summarized in Table 1.

Table 1. Key indicator species and potential interaction from a dam breach

Key Indicator	Seasonal Occurrence	Potential Interaction from a TMF dam breach
Klaza caribou herd	All seasons	Unlikely interaction because caribou primarily use higher elevation habitats
Moose	All seasons	Interaction with moose as they are commonly observed using habitat adjacent to streams and are documented using the Dip Creek mineral lick
Grizzly bear	All seasons	Limited interaction because grizzly bears generally use higher elevation terrain for foraging and denning
Collared pika	All seasons	No interaction because pika exclusively use alpine habitats
Cliff nesting raptors	Migratory, primarily summer	No interaction with falcon and golden eagle nesting habitat, minimal interaction with summer foraging habitat
Bird species at risk	Migratory, summer	Interaction with bird species at risk that use lowland, wetland and riparian habitats
Passerine birds	Migratory, summer	Interaction with bird species that use lowland, wetland and riparian habitats
Waterfowl	Migratory, summer	Interaction with waterfowl species

Effect Mechanisms

A TMF dam breach would result in a flood that would inundate a large area below the TMF facility. At peak discharge the flood wave would scour the inundated area resulting in a debris flow that would carry vegetation and soils downstream. As the flood subsides, the wave would leave behind embankment material and mobilized tailings along with soils and vegetation that were removed during the flood event. New stream channels would form in the stripped valleys. Stream channels would be dynamic for years as there would be no vegetation stabilizing the terrain and exposed permafrost would slump into the streams.

A dam breach would affect wildlife through the potential mortality of animals that are in the area at the time of the breach, a change in the availability of terrestrial habitat and habitat features, and could result in exposure to constituents of potential concerns over time.

Assessment of Potential Effects

A dam breach would cause significant wildlife mortality and loss of wildlife habitat within the Casino and Dip creeks and the Klotassin River. Wildlife and wildlife habitat adjacent to the Donjek, White and Yukon rivers would be less affected as the magnitude of the flooding would be within the range that the area experiences during naturally occurring large flood events.

The magnitude of effects from a dam breach is dependent on the timing and local conditions (e.g., winter or summer) because species occurrence in the area is seasonal. The seasonal abundance and diversity of animals increase during the summers when migratory species return to the area and juvenile animals are present; consequently, a dam breach event would be experienced by a larger number of species and individuals in summer compared to winter.

The risk of mortality for animals in the inundated area from the initial flood wave/debris flow would be short-term—lasting several hours. Some terrestrial animals will occur within the inundation area and would be unable to leave the area prior to flooding; consequently, a dam breach would likely result in individual mortalities. There are no known isolated populations of wildlife that occur within the potentially inundated area and all species would likely reoccupy the area within several years of the event. An apparent change in species composition within the affected area would result from changes to habitat availability.

Loss of habitat associated with geomorphic change will be long-term as removal of vegetation and soils will permanently change the landscape. The affected habitat would eventually be revegetated and provide habitat for a number of wildlife species. Soil reclamation treatments would be required to accelerate habitat recovery. After application of treatments to reclaim soils, the area would likely be revegetated with shrubs such as willow and birch or other forbs able to colonize low nutrient environments. Those wildlife species that benefit from early successional forests would be the first to occupy the area. The region commonly experiences large habitat disturbances in the form of wildland fires. Recovery time from fires is relatively fast as many of the plants in the region benefit from disturbances. Disturbance from a dam breach would be different from fire because the soil will be removed by scouring or covered by tailings, so the revegetation immediately post-breach would be limited without reclamation efforts.

Wetland habitats are used by a number of animal species. The TMF will be developed into a wetland at closure, so a dam breach would result in the loss of the large constructed wetland as well as the natural wetlands downstream of the dam. The wetlands in the Dip Creek and Klotassin River valleys would be affected as they would be temporarily inundated by the initial flood wave and tailings would be deposited in the wetlands. The size and abundance of wetlands adjacent to Dip Creek and Klotassin River would change as a result of a dam breach.

One mineral lick is known to occur within the inundation area (Map 1). The mineral lick would be removed temporarily and could potential be removed permanently. If mineral licks are limited in the region, then the loss of the lick could reduce the capacity of the area to support moose.

The exposure to constituents of potential concern could reduce the health of animals that spend the majority of their life feeding in the area (i.e. animals with limited mobility and/or small home ranges).

Mitigation Measures

No measures are proposed to mitigate the effect of a dam breach on wildlife, as a dam breach is not part of the Project Description.

Reclamation/Reversibility

A dam breach will result in permanent habitat changes. However, efforts to restore soils that result in revegetation would return the area to functional wildlife habitat. Reclamation efforts would be a long-term commitment.

Summary

A breach of the TMF dam would result in wildlife mortality and habitat loss. There will be individual wildlife mortalities for those animals using the inundation zone at the time of the dam breach, depending on seasonality. No unique or isolated population of wildlife occur within the area potentially inundated by the flood wave. Although a dam breach will clearly result in substantial damage and unanticipated changes to habitat conditions, the effect of a breach on wildlife would not be significant in the region. The dam breach would remove terrestrial habitat, wetlands and one known mineral lick. Those losses would result in a likely significant loss of wildlife habitat. Effects on wildlife habitat could be partly reversed if soils in the area were re-established. The long-term effect of exposure to tailings on wildlife health is an unknown.

Yours truly,

EDI Environmental Dynamics Inc.

Graeme Pelchat, P.Biol.
Wildlife Biologist

Mike Setterington, R.P.Bio.
Wildlife Director/Senior Biologist

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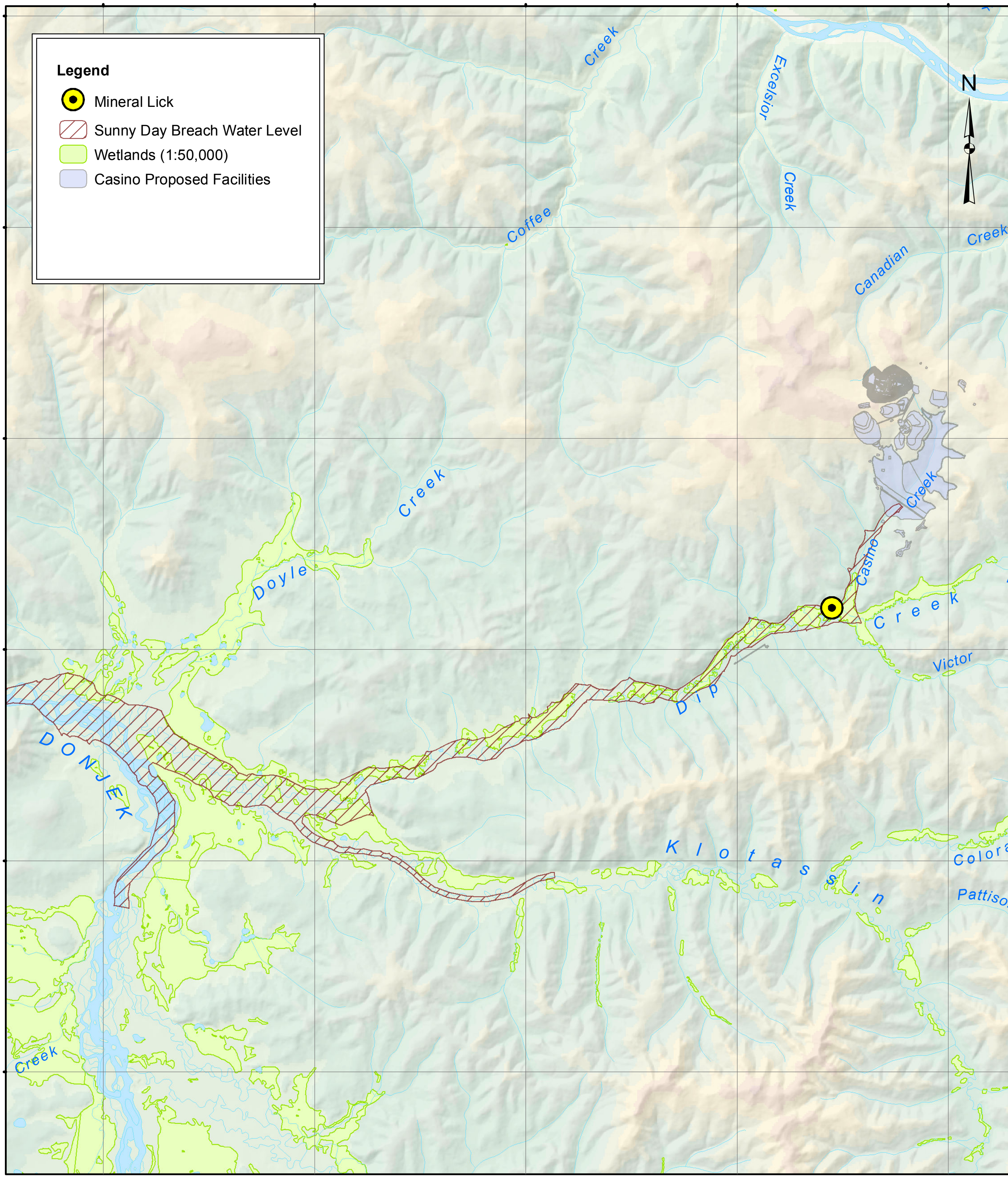
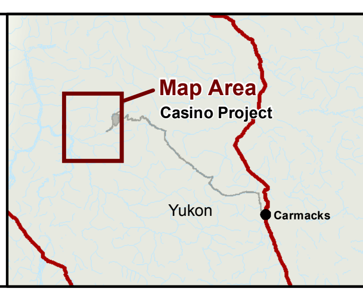


1:250,000 and 1: 50,000 Topographic Spatial Data, National Road Network, Ecoregions; courtesy of Her Majesty the Queen in Right of Canada, Department of Natural Resources. All Rights Reserved.

Inundation data provided by Knight Piesold (September, 2015)

Digital Elevation Models (30 m and 90 m) provided by Yukon Government - Geomatics Yukon; online Corporate Spatial Warehouse. www.geomaticsyukon.ca



Casino Project: Extent of Tailings Dam Breach Inundation Area on Dip Creek

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Kilometres

Map scale 1:500,000 (printed at 8.5x11)
North American Datum 1983 CSRS Yukon Albers

CASINO
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PALMER
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CONSULTING
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470 Granville Street, Suite 630, Vancouver, BC V6C 1V5 t 604-629-9075

Memorandum

Date: December 11, 2015

P1001
Project: Casino Project

To: Mary Mioska, Casino Mining Corporation.

From: Nicola Lower, Palmer Environmental Consulting Group Inc., Hans Voight and Tom Gast, Thomas Gast & Associates Environmental Consultants

cc Rick Palmer, Palmer Environmental Consulting Group.

Subject: Evaluation of a Casino Mine Dam Breach on Fisheries Values

1 INTRODUCTION

Casino Mining Corporation (CMC) is proposing the development of the Casino Project (the 'Project'), an open pit copper-gold-molybdenum mine in the Yukon. The project is located in the Dawson Range Mountains of the Klondike Plateau approximately 300km northwest from Whitehorse. The Tailings Management Facility (TMF) is located within the Casino Creek valley. Knight Piesold (KP) has completed a dam breach and inundation study for the Project TMF, in accordance with the Canadian Dam Association (CDA) Guidelines (2007; revised 2013). The CDA Guidelines also provide for the classification of dams in terms of the consequence of failure. The purpose of this technical memorandum is to support the classification of the Project TMF dam, by providing an evaluation of the potential effects of a hypothetical dam breach on fisheries in the area. The extent of impacts and the understanding of the potential failure of the dam are as outlined in the following documents by KP: TMF Dam Breach Inundation Study for Casino Mining Corporation, June 18 2015; Geomorphic Effects of Casino TMF Dam Breach (memorandum DRAFT), July 28 2015; Figure illustrating dam breach scenarios (DRAFT), August 14 2015.

2 FISHERIES BACKGROUND

Extensive baseline surveys have been conducted on fish and fish habitat in the Project area from 2008 to 2013 (Palmer Environment Consulting Group, 2013). The Casino Project is located wholly within the Yukon River watershed. The proposed mine is situated in the upper watersheds of Casino Creek and Canadian Creek (a tributary to Britannia Creek). The Project TMF is located within the valley formed by the headwaters of Casino Creek. Slimy sculpin (*Cotus cognatus)* and Arctic grayling (*Thymallus arcticus*) are the dominant species within the high-elevation mine area, where cold water temperatures, high gradients and velocities, a lack of overwintering habitat, and locally poor water quality and benthic

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community greatly limit productive capacity. Low numbers of burbot (*Lota* lota) and round whitefish (*Prosopium cylindraceum*) are present in the lower watersheds.

Fish abundance and species diversity generally increase downstream within the watersheds, particularly in close proximity to the Yukon River. Juvenile Chinook salmon (*Oncorhynchus tshawytscha*) have been captured in lower Britannia Creek, near its confluence with the Yukon River. Habitats in the Project area mainly support rearing, with limited opportunities for spawning, and overwintering restricted to larger, downstream watercourses with sufficient base flows and deep pools. According to the Yukon Placer Stream Classification Model, the entire Casino Creek watershed is classified as 'low' suitability habitat, whereas most middle to lower reaches of Britannia Creek have been classified as 'low-moderate' to 'moderate' suitability (Yukon Placer Secretariat, 2012). The lowermost reach of Britannia Creek has been designed as an 'area of special consideration', subject to the most restrictive conditions for placer mining in order to protect Chinook habitat near the mouth.

The remoteness and inaccessibility of the Casino and Dip Creek watersheds likely limits any recreational or Aboriginal fishing in the mine site area. However, watersheds in the Project area support important life history stages for subsistence, recreational and commercial species of Yukon River fish, including Arctic grayling and Chinook salmon. The Yukon river supports regionally significant commercial, Aboriginal and recreational fisheries, with an average of 14,000 and 16,000 Chinook and Coho salmon harvested per year, respectively, during the 1992 to 2002 period (Yukon River Panel, 2008). These salmon species are therefore at the forefront of people's mind in the local area.

3 EVALUATION OF IMPACTS TO FISHERIES

Catastrophic floods have been shown to seriously damage resident fish assemblages in mountain streams (George *et al.,* 2015). Although lotic fish communities have evolved with dynamic geomorphological conditions and are relatively resilient to extreme hydrologic events, severe floods may reduce fish density and biomass and influence community composition (Roghair *et al*., 2002; Carline & McCullough, 2003; Warren et al., 2009; Milner *et al*., 2012). Direct effects involve displacement-related mortality and destruction of incubating eggs, while indirect effects to habitat can affect carrying capacity or favor one species or guild over others (Elwood & Waters, 1969).

In the event of a Casino TMF sunny day failure (worse case scenario), the estimated peak discharge would be orders of magnitude greater than the natural flood with a 200-year return period for both Casino Creek (1000x greater), and Dip Creek (100x greater). In these watercourses, it is predicted that the debris flow/flood wave would strip the valley bottom and lower hillslopes within the complete inundated width of the valley. Some deposition of tailings, dam materials, and eroded valley materials are expected to occur along the margins of inundated area during the peak of the flood, and throughout the eroded area on the falling limb of the flood. This would mostly be comprised of sand-sized materials, while sizes finer than sand would be transported further downstream as suspended sediment.

In the event of such a failure, the greatest effects on fish would be realized in both Casino and Dip Creeks due to their proximity to the TMF. During the flood wave, fish could be flushed out of Casino and Dip Creeks, and possibly stranded if a rapid rise and fall of water surface elevation occurred. Fish habitat in the Casino and Dip Creeks generally support low abundances of resident fish, although fish abundance and habitat size do increase in Dip Creek downstream of the Casino Creek confluence. The existing productivity of the fish habitat in these Creeks is low, and there exists suitable habitat for all life histories of the fish community in neighbouring streams and watersheds. Therefore, although the removal of the habitat in the inundated area would permanently alter the availability of fish habitat within the inundation zone, this would be unlikely to influence the resident fish community on a regional scale. The initial loss of vegetation, erosion of streambeds and chronic high levels of turbidity would mean that streambed and riparian habitat quality may remain degraded for some time, if left unrestored.

Moving further downstream from Casino and Dip Creeks, the estimated peak discharge in the Sunny Day dam breach scenario is on the same order of magnitude as the natural Q200 floods in these watercourse (7x greater in Klottasin, and approximately equivalent in Donjek). The debris flood wave generated by the dam breach would still constitute extreme flood events in these rivers, but it is less certain if the complete valley width would be stripped of vegetation, soil, and alluvium. There would likely be localized effects on fish that are present, including changes in behaviour over the short-term (including avoidance behaviour). As these peak discharges are likely to be on the same order of magnitude as naturally occurring Q200 flood, natural channel and biological processes would commence after the flood wave had passed.

There is evidence of Chinook salmon rearing in the Klotassin River at the confluence with Dip Creek, and salmon do migrate through the White River and into the Donjek and Klotassin to spawn in the headwaters of the Klotassin River. Depending on the time of year of the hypothetical dam breach, there could be impacts on this species, particularly if the peak discharge and sediment plume coincided with adult spawning behaviour and egg incubation. Such a peak discharge could flush eggs from gravels, as well as disrupt migration routes and successful spawning. Impacts at these life cycle stages would potentially have the greatest impacts and likely reduce recruitment back into the population on the short to medium term. Impacts are unlikely to have long-lasting impacts on a regional scale, although these species do support commercial, recreational and Aboriginal fisheries in the area. Even short-term effects could affect the productivity of local fisheries, and the impacts from this are difficult to predict.

The estimated peak discharge in the sunny day dam breach scenario is on the same order of magnitude as the natural mean annual flood in the White River valley. The debris flood wave generated by the dam breach would be similar to floods that occur fairly regularly, so the erosion/transport/deposition of channel bed material would not be unusual. The White River is a glacially fed river that presumably transports a large suspended sediment load, so the suspended sediment generated from the dam breach might not be exceptional compared to natural load during freshet flows. Any fisheries impacts from the flood wave in this river would therefore be similar to those observed on a natural scale. Based on existing information, it is also unlikely that Chinook salmon spawning occurs in the mainstem portions of the White, Donjek or Kluane Rivers because of high levels of suspended solids and the changeable nature of river channels that provide unsuitable habitat. These rivers are important migratory routes though, and provide access to clear-water side channels, where spawning often occurs. The White sub-basin did not appear to be an important producer of Chinook salmon because of a lack of good spawning and rearing habitat (Milligan *et al*., 1985). This sub-basin has received low priority in terms of escapement surveys and fisheries research.

However, the fine tailings (sizes finer than sand) would be carried in suspension and are expected to remain in suspension downstream of the confluence with the Yukon River. This factor would likely result in the most significant impact to fisheries, particularly to salmon which are migratory species that rely on chemical cues for critical life processes, including spawning. The sediments and fine tailings would be carried in suspension downstream of the confluence with the Yukon River and may affect fish (salmon) migratory behaviour in these systems, and possibly smother gills that cause some mortalities over the short-term. The turbidity levels in the creeks would remain high for an extended period of time (during the thaw seasons) due to erosion of exposed surface materials, and the reworking of deposited tailings and dam materials. There exists potential for significant deterioration of critical fish habitat. There also exists potential for adverse effects on salmon habitat in the Yukon River, depending on the transportation and deposition of suspended solids.

Depending on the timing of the peak concentration, the suspended sediment concentrations could significantly affect salmon migration and spawning in the larger downstream rivers (White and Yukon). The peak concentration of turbidity may restrict access to tributaries and upstream spawning areas, which could be considered critical if on a spatial and temporal scale that would affect recruitment back into the populations. Based on an analysis of Chinook salmon migrating past the Eagle sonar site near the Yukon-Alaska border, the major regional stocks contributing to the run were the Teslin River (38%), mainstem Yukon River (19%), Carmacks area tributaries (13%), Pelly River (10%), Stewart River (6%), upper Yukon tributaries (6%), lower Yukon tributaries (4%), and White River (4%) (Beacham and Candy, 2012). There are therefore several sources of potential resilience in the Yukon River Chinook salmon, including multiple age classes in spawning runs, which reduces the risk of production failure across several cohorts. Complex and interacting environmental and biological factors contribute to variation in annual run sizes, and these can be difficult to predict.

George *et al*. (2015) recently investigated the effects of extreme floods on trout populations and fish communities in a Catskill Mountain river. Study findings indicated that within 10-11 months post-disturbance, that fish assemblages were not strongly impacted (density/biomass) and appeared highly resilient on a basinwide scale. Community composition did not differ significantly between years of the study or between the pre- and post-flood periods. These data provide evidence that resident fish species and their communities may be able to resist or recover rapidly from extreme flood events. Chance events play a large role in determining the effects and recovery from this major flood. George *et al.* (2015) determined that the seasonal timing of the flooding was significant: late summer floods may have been less damaging to stream fish communities than winter or spring floods because spawning activity is negligible and early life stages of many fish species are generally larger and less susceptible to

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displacement and mortality (George *et al.,* 2015). The timing of any failure of the Casino TMF dam will therefore be any important factor in the severity of any impacts to fisheries.

4 EVALUATION OF RESTORATION POTENTIAL

Historically, watershed restoration efforts following catastrophic disturbance (*e.g.* a large flood) have sought a return to preexisting conditions, and this approach was typically equated to achieving “recovery;” (Bradshaw 1993; Norton *et al*., 2009), or, in this hypothetical case, a return to pre-dam breach conditions. Over the past three decades, however, a new understanding of disturbance and recovery has emerged: that these processes are dynamic and site-specific, and re-attainment of pre-existing steady-state conditions may be unrealistic due to numerous complex and interacting factors (abiotic, biotic, and societal/anthropogenic) (Stanley *et al*., 2010).

After the initial flood wave, and stabilization of the new channels, fisheries recolonization could occur due to seasonal migrations from White, Klotassin and Donjek River systems, depending on the time of year. Benthic macro-invertebrate recolonization could occur from downstream drift and tributaries downstream of the dam. However, restoration of the channel and riparian systems in the inundation area would be prolonged and it is unlikely that aquatic habitat will be restored to ‘previous conditions’. Complete restoration at Casino and Dip Creeks would be impractical given the change to unstable, fine-textured bed material and lack of riparian vegetation. The post-event soft muddy conditions would make channel restoration difficult.

Norton *et al*., (2009) defined “recovery” as the probability of an environment to re-attain “valued attributes”, given its ecological capacity to regain lost functionality, its exposure to stressors, and the social context affecting efforts to improve its condition. An understanding of “restoration potential” in the aftermath of a hypothetical Casino TMF dam breach would assist resource managers in formulating restoration strategies for two primary reasons: 1) the large spatial scale and ecological connectivity of the affected area; and 2) long-term exposure of affected stream habitats to environmental stressors (e.g.: “press disturbances” such as chronically elevated levels of suspended and dissolved fine sediments (Lake, 2000).

Geomorphological processes, such as those occurring in a flood, can operate in sequence down gravitational flowpaths, forming a cascade of disturbance processes that can drastically alter stream and riparian ecosystems (Nakamura *et al*., 2000). In the aftermath of a catastrophic flood, the affected stream and its watershed can be viewed through time as a network containing a shifting mosaic of disturbance patches. In between patches of disturbance, the pockets of “biological refugia” that persist lend resilience by providing the organisms and energy sources for recolonizing degraded habitats, thereby promoting initial recovery of the disturbed stream network structure (Nakamura *et al*., 2000).

Restoration of riparian and stream systems in Casino Creek and Dip Creek following a Casino TMF breach would be problematic and prolonged, and could have direct ramifications on the recovery of fisheries and benthic macroinvertebrate populations, despite the ability of some local biota to recolonize disturbed habitats relatively quickly. In the Casino drainages, fisheries recolonization could occur due to seasonal migrations from mainstem White River, mainstem White River tributary habitats, and potentially from tributaries within the Klotassin and Donjek systems, depending on depending on time of year. Benthic macro-invertebrate recolonization could occur from habitats upstream of the Casino Dam (downstream drift), as well as from tributaries downstream of the dam (Klotassin and Donjek systems), and mainstem White River and its tributaries (aerial movements).

However, the initial massive loss of vegetation, erosion of streambeds and floodplains, and chronic high levels of turbidity would inhibit initial recolonization efforts since stream and riparian habitat quality are likely to remain heavily degraded for some time. The soft, muddy, partially frozen, and unstable terrain will create logistical hurdles for vehicle and heavy equipment access, as well as create poor conditions (low probability of success) for restoration techniques ranging from riparian tree planting to instream habitat enhancement.

This information indicates it would not likely be feasible to restore affected aquatic habitats to “previous conditions” in the event of a hypothetical Casino TMF breach (for both rainy day and sunny day scenarios). Restoration objectives for aquatic habitats would need to be based on realistic expectations of recovery.

5 CONCLUSION

Based on the known fisheries in the Project area, as well as the likely scenarios from the hypothetical dam breach, the impact on fisheries could range between ‘High’ and ‘Very High’ according to the CDA Guidelines. There are no known endangered fish species that would be displaced from the dam failure. Direct mortality of fish in the initial flood wave would likely be limited to the immediate downstream reaches of Casino and Dip Creek. Both these creeks have existing low fish productivity and the fish species are present in neighbouring streams and watersheds. This could facilitate any recolonization after the event.

The effects on Casino and Dip Creek however, would make restoration efforts impractical and there would be a significant loss of habitat in this area. The effects further downstream would likely be less severe on a habitat scale as the magnitude of the event becomes more similar with natural flood events. The deposition of tailings and sediment into the White and Yukon River does have the potential to cause a significant deterioration of critical fish habitat, in particular for salmon species. These species are an important component of Yukon River fisheries and depending on the timing of turbidity, may restrict fish access to tributaries and upstream spawning areas. This could be considered critical if on a spatial and temporal scale that would affect recruitment back into the populations.

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MEMORANDUM

Date:	October 15, 2015
To:	Casino Mining Corporation
From:	Hemmera
Re:	Tailings Management Facility Dam Breach Inundation Study IR (R2-30) - Socio-economic Assessment

1.0 PURPOSE OF SOCIO-ECONOMIC ASSESSMENT

In July 2015 Hemmera was contracted to undertake a socio-economic assessment of the Tailings Management Facility (TMF) Dam Breach Inundation Study, prepared by Knight Piésold, for Casino Mining Corporation's Casino Mine. As per the safety guidelines issued by Canadian Dam Association (CDA, 2007), Casino's TMF Dam Breach Inundation Study, along with assessments for terrestrial, aquatic and socio-economics are required to evaluate potential downstream consequences resulting from hypothetical dam failures.

The socio-economic assessment describes the consequences in terms of incremental impacts during two hypothetical breach scenarios, a 'Sunny Day' and 'Flood Induced', within the TMF Dam Breach Inundation Study's modelled inundation zone. The incremental impact is the inundation that is over and above the natural mean annual discharge or 1:200 year flood for the 'Sunny Day' and 'Flood induced' scenarios, respectively. This assessment describes the incremental consequences of a dam breach in three categories: loss of life; loss of environmental and cultural values; and infrastructure and economic losses. In accordance with the CDA Guidelines (2007; revised 2013), the dam breach evaluation addresses two initial hydrologic conditions:

- Sunny day failure – a sudden dam failure that occurs during normal operations, which may be caused by internal erosion, piping, earthquakes, mis-operation leading to overtopping, or another event.
- Flood induced or rainy day failure – a dam failure resulting from a natural flood of a magnitude that is greater than what the dam can safely pass.

1.1 METHODOLOGY OF SOCIO-ECONOMIC ASSESSMENT

Hemmera has conducted secondary research to complete the socio-economic assessment. These secondary information sources include:

- Tailings Management Facility Dam Breach Inundation Study prepared by Knight Piésold
- Existing dam inundation studies for mining projects
- Yukon Geological Survey information for First Nation lands and recreation trails
- Casino Mining Corporation's Project Proposal Submitted to Yukon Environmental and Socio-economic Assessment Board (YESAB) – sections include Project Description and Land Use

Due to the scope and limited secondary information sources available for Hemmera's socio-economic assessment it does not include an assessment of the impacts from sediment and tailings waste or an assessment of impacts on community wellbeing as a result of a TMF dam breach or flood.

2.0 LIFE SAFETY

Many factors can affect the severity of the Loss of Life consequences to the 'Population at Risk' including, depth of flow, velocity of flow, topography and advance warning time throughout the inundated area. The 'Population at Risk' is defined by the Canadian Dam Association (2007) (see **Table 1** and **Section 2.1.1** below).

As per **Section 5.0** and illustrated in Figures 5.3 and 5.6 of the TMF Dam Breach Inundation Study (Knight Piésold, 2015) the modelled inundation area includes one recreation cabin, a proposed air strip access road, bridge crossing at Dip Creek and air strip located downstream of the TMF. First Nation Category B lands and a heritage trail are not referenced in the TMF Dam Breach Study; however they fall within the inundation zone and are included in this assessment. The inundation area does not include the camp or any other related site infrastructure. Other First Nations land is located downstream of the modelled inundation zone; however these lands were not assessed. **Table 2** details the locations within the inundation area where there may be 'Population at Risk'.

Studies related to recreation and tourism use and First Nation traditional and current use have not been conducted in relation to the modelled inundation area; however aside from the Tetlin to Dawson Heritage Route no other trail thoroughfares were identified in the secondary source materials reviewed.

Table 1 Dam Classification (Reproduced from Table 2-1 in CDA (2007))

Dam Class	Population at Risk[1]	Incremental losses		
		Loss of Life[2]	Environmental and Cultural Values	Infrastructure and Economics
Low	None	0	Minimal short-term loss No long-term loss	Low economic losses; area contains limited infrastructure or services
Significant	Temporary only	Unspecified	No significant loss or deterioration of fish or wildlife habitat Loss of marginal habitat only Restoration or compensation in kind highly possible	Losses to recreational facilities, seasonal workplaces, and infrequently used transportation routes
High	Permanent	10 or fewer	Significant loss or deterioration of *important* fish or wildlife habitat Restoration or compensation in kind highly possible	High economic losses affecting infrastructure, public transportation, and commercial facilities

Dam Class	Population at Risk[1]	Incremental losses		
		Loss of Life[2]	Environmental and Cultural Values	Infrastructure and Economics
Very high	Permanent	100 or fewer	Significant loss or deterioration of *critical* fish or wildlife habitat Restoration or compensation in kind impossible	Very high economic losses affecting important infrastructure or services (e.g., highway, industrial facility, storage facilities for dangerous substances)
Extreme	Permanent	More than 100	Major loss of *critical* fish or wildlife habitat Restoration or compensation in kind impossible	Extreme losses affecting critical infrastructure or services (e.g., hospital, major industrial complex, major storage facilities for dangerous substances)

Note: [1]Definitions for population at risk:
None—There is no identifiable population at risk, so there is no possibility of loss of life other than through unforeseeable misadventure.
Temporary—People are only temporarily in the dam-breach inundation zone (e.g., seasonal cottage use, passing through on transportation routes, participating in recreational activities).
Permanent—The population at risk is ordinarily located in the dam-breach inundation zone (e.g., as permanent residents); three consequence classes (high, very high, extreme) are proposed to allow for more detailed estimates of potential loss of life (to assist in decision-making if the appropriate analysis is carried out).
[2] Implications for loss of life:
Unspecified – The appropriate level of safety required at a dam where people are temporarily at risk depends on the number of people, the exposure time, the nature of their activity, and other conditions. A higher class could be appropriate, depending on the requirements. However, the design flood requirement, for example, might not be higher if the temporary population is not likely to be present during the flood season.

2.1.1 Population at Risk

The ‘Population at Risk’ can be defined as the population at any given time that is downstream of the TMF within the inundation zone during the operational and active closure periods. The group includes the in-transit workforce and site visitors (together called site personnel) who use the air strip access road and bridge, along with First Nation members occupying Category B lands for traditional or current use purposes, and recreation users including occupants at the cabin above Dip Creek and users of the Tetlin to Dawson Heritage Trail and White, Donjek and Klotassin Rivers.

During the operational period, based on the ‘Population at Risk’ categories defined in **Table 1** (i.e. None, Temporary, or Permanent), the ‘Temporary’ category is considered appropriate based on the personnel using the air strip access road and bridge as a transportation route and First Nation members and recreation users occupying lands within the modelled inundation zone on a seasonal basis. However this is based on assumptions that cannot be verified without traditional land use studies and other primary data collection methods.

During the post-closure period, intermittent presence within the inundation area will occur from mine personnel and may occur from First Nation members and recreation users. There is anticipated to be no permanent workforce based on site during post-closure. For the post-closure period, the 'Temporary' category for 'Population at Risk' is appropriate.

2.1.2 Loss of Life

During the operational period, the expected 'Loss of Life' in the event of a catastrophic dam failure is related to a subset of site personnel (i.e. work force and site visitors) travelling to/from the airstrip along the access road. The subset also includes First Nation members using their surrounding lands seasonally and recreation users on the Tetlin to Dawson Heritage Trail and White, Donjek and Klotassin Rivers seasonally, within the modelled inundation zone. As noted in **Section 5.0** of the TMF Dam Breach Inundation Study, all other mine infrastructure will be located outside the maximum inundation zone and workers in the active mine zone will not be at risk during a TMF dam breach or flood.

Site Personnel

Based on the Casino Project Proposal for Executive Committee Review submitted to Yukon Environmental and Socio-economic Assessment Board, Casino has estimated that the mine will have 1000 staff employed during construction and 600 employed during operations (Casino Mining Corporation, 2014). The construction schedule will likely consist of staff working 4 weeks on with 2 weeks off or 2 weeks on and 2 weeks off. The 2/2 shift is anticipated to be the schedule during operations. The staff rotation for operations is not yet determined, however it is assumed there will be multiple flights during travel days.

For logistical purposes Hemmera has assumed that there will be trucks hauling cargo and either one large full-sized bus (i.e. school bus with maximum 72 passengers) travelling in one direction or multiple passenger vans (i.e. maximum 12 passengers each van) in either direction. The passengers will be temporarily in transit on the air strip access road or bridge crossing during travel days during a 'Sunny Day' or 'Flood Induced' scenario. In terms of risk if a dam breach or TMF flood were to occur, one large transport bus would a have higher consequence yet lower likelihood of being in the inundation zone compared to multiple vans that would have a lower consequence yet higher likelihood of being within the inundation zone.

First Nations

Within or adjacent to the modelled inundation zone White River First Nation has six R blocks as lands set aside (see **Table 2** and **Figure 2** and **Figure 3**) and Tr'ondek Hwech'in hold one Category B settlement parcel above the White River (see **Table 2** and **Figure 4**). The usage and occupancy related to First Nation lands is not known at this time, however cabins may be located in the general area and may be used seasonally. As a result of the limited data, it is unknown what the potential for loss of life on those land parcels may be.

Tr'ondek Hwech'in hold Category A and B lands downstream of the confluence of the White River on the Yukon River; however these lands are outside of the modelled inundation zone and have not been assessed for socio-economic impacts.

Recreation Users

There is one cabin located within the modelled inundation zone and it is located above Dip Creek. The mine site will be closed to public access and recreation users will not be able to access the airstrip access road and bridge.

The Tetlin to Dawson Heritage Trail runs along the northern side of the White River and forks to Alaska to the west and Dawson City to the north. Portions of the trail are located within the modelled inundation zone; however most of the route is outside of the inundation zone (see **Table 2** and **Figure 1**). Usage of this area has been assumed as seasonal and temporary; however the total usage numbers have not been gathered through primary data collection means.

Based on the limited sources available it is not known if there are recreation users using other areas of the White River or the Donjek and Klotassin Rivers within the modelled inundation zone. If there is usage it can be assumed to be temporary or transient use of these rivers by fishers, campers and other users.

Recreation users of the Tetlin to Dawson Trail and White River, along with potential users on the Donjek and Klotassin Rivers are anticipated to be seasonal and recreating on a temporary basis. A scenario during warm weather seasons may increase the number of travellers within the inundation zone.

As noted above, studies related to First Nations, recreation and tourism use have not been conducted in relation to the inundation area therefore impacts cannot be fully assessed.

Airstrip Access Road and Bridge Crossing at Dip Creek

A single lane 14km air strip access road has been proposed to originate from the southwest corner of the TMF and continue south along the northwest side of Dip Creek. A bridge crossing is proposed to allow access to the south side of Dip Creek where the road will continue uphill to the air strip. The air strip is above the modelled inundation area and is 11.3 km downstream of the potential TMF breach location. If a breach were to occur in either scenario most of the road located along the lower elevation of Casino and Dip Creeks and the entire bridge crossing are expected to be washed out.

Cabin above Casino Creek

The cabin is located 3.4km downstream of the proposed TMF and is built above the Casino Creek channel on the northwest hill slope and ~100m above the modelled inundation area; therefore no inundation is anticipated to occur.

No other known existing or proposed settlements or infrastructure are predicted to incur damage during a breach.

The severity of life safety consequences are affected by many factors such as the depth of inundation, velocity of flow, topography and advance warning time within the inundated area. **Table 2** describes the characteristics for a 'Sunny Day' and 'Flood Induced' breach and the corresponding impacts to downstream infrastructure and First Nations land. The incremental impact is the inundation that is over and above the natural mean annual discharge or 1:200 year flood for the 'Sunny Day' and 'Flood induced' scenarios, respectively.

Based on the 'Loss of Life' categories defined in **Table 2** (i.e. Zero, Unspecified, 10 or fewer, 100 or fewer, More than 100) and the mitigation measures proposed by Hemmera, the '100 or fewer' category and 'Very High' classification is considered appropriate. Casino's population is 'temporary' and that usually carries a 'Significant' dam classification; however a 'Very High' classification has been given based on:

- The high volume and regular frequency of non-permanent personnel travelling throughout the year on a weekly/semi-weekly basis on the air strip access road and bridge crossing within the inundation zone.
- The number of First Nation land parcels within the inundation zone and the lack of available data to assess land parcel usage.
- The lack of information on the potential of recreation users that may be present in the inundation zone on a seasonal and temporary basis.
- All major mine activities, including the air strip, are located outside of the inundation zone.

Hemmera proposes the following mitigation measures to reduce the potential for Loss of Life within the inundation zone:

- Casino to limit the amount of transport and cargo vehicles on the air strip access road to no more than 80 passengers on the road in either direction at one time.
- Casino to setup a warning system at frequently used locations potentially affected by a dam breach or TMF flood. These sites include transportation corridors and locations such as the mine site complex, cabin, air strip road, bridge, air strip and recreation and First Nation lands. The warning will help mitigate the total 'Population at Risk' present during a breach or flood conditions.
- Casino to construct elevated road pull-off areas along the north and south sides of the air strip access road that will be safely above the maximum anticipated depth of flow in the inundated areas.

Table 2 List of Structures and First Nations Land within the Modelled Inundation Zone Potentially Impacted by TMF Dam Breach

List of Infrastructure and First Nations Land	Distance Downstream, Corresponding Study Area[1] and Assessment Figure	Location in Relation to Modelled Inundation Zone	Flood Peak Arrival Times	Incremental Change in Maximum Flow Depth and Change in Maximum Cross Sectional Discharge (m^3/s)	Incremental Impacts of Dam Breach Within Modelled Inundation Zone
Infrastructure					
Airstrip Access Road	1km downstream Study CS #1	Runs along westside of Casino Creek, crosses Dip Creek, continues downstream on south side of Dip Creek	'Sunny Day': .7hr 'Flood Induced': 1hr	'Sunny Day': 15m and 22,400 m^3/s 'Flood Induced': 19m and 40,270 m^3/s	Sections of the road along Casino and Dip Creek would be inundated and washed out in both scenarios. Elevated pullouts, traffic restrictions and advanced warning system will mitigate impacts.
Cabin	3.4km downstream Study CS #2	~100m above Casino Creek downstream of TMF	'Sunny Day': .8hr 'Flood Induced': 1hr	'Sunny Day': 15m and 19,498 m^3/s 'Flood Induced': 20m and 47,890 m^3/s	Above inundation zone and not likely impacted. Elevated pullouts, traffic restrictions and advanced warning system will mitigate impacts to occupants.
Bridge	3.4km downstream Study CS #2	Crosses Dip Creek	'Sunny Day': .8hr 'Flood Induced': 1hr	'Sunny Day': 15m and 19,498 m^3/s 'Flood Induced': 20m and 47,890 m^3/s	Inundation will occur in both scenarios. Elevated pullouts, traffic restrictions and advanced warning system will mitigate impacts.
Airstrip	11.3 km downstream Study CS #5	Above Dip Creek	'Sunny Day': 1.5hr 'Flood Induced': 1.5hr	'Sunny Day': 9m and 11,697 m^3/s 'Flood Induced': 11m and 33,360 m^3/s	Above inundation zone and not likely impacted. Muster locations are accessible, traffic restrictions and advanced warning system will mitigate impacts.
Tetlin to Dawson Heritage Trail	186 km downstream Study CS #12 **Figure 1**below	Crosses the Yukon River downstream of the White River confluence and continues a route westward along the north side of the White River within and outside of the inundation zone	'Sunny Day': 36 hr 'Flood Induced': 24hr	'Sunny Day': 1m and 1,402 m^3/s 'Flood Induced': 1m and 5,800 m^3/s	Inundation will occur at lower elevations along the trail in both scenarios and greater during warm weather seasons. Trail users can access many areas outside of the inundation zone.
First Nations Land					
White River First Nation WRFN S-144B (Poly ID 481)	32.7km downstream Study CS# 6 **Figure 2** below	Confluence of Klotassin and Donjek River	'Sunny Day': 4.7hr 'Flood Induced': 3.5hr	'Sunny Day': 5m and 5,295 m^3/s 'Flood Induced': 5m and 18,920 m^3/s	Inundation will occur in both scenarios and greater on a 'Sunny Day'.
White River First Nation WRFN S-145B (Poly ID 568)	32.7km downstream Study CS# 6 **Figure 2** below	Confluence of Klotassin and Donjek River	'Sunny Day': 4.7hr 'Flood Induced': 3.5hr	'Sunny Day': 5m and 5,295 m^3/s 'Flood Induced': 5m and 18,920 m^3/s	Inundation will occur in both scenarios and greater on a 'Sunny Day'.
White River First Nation WRFN S-175B (Poly ID 253)	77.2km downstream CS# 10 **Figure 3** below	Along Donjek River upstream of confluence with White River	'Sunny Day': 14 hr 'Flood Induced': 10hr	'Sunny Day': 2m and 2,403 m^3/s 'Flood Induced': 2m and 9,040 m^3/s	Inundation in both scenarios.
White River First Nation WRFN S-143B (Poly ID 229)	77.2km downstream CS# 10 **Figure 3** below	At confluence of White and Donjek River	'Sunny Day': 14 hr 'Flood Induced': 10hr	'Sunny Day': 2m and 2,403 m^3/s 'Flood Induced': 2m and 9,040 m^3/s	Inundation will occur in both scenarios and greater on a 'Sunny Day'.
White River First Nation WRFN S-153B (Poly ID 165)	77.2km downstream CS# 10 **Figure 3** below	Along the shore of White River (downstream of confluence with Donjek River)	'Sunny Day': 14 hr 'Flood Induced': 10hr	'Sunny Day': 2m and 2,403 m^3/s 'Flood Induced': 2m and 9,040 m^3/s	Inundation will occur in both scenarios and greater on a 'Sunny Day'.
White River First Nation WRFN S-188B (Poly ID 127)	77.2km downstream CS# 10 **Figure 3** below	~350m above White River and inundation zone	'Sunny Day': 14 hr 'Flood Induced': 10hr	'Sunny Day': 2m and 2,403 m^3/s 'Flood Induced': 2m and 9,040 m^3/s	Above inundation zone and not likely impacted.
Tr'ondëk Hwëch'in TH S-17B1 (Survey ID 723388) (surface rights)	77.2km downstream CS# 10 **Figure 4** below	~1,600m above White River and inundation zone	'Sunny Day': 14 hr 'Flood Induced': 10hr	'Sunny Day': 2m and 2,403 m^3/s 'Flood Induced': 2m and 9,040 m^3/s	Above inundation zone and not likely impacted.

[1] Closest Cross Section Number from Table 5.1 and 5.2 of the Tailings Management Facility Dam Breach Inundation Study (Knight Piésold, 2015)

3.0 CULTURAL LOSSES

The Yukon Dam Guide (2012) requires consideration of any cultural losses, which includes “damage to irreplaceable historic and cultural features”. Under CDA (2007) damage to irreplaceable historic and cultural features that cannot be evaluated in economic terms, should be considered on a site-specific basis.

The inundation zone is located within the traditional territory of the Selkirk First Nation, the Tr’ondëk Hwëch’in, Kluane First Nation and White River First Nation. As mentioned in the ‘Loss of Life’ section above, White River First Nation (see **Figure 2** and **Figure 3**) and Tr’ondëk Hwëch’in (see **Figure 4**) have lands within the modelled inundation zone. Any losses to wildlife or aquatic resources may impact First Nations hunting, trapping, and fisheries.

Heritage trails are an important part of the culture in Yukon and provide opportunities for both Yukoners and visitors to recreate, explore the wilderness and learn about Yukon’s history (Yukon Government, 2015a).The Dawson to Tetlin Heritage Route is located within the Casino modelled inundation zone and therefore may hold cultural value for trail users (see **Figure 1**). The usage and the cultural connection to the section of the Dawson to Tetlin Heritage trail within the inundation zone are not known and as such were not part of this assessment.

4.0 ECONOMIC IMPACTS

The *Dam Safety Guidelines* (CDA 2013), “consider the economic losses to third parties beyond the limits of the mining lease on which the mining dam is situated”; therefore economic loses to the company are not included.

Yukon Dam Guide (2012) requires an assessment on the impacts to tenured land including First Nations settlement land. White River First Nation has six R blocks as lands set aside along the Donjek and White Rivers within or near the inundation zone and Tr’ondëk Hwëch’in has one Category B settlement parcel along the White River. Other areas of use by First Nations within the modelled inundation zone are not known. Selkirk First Nation’s settlement lands are not located with inundation zone. Other First Nations land is located downstream of the modelled inundation zone; however these lands were not assessed.

Specific information related to the value of land use activities such as hunting, trapping and fishing along with the current or future value of surface resources and activities is not known. **Table 2** above details the First Nation lands within the inundation zone and whether inundation would occur.

Tourism and recreation pursuits are accessible downstream of the TMF. The Tetlin to Dawson Heritage Trail runs along the north side of the White River and parts of it lie in the inundation zone and parts of it are adjacent to the inundation zone (see **Table 2**). Data is not available to asses where and how much fishing takes place along the White, Donjek and Klotassin Rivers where a dam breach or TMF flood would potentially impact. Outside of the modelled inundation area tourism and recreation companies including Canadian Wilderness Travel Ltd., as described in Casino's Environmental Assessment Project Proposal, operate along the Yukon River (Casino Mining Corporation, 2014).

Information regarding tourism and recreation businesses and spending within the modelled inundation zone was not available and is not part of the socio-economic assessment.

No other permanent settlements, public infrastructure or services and commercial facilities are within the inundation zone based on the data assessed.

Economic information for hunting, harvesting, trapping, recreational and tourism land uses that may be taking place within the modelled inundation zone is not publically available. Without identifying and quantifying the estimated dollar value associated to land use including the restoration potential and costs to First Nations land, an assessment on economic impacts cannot be completed.

5.0 REFERENCES

Casino Mining Corporation. 2014. Proposal for Executive Committee Review, Pursuant to the Yukon Environmental and Socio-Economic Assessment Act.

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

Knight Peisold. 2015. TMF Dam Breach Inundation Study. VA101-325-20-2, Rev 0. September 21, 2015.

The Yukon Dam Guide. 2012. Dam Guide Design Expectations and Required Information. Available at: http://www.env.gov.yk.ca/publications-maps/documents/env_yk_dam_guide_2012.pdf. Accessed August 3, 2015.

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Yukon Government. 2015b. Yukon Geomatics Heritage and First Nation Heritage Routes. Displayed in Google Earth: *63°25'52.95"N, 139°51'18.33"W, elevation 2586ft*. Available at: ftp://ftp.geomaticsyukon.ca/GeoYukon/Culture_and_Heritage/First_Nation_Heritage_Routes/. Accessed August 18, 2015.

Yukon Government. 2015c. Yukon Geomatics First Nation Land. Displayed in Google Earth: *62°34'01.16"N, 139°30'13.23"W, elevation 517M*. Available at: ftp://ftp.geomaticsyukon.ca/GeoYukon/First_Nations. Accessed August 18, 2015.

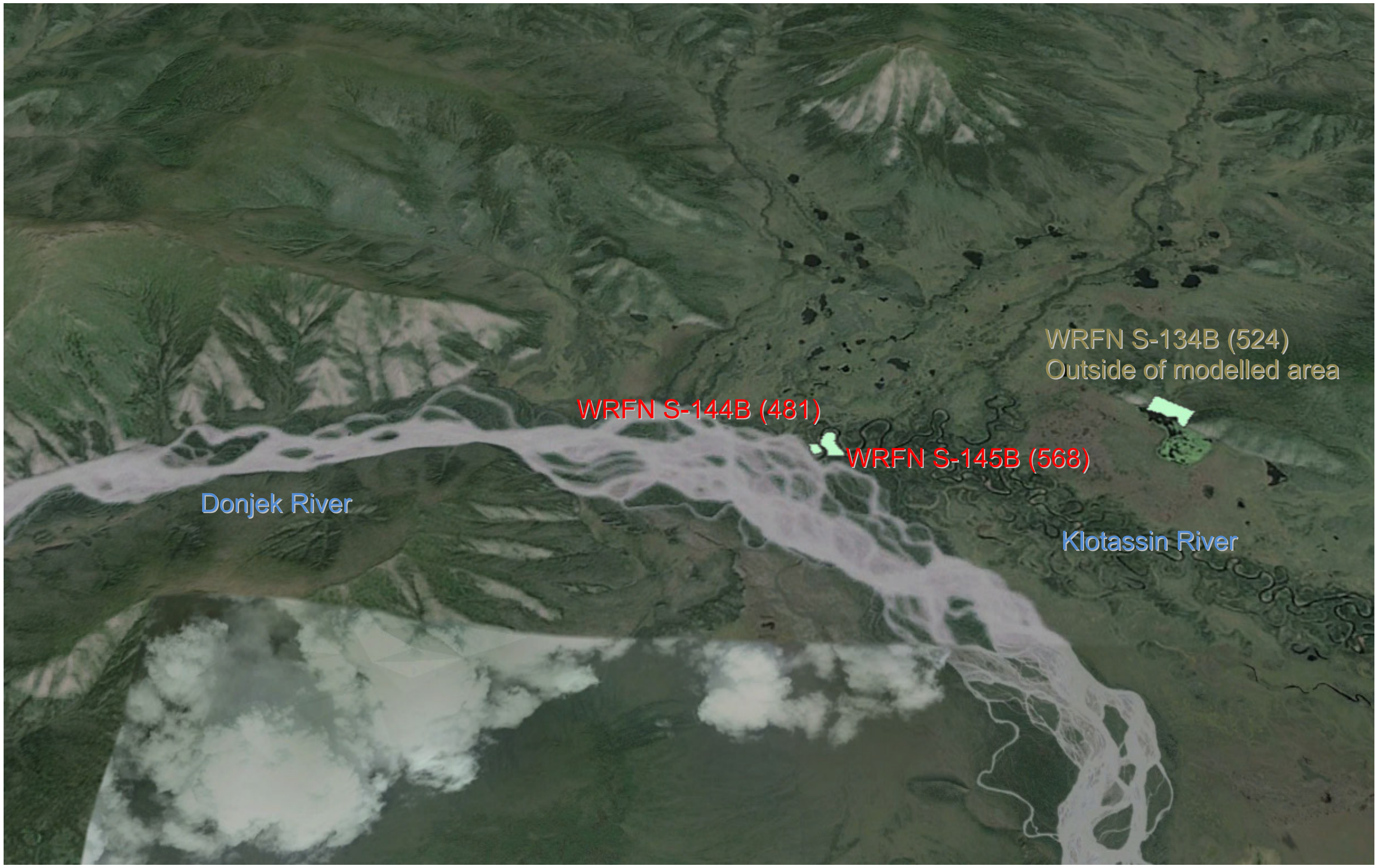
Yukon Government. 2015d. Yukon Geomatics First Nation Land. Displayed in Google Earth: *62°34'56.11"N, 139°54'51.18"W, elevation 700M*. Available at: ftp://ftp.geomaticsyukon.ca/GeoYukon/First_Nations. Accessed August 18, 2015.

Yukon Government. 2015e. Yukon Geomatics First Nation Land. Displayed in Google Earth: *63°08'47.20"N, 140°05'16.12"W, elevation 518M*. Available at: ftp://ftp.geomaticsyukon.ca/GeoYukon/First_Nations. Accessed August 18, 2015.

Figure 1 Tetlin to Dawson Heritage Trail

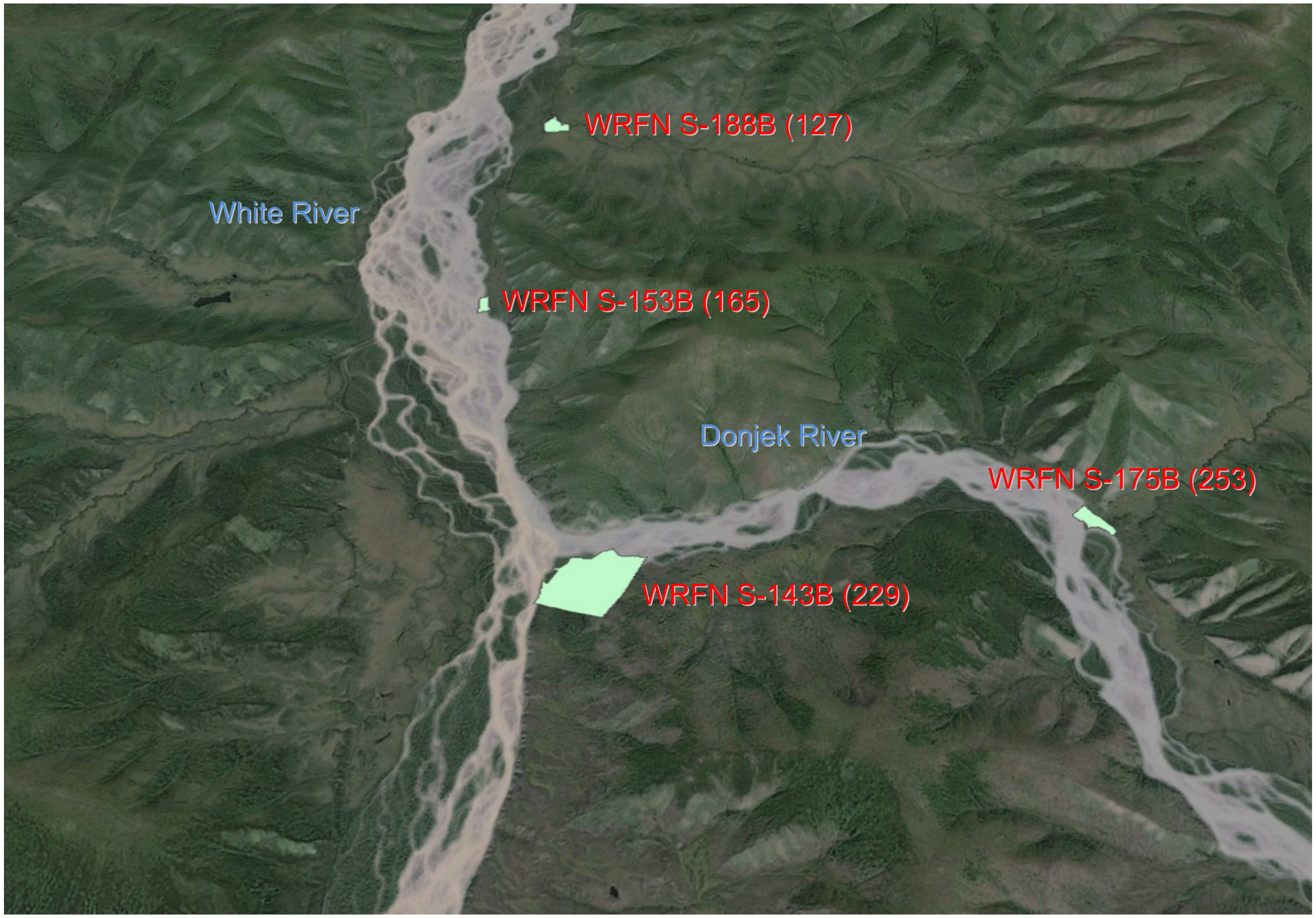
Data sourced: Yukon Government, 2015b: ftp://ftp.geomaticsyukon.ca/GeoYukon/Culture_and_Heritage/First_Nation_Heritage_Routes/. Displayed in Google Earth.

Figure 2 **White River First Nation Land: WRFN S-144B (481) and WRFN S-145B (568)**



Data sourced: Yukon Government, 2015c: ftp://ftp.geomaticsyukon.ca/GeoYukon/First_Nations. Displayed in Google Earth.

Figure 3 White River First Nation Land: WRFN S-175B (253), WRFN S-143B (229), WRFN S-153B (165), WRFN S-188B (127)



Data sourced: Yukon Government, 2015d: ftp://ftp.geomaticsyukon.ca/GeoYukon/First_Nations. Displayed in Google Earth.

Figure 4 Tr'ondëk Hwëch'in Land: TH S-17B1 (Survey ID 723388)

Data sourced: Yukon Government, 2015e: ftp://ftp.geomaticsyukon.ca/GeoYukon/First_Nations. Displayed in Google Earth.

APPENDIX B.4D: Tailings Management Operation, Maintenance and Surveillance Manual

VOLUME B.I: PROJECT INTRODUCTION & OVERVIEW

- **B.1** Introduction
  - **B.IA** Concordance Table to the Executive Committee's Request for Supplementary Information
- **B.2** First Nations and Community Consultation
- **B.4** Project Description
  - **B.4A** Guide to the Management of the Casino Tailings Facility
  - **B.4B** Mine Waste Management Alternatives Assessment
  - **B.4C** Tailings Management Facility Dam Breach Inundation Study
  - **B.4D** Tailings Management Operation, Maintenance and Surveillance Manual
  - **B.4E** 2014 and 2015 Geotechnical Testing of Leach Ore
  - **B.4F** Ore Characterization
  - **B.4G** Review and Updates to the Conceptual Wetland Water Treatment Design

CASINO PROJECT

TAILINGS MANAGEMENT FACILITY

OPERATION, MAINTENANCE AND SURVEILLANCE MANUAL

PRELIMINARY DRAFT

Prepared by:

Casino Mining Corporation

December 2015

Foreword

The Casino Project, Tailings Management Facility Operation, Maintenance and Surveillance Manual for Tailings (OM&S Manual) will be developed as a companion guide to the Guide to the Management of the Casino Tailings Facility (TMF Guide). Both guides are based upon the Mining Association of Canada's (MAC) guidelines for the design & management of tailings facilities. CMC wishes to acknowledge and thank the MAC for use of their guides and their support in our development of project specific guides, consistent with the MAC guidelines.

This document is intended to provide guidance to those responsible for the management and operation of the Casino tailings management facility (TMF) to enable them to meet the objectives and commitments articulated in the Guide to the Management of the Casino Tailings Facility.

The guide focus is a site-specific operation, maintenance and surveillance (OM&S) manual and an integral component of an overall tailings management system. The document is designed to assist operations to comply with government regulation and corporate policy, demonstrate voluntary self-regulation and due diligence, practise continual improvement, and protect employees, the environment and the public.

Casino Mining Corporation

Preface

The OM&S Manual is being developed to provide a comprehensive and detailed guidance for the management, operation, and documentation of the Casino TMF from the initial construction, through on-going construction during operations, and ultimately the close-out of the facility. The OM&S Manual is intended to assist the management and operators in the understanding of the design intent, safety and environmental requirements, and regulatory obligations and commitments. Guidance is also provided on how to document operations and construction activities in detail to demonstrate full compliance with the design requirements and operating license conditions.

The OM&S Manual, together with the TMF Guide details how inevitable changes to the design or operating procedures are to be addressed to ensure the design integrity is maintained. The OM&S Manual is a revision controlled document. Any and all changes must be approved by the individual responsible for revision control and distribution of this document. The OM&S Manual, as presented here, represents a preliminary draft intended to illustrate the scope and content of the fully developed document. Further development of this document will take place during the detailed engineering phase of the Casino Project when the necessary design documents and other material necessary for the development of the manual becomes available.

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List of Figures

1 - INTRODUCTION

Tailings and water management facilities are integral components of mine and mill operations. They must be managed for the long term to ensure that safe and environmentally responsible stewardship is achieved. Toward this end, in 1998, The Mining Association of Canada (MAC) published *A Guide to the Management of Tailings Facilities* (MAC, 2011a), which recommended the implementation of a tailings management framework (Figure 1-1) to integrate environmental and safety considerations into each stage of the life cycle of a tailings facility, from initial site selection and design, through construction and operation, to eventual decommissioning and closure. Actions should be planned within the context of policies and commitments, implemented in accordance with plans, checked and corrected, and subjected to management review.

The document, *Developing an Operation, Maintenance and Surveillance Manual for Tailings and Water Management Facilities* (MAC, 2011b) has been compiled to provide additional guidance for preparing manuals that outline procedures for the safe operation, maintenance and surveillance (OM&S) of tailings and water management facilities.

The OM&S Manual will provide the planning context for its application through the facility's life cycle (Figure 1-2). It will be in place upon commissioning, and maintained thereafter until closure, providing a clear, documented framework for actions. It will also provide a sound basis for measuring performance and demonstrating due diligence.

The level of detail of an OM&S Manual will reflect site requirements. It will be kept current and revised periodically with a view to continual improvement. Need for revision may be triggered, for example, by changes in dam classification, operational performance, personnel or organizational structure, regulatory or social considerations, or following changes in life cycle and/or design philosophy.

Figure 1-1 Elements of the Tailings Management Framework

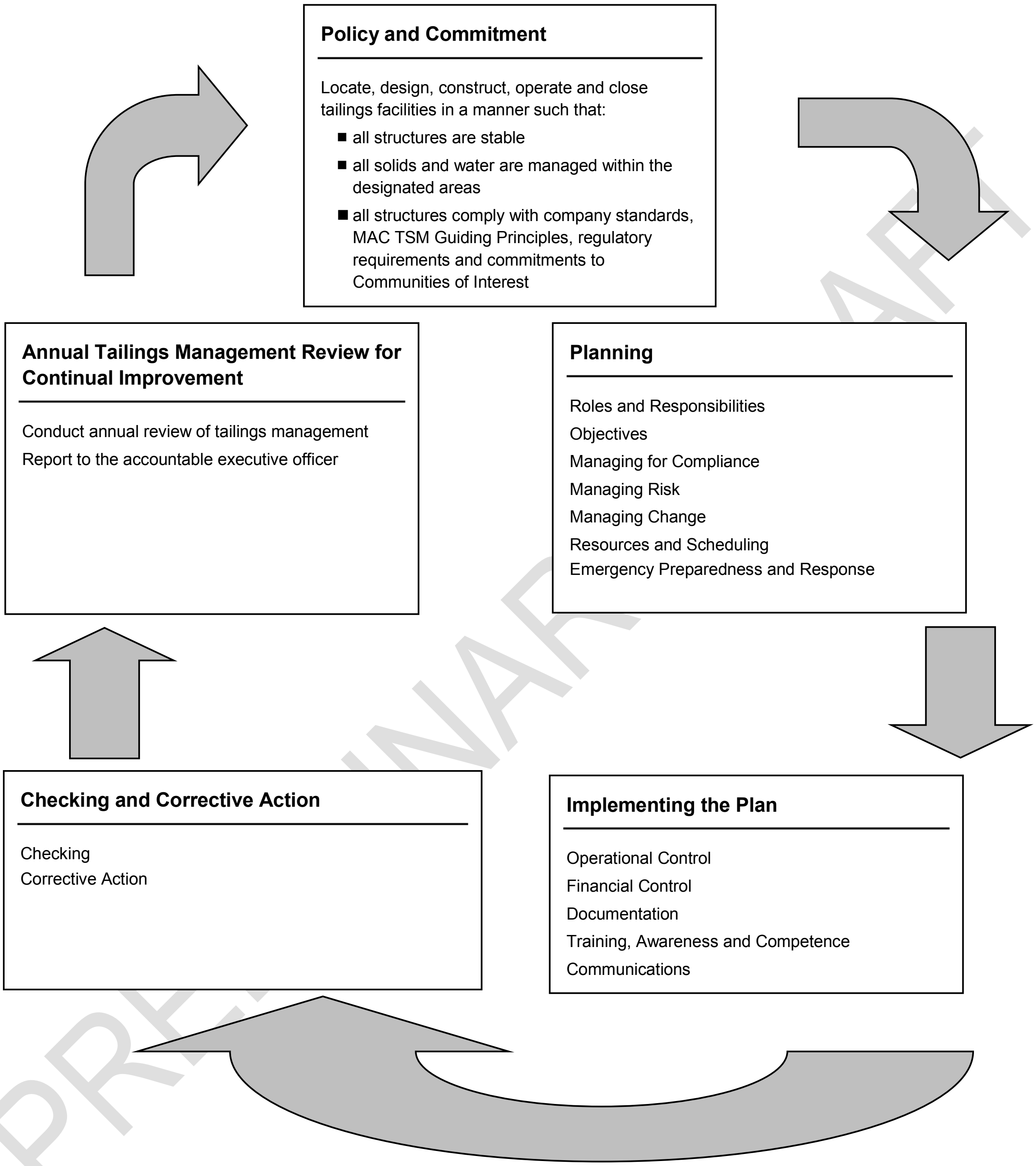
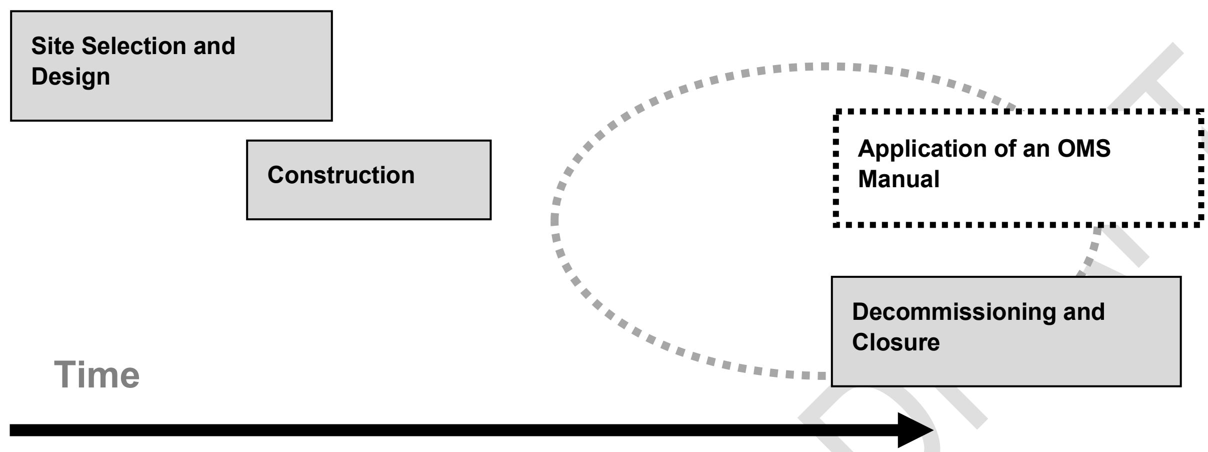


Figure 1-2 Application of an OM&S Manual through the life cycle of a tailings or water management facility



This document serves as a guide to the preparation of an OM&S Manual as a component of an overall site management framework. It recommends rationale, organization and contents for an OM&S Manual, and describes procedures that should be addressed. Tailings and water management facility owners are encouraged to use this guide to prepare their own site-specific OM&S Manual.

This guide does not replace professional expertise. Professional advice should be obtained in order to be sure that site and operational requirements are addressed and all regulatory requirements are met.

Regulatory requirements establish minimum standards for safety and environmental performance of tailings and water management facilities. The OM&S Manual will include reference to all relevant regulatory requirements and, to facilitate due diligence, delineate the performance measures that will demonstrate these requirements are being met.

The OM&S Manual will incorporate the principles outlined in *A Guide to the Management of Tailings Facilities* (MAC, 2011a), which require tailings facilities to be located, designed, constructed, operated and closed in a manner such that:

- all structures are stable;
- all solids and water are managed within the designated areas intended in the design; and
- all structures are in compliance with company standards, the MAC Environmental Policy, regulatory requirements and commitments to stakeholders.

2 - PREPARING AN OM&S MANUAL

The preparation of the OM&S Manual requires:

- setting up a team to develop the OM&S Manual;
- establishing objectives, a realistic budget and schedule to develop the manual;
- compiling information from many sources, within the company and beyond;
- establishing procedures for implementing, controlling and updating the OM&S Manual; and
- assuring that operational, engineering, corporate and regulatory issues are addressed.

These requirements are detailed further below.

2.1. OM&S MANUAL DEVELOPMENT TEAM

One individual should be assigned primary responsibility for the preparation of the OM&S Manual. This person should be actively assisted by a broader team with representation from the facility designers, site operations personnel, management and others having a direct interest in the performance and management of the facility.

2.2. OBJECTIVE OF AN OM&S MANUAL

The objective of the OM&S Manual is to define and describe:

- roles and responsibilities of personnel assigned to the facility;
- procedures and processes for managing change;
- the key components of the facility;
- procedures required to operate, monitor the performance of, and maintain a facility to ensure that it functions in accordance with its design, meets regulatory and corporate policy obligations, and links to emergency planning and response; and
- requirements for analysis and documentation of the performance of the facility.

The OM&S Manual will present information in a clear, logical and user-friendly manner. Any supporting documentation will be clearly referenced. The reader should be able to identify easily what is required and how to access the information needed.

The OM&S Manual will enable the performance of a facility to be compared to expectations, design criteria and operating intent, particularly in the event of significant incidents.

2.3. RESOURCES AND SCHEDULING

A realistic budget and an achievable schedule should be established for preparation of the OM&S Manual, as well as for its maintenance, continual improvement, periodic review and update.

2.4. OM&S MANUAL CONTROL AND UPDATE

The OM&S Manual will be a controlled document, with specified procedures for:

- distributing and filing the manual and supporting documents;
- reviewing and updating the manual; and
- removing and archiving out-of-date materials.

OM&S procedures and requirements should be reviewed and the manual updated regularly, consistent with continual improvement, and particularly after significant incidents.

Annual tailings and water management system reviews should include evaluation of the OM&S Manual.

3 - ROLES AND RESPONSIBILITIES

3.1. ORGANIZATION, STRUCTURE, INDIVIDUAL RESPONSIBILITIES

This section of the OM&S Manual will describe the site management structure. Individuals having responsibilities for operation, maintenance, surveillance or emergency preparedness and response of the facility will be identified. All individuals (including external advisors and service providers) will be listed by name, position within the organization, roles, responsibilities and contact information.

Organization charts showing reporting links within the organization and communication links to external organizations will be provided.

It is essential for the integrity of operations that the facility management structure and individual roles, responsibilities and required competencies of personnel be clearly defined, such as in the table below.

Personnel need to understand the factors that constitute sound performance of a tailings or water management facility, how deviations from expected performance may indicate developing problems, and their individual roles in the OM&S. A new member of the team should be able to comprehend readily the facility management, organization and reporting structures, and be able to contact the appropriate management personnel using the information provided.

Typical Designated Personnel for OM&S	**Operation**	**Maintenance**	**Surveillance**	**Emergency Preparedness**
Mine/mill general manager				
Tailings area supervisors				
Tailings engineers and technicians				
Environmental engineers and coordinators				
Personnel responsible for facility inspections				
Personnel responsible for dam raising				
Tailings area operators and foremen				
Water management/treatment area operators and foremen				
Mill foremen (attending tailings discharge and recycle water requirements)				
Tailings backfill plant operators				
Site emergency/security personnel				
External advisors/consultants				
Mechanical/electrical foremen				
Electricians				
Mechanics				
Heavy equipment operators				

Typical Designated Personnel for OM&S	Operation	Maintenance	Surveillance	Emergency Preparedness
Scientists				
Administration support				
External liaison/public affairs personnel				
Legal and regulatory affairs personnel				
Engineer(s) of record				

3.2. COMPETENCY AND TRAINING

The OM&S Manual will set minimum knowledge and competency requirements for each position with defined responsibilities.

Procedures will be defined to ensure that appropriate training is provided to all personnel working at the facility, including contractors and suppliers, and that all personnel have an appropriate understanding of the OM&S Manual and their respective roles and responsibilities. The responsibility of all site personnel to be continually aware of visual indications of facility performance will be highlighted.

3.3. MANAGING CHANGE

This section will outline the procedures to track tailings management facility changes. Revisions to design during operations will follow a defined review and approval process, appropriately involving company management, site personnel and regulators.

Procedures for making changes to design or operating plans, such as where conditions encountered in the field differ from design will be defined. The process of changing design will include obtaining authorization of the changes.

Responsibility for reviewing, updating and improving the OM&S Manual, to respond to the following will be identified:

- evolution of design through capacity changes, operational efficiencies, closure requirements, performance feedback and life-cycle changes;
- incorporation of as-built records of construction;
- variation of performance from design;
- changes in site management organization, facility description, roles and responsibilities, and operating and reporting procedures;
- suggestions for improvement;
- succession planning/training; and
- regulatory change.

4 - FACILITY DESCRIPTION

This section will provide essential information about the facility – site conditions and facility components, regulatory requirements, basis of design and design criteria, construction history, and location of all relevant documentation. The facility description may be presented in summary format with reference to more detailed information in supporting documents and reports.

4.1. FACILITY OVERVIEW

This sub-section will provide an overview of the facility, setting the context of its surroundings, related operations and its history, including those details provided in the table below.

Typical Facility Overview
Ownership – current and historic Location Site layout plan, showing the major components and appurtenances of the tailings or water management facility, mine, mill, drainage features and access roads The broader site context, including: • mine, mill, smelter and/or refinery operations and process • ore type • tailings output • history – changes to ore type, mining, milling and processing Features within the site area, such as topography, creeks, streams, rivers, lakes, roadways, ditches, pipeline corridors and utility corridors, which are not part of the actual facility History of design, construction and operation, key milestones and significant changes

4.2. SITE CONDITIONS

The physical site conditions that provide the basis for design and operation of the facility will be described. Extensive information may be available on site conditions, the essential elements of which will be summarized, with reference to supporting documents for additional detail, including those details outlined in the table below.

Typical Site Conditions
Climate – temperature, wind, precipitation, evaporation, seasonal and extreme events, precipitation and runoff, air quality Water • hydrology – regional creeks, streams, rivers, ponds and lakes, marine conditions, catchment area, downstream areas that may be affected, and water flow, volume, chemistry/quality, and biology

• hydrogeology – aquifers, and water flow, volume, direction and chemistry/quality
Land forms – topography, including muskeg, peat or talus slopes
Geology and geochemistry – surficial deposits and bedrock characteristics (moisture content, gradation, mineralogy, geochemistry, shear strength, compressibility, permeability and index tests), stratigraphy, geomorphology, mineral and petroleum resources, background elemental content
Natural hazards – landslides, avalanches and debris torrents, seismicity, flood potential, frost action, wind, ice movement, frazil ice
Surrounding land and water tenure and use
Biological – ecosystem identification, flora and fauna

Location, and essential supporting field and analytical program data related to the site, as listed in the table below, will be provided.

Typical Site Reference Data
Grid system and contour maps
Datum, location of survey benchmarks
Test hole logs and locations, drill holes, penetration holes, core holes, auger holes, geophysical tests, test pits, etc.
Instrumentation type and location: piezometers, inclinometers, settlement gauges, flow gauges, etc.
Geophysical surveys
Tailings/soil/rock conditions or characteristics – moisture content, gradation, mineralogy, geochemistry, shear strength, compressibility, permeability and index tests
Groundwater and surface water sampling points
Regulatory compliance points
Water characteristics, naturally occurring background
Weather

4.3. FACILITY COMPONENTS

A listing of significant equipment and structures that comprise the facility, including those associated with tailings delivery and tailings or water management, as per the table below, will be provided.

Typical Components of a Facility		
Tailings/Water Management		
Dams, dykes and containment structures	Culverts	Seepage reclaim pumping and ditch systems
Tailings beaches	Drains	

Perimeter containment slopes	Drop structures	Decant structures
Dam crest	Liners	Spillways
Starter dykes, berms	Control structures	Siphons
Impoundment area	Tailings and water pipelines	Reclaim barge
Appurtenances	Pumps and pump houses	Creek diversions
Vegetation	Pipeline bridges	Ditch diversion
Dust control systems	Water	Water treatment plant
Ditches		
Infrastructure		
Utility corridors	Power supply, main and backup	Enclosures
Gas lines	Telecommunications	Signage
Product lines	Transmission lines	Gates
Roads, ramps, railroads	Switches	Fences
Buildings		
Instrumentation		
Piezometers	Inclinometers	Slurry density gauges
Groundwater wells	Surface movement monuments	Water-level gauges
Weirs	Computerized controls	

Relevant supporting data and references for components of the facility in a summary table, including appurtenances and instrumentation types, as per the table below, will be provided.

Typical Component Details
Important component dimensions
Pipeline diameter, thickness and composition
Type of dam, method of construction, failure consequence classification
Plans, maps, photographs and drawings which show the location of fixed equipment and structures, above ground and buried
Tailings and construction material characteristics and capacity
Date of construction/installation
Where to find:

- design/construction documents, manuals and drawings
- basis of design/design criteria
- as-built documents – manuals, drawings and specifications

4.4. REGULATORY REQUIREMENTS

All regulatory approvals will be listed. Their purpose, compliance and reporting requirements, and respective periods of applicability will be described. Reference to the personnel responsible for ensuring compliance, permit tracking procedures, and the locations of all regulatory documentation will be included. See the table below for details of typical regulatory compliance issues.

Typical Regulatory Compliance Issues	
Financial assurance	Vegetation, wildlife and fish impacts
Environmental assessment	Progressive reclamation
Water import and usage	Decommissioning and closure
Receiving water and effluent criteria (surface and groundwater)	Dust, steam and fugitive emissions
Water recycling	Noise and odour tolerance
Dam safety	Hazardous materials and designated substances
Land use and disturbance	Regulatory reporting
Waste management	Community outreach

4.5. BASIS OF DESIGN AND DESIGN CRITERIA

Assumptions are generally made to facilitate the initial design of a tailings or water management facility, which may be carried out when there are only limited data available on the site conditions, tailings characteristics and the longer term operational and closure requirements of the site. As additional data is generated during the construction and operation phases of the facility, these assumptions can be verified or adjusted, which may lead to changes in design.

Changes to the documented design may have significant impact on facility risk, and should therefore be implemented only after due consideration, approved by the EOR, management approval and regulatory authorization.

Closure requirements also influence the operating design of a facility. Therefore, the design basis and criteria for closure, including decommissioning and reclamation, approved by the Regulator, will be included in the OM&S Manual. Closure plans often evolve through the operation stage of the facility. Changes in design must be approved by the EOR and the Regulator; all changes will be tracked in the OM&S Manual.

The basis of design and design criteria of the facility will be described as follows (see tables below for more details):

- **basis of design** addresses conditions imposed by the site, requirements of the project, and regulations; and
- **design criteria** are standards set by engineering practice and/or regulation, in accordance with the basis of design.

Modifications to the design along with associated risk assessments and management authorization for such changes will be documented.

Sufficient information to conduct the following will be provided:

- convey the capacity and the design basis of the tailings or water management facility;
- ensure that the current design criteria are always available to enable comparison of performance of the facility with design intent; and
- guide review of the design as necessary to assess the need for changes in design or OM&S procedures.
- document that proposed changes are duly approved by the EOR and authorized by the Regulator.

References to supporting documents, including initial and subsequent design and engineering reports which describe the basis of design and details of changes, will be provided.

Basis of Design **Site conditions and requirements or limitations of the project**		
Site Characteristics		
Basin capacity, footprint, hydrology, operational life Siting constraints, natural hazards Climatic considerations	Elevation change and distance from mill Foundation conditions Surficial and bedrock geology	
Operating Requirements		
Ore reserve, life of mine, annual through-put Tailings pulp density in delivery pipeline Tailings production and basin filling rates, impoundment raising schedule Tailings characteristics, including gradation, chemistry, mineralogy, dry settled density Tailings deposition procedures – cycloning, spigotting, cell construction,	Slurry water chemistry Dam crest width Tailings beach width and slope Water quality standards for surface and groundwater Water balance, mill reclaim water rate, treatment plant capacity Water management (including diversion works, outlet structures	Regulations Acid-generating potential Pond retention time, pond chemistry Pond seepage control measures, perimeter surface and groundwater chemistry requirements Catchment area runoff diversion

Basis of Design Site conditions and requirements or limitations of the project		
end discharge	and freeboard requirements)	requirements
	Pond freeboard, settlement and consolidation	Decommissioning, closure and reclamation

Design Criteria **Standards set by engineering practice and/or regulation**
Maximum height and slopes of dam and tailings
Dam construction materials
Dam construction methods
Seismic design criteria
Development stages, seepage and deformation limits
Liquefaction and compaction
Influent flood storage and routing criteria
Factor of safety for perimeter slopes for operation and closure
Impoundment failure consequence classification
Acceptable risk
Triggers for seismic or flood events that require site inspection & reporting

4.6. CONSTRUCTION HISTORY

A summary of the construction history of a facility, including, as available, reference to any problems or unique circumstances encountered, and a description of the construction procedures will be provided, as outlined in the table below. Ongoing inspection and review will expand the documented record over time.

Typical Construction History Data
Dates of construction
General description of the construction
Engineer of record, construction contractor
Size, scale, complexity and ease (or difficulty) of construction of each stage
Summary of the key elements of the facility that were constructed

Type and source of construction materials Summary of problems or unique circumstances encountered, including natural (ground conditions, weather, etc.) or human-made (changes from approved design, construction methods differing from standard, etc.) conditions List of supporting documentation providing more specific details relating to the construction • investigations, designs, specifications, as-built records, photographs, etc. • list of key individuals supervising and documenting the construction • stage construction linkages to tailings and water management, etc.

4.7. DOCUMENT CONTROL

The impact of decisions made in designing and managing tailings and water management facilities accrue over long periods of time. Resulting impacts may not be evident until some future date. It is, therefore, important that essential information be passed on to future operators so that operating methodologies and past intentions are not lost with time.

Documentation provides the means to rely less on a person's memory, and more on a formalized system from which knowledge can be transferred.

This section will define procedures for the management and retention of information, data, design and performance documents, both hard copy and electronic, including the revision or version number, location, circulation, archiving and backup practices. The basis and schedule for retention of essential information, and removal and archiving of non-essential information, during the life of the facility will be included.

The availability and access controls for key documents, as summarized in the table below, to ensure both continued accessibility and integrity of the data record, and to avoid files being lost, removed or misplaced will be delineated. The method for retrieving information from electronic databases will be described.

Up-to-date listings of pertinent supporting documents and reports, together with the locations of the documents and reports not bound into the manual will be provided.

Typical Reference Documents and Reports	
Site investigation, geological and environmental baseline reports Environmental assessment Laboratory and field testing results Design reports Design drawings Design & construction specifications Testing protocols & records Construction reports	Photographic documentation Dam inspection and dam safety review reports Environmental control and monitoring Instrumentation, surveillance and monitoring manuals and reports Risk assessments and reports Serious incident reports Emergency preparedness, response and contingency plans

Periodic survey of monitoring monuments	Decommissioning and closure plan
Seismic activity measurements	
Hydrological and meteorological reports	
Vendor manuals and drawings	
Tailings deposition and water management plans	

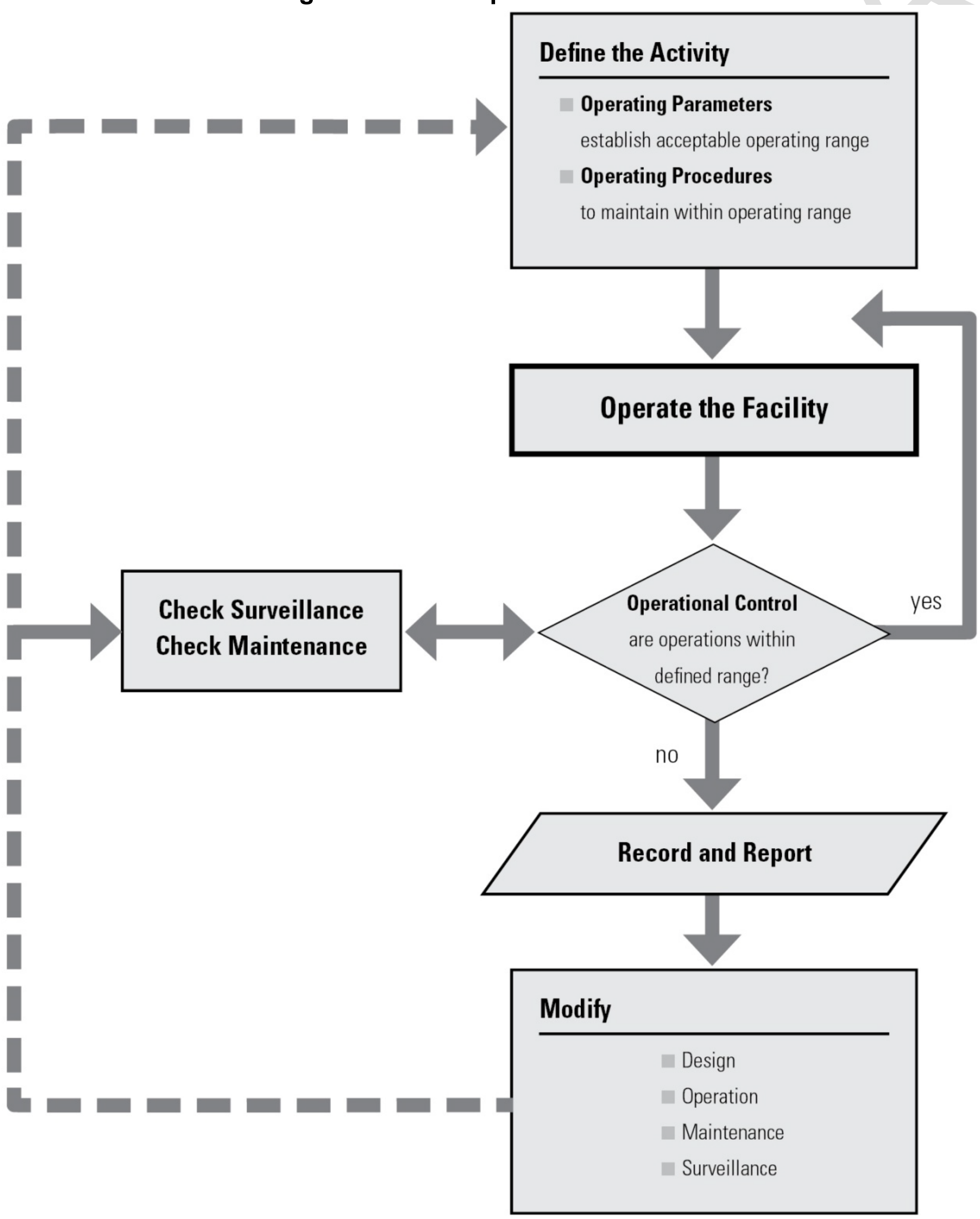
5 - OPERATION

The operation plan for a tailings or water management facility will address the transport and containment of tailings, solid waste, process water, effluents and residues, and the recycle of process water.

5.1. OBJECTIVE

This section will define operating standards and procedures in accordance with design criteria, regulatory requirements, company policies and sound operating practices, encompassing all significant aspects of, and activities for, the economical, safe and environmentally responsible disposal and storage of tailings and management of water (Figure 5-1).

Figure 5-1 Operation flowchart



5.2. TAILINGS TRANSPORT AND DEPOSITION

During operation of a facility, the tailings might vary in physical, chemical and mineralogical characteristics. Representative samples of tailings will be collected periodically for analysis. These analyses will be useful to verify any change in the physical, chemical and mineralogical characteristics of the tailings that could impact the deposition plan (a modification in the tailings specific gravity can affect the deposition slope of the material), tailings deposit density, the final effluent water quality or the rehabilitation strategy.

This section will describe the deposition plan, with details provided as summarized in the tables below. A summary of the full life-cycle deposition plan, together with detailed, current-year annual plans identifying discharge locations, discharge schedule and planned construction, with reference to supporting reports and plans will be provided.

Key operating parameters and procedures, and a schedule for periodic review against design will be identified.

Typical Tailings Transport and Deposition Parameters
Tailings slurry quantity and flow rate projections Pumping and pipeline operating pressures Slurry density and other physical and chemical properties, temperature Tailings gradation, mineralogy, specific gravity, density, angularity, clay content and plasticity, acid-generating and metal-leaching potential Tailings deposition technique and compaction Tailings beach and underwater slopes Maximum beach crest elevation Maximum and minimum beach width Chemical properties of tailings pore water and decant water

Typical Tailings Transport and Deposition Procedures
Tailings deposition • dam safety • staging of dam lifts • solids storage capacity • water recycling • water treatment requirements • cell construction, spigotting, contained beaching

- compaction
- Operating instructions for pipes, pumps, etc.
- tailings line relocation
- line pressure
- pulp density
- pipe rotation
- valve openings
- vacuum breaks
- measures to prevent line or pump sanding or freezing
- measures to flush or thaw lines

Response to deviations in physical, chemical or mineralogical properties from the design

Response to unusual operating conditions, such as severe winter conditions, periods of high rainfall, drought, and high winds

Mechanical functions, such as line rotation, line relocation and valve openings

5.3. DAM AND BASIN RAISING

This section will identify requirements and plans for staged dam construction over the life of the facility (see tables below), to maintain adequate solids storage capacity and allow adequate polishing of supernatant during operation, including:

- methods of dam construction – spigotting, cell construction, upstream, downstream, etc.;
- tailings deposition procedures, taking into consideration dam safety – staging of dam lifts, solid storage capacity, water recycling and water treatment requirements; and
- quality control measures to ensure that the construction is completed properly.

Typical Dam and Basin Raising Parameters	
Maximum and minimum height	Phreatic surface and pore water pressures
Dam-raising schedule	Beach width
Construction material sources	Foundation and dam building material characteristics
Placed material density	Slurry density
Perimeter slopes	Tailings delivery volume
Progressive reclamation	

Typical Dam and Basin Raising Procedures

Erosion control Compaction Material placement, spigotting, cell construction, single point discharge	Site preparation, vegetation/overburden removal, earth and rock fill Filter construction Instrumentation installation and/or extension

5.4. WATER MANAGEMENT

This section will describe procedures for management of water flow through a facility under normal operating practice, as well as under special circumstances such as spring runoff, severe rainfall events or drought. Describe water balance, including identification of all inputs, inventory of pond and interstitial water, and outflows.

Key operating parameters and operating procedures (tables below) related to water balance and water management for the facility, including spillways, decant systems, siphons, ditches, swales and drop structures will be identified. Reference to supporting reports and plans will be provided.

Typical Water Management Operating Parameters
Minimum freeboard
Stage storage curves
Maximum and minimum operating water levels and beach widths (seasonal considerations, wind, flood and drought events, and the treatment schedule)
Tables of target pond levels
Water discharge, volume and quality (normal operating conditions and special circumstances)

Typical Water Management Operating Procedures
Control of inflows and outflows
Flood routing
Seepage water return
Reclaim water

5.5. ENVIRONMENTAL PROTECTION

This section will define parameters and procedures to protect the environment by controlling tailings and water through treatment and management (see tables below). Regulatory reporting requirements will be documented.

Typical Environmental Protection Parameters
Water/effluent discharge quality and flow rate

Chemical properties of tailings pore water, groundwater, seepage and decant water
Dust/particulate loading, quantity and quality
Fog or steam emission criteria
Basin footprint
Biomass/biodiversity, wildlife, aquatic life, livestock and habitat

Typical Environmental Protection Procedures
Treatment plant • unit operations • reagent addition • instrumentation and process control
Surface water, groundwater and seepage collection, treatment and transport, including pump back
Dust abatement
Fog or steam abatement
Wildlife, aquatic life and livestock protection
Handling of hazardous materials and designated substances
Reclamation and revegetation
Progressive rehabilitation

5.6. SAFETY AND SECURITY

This section will define parameters and procedures to control site access, to assure both facility integrity and safety of site personnel and the general public. Details to address hazards or safety restrictions related to human contact with tailings or decant materials (see table below), including risk to personnel walking or operating equipment at the facility will be provided.

Typical Safety and Security Parameters	
Site access and egress limitations	Signage, fencing and gates
Workplace hazards	Security patrols
Personal protective equipment	Workplace safe operating procedures

5.7. DOCUMENTATION

This section will define information to be collected and recorded as part of the facility's operation (see table below). Checklists and report forms might be included or referenced.

Typical Operation Documentation
Quality control records and statistical summaries
Instrumentation records, daily diary entries
Communications and activity records
Photographic summaries and/or videos
Schedules
Change orders, memos, reports
As-constructed drawings and reports, especially of dam raising

5.8. REPORTING

Define operating performance information to be reported.

Specify procedures for reporting of:

- operational conditions requiring maintenance; and
- observations which may identify significant change in conditions at the facility.

6 - MAINTENANCE

The maintenance program for a tailings or water management facility will identify and describe critical parts, routine, predictive and event-driven maintenance, and operating and surveillance observations for all civil, mechanical, electrical and instrumentation components of the facility (Figure 6-1).

6.1. OBJECTIVE

Key maintenance parameters and procedures will be identified to ensure that the individual components of a facility are maintained in accordance with performance criteria, company standards, legislative requirements and sound operating practices (see typical contents in table below). Maintenance plans will be tailored to unique facility characteristics and site conditions.

Typical Contents of a Maintenance Plan

Statement of objective

Overall responsibility for maintenance

- maintenance organization chart
- position, name and contact information
- required qualifications and familiarity with the OM&S Manual

Inventory of components subject to maintenance, and for each component

- where it is located
- when it should be maintained
- if routine or predictive maintenance, what frequency
- if event-driven maintenance, what trigger
- reference standards
- design or performance standards
- equipment operating and maintenance manuals

Schedule for checking emergency equipment and critical spare parts list

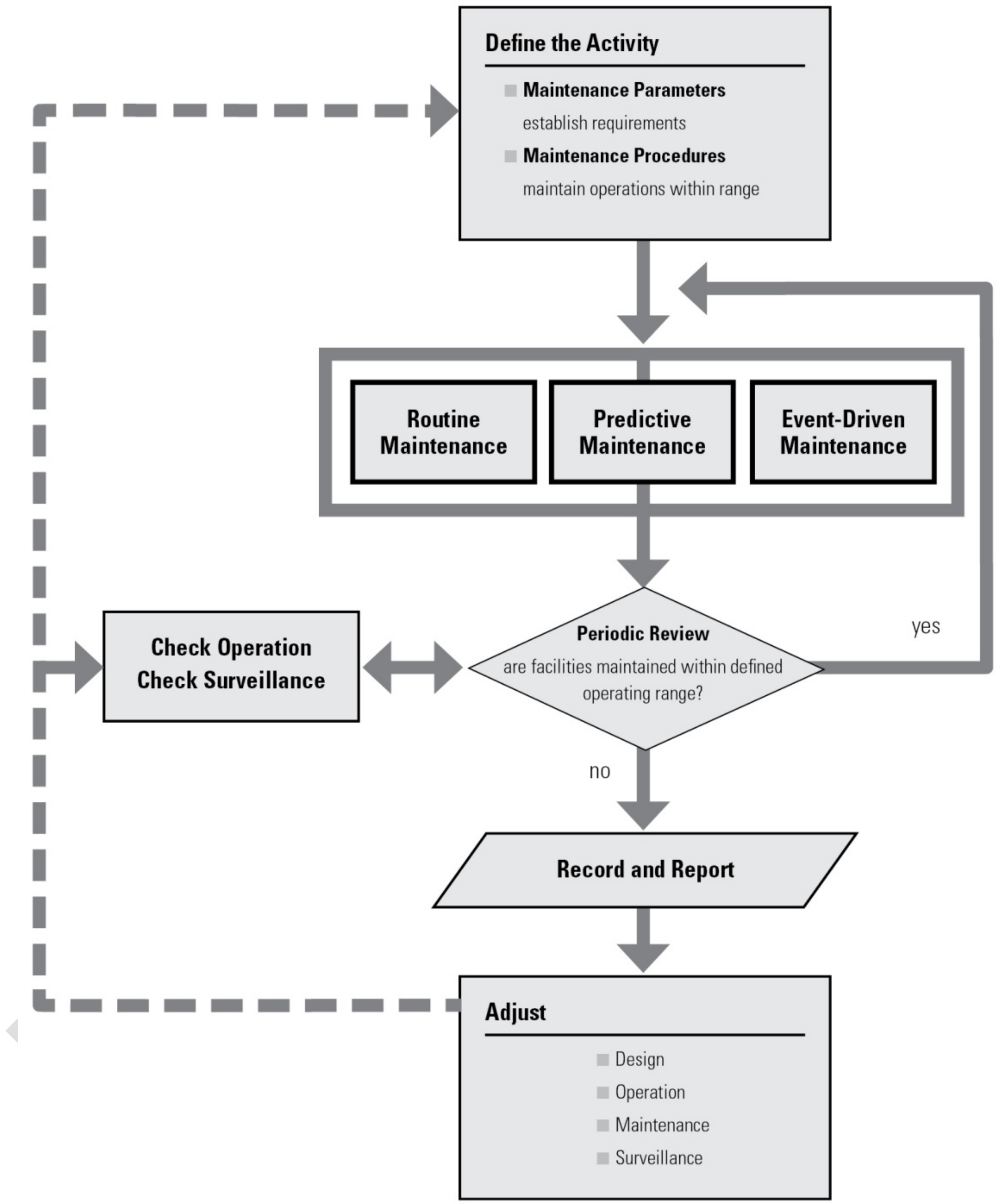
What is to be documented

- component condition
- maintenance action undertaken, standard met
- recommendation for next action

Reporting

- to whom
- when
- how, and in what form

Figure 6-1 Maintenance flowchart



6.2. MAINTENANCE PARAMETERS

This section will define maintenance parameters that address civil, mechanical, electrical and instrumentation requirements, as outlined in the table below.

Typical Maintenance Parameters	
Site access	Process and surveillance instrumentation controls
Ditch, spillway and drop structure capacity	Switches, interlocks and meters
Support structure integrity	Erosion
Equipment availability and reliability	Vegetation
Pipeline wear and thickness criteria	Design economic life
Minimal tailings line thickness, and associated requirements	

6.3. ROUTINE AND PREDICTIVE MAINTENANCE

Predictive maintenance utilizes feedback from the following, to assist in the identification of on-time servicing needs to avoid costly, lengthy or untimely breakdowns:

- Equipment operating history;
- Maintenance effort (costs); and
- Site conditions.

A key component of maintenance planning is preparedness to respond to breakdowns, incidents or conditions requiring maintenance. It is important, however, to distinguish between requirements for maintenance and emergency response; maintenance actions do not address emergency situations, which should be covered in the emergency preparedness plan and/or emergency response plan.

This section will outline routine and predictive maintenance procedures for all identified components of the facility, specifying:

- prioritization, based on risks and consequences;
- material and equipment availability;
- maintenance action plans, including repairs and replacement as required; and
- documentation of maintenance undertaken.

6.4. EVENT-DRIVEN MAINTENANCE

This section will provide procedures to address conditions or incidents requiring maintenance, which may arise from observations from other OM&S activities, and result in planned or unplanned maintenance actions, specifying:

- prioritization, based on risks and consequences;

- maintenance team "call-out" procedures;
- material and equipment availability;
- maintenance action plans, including repairs and replacement as required;
- lock-out and safety procedures/concerns;
- return to normal operation; and
- documentation of maintenance undertaken.

6.5. DOCUMENTATION

Information to be collected and recorded as part of the facility's maintenance will be defined, with typical requirements outlined in the table below. Checklists and report forms might be included or referenced.

Typical Maintenance Documentation	
Up-to-date equipment logs	Photographic summaries and/or videos
Work history	Inventory of spares, materials, tools and equipment
Frequency and cause of problems	Critical spares list
Component reliability	Schedules
Quality control records	Change orders
Daily diary entries	Memos
Communications and activity records	Reports

6.6. REPORTING

This section will define maintenance information to be reported and will specify procedures for:

- reporting operational conditions requiring maintenance; and
- reporting significant observations from maintenance activities, including greater than expected maintenance requirements and excess event-driven maintenance.

Such reporting may be instrumental in identifying and dealing with changed conditions at the facility.

7 - SURVEILLANCE

Surveillance involves inspection and monitoring of the operation, structural integrity and safety of a facility (Figure 7-1). It consists of both qualitative and quantitative comparison of actual to expected behaviour. It must be a designed program, fully integrated with operation and maintenance activities, consistent with life cycle and regulatory requirements.

Regular review of surveillance information can provide an early indication of performance trends that, although within specification, warrant further evaluation or action.

All personnel working at a tailings or water management facility should be involved in surveillance as a routine part of daily activities, maintaining visual awareness of the facility in the course of their regular and/or routine duties, in addition to surveillance-specific site engineering, instrument monitoring, analysis, inspection, periodic review and oversight.

Surveillance is not a substitute for design; it is a necessary component of good design practice which, to be effective, must be implemented through a designed program.

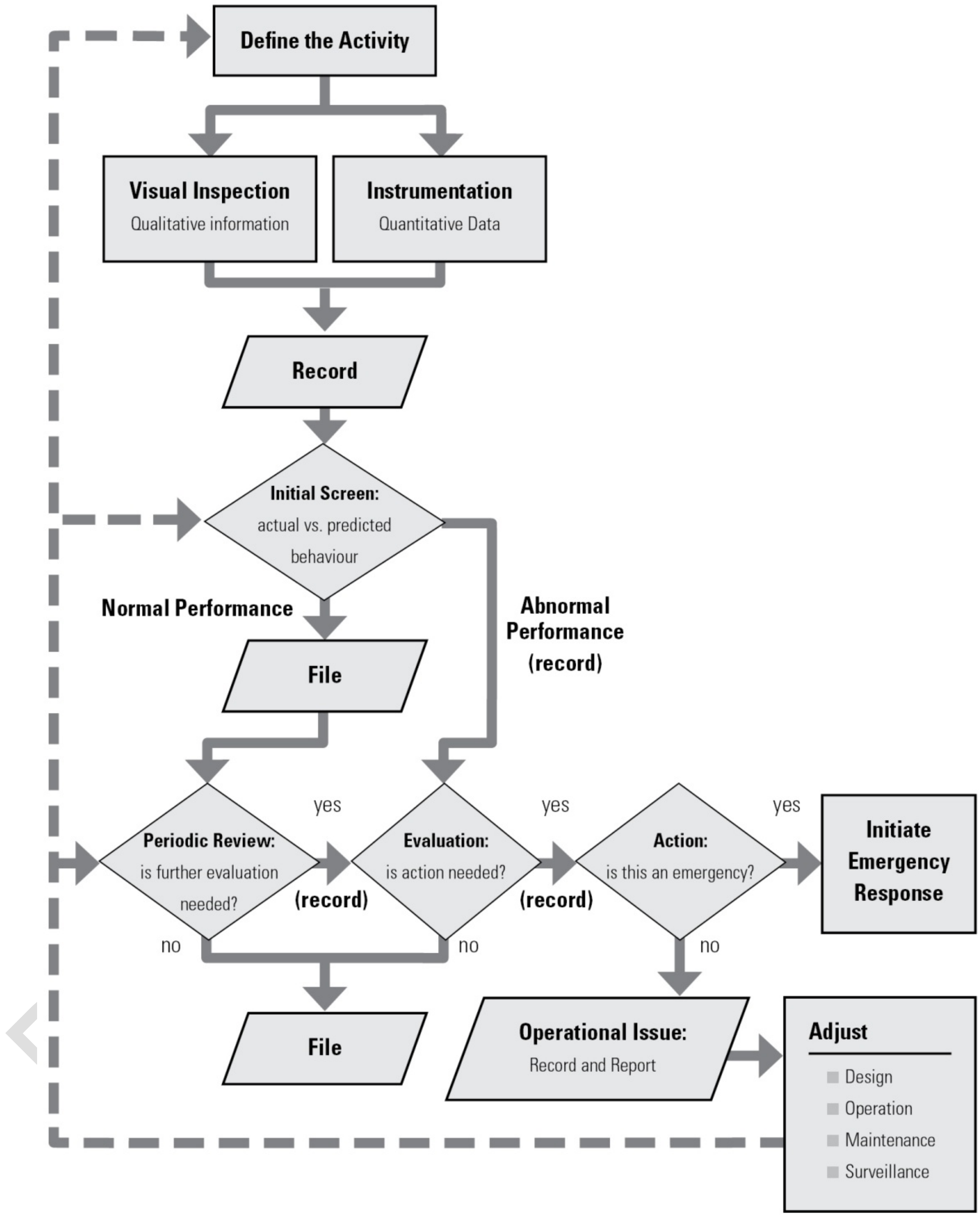
7.1. OBJECTIVE

This section will identify key surveillance parameters and procedures for:

- monitoring the operation, safety and environmental performance of tailings and water management facilities;
- promptly identifying and evaluating deviations from expected behaviour that affect operational safety, structural integrity and environmental performance of the facility; and
- reporting significant observations for response.

Personnel will be made aware of the need to report and act on observed departures from expected behaviour.

Figure 7-1 Surveillance Flowchart



7.2. SURVEILLANCE PARAMETERS

This section will identify and describe potential failure modes for assessment and inclusion in a surveillance program. The key parameters of surveillance to support the operation of the facility, building on the identified modes of failure will be defined.

There are key performance parameters for which expected behaviour can be monitored – freeboard, seepage rate, containment structure displacements, pore pressures, and chemistry of the seepage and the surrounding surface water, and these details will be provided, as summarized in the table below.

Typical Surveillance Parameters
Explanation and illustration of how failure could develop, together with probable triggers, visual and instrumentation effects
Visual observations
Surface – cracking, bulging, depressions, sink holes, vegetation Slope erosion Water levels Seepage – new seepage areas, changes in seepage area Beach slopes Classification of possible observations which would be consistent with expected behaviour, and which would not
Instrumentation
Slope displacement – survey monuments, slope inclinometers Pore pressure monitoring – standpipes, pneumatics Seismic monitoring Water quality monitoring – surface, borehole, turbidity Biological monitoring Dust sampling Weather Communications Power supply Pipeline flow and pressure Water levels

7.3. SURVEILLANCE PROCEDURES

Surveillance provides a backstop to design and operation. It provides the trigger to change operations and/or maintenance, or to initiate emergency response. It consists of a series of procedures that must be clearly defined and followed. Preparation of a surveillance program is an essential part of facility design.

Surveillance consists of both routine and event-driven procedures. Visual inspections and instrument reading which are integral to, and done as part of, routine surveillance may also be essential within the context of event-driven surveillance. Information provided related to surveillance procedures is detailed in the table below.

Typical Surveillance Procedures
Visual monitoring and Inspection
Routine visual monitoring by site personnel Periodic inspections by engineering and/or specialist personnel
Instrument measurement
Surveying Instrument reading Material testing
Data collation and analysis
Initial screening of visual inspection observations and field data as collected to determine that operations are within performance criteria Periodic follow-up screening of collated observations and data to determine trends as related to performance criteria
Periodic inspection and review
Of collected observations from visual inspection and instrument readings Of total facility performance Of continuing validity of facility design and performance criteria, including for surveillance
Documentation
Reporting

7.4. VISUAL MONITORING

Visual monitoring is not just a specialist activity – all site personnel should be trained to observe and document the performance of the facility, providing at least qualitative awareness of departures from normal performance of the tailings or water management facility, or from performance criteria.

This section will outline the types of visual indicators of which site personnel should be routinely aware. For example, appearance of, or changes to cracks, slumps, seepage and/or anomalous vegetation within the tailings or water management area or its immediate vicinity could provide a trigger for specific site inspection.

The following information will also be specified:

- The frequency of visual inspections.
- The mode of recording visual inspections, preferably on standard forms or checklists, which encourage quantification of observations where appropriate, such as width of cracks, seepage area, volume, colour and clarity, etc.
- Criteria for initial screening and reporting of observations.
- The frequency, mode of reporting and documentation standards for routine visual inspection of the entire facility by engineering and/or specialist personnel.
- Conditions, such as suspension of operation or closure of the facility, during which the frequency of routine inspections may be changed.
- Procedures for required action in the event of any sudden change in behaviour, such as abnormal water levels, increased seepage, crest drops, slumping and cracking, which may require specific incident reporting, and which would normally trigger some action.
- Criteria which trigger special event-driven inspections, along with the required documentation and follow-up. Such events typically include first filling, earthquake, extreme precipitation, flood or operational upsets. Facility performance through these events is especially important as it defines the capacity to cope with extreme events.

7.5. INSTRUMENT MEASUREMENT

Instrument measurement and monitoring quantifies facility behaviour in comparison to performance criteria, and extends operational observation to beneath the surface, beyond the range of visual inspection. Information to be included in the OM&S Manual regarding instrument measurements is summarized in the table below.

Typical Instrument Measurement and Monitoring	
Surveying of • beach profile, pond level and bathymetry • ice and snow cover • dam profile • settlement and displacement	Sampling and testing • tailings characteristics and properties • tailings mineralogy, in situ density and gradation • water chemistry Flow measurements

Typical Instrument Measurement and Monitoring	
• wildlife and aquatics • vegetation	Piezometers Slope inclinometers Settlement gauges Thermistors Meteorological stations

A complete listing of all instrumentation, will be provided, including:

- instrument identification;
- location identified on a site plan;
- record of installation, date installed, surveyed position, test hole depth, elevation of top of hole, diameter, backfill details, instrument type, depth, serial number;
- data collection and validation procedures;
- frequency of monitoring;
- data reduction and interpretation procedures;
- calibration issues; and
- data management and storage.

Data collection, instrument reading and monitoring frequencies with regard to design, operating requirements and site conditions will be specified, as will criteria for initial screening of instrumentation readings in the field at the time of collection, and the basis for rechecking of anomalous readings (which should remain on record).

7.6. COLLATION AND ANALYSIS OF DATA

Data are not collected just to fill log books – they are collected to be used, and will help future operation, maintenance and surveillance to operate more efficiently and effectively, while managing risk and change.

It is not sufficient to simply collect data. The data should be screened in the field to identify both false data and critical situations. This should be followed by collation of data collected from various points around a facility and analysis against overall performance criteria.

This OM&S Manual section will specify procedures for initial screening, data documentation and collation from visual inspection and instrument measurement. Data reduction and analysis parameters will be defined, and criteria for analysis of visual observation and inspection reports and instrument measurements against performance criteria will be specified. Parameter ranges representing the following will be defined:

- (acceptable) normal performance, normal follow-up;
- abnormal performance, additional surveillance or evaluation to be initiated;
- abnormal performance, change in operation, maintenance and/or facility design to be initiated; and
- abnormal performance, emergency alert and actions to be taken.

A schedule for periodic review of collated visual observation and inspection reports and instrument measurements, to analyze data and facility performance trends will be established.

Documentation and reporting procedures for analysis of visual observation and inspection reports and instrument measurements will be specified.

7.7. PERIODIC INSPECTION AND REVIEW

This section of the OM&S Manual will:

- Identify the periodic basis for facility inspection and review, considering site and operating characteristics, jurisdiction and consequence classification.
- Establish a schedule for regular periodic inspection of the tailings or water management facility and audit of the surveillance program results by a qualified engineer who is familiar with the tailings facility.
- Establish criteria for independent checks of the facility and the surveillance program to be done after significant events such as earthquakes, floods and significant operational upsets.
- Establish a schedule and criteria for comprehensive review of the facility – typically, every five to ten years as per failure consequence classification or by regulation. This comprehensive review should provide independent verification of the safety and environmental performance of the facility, the adequacy of the surveillance program, and the adequacy of delivery of OM&S within the management framework, plus review and analysis of the facility design with respect to current standards and possible failure modes.

7.8. DOCUMENTATION

The surveillance program must include clear identification of trigger points or changes for mandatory communication between those who monitor performance and those who control the means to improve performance. The surveillance program must be linked to the emergency response plan so that action is initiated if the performance of the facility falls below design standard.

Documentation standards for surveillance, including for recording of the following will be established:

- observations from routine visual observation (departures from or exceptions to normal conditions);
- instrumentation monitoring and testing;
- evaluations;
- inspections; and
- reviews.

Where practicable, standard forms and checklists will be provided.

A hard copy (paper) and electronic filing system for all inspection reports, photographic and video records, incident reports, instrumentation readings, instrumentation plots, annual inspections and third-party reviews, so that they can be quickly retrieved for review and in the case of an emergency will be established.

Procedures for initiating emergency response alerts, reporting operational performance that meets expectations, and reporting conditions requiring adjustment to design, operation, maintenance or surveillance will be specified. As will reporting procedures and schedule for regulatory requirements.

8 - EMERGENCY PLANNING AND RESPONSE

Tailings and water management facilities pose a risk that must be managed. Despite best efforts to ensure that facilities are designed, operated and closed safely and responsibly, it is important to have emergency preparedness and response plans and procedures in place in the event of an incident. A site's overall emergency preparedness and response plans will include plans and procedures for the tailings management facility specifically and these, in turn, will be part of the OM&S Manual.

The emergency preparedness and response plans will identify the actions to be taken by the owner/ operator and responsibilities assigned to appropriate individuals at the site, as well as those of other agencies and affected parties.

Emergency preparedness and response (EPR) plans will be defined to identify the potential for accidents, to respond in emergency situations, and to prevent and mitigate the environmental and safety impacts, both on- and off-site, associated with emergency situations. Typical contents are detailed in the table below.

Warning signs with reference to potential tailings and water management facility failure modes or emergencies – both from a structural failure and failure due to environmental impacts will be listed and classified. Examples include:

- equipment failure;
- slope or foundation failure;
- overtopping;
- power line failure;
- seepage or piping;
- loss of process control; and
- flooding.

Warning signs and potential emergencies are site-specific. For each one listed and classified, the appropriate actions and responses will be identified.

A "call-out" process as appropriate, in the event of an incident will be specified and initiated. Lines of communication within the site (involving, for example, management, operations, engineers, consultants) and names, positions, telephone numbers (work and home) and e-mail addresses will be detailed. Relevant off-site contacts, such as contractors or equipment suppliers will be provided.

The process for notifying affected external stakeholders – municipalities, government agencies, local organizations, first aid, fire department, ambulance, other individuals, etc. – including telephone numbers and e-mail addresses will be provided.

Verification and follow-up procedures to ensure that appropriate parties have been contacted will be established, and the call-out process will be kept up to date.

Contingency plans will be developed and maintained as part of EPR plans. The plans will be tested for effectiveness, regularly reviewed and updated as appropriate.

The contingency and EPR plans will be widely distributed to appropriate personnel within the organization, as well as to potentially affected external stakeholders.

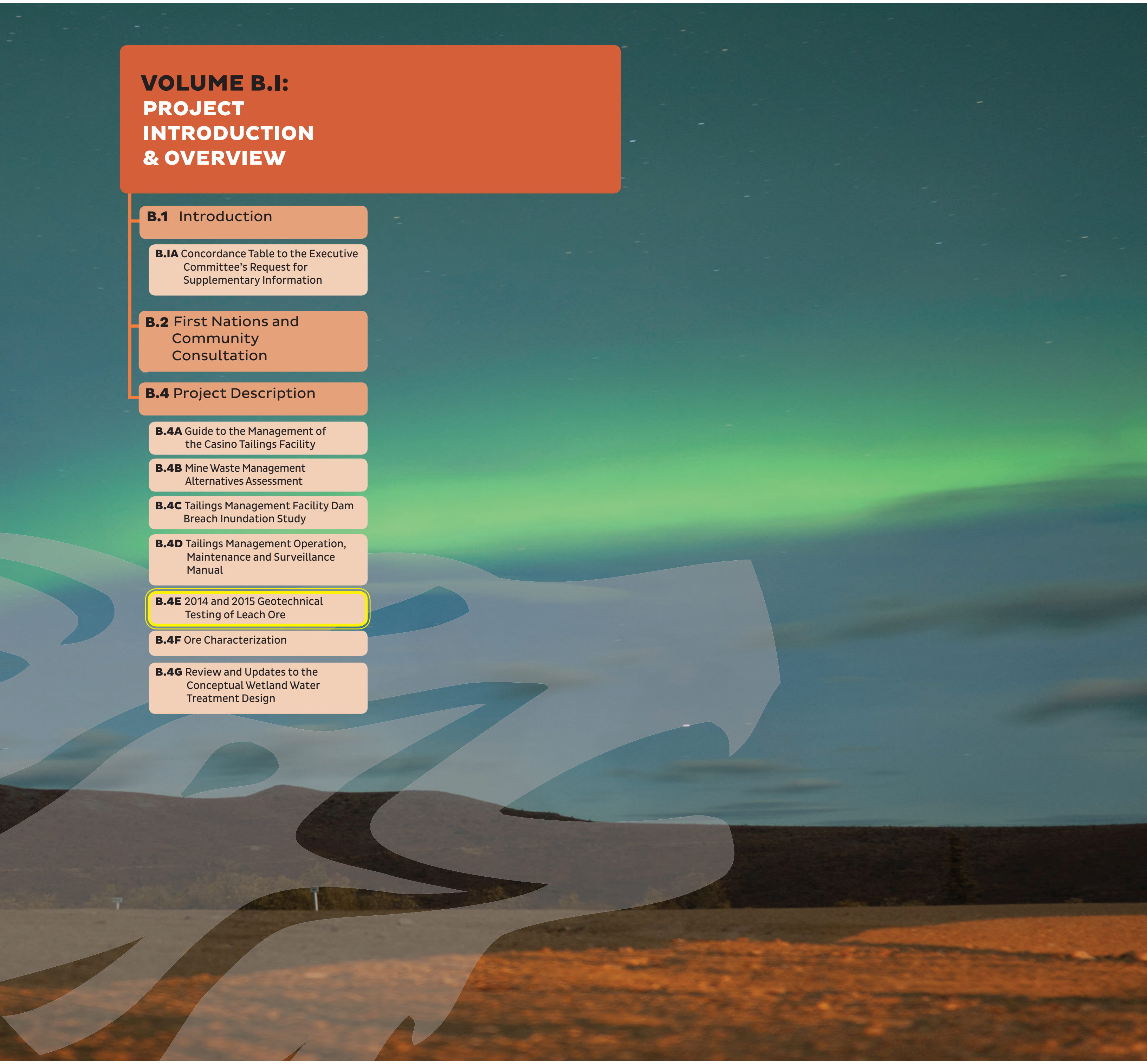
Typical Contents of Emergency Preparedness and Response Plans
Identification of failure modes
Identification of roles and responsibilities
Identification of requirements of legislation, codes of practice, notification and reporting obligations
Identification of available resources
Mutual aid agreements
Public relations plans
Telephone lists
Establishment of communication system for notifications and for post-notification purposes
Risk analysis for on-site and off-site effects
Inundation study, maps and tables for both physical and environmental releases (including dam break)
Basis for activation of emergency response plan and emergency decision making
Training of personnel
Investigation and evaluation of incidents and accidents
Contingency plans
Restoration of safe operating conditions
Validation drills, test of the system

9 - REFERENCES

Mining Association of Canada (MAC). 2011a. A Guide to the Management of Tailings Facilities; Second Edition. Mining Association of Canada. Ottawa. www.mining.ca

Mining Association of Canada (MAC). 2011b. Developing an Operation, Maintenance and Surveillance Manual for Tailings and Water Management Facilities. Mining Association of Canada. Ottawa. www.mining.ca

APPENDIX B.4E: 2014 and 2015 Geotechnical Testing of Leach Ore



VOLUME B.I: PROJECT INTRODUCTION & OVERVIEW

CASINO MINING CORPORATION
CASINO PROJECT



2014 AND 2015 GEOTECHNICAL TESTING OF LEACH ORE

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CASINO MINING CORPORATION
CASINO PROJECT

2014 AND 2015 GEOTECHNICAL TESTING OF LEACH ORE
VA101-325/18-1

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EXECUTIVE SUMMARY

This report presents the results of the 2014 and 2015 geotechnical test program of ore samples subjected to leach column testing for the Casino Project. The tests program included index, strength, hydraulic conductivity and durability testing of leached ore. All laboratory testing was completed at the Knight Piésold (KP) laboratory in Denver, Colorado. The 2014 and 2015 test program supplements testing completed in 2013 on leach ore not subjected to leach column tests. The additional testing was conducted to further characterize the ore and to determine the effect of the leaching process on ore properties.

The samples were subjected to leaching for a limited amount of time during the leach column tests, and it is recommended to study the mineralogy of the various types of ore to assess the potential effects of long term exposure to leaching conditions.

Three types of leach ore (Diorite, Intrusive Breccia and Patton Porphyry) were sampled by excavator in 2013 and processed to produce gradations representative of the design crushing process. Six samples were taken from the leach ore composites and subjected to leach column testing prior to shipment to the KP laboratory.

The gradations of the leached samples are very similar to the 2013 samples not subjected to leaching, with no signs of degradation. The samples are classified as non-plastic, suggesting no significant amounts of clay minerals have developed during the leach column testing.

The Patton Porphyry and Intrusive Breccia samples have a coarser gradation than the Diorite samples, resulting in a hydraulic conductivity that is about one order of magnitude higher. The 2014 and 2015 saturated hydraulic conductivity test results are generally similar to the 2013 results, which indicates leaching did not affect the saturated hydraulic conductivity significantly. The ore samples are generally competent and exhibit minor particle breakage under loading. The Diorite sample is most susceptible to crushing under load, and exhibits a lower hydraulic conductivity after leaching at the highest stress level (2720 kPa). This may be caused by deterioration of this type of ore due to the leaching process.

The solution application rate should be well below the saturated hydraulic conductivity of the ore to avoid saturated conditions. Test results indicate the saturated hydraulic conductivities of Patton Porphyry and Intrusive Breccia ore samples are approximately 1,000 times the application rate. The saturated hydraulic conductivity of Diorite ranges from about 30 to 1,000 times the application rate. The Diorite ore has the highest potential to saturate during operations if degradation has occurred and the ore is subjected to high confining stresses.

It is recommended to selectively place the most durable and permeable Patton Porphyry and Intrusive Breccia ores in the parts of the heap subjected to the highest stresses to reduce the potential for saturation of the ore. Agglomeration may further improve the hydraulic performance of the heap.

The tested leach ore samples are characterized by an effective friction angle of 39 degrees or higher and zero cohesion for large strain conditions. The leach ore samples do not show significant loss of strength beyond the peak strength, except for sample CL-05 (Patton Porphyry) which exhibits a post-peak strength reduction of about 10%.

The durability of the various types of ore has been assessed using the slake durability test and the freeze-thaw test. The leach ores are relatively insensitive to weathering due to repeated drying and wetting, and have a very high slake durability classification according to Gamble's classification system. The freeze-thaw durability test results indicate Diorite ore is considerably more susceptible to frost degradation than Intrusive Breccia and Patton Porphyry. Degradation of the ore may lead to a finer gradation with a corresponding lower hydraulic conductivity. It is recommended to cover the Diorite ore with a sufficient thickness of durable ore or rock fill to protect it from seasonal freeze-thaw action.

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ABBREVIATIONS

AASHTO .... American Association of State Highway and Transportation Officials
ASTM .... American Society for Testing and Materials
KP .... Knight Piésold Ltd.
PI .... Plasticity Index
PVC .... Polyvinyl Chloride
SWCC .... soil-water characteristic curves
USBR .... United States Bureau of Reclamation

1 – INTRODUCTION

This report presents the findings of the laboratory testing program to determine the geotechnical characteristics of the leach ore for the Casino Project. The report “Geotechnical Laboratory Testing of Leach Ore” (Knight Piésold, 2014) reported the index and hydraulic conductivity properties of leach ore that was not subjected to leaching. However, the leaching processes in the proposed Heap Leach Facility could lead to degradation of the ore. Additional testing was conducted in 2014 and 2015 on ore samples subjected to leach column testing to determine the effects of leaching on the ore characteristics. The results of these tests are presented in this report. The testing program consisted of index, strength, hydraulic conductivity and durability testing of the leached ore, including slake durability and freeze-thaw testing. All laboratory testing was completed at the Knight Piésold (KP) laboratory in Denver, Colorado.

Three types of leach ore were sampled by excavator in 2013 and processed to produce composites with gradations representative of the design crushing process described in the feasibility study (M3 Engineering and Technology Corporation, 2013). The sampling methodology is described in Appendix A of KP (2014) and details of the sample processing are provided by SGS (2014). Six samples (CL-01 to 06) were taken from the leach ore composites and subjected to leach column testing by SGS in 2014. Samples CL-01 and CL-02 were taken from Composite 1 and comprise Dawson Range Batholith Diorite. Samples CL-03 and CL-04 consist of intrusive Breccia from the Proctor Mountain Suite, containing Granodiorite, Diorite and metamorphic fragments (Composite 2). The lithology of samples CL-05 and CL-06 (Composite 3) is Patton Porphyry from the Proctor Mountain Suite.

SGS subjected the samples to open cycle column leach tests using 6-inch in diameter by 3 meter tall PVC columns. Approximately 70% of the expected calcium oxide consumption was blended into the test charge and the mix was then placed into the column. All the columns were leached for 47 to 53 days and then either rinsed with tap water (CL-02, 04 and 06) or recirculated with pregnant leach solution (CL-01, 03 and 05) for an additional 44 to 79 days. The column was irrigated at a flow rate of 10 liters per hour per square meter. The feed solution used to leach the ore samples contained approximately 500 mg/L of free sodium cyanide and 300 mg/L of copper. Copper sulfate was added to feed solution to achieve the targeted concentration. The feed solution pH was maintained between 11 and 11.5 by adding reagent grade calcium oxide.

The columns were drained after testing was completed, and approximately 24 kg of the remaining ore residue from each column was dried and sent to the KP laboratory for geotechnical testing.

2 – INDEX TESTS

Index testing completed in 2014 on the leached ore samples included particle size distributions (screen and hydrometer), Atterberg Limits (Plastic and Liquid Limits) and specific gravities.

The specific gravity was determined for one sample of each lithology in accordance with ASTM standard D854 for materials smaller than 4.75 mm (#4 sieve) and ASTM standard C127 for material retained on the #4 sieve. The weighted average of the specific gravity for each leached ore sample varies from 2.69 to 2.73, which is within the range determined during the 2013 testing of samples not subjected to leaching (2.64 to 2.75).

Atterberg Limits testing was conducted on the samples CL-01 to 06 in accordance with ASTM standard D4318. The testing indicated that all leached samples are non plastic. Plasticity test results from the 2013 testing show the unleached samples to be non plastic to slightly plastic, with a Plasticity Index (PI) of 5 or less. The leaching process has not resulted in an increase of plasticity, which suggests no significant amounts of clay minerals have developed during the leach column testing.

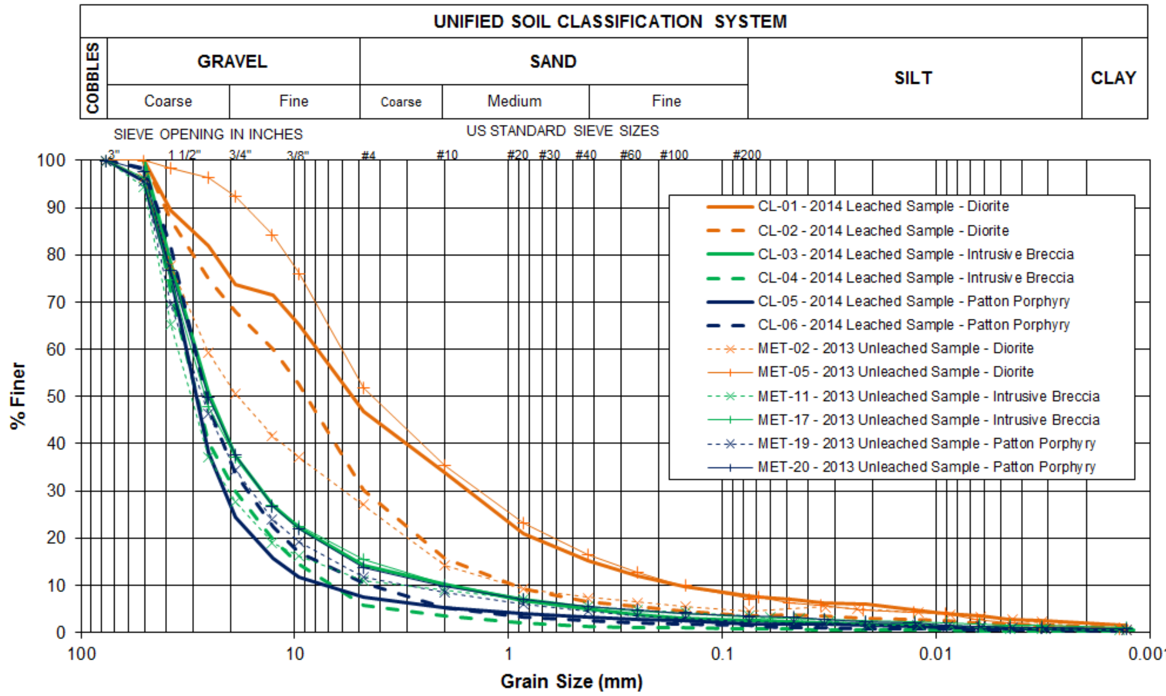
The geotechnical and hydrological properties of the ore depend on the gradation of the material. Mechanical sieve and hydrometer particle size analyses were carried out on leached samples in accordance with ASTM standard D422 procedures. The hydrometer analysis was used to determine the silt and clay fraction particle sizes. The particle size distributions of the 2014 leach samples are presented on Figure 2.1, as well as gradations from the unleached samples from 2013. Samples with the same lithology are represented by the same colour.

The gradations of Intrusive Breccia and Patton Porphyry samples are similar and show little variation. These samples are predominantly gravel, with about 5 to 15 % sand and less than 4% fines (silt and clay). The Diorite samples are finer grained and show more variability, which is likely caused by the weaker nature of this material. The Diorite samples are classified as sandy gravels to sands and gravels with trace (less than 10%) silt and clay.

The gradations of the leached samples are very similar to the 2013 samples not subjected to leaching, with no signs of degradation. The variations in gradations are likely introduced as a result of sampling and handling, and not the result of the leaching process.

The 2014 samples are only subjected to leaching conditions for a limited time (several months). The Atterberg limit and particle size analyses indicate that the leach column testing in the laboratory has not resulted in significant degradation. It is recommended to study the mineralogy of the various types of ore to assess the potential effects of long term exposure to leaching conditions.

Detailed results of the index tests are included in Appendix A.



NOTES:

1. Samples CL-01, CL-03 and CL-05 were recirculated with pregnant leach solution after the leach cycle.
2. Samples CL-02, CL-04 and CL-06 were rinsed with tap water after the leach cycle.

Figure 2.1 Particle Size Distributions for Leach Ore Samples

3 – SATURATED HYDRAULIC CONDUCTIVITY TESTS

3.1 GENERAL

Saturated hydraulic conductivity tests were completed in 2014 using rigid wall permeameters at the KP soil laboratory in Denver, Colorado. Previous hydraulic conductivity tests on samples not subjected to leaching include saturated hydraulic conductivity testing, determination of the soil-water characteristic curves (SWCC) and load-percolation testing (KP, 2014). The objective of the 2014 tests was to determine if the leaching process has resulted in a reduction of the saturated hydraulic conductivity of the leach ore due to degradation.

One sample was prepared for each type of leach ore to assess if certain lithologies are more susceptible to degradation than others. These samples were used for the saturated hydraulic conductivity testing, and also for the shear strength and the durability testing described in Section 4 and 5. A composite Diorite sample was prepared by combining CL-01 and CL-02. Sample CL-03 was selected for Intrusive Breccia and CL-05 for Patton Porphyry.

The KP laboratory conducted saturated hydraulic conductivity tests on samples CL-01&02, CL-03 and CL-05 using the constant head method. The tests were completed using an 8-inch rigid wall permeameter following USBR Procedure 5600 and 5605. Sample material greater than 1.5 inches was removed and replaced with finer gravel. The material was placed loosely in the mould and tested at normal stresses of 200, 800 and 2720 kPa.

Sieve analyses were completed on each sample material after the hydraulic conductivity tests to determine if the applied normal stress resulted crushing of the ore.

3.2 RESULTS AND INTERPRETATION

The results of the saturated hydraulic conductivity tests are summarized in Table 3.1. Detailed test results are included in Appendix C. The densities resulting from the applied normal load are presented on Figure 3.1.

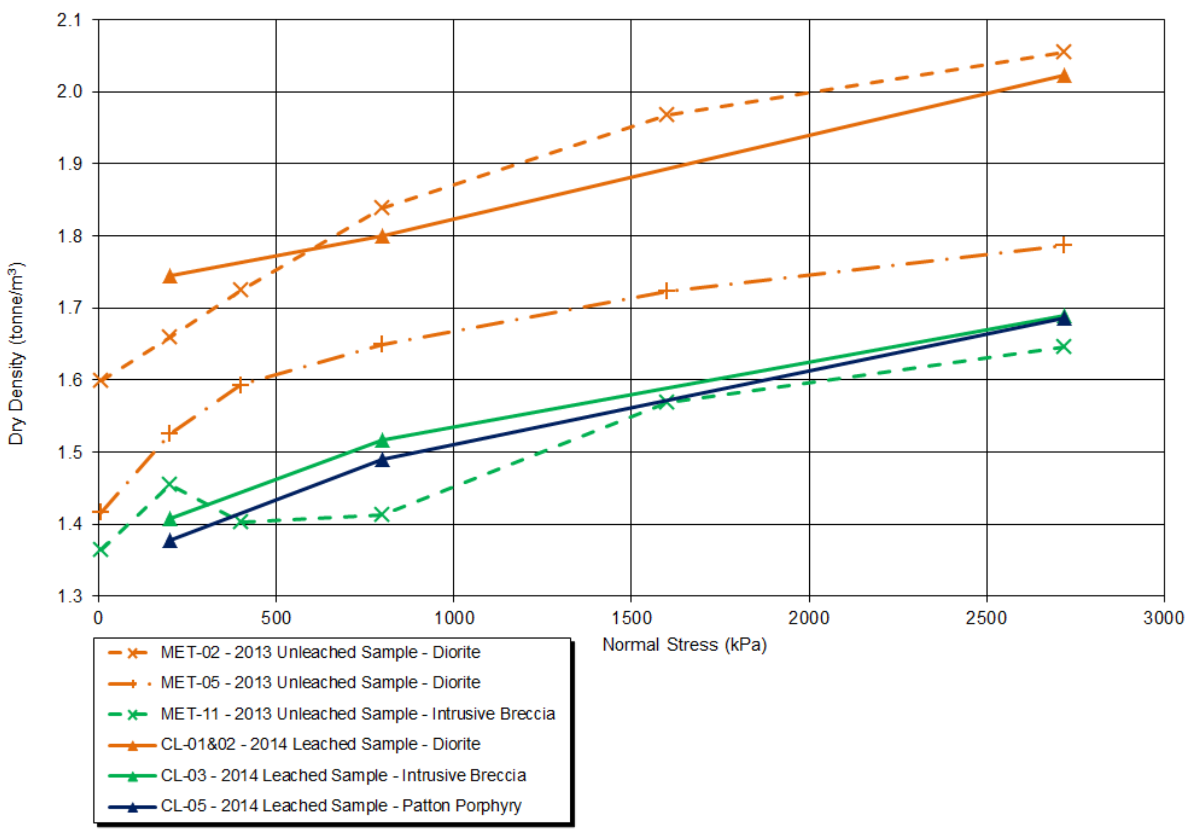
A correction is required for high permeability materials to account for head loss in the testing apparatus. A trial test without an ore sample was conducted to determine head loss in the apparatus, and the measured ore hydraulic conductivities were corrected for this head loss.

Figure 3.2 shows the saturated hydraulic conductivity test results as a function of the normal stress, with and without head loss correction. The results of the 2013 tests on materials not subjected to leaching are also included on this figure.

Table 3.1 Summary of 2014 Saturated Hydraulic Conductivity Test Results

Sample ID	Normal Stress (kPa)	Dry Density (tonne/m³)	K_{sat} (cm/s)	$K_{sat,head\ corrected}$ (cm/s)
CL-01 & CL-02	200	1.75	2.0×10^{-1}	2.9×10^{-1}
CL-01 & CL-02	800	1.80	1.4×10^{-1}	1.8×10^{-1}
CL-01 & CL-02	2720	2.02	9.6×10^{-3}	9.6×10^{-3}
CL-03	200	1.41	4.2×10^{-1}	9.2×10^{-1}
CL-03	800	1.52	4.0×10^{-1}	9.0×10^{-1}
CL-03	2720	1.69	2.9×10^{-1}	5.2×10^{-1}
CL-05	200	1.38	5.3×10^{-1}	1.6
CL-05	800	1.49	4.6×10^{-1}	1.2
CL-05	2720	1.69	3.6×10^{-1}	8.3×10^{-1}

NOTES:
1. No oversize correction applied.
2. K_{sat} = saturated hydraulic conductivity, not corrected for head loss in testing apparatus.
3. $K_{sat,head\ corrected}$ = saturated hydraulic conductivity, corrected for head loss in testing apparatus.



NOTES:
1. Tested on fraction of material passing 1.5 inch.
2. All tests conducted by KP using an 8-inch rigid wall permeameter.

Figure 3.1 Dry Density versus Normal Stress

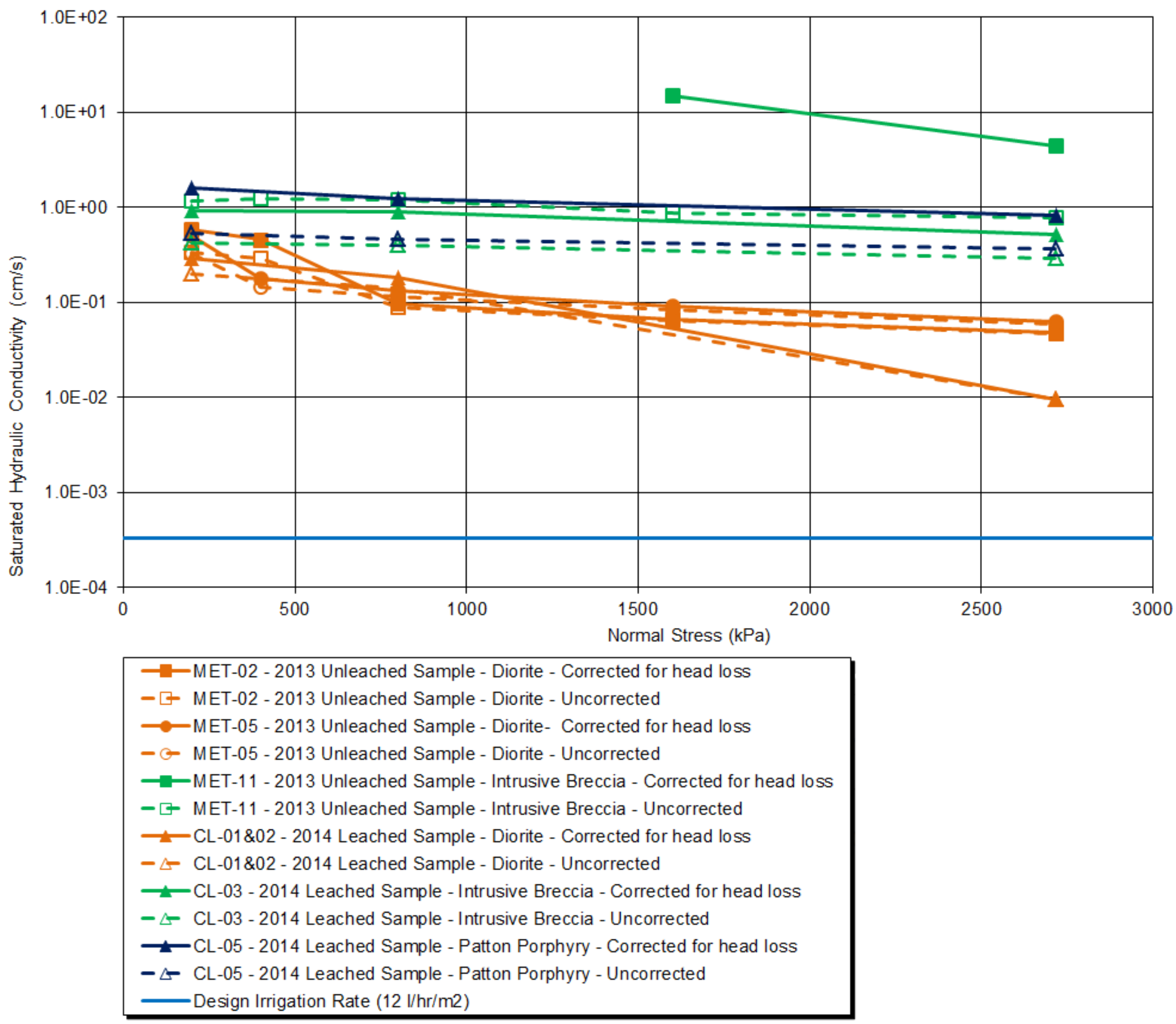


Figure 3.2 Saturated Hydraulic Conductivity versus Normal Stress

The 2013 and 2014 test results are very similar, which indicates leaching did not affect the saturated hydraulic conductivity significantly. The samples have decreasing saturated hydraulic conductivity with increasing normal stress and density. An increase of normal stress from 200 kPa to 2720 kPa generally decreases the saturated hydraulic conductivity by one order of magnitude or less. However, the leached Diorite sample (CL-01&02) has a considerably lower hydraulic conductivity than the unleached Diorite samples at the highest stress level (2720 kPa). This may be caused by deterioration of the ore due to the leaching process.

The hydraulic conductivity of the Patton Porphyry is very similar to that of the Intrusive Breccia, and about one order of magnitude higher than that of Diorite. This can be explained by examining the gradation of the various rock types in Figure 3.3. The Patton Porphyry and Intrusive Breccia samples have a coarser gradation than the Diorite samples.

The saturated hydraulic conductivity represents the maximum rate at which solution can flow through the ore. A solution application rate higher than the saturated hydraulic conductivity results in saturation of the ore and ponding at the surface. This may affect the leaching efficiency and the stability of the heap.

Results from laboratory tests may not be representative of conditions in the heap, for example, due to variability from day to day operations and degradation of ore over the life of a facility. The solution application rate should be well below the saturated hydraulic conductivity of the ore to account for these effects and limit the potential for saturated conditions.

The current design solution application rate for ore leaching (12 $l/hr/m^2$) is included on Figure 3.2. All test results indicate saturated hydraulic conductivities higher than the design irrigation rate. The saturated hydraulic conductivities of Patton Porphyry and Intrusive Breccia ore samples are approximately 1,000 times the application rate. The saturated hydraulic conductivity of Diorite ranges from about 30 to 1,000 times the application rate, depending on whether the sample was leached and the applied confining stress. It is recommended to selectively place the most durable and permeable Patton Porphyry and Intrusive Breccia ores in the parts of the heap subjected to the highest stresses to reduce the potential for saturation of the ore. Agglomeration may further improve the hydraulic performance of the heap.

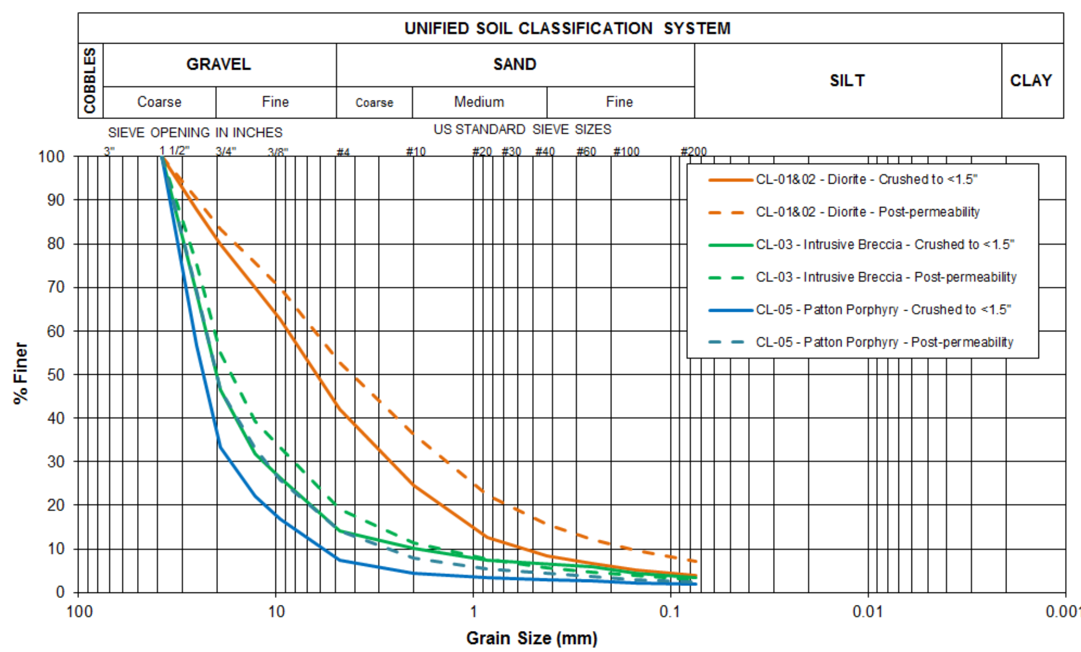


Figure 3.3 Gradations Before and After Saturated Hydraulic Conductivity Tests

Figure 3.3 displays the particle size distributions of samples CL-01&02, CL-03 and CL-05 before and after hydraulic conductivity testing. Each sample has a slightly finer gradation after the hydraulic conductivity testing, which is indicative of crushing of the particles during loading of the sample. The laboratory staff could hear the crushing of the rock fragments when loads of 800 kPa and higher were applied. The Diorite sample is most susceptible to crushing under load.

4 – STRENGTH TESTS

Consolidated Undrained triaxial compression tests were carried out on the leach ore samples CL01&02, CL-03, and CL-05 to determine the shear strength over a range of confining stresses. The tests were completed according to U.S. Army Corps of Engineers EM 1110-2-1906 procedures at effective confining stresses of approximately 200 kPa, 800 kPa and 2700 kPa. The confining stress of 2700 kPa is representative of the maximum heap height of 150 m. The maximum confining stress for samples CL-03 and CL-05 was limited to approximately 2000 kPa due to repeated rupturing of the test membrane at higher stresses.

The samples from the saturated hydraulic conductivity tests were re-used to prepare samples for triaxial shear testing. Particles greater than 1-inch were replaced with finer gravel to facilitate testing in a 6-inch cell. The samples were prepared in a loose state, yet sufficiently dense to prevent collapse during application of the confining stress, at densities ranging from 1.54 to 1.62 tonnes/m^3.

Single stage testing was conducted on the composite sample CL-01&02, which requires preparation of individual specimens for each confining stress. Multi-stage testing was completed for CL-03 and CL-05, as the limited size of these samples did not allow for single stage testing. During the initial loading stage of multi-stage testing, the consolidated specimen is subjected to a limited amount of shear strain until the peak strength is mobilized. The specimen is then released from deviator stress and subjected to a higher consolidation stress before the next loading stage takes place. This is repeated until the final shearing stage, when the specimen is loaded to large strains to determine the post-peak strength behaviour.

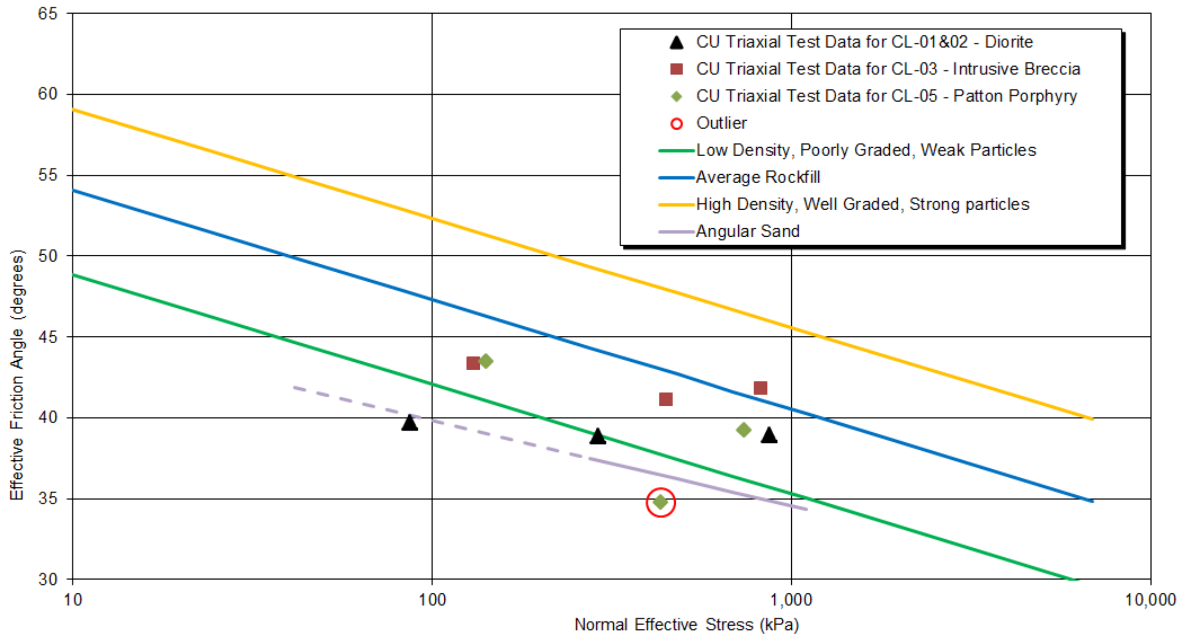
Detailed results for the triaxial shear strength testing are presented in Appendix C. The peak strength is typically reached at approximately 3% axial strain. The leach ore samples do not show significant loss of strength beyond the peak strength, except for sample CL-05 which exhibits a post-peak strength reduction of about 10%.

The effective shear strength of the leach ore is characterized by an effective friction angle and zero cohesion. The relationship between friction angle and effective stress is presented on Figure 4.1. The friction angles were typically derived for the large strain conditions (>10%), except for the first two loading stages of the multi-stage tests (200 and 800 kPa for sample CL-03 and CL-05), which were only loaded to strains less than 5%.

The test results have been compared to published information on the strength characteristics of granular materials (rock fill and angular sands) provided by Leps (1970). The strength of granular materials is typically high at low stresses, while particle crushing at higher stresses may result in a lower strength.

The test results on the leach ore show little effect of confining stress on the strength of Diorite (CL-01&02) and Intrusive Breccia (CL-03). The Intrusive Breccia exhibits a higher strength (friction angle of 41 degrees or higher) than the Diorite (friction angle of 39 degrees). A wider range of friction angle values is observed in the test results of the Patton Porphyry (CL-05). The intermediate loading stage at CL-05 is considered an outlier and is excluded from the interpretation. Insufficient shearing is interpreted to have taken place to mobilize the peak strength during this loading stage.

In summary, the tested leach ore samples are characterized by an effective friction angle of 39 degrees or higher and zero cohesion. These strength parameters may need to be reduced if long term degradation of the ore is expected.



NOTES:

1. Relationship between normal stress across the failure plane and friction angle for 1) high density, well graded, strong particles, 2) average rockfill, 3) low density, poorly graded, weak particles, and 4) angular sand after Leps (1970).
2. Relationship for angular sand is extrapolated to normal effective stresses below 275 kPa.
3. Friction angles are determined for large strain conditions (>10%), except for CL-03 and CL-05 at 200 and 800 kPa confining stress which were tested up to 5% strain.

Figure 4.1 Relationship Between Effective Friction Angle and Normal Effective Stress for Leach Ore Samples and Reference Materials

5 – DURABILITY TESTS

5.1 GENERAL

Some rock types, particularly shales and other weak rocks, are subject not only to loading failure, but also to abrasion failure. The ability of the material to resist abrasion, wear, breakdown with time is known as its durability. The durability of rock depends strongly on the interaction between the rock and water. This interaction is referred to as "slaking" and it often results in dissolution of particles, creation of fractures, and flaking of surface layers. The durability of shales and other weak rocks is often measured with slaking tests because of the physical interdependence between durability and slaking.

Rocks can also deteriorate as a result of repeated freezing and thawing. Freeze thaw weathering starts with water entering the joints, fractures or pore space in rock. The water then expands as it freezes, straining the walls of the joints and causing the joints to deepen and widen. Thawing of the ice allows the water to flow further into the rock. Repeated freeze-thaw cycles weaken the rocks which, over time, break up along the joints into angular pieces. Freeze thaw weathering is common at the Casino project site, and has resulted in the formation of tors at mountaintops and talus (scree) along slopes.

The durability of the various types of ore has been assessed using the slake durability test and the freeze-thaw test as described in the following sections.

5.2 SLAKE DURABILITY TESTS

Slake durability test were conducted in accordance with ASTM standard D4644 procedures to assess the durability of the leach ore. This test determines the slake durability index of rock after two drying and wetting cycles with abrasion.

The ore samples of Diorite, Intrusive Breccia, and Patton Porphyry are prepared to equidimensional rock fragments of 40 to 60 g each. The samples are then oven dried and subjected to 10 minutes of soaking in water with a standard tumbling and abrasion action, followed by a second drying and wetting cycle. The percentage by dry mass of rock fragments retained on a 2 mm (No. 10) sieve after these two cycles is the slake durability index.

A summary of the slake durability test results is presented in Table 5.1. Detailed results and photos before and after the tests are included in Appendix D1.

Table 5.1 Summary of Slake Durability Test Results

Sample ID	Lithology	% Retained after One 10-min Cycle	% Retained after Two 10-min Cycles
CL-01&02	Diorite	98.9	98.4
CL-03	Intrusive Breccia	99.7	99.5
CL-05	Patton Porphyry	99.5	99.2

NOTES:
1. % retained based on dry weight basis.
2. % retained after two 10-minute cycles is also known as slake durability index.

Gamble (1971) proposed a classification of slake durability as presented in Table 5.2. This classification system was developed to assess the suitability of shale rocks for use as embankment fill in highway construction. The classification system is not directly applicable to classifying ore for heap leaching applications, however, it does provide context for the slake durability test results and it offers a relative ranking of rock durability.

The leach ores are relatively insensitive to weathering due to repeated drying and wetting, and have a very high slake durability classification according to Gamble's classification system. Comparison of the photos before and after the test also indicate the retained rock fragments remain virtually unchanged.

Table 5.2 Gamble's Slake Durability Classification

Slake Durability Classification	% Retained after One 10-min Cycle	% Retained after Two 10-min Cycles
Very high durability	>99	>98
High durability	98-99	95-98
Medium high durability	95-98	85-95
Medium durability	85-95	60-85
Low durability	60-85	30-60
Very low durability	<60	<30

NOTES:
1. % retained based on dry weight basis.

5.3 FREEZE-THAW TESTS

The resistance to disintegration by freezing and thawing was determined by conducting freeze-thaw durability tests per AASHTO T103, procedure A. This test starts with completing a sieve analysis on each leach ore sample, which is then split into a fine and coarse fraction. The samples are immersed in water and allowed to saturate before placing them in the freeze apparatus and subjecting them to 25 freeze-thaw cycles. The material is dried and weighed after the final cycle, followed by a sieve analysis. The weighted average percent loss is calculated from the mass retained by each sieve size before and after the test.

The results are summarized in Table 5.3 and detailed results are presented in Appendix D2.

Table 5.3 Summary of Freeze-Thaw Test Results

Sample ID	Lithology	Weighted % Loss	
		Coarse Fraction	Fine Fraction
CL-01 & CL-02 Composite	Diorite	39.1	10.7
CL-03	Intrusive Breccia	0.9	6.0
CL-05	Patton Porphyry	2.1	9.8

NOTES:
1. The coarse fraction constitutes material retained on No.4 sieve, the fine fraction passes the No.4 sieve (4.75 mm).

The test results indicate Diorite ore is significantly more susceptible to frost degradation than Intrusive Breccia and Patton Porphyry. Degradation of the ore may lead to a finer gradation with a corresponding lower hydraulic conductivity. Seasonal variations in temperature are the primary source of repeated freeze-thaw cycles, which effects extend to the maximum depth of frost penetration. It is recommended to cover the Diorite ore with a sufficient thickness of durable ore or rock fill to protect it from seasonal freeze-thaw action.

6 – CONCLUSIONS

The leach ore samples are generally competent and exhibit minor particle breakage under loading. The leach column testing has not affected the gradation and hydraulic conductivity of the Intrusive Breccia and Patton Porphyry ore. The Diorite ore sample is most susceptible to crushing under load, and exhibits a lower hydraulic conductivity after leaching at the highest stress level (2720 kPa). This may be caused by deterioration of this type of ore due to the leaching process. The Diorite ore has also the lowest saturated hydraulic conductivity and is susceptible to frost degradation, and is therefore considered the ore type with the least favourable geotechnical properties.

The gradations of Intrusive Breccia and Patton Porphyry samples are similar and show little variation. These samples are predominantly gravel, with about 5 to 15 % sand and less than 4% fines (silt and clay). The Diorite samples are finer grained and show more variability, which is likely caused by the weaker nature of this material. The Diorite samples are classified as sandy gravels to sands and gravels with trace (less than 10%) silt and clay. The samples are classified as non-plastic, suggesting no significant amounts of clay minerals have developed during the leach column testing.

Laboratory test results indicate the saturated hydraulic conductivities of Patton Porphyry and Intrusive Breccia ore samples are approximately 1,000 times the design solution application rate. The saturated hydraulic conductivity of Diorite ore ranges from about 30 to 1,000 times the application rate. The Diorite ore has the highest potential to saturate during operations if degradation has occurred and the ore is subjected to high confining stresses.

The tested leach ore samples are characterized by an effective friction angle of 39 degrees or higher and zero cohesion for large strain conditions. The leach ore samples do not show significant loss of strength beyond the peak strength, except for sample CL-05 (Patton Porphyry) which exhibits a post-peak strength reduction of about 10%.

The leach ores are relatively insensitive to weathering due to repeated drying and wetting, and have a very high slake durability classification according to Gamble’s classification system. Comparison of the photos before and after the test also indicate the retained rock fragments remain virtually unchanged.

The freeze-thaw durability test results indicate Diorite ore is considerably more susceptible to frost degradation than Intrusive Breccia and Patton Porphyry. Degradation of the ore may lead to a finer gradation with a corresponding lower hydraulic conductivity.

7 – RECOMMENDATIONS

Results of the Atterberg limit tests and particle size analyses indicate that the leach column testing has not lead to significant degradation of the ore samples. However, the samples are subjected to leaching conditions for a limited time only during the leach column tests. It is recommended to study the mineralogy of the various types of ore to assess the potential effects of long term exposure to leaching conditions.

It is recommended to selectively place the most durable and permeable Patton Porphyry and Intrusive Breccia ores in the parts of the heap subjected to the highest stresses to reduce the potential for saturation of the ore. Agglomeration may further improve the hydraulic performance of the heap.

It is recommended to cover the Diorite ore with a sufficient thickness of durable ore or rock fill to protect it from seasonal freeze-thaw action.

8 – REFERENCES

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9 – CERTIFICATION

This report was prepared and reviewed by the undersigned.

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APPENDIX A

INDEX TEST RESULTS

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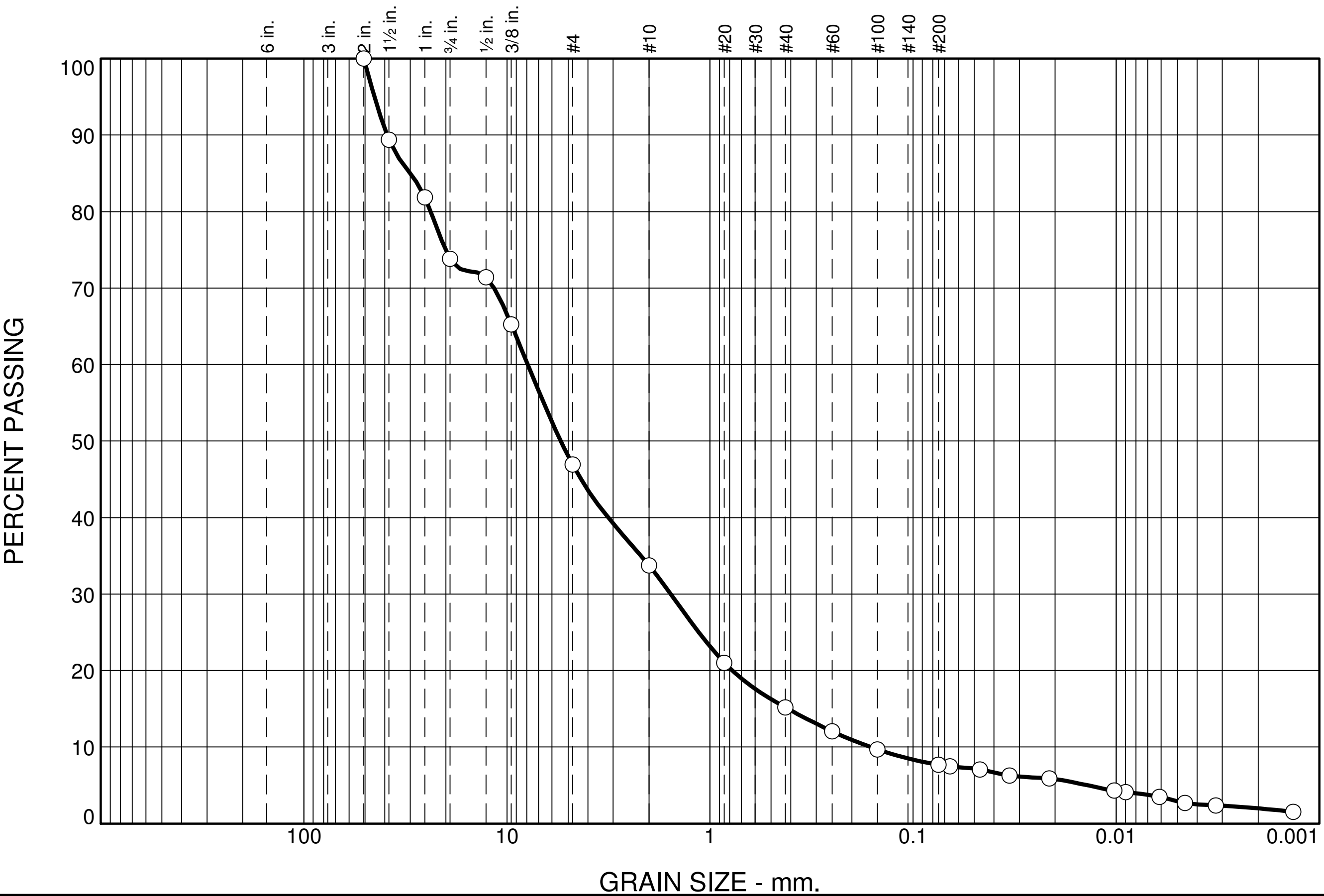
Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	26.2	26.9	13.1	18.6	7.5	5.7	2.0

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
2	100.0		
1.5	89.4		
1	81.9		
.75	73.8		
.5	71.4		
.375	65.2		
#4	46.9		
#10	33.8		
#20	21.0		
#40	15.2		
#60	12.0		
#100	9.7		
#200	7.7		
0.0658 mm.	7.5		
0.0468 mm.	7.1		
0.0335 mm.	6.3		
0.0213 mm.	5.9		
0.0102 mm.	4.3		
0.0090 mm.	4.1		
0.0061 mm.	3.5		
0.0046 mm.	2.7		
0.0032 mm.	2.4		
0.0013 mm.	1.5		

* (no specification provided)

Soil Description

well-graded gravel with silt and sand

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{90}= 38.9362 D_{85}= 29.9643 D_{60}= 7.8963
D_{50}= 5.4337 D_{30}= 1.5618 D_{15}= 0.4124
D_{10}= 0.1617 C_u= 48.84 C_c= 1.91

Classification

USCS= GW-GM AASHTO= A-1-a

Remarks

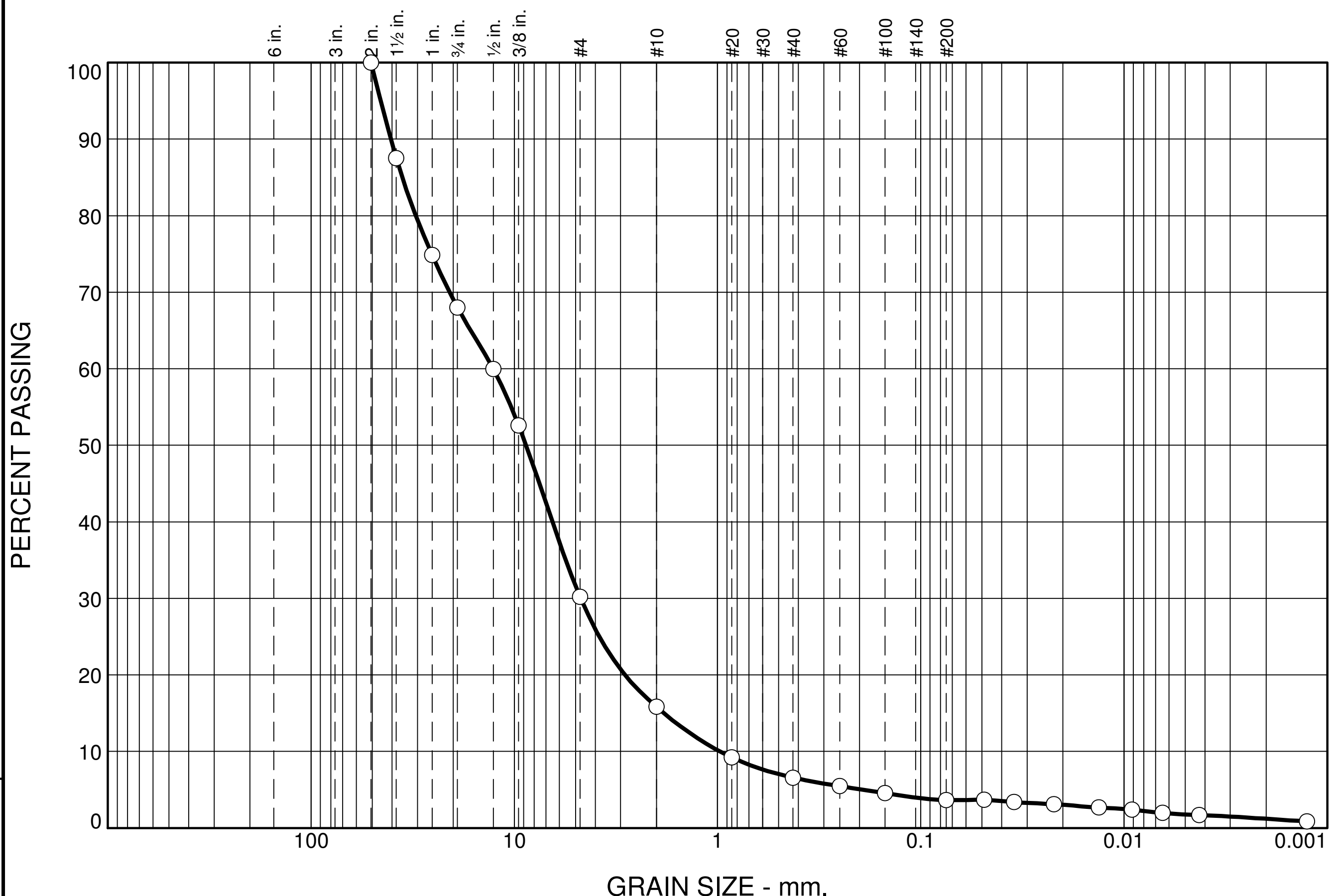
Sample No.: CL-01 **Source of Sample:** **Date:** 10/10/14
Location: **Elev./Depth:**

Knight Piésold CONSULTING

Client:
Project: Casino
Project No: VA101-325/18 **Figure**

The USCS classification pertains only to the portion of sample that passes the 3" sieve as per ASTM D2487.

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	32.0	37.8	14.4	9.2	3.0	2.4	1.2

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
2	100.0		
1.5	87.5		
1	74.9		
.75	68.0		
.5	60.0		
.375	52.6		
#4	30.2		
#10	15.8		
#20	9.2		
#40	6.6		
#60	5.5		
#100	4.6		
#200	3.6		
0.0488 mm.	3.7		
0.0347 mm.	3.4		
0.0221 mm.	3.1		
0.0133 mm.	2.7		
0.0091 mm.	2.4		
0.0065 mm.	2.0		
0.0043 mm.	1.7		
0.0013 mm.	0.9		

* (no specification provided)

Soil Description

well-graded gravel with sand

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{90}= 40.5213 D_{85}= 35.5861 D_{60}= 12.7234
D_{50}= 8.7504 D_{30}= 4.7137 D_{15}= 1.8377
D_{10}= 0.9733 C_u= 13.07 C_c= 1.79

Classification

USCS= GW AASHTO= A-1-a

Remarks

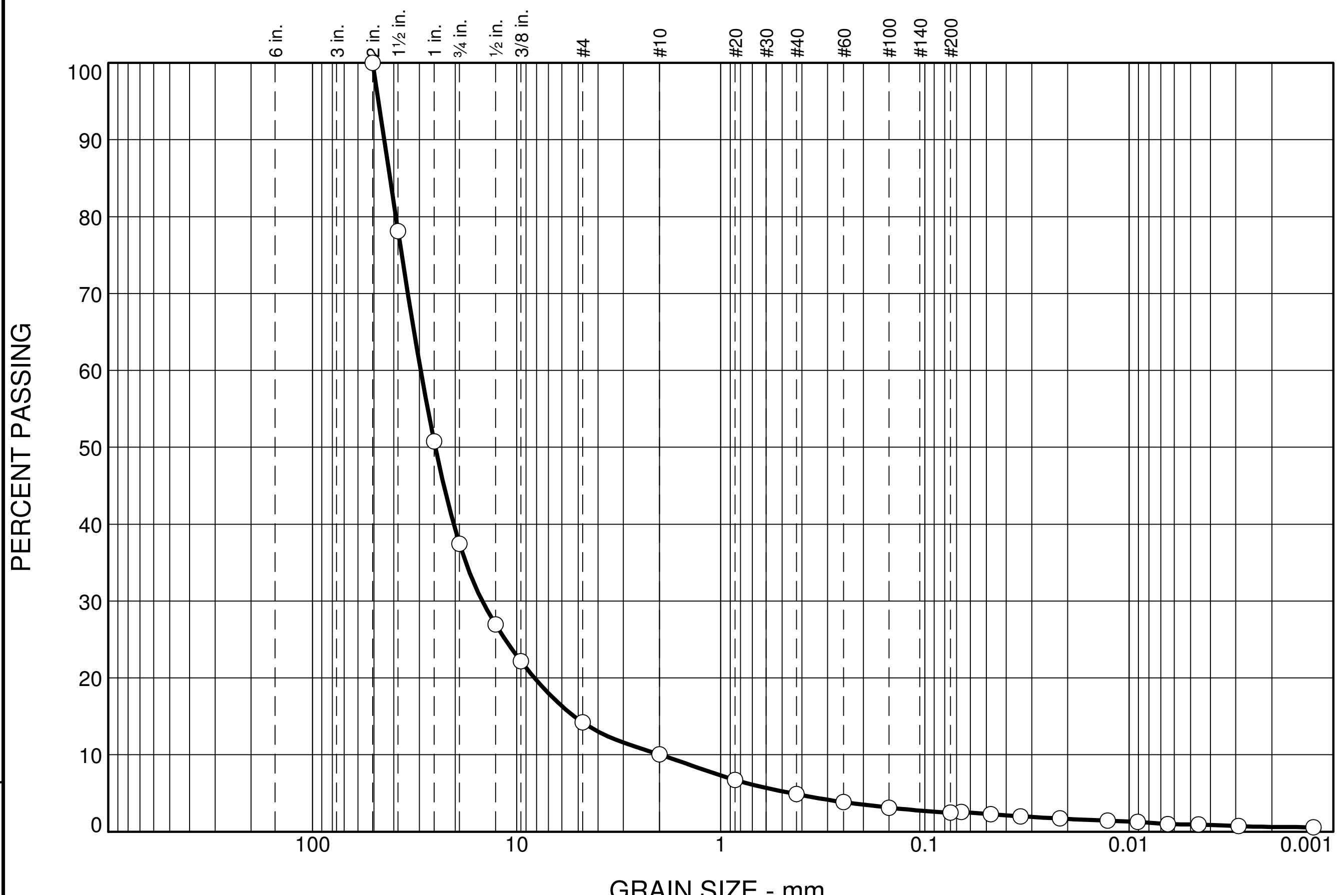
Sample No.: CL-02 **Source of Sample:** **Date:** 10/10/14
Location: **Elev./Depth:**

Knight Piésold CONSULTING

Client:
Project: Casino
Project No: VA101-325/18 **Figure**

The USCS classification pertains only to the portion of sample that passes the 3" sieve as per ASTM D2487.

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	62.6	23.2	4.1	5.2	2.4	1.9	0.6

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
2	100.0		
1.5	78.1		
1	50.8		
.75	37.4		
.5	26.9		
.375	22.2		
#4	14.2		
#10	10.1		
#20	6.7		
#40	4.9		
#60	3.8		
#100	3.1		
#200	2.5		
0.0663 mm.	2.6		
0.0475 mm.	2.3		
0.0340 mm.	2.0		
0.0218 mm.	1.7		
0.0127 mm.	1.4		
0.0091 mm.	1.3		
0.0065 mm.	1.0		
0.0046 mm.	0.9		
0.0029 mm.	0.7		
0.0012 mm.	0.6		

* (no specification provided)

Soil Description

poorly graded gravel

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{90}= 44.5896 D_{85}= 41.7534 D_{60}= 29.5082
D_{50}= 25.0468 D_{30}= 14.7346 D_{15}= 5.2171
D_{10}= 1.9719 C_u= 14.96 C_c= 3.73

Classification

USCS= GP AASHTO= A-1-a

Remarks

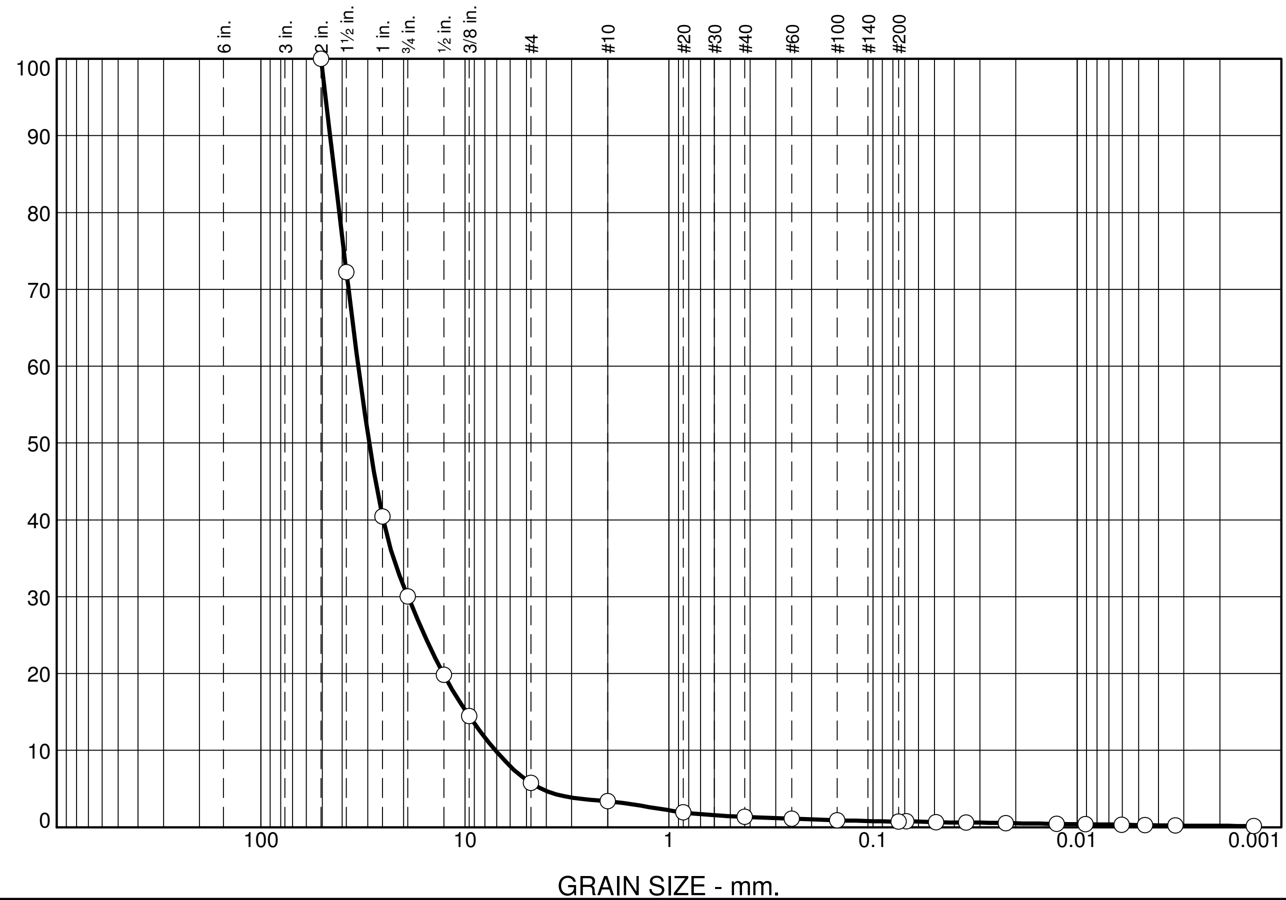
Sample No.: CL-03 **Source of Sample:** **Date:** 10/10/14
Location: **Elev./Depth:**

Knight Piésold CONSULTING

Client:
Project: Casino
Project No: VA101-325/18 **Figure**

The USCS classification pertains only to the portion of sample that passes the 3" sieve as per ASTM D2487.

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	70.0	24.2	2.4	2.1	0.6	0.5	0.2

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
2	100.0		
1.5	72.3		
1	40.4		
.75	30.0		
.5	19.8		
.375	14.5		
#4	5.8		
#10	3.4		
#20	1.9		
#40	1.3		
#60	1.1		
#100	0.9		
#200	0.7		
0.0687 mm.	0.8		
0.0492 mm.	0.7		
0.0350 mm.	0.6		
0.0224 mm.	0.5		
0.0126 mm.	0.4		
0.0091 mm.	0.4		
0.0061 mm.	0.3		
0.0046 mm.	0.3		
0.0033 mm.	0.2		
0.0014 mm.	0.2		

* (no specification provided)

Soil Description

well-graded gravel

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{90}= 45.8518 D_{85}= 43.5475 D_{60}= 33.3009
D_{50}= 29.4515 D_{30}= 19.0180 D_{15}= 9.8363
D_{10}= 7.0912 C_u= 4.70 C_c= 1.53

Classification

USCS= GW AASHTO= A-1-a

Remarks

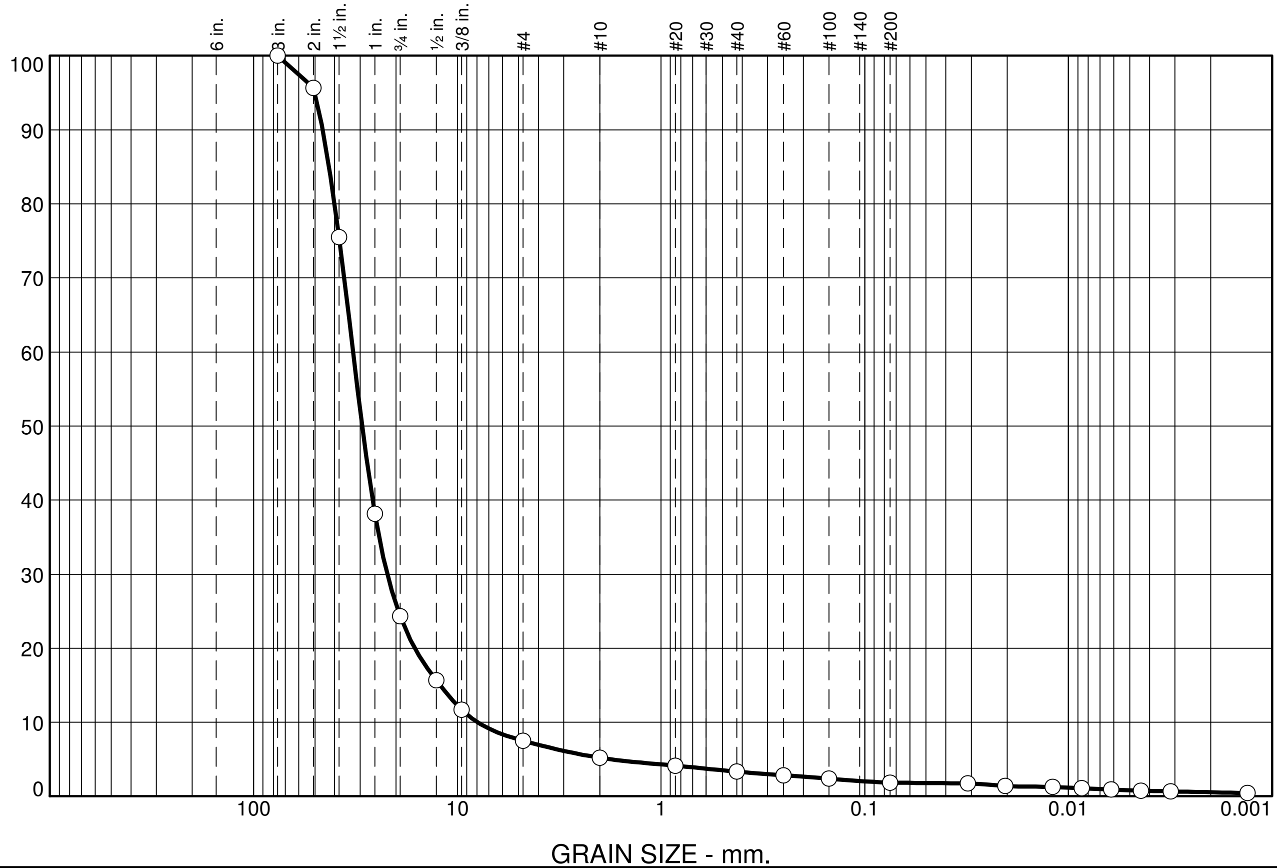
Sample No.: CL-04 **Source of Sample:** **Date:** 10/10/14
Location: **Elev./Depth:**

Knight Piésold CONSULTING

Client:
Project: Casino
Project No: VA101-325/18 **Figure**

The USCS classification pertains only to the portion of sample that passes the 3" sieve as per ASTM D2487.

Particle Size Distribution Report



The USCS classification pertains only to the portion of sample that passes the 3" sieve as per ASTM D2487.

% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	75.7	16.8	2.3	1.9	1.5	1.3	0.5

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3	100.0		
2	95.7		
1.5	75.5		
1	38.1		
.75	24.3		
.5	15.7		
.375	11.7		
#4	7.5		
#10	5.2		
#20	4.1		
#40	3.3		
#60	2.8		
#100	2.4		
#200	1.8		
0.0312 mm.	1.7		
0.0204 mm.	1.4		
0.0120 mm.	1.3		
0.0086 mm.	1.1		
0.0062 mm.	0.9		
0.0044 mm.	0.8		
0.0032 mm.	0.7		
0.0013 mm.	0.4		

* (no specification provided)

Soil Description

poorly graded gravel

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{90}= 45.7387 D_{85}= 42.6223 D_{60}= 32.4684
D_{50}= 29.2774 D_{30}= 22.0948 D_{15}= 12.1569
D_{10}= 7.9476 C_u= 4.09 C_c= 1.89

Classification

USCS= GW AASHTO= A-1-a

Remarks

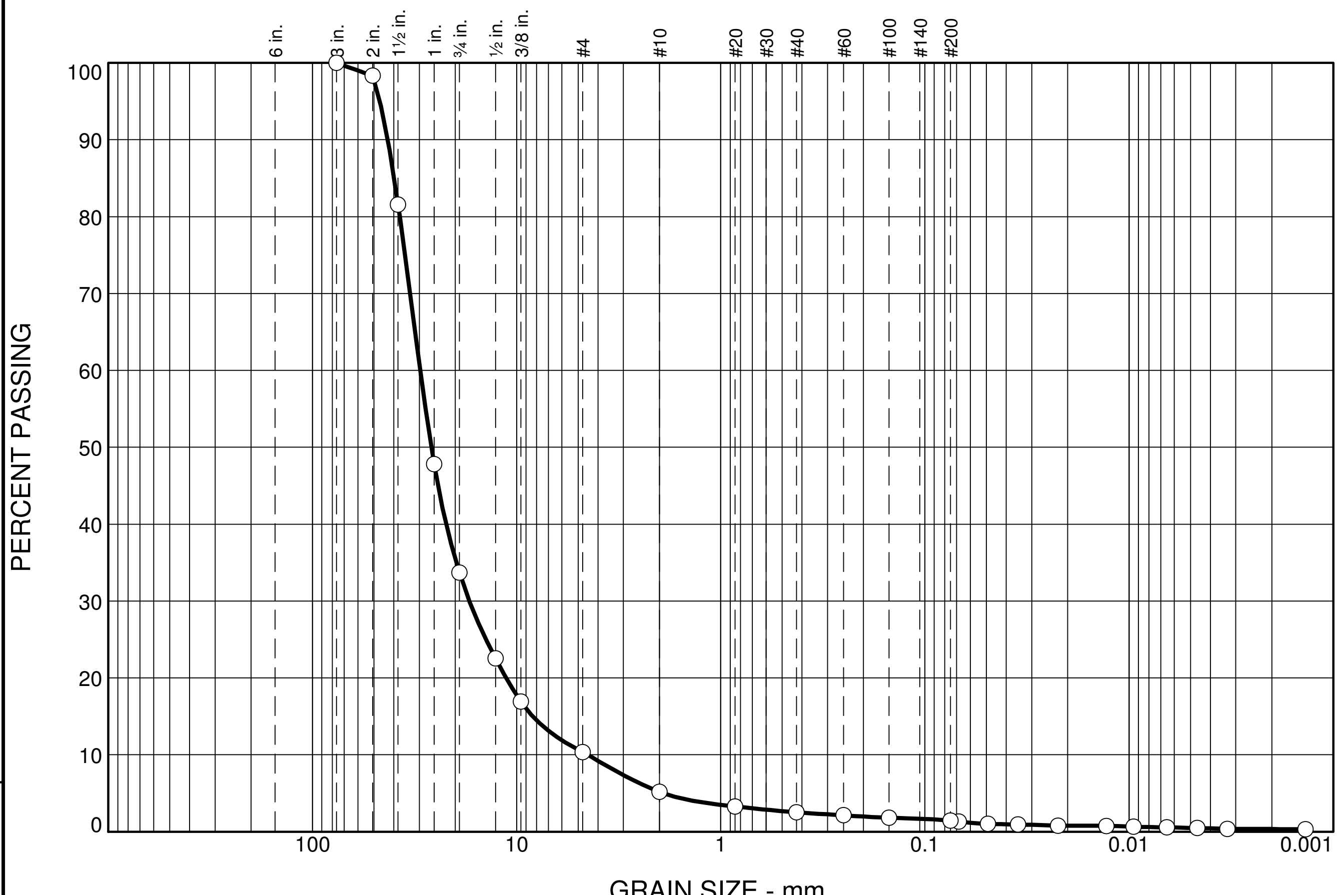
Sample No.: CL-05 **Source of Sample:** **Date:** 10/10/14
Location: **Elev./Depth:**

Knight Piésold CONSULTING

Client:
Project: Casino
Project No: VA101-325/18 **Figure**

Tested By: DAB **Checked By:** JDB

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	66.3	23.3	5.2	2.7	1.1	1.1	0.3

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3	100.0		
2	98.3		
1.5	81.6		
1	47.8		
.75	33.7		
.5	22.5		
.375	16.9		
#4	10.4		
#10	5.2		
#20	3.3		
#40	2.5		
#60	2.1		
#100	1.8		
#200	1.4		
0.0682 mm.	1.3		
0.0492 mm.	1.0		
0.0350 mm.	0.9		
0.0223 mm.	0.8		
0.0129 mm.	0.7		
0.0095 mm.	0.7		
0.0065 mm.	0.6		
0.0046 mm.	0.5		
0.0033 mm.	0.4		
0.0014 mm.	0.3		

* (no specification provided)

Soil Description

well-graded gravel

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{90}= 42.8474 D_{85}= 39.8455 D_{60}= 29.6698
D_{50}= 26.1968 D_{30}= 17.0291 D_{15}= 8.3278
D_{10}= 4.4956 C_u= 6.60 C_c= 2.17

Classification

USCS= GW AASHTO= A-1-a

Remarks

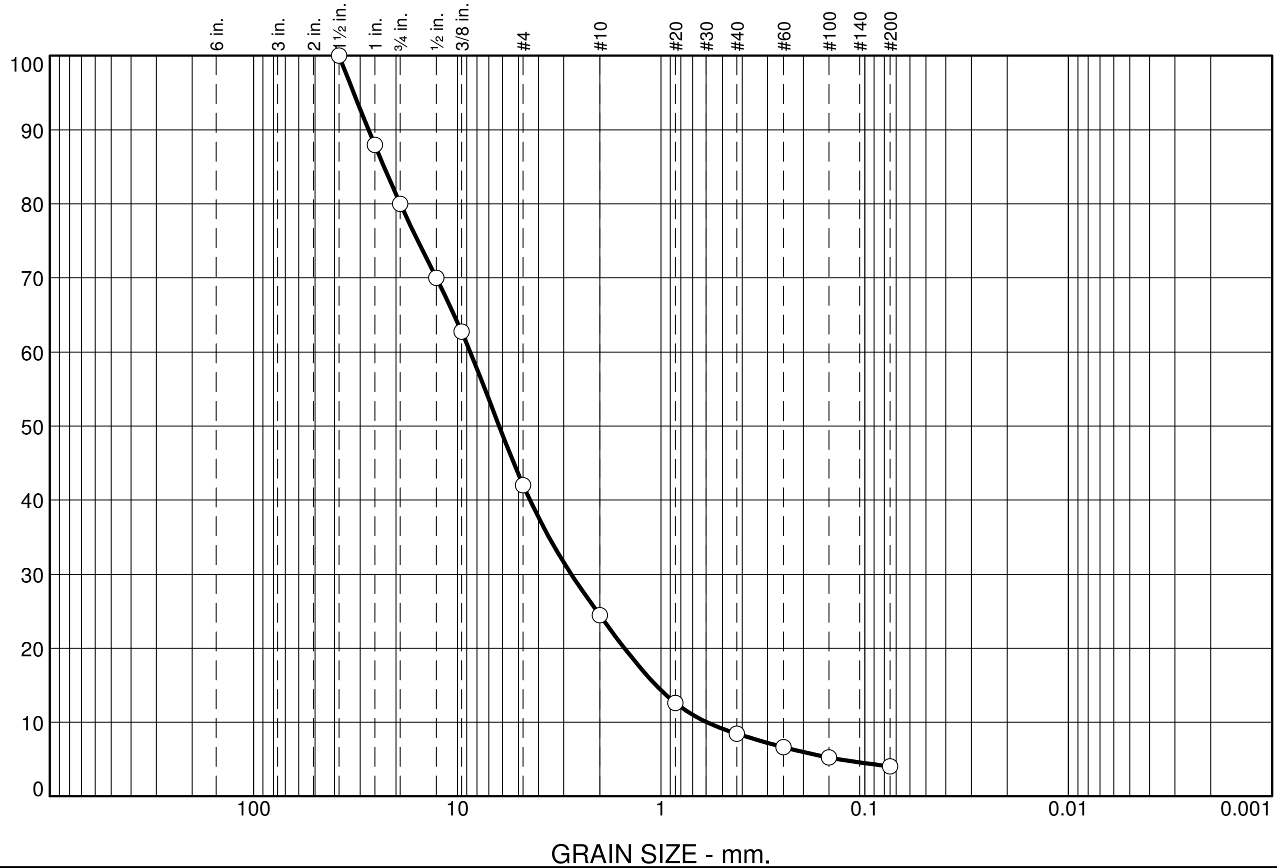
Sample No.: CL-06 **Source of Sample:** **Date:** 10/10/14
Location: **Elev./Depth:**

Knight Piésold CONSULTING

Client:
Project: Casino
Project No: VA101-325/18 **Figure**

The USCS classification pertains only to the portion of sample that passes the 3" sieve as per ASTM D2487.

Particle Size Distribution Report



The USCS classification pertains only to the portion of sample that passes the 3" sieve as per ASTM D2487.

% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	20.0	38.0	17.5	16.0	4.5	4.0	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1.5	100.0		
1	87.9		
.75	80.0		
.5	70.0		
.375	62.7		
#4	42.0		
#10	24.5		
#20	12.6		
#40	8.5		
#60	6.6		
#100	5.2		
#200	4.0		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 27.2670 D_{85}= 22.9003 D_{60}= 8.6495
D_{50}= 6.2361 D_{30}= 2.7585 D_{15}= 1.0573
D_{10}= 0.5955 C_u= 14.52 C_c= 1.48

Classification

USCS= GW AASHTO=

Remarks

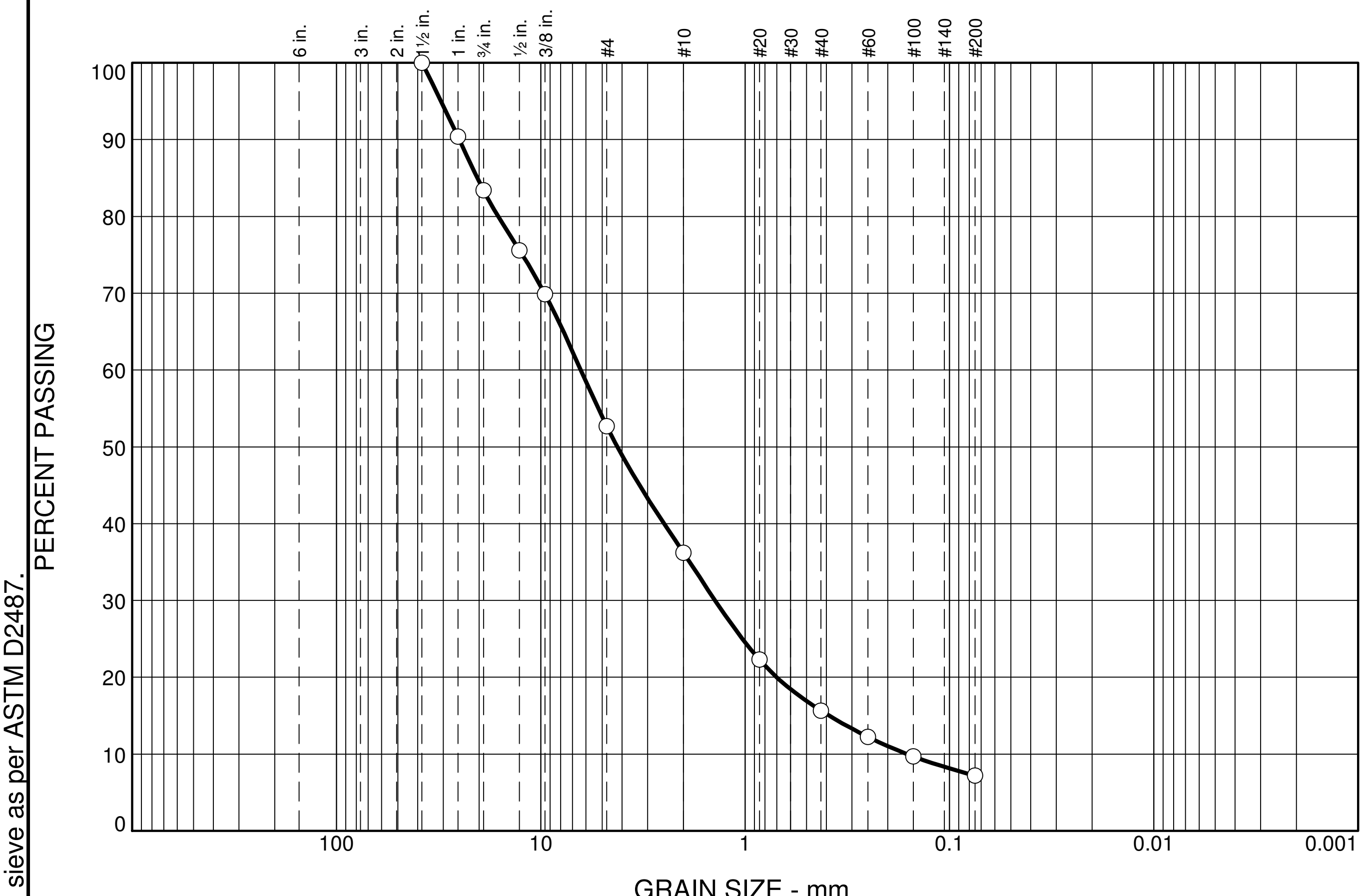
Sample No.: CL-01&CL-02 Blend **Source of Sample:** **Date:** 10/28/14
Location: **Elev./Depth:**

Knight Piésold CONSULTING

Client:
Project: Casino
Project No: VA101-325/18 **Figure**

Tested By: DAB **Checked By:** JDB

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	16.6	30.7	16.5	20.5	8.5	7.2	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1.5	100.0		
1	90.4		
.75	83.4		
.5	75.6		
.375	69.9		
#4	52.7		
#10	36.2		
#20	22.3		
#40	15.7		
#60	12.2		
#100	9.7		
#200	7.2		

* (no specification provided)

Material Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 20.4353 D_{60}= 6.3693 D_{50}= 4.2130
D_{30}= 1.4020 D_{15}= 0.3875 D_{10}= 0.1614
C_u= 39.45 C_c= 1.91

Classification

USCS= AASHTO=

Remarks

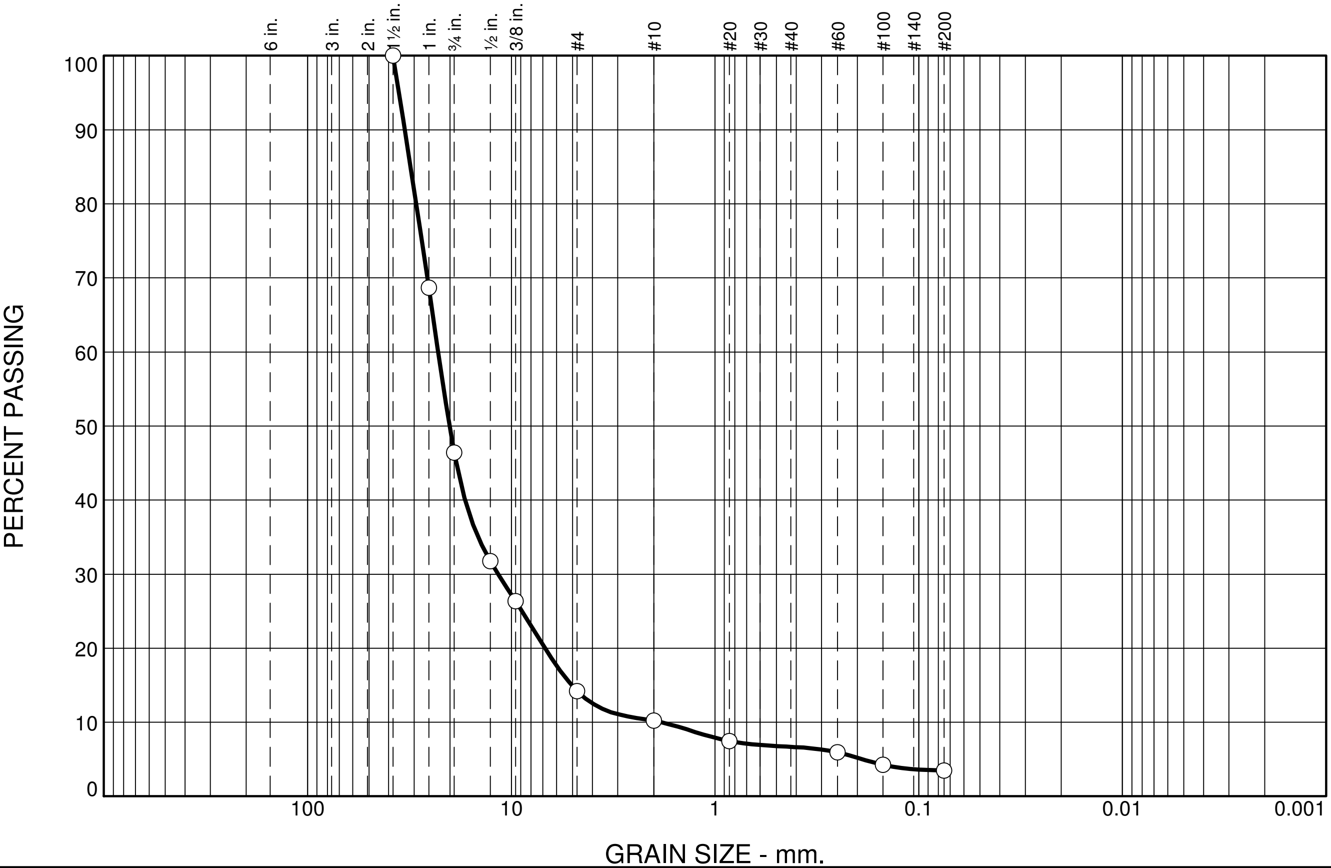
Sample No.: CL-01&02 Post Perm **Source of Sample:** **Date:** 10/31/14
Location: **Elev./Depth:**

The USCS classification pertains only to the portion of sample that passes the 3" sieve as per ASTM D2487.

Knight Piésold CONSULTING

Client: Casino Mining Corporation
Project: Casino
Project No: VA101-325/18 **Figure**

Particle Size Distribution Report



The USCS classification pertains only to the portion of sample that passes the 3" sieve as per ASTM D2487.

% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	53.6	32.1	4.1	3.5	3.2	3.5	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1.5	100.0		
1	68.7		
.75	46.4		
.5	31.8		
.375	26.3		
#4	14.2		
#10	10.2		
#20	7.5		
#60	5.9		
#100	4.3		
#200	3.5		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 33.3454 D_{85}= 31.2234 D_{60}= 22.8813
D_{50}= 20.1086 D_{30}= 11.6132 D_{15}= 5.0373
D_{10}= 1.8243 C_u= 12.54 C_c= 3.23

Classification

USCS= GP AASHTO=

Remarks

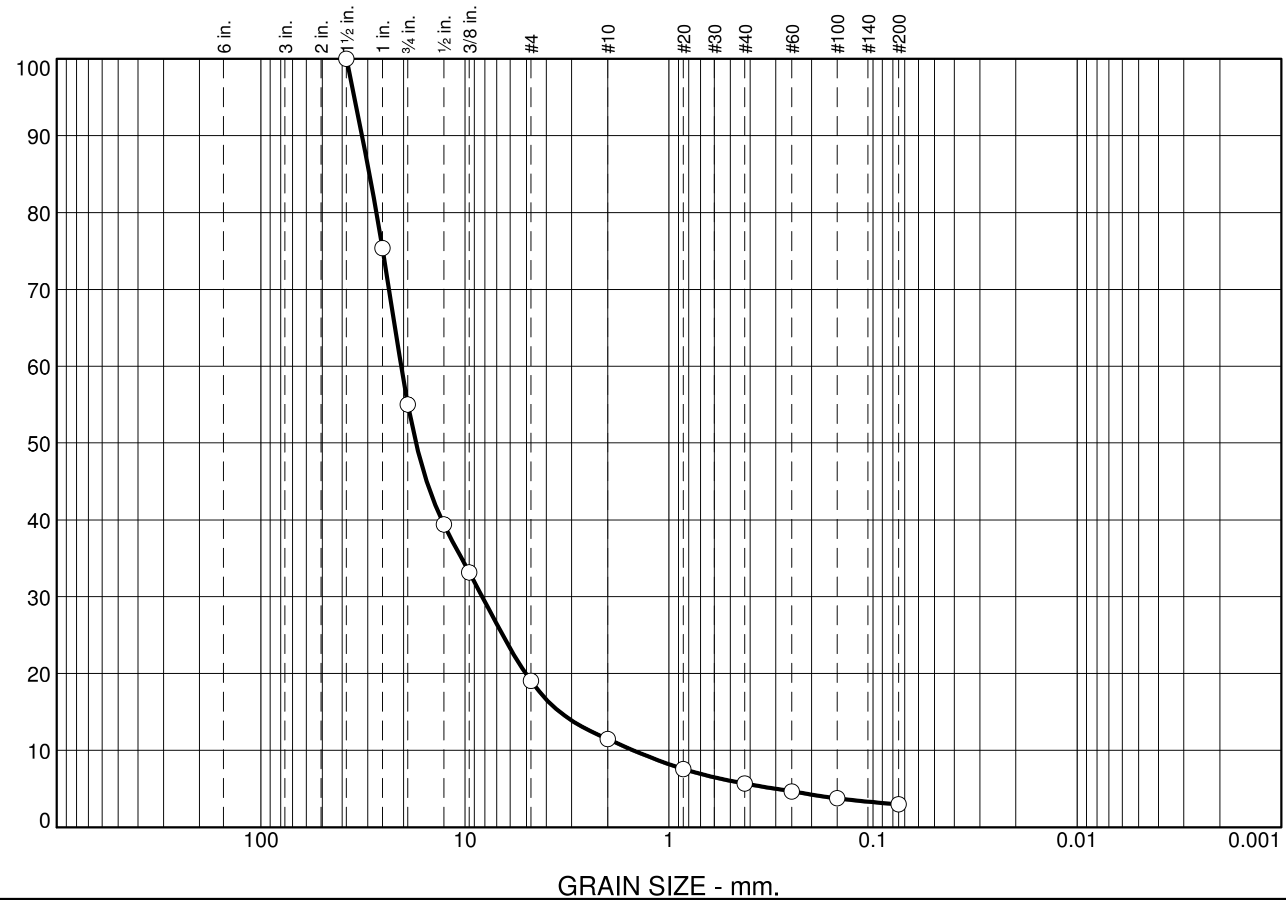
Sample No.: CL-03 Post Crushing **Source of Sample:** **Date:** 11/4/14
Location: **Elev./Depth:**

Knight Piésold CONSULTING

Client:
Project: Casino
Project No: VA101-325/18 **Figure**

Tested By: DAB **Checked By:** DAB

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	53.5	32.3	6.2	3.7	1.9	10.9	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1.5	100.0		
1	75.4		
.75	55.0		
.5	39.4		
.375	33.2		
#4	19.0		
#10	11.5		
#20	7.6		
#40	5.7		
#60	4.7		
#100	3.8		
#200	3.0		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 33.2184 D_{85}= 31.0622 D_{60}= 22.8136
D_{50}= 20.0829 D_{30}= 11.2053 D_{15}= 5.0972
D_{10}= 2.9172 C_u= 7.82 C_c= 1.89

Classification

USCS= GW AASHTO=

Remarks

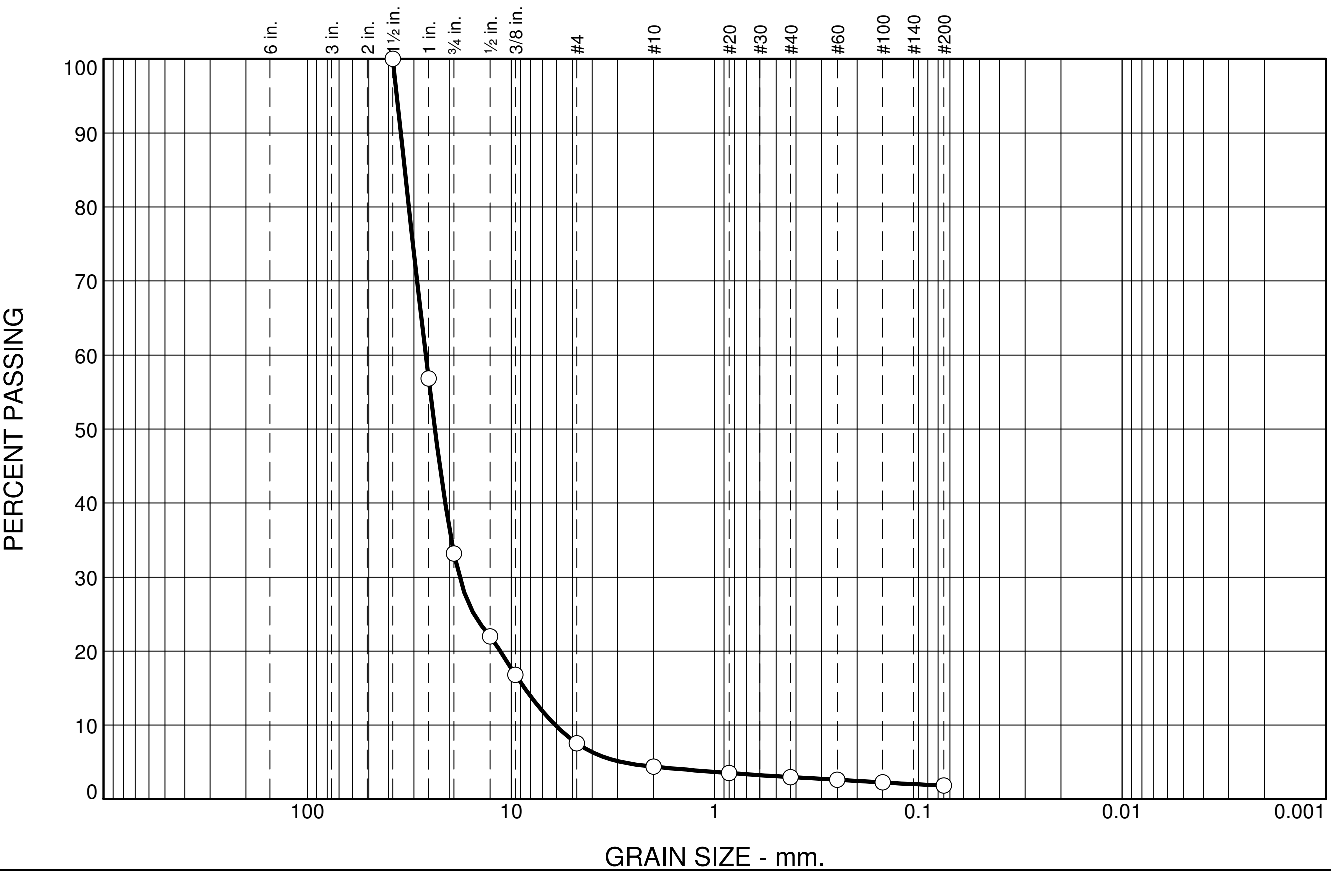
Sample No.: CL-03 Post Perm **Source of Sample:** **Date:** 11/8/14
Location: **Elev./Depth:**

The USCS classification pertains only to the portion of sample that passes the 3" sieve as per ASTM D2487.

Knight Piésold CONSULTING

Client: Casino Mining Corporation
Project: Casino
Project No: VA101-325/18 **Figure**

Particle Size Distribution Report



The USCS classification pertains only to the portion of sample that passes the 3" sieve as per ASTM D2487.

% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	66.8	25.4	3.3	1.4	1.2	1.9	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1.5	100.0		
1	56.8		
.75	33.2		
.5	22.0		
.375	16.8		
#4	7.5		
#10	4.4		
#20	3.5		
#40	3.0		
#60	2.6		
#100	2.2		
#200	1.8		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 34.7919 D_{85}= 33.2371 D_{60}= 26.2192
D_{50}= 23.6587 D_{30}= 17.8759 D_{15}= 8.5712
D_{10}= 5.9786 C_u= 4.39 C_c= 2.04

Classification

USCS= GW AASHTO=

Remarks

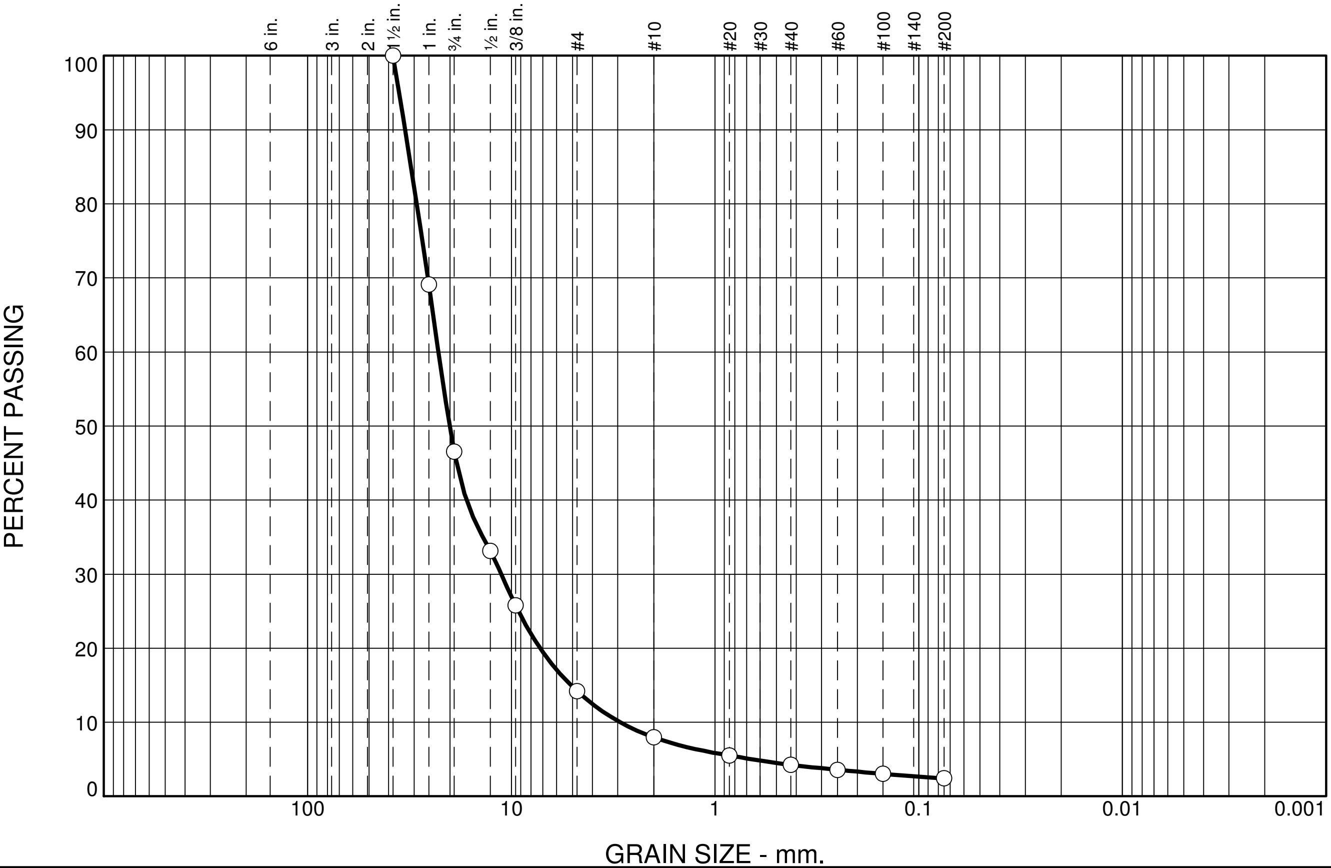
Sample No.: CL-05 Post Crushing **Source of Sample:** **Date:** 11/4/14
Location: **Elev./Depth:**

Knight Piésold CONSULTING

Client:
Project: Casino
Project No: VA101-325/18 **Figure**

Tested By: DAB **Checked By:** DAB

Particle Size Distribution Report



The USCS classification pertains only to the portion of sample that passes the 3" sieve as per ASTM D2487.

% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	53.5	32.3	6.2	3.7	1.9	2.4	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1.5	100.0		
1	69.1		
.75	46.5		
.5	33.1		
.375	25.8		
#4	14.2		
#10	8.0		
#20	5.5		
#40	4.3		
#60	3.6		
#100	3.0		
#200	2.4		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 33.2184 D_{85}= 31.0622 D_{60}= 22.8136
D_{50}= 20.0829 D_{30}= 11.2053 D_{15}= 5.0972
D_{10}= 2.9172 C_u= 7.82 C_c= 1.89

Classification

USCS= GW AASHTO=

Remarks

Sample No.: CL-05 Post Perm **Source of Sample:** **Date:** 11/10/14
Location: **Elev./Depth:**

Knight Piésold CONSULTING

Client: Casino Mining Corporation
Project: Casino
Project No: VA101-325/18 **Figure**

Tested By: DAB **Checked By:** JDB

Knight Piésold
CONSULTING

Specific Gravity - Soil
ASTM D 854-10

Project	Casino	**Project No.**	VA101-325/18
Date Staged	10/15/2014	**Act. Code**	
Date Completed	10/16/2014	**Lab No.**	L2014-099
Tested By	JHK	**Checked By**	JDB

Sample No.	CL-02		CL-04		CL-06					
Sample Prep. Method A or B										
Flask No.										
1) Wt. of Flask + Soil										
2) Wt. of Flask										
3) Wt. of Soil (1-2)	82.63		78.66		82.37					
4) Calibrated Wt. of Flask + Water	342.36		343.74		352.55					
5) #3 + #4	424.99		422.40		434.92					
6) Wt. of Flask + Water + Soil	394.82		393.44		405.02					
7) Volume of Soil (5 - 6)	30.17		28.96		29.90					
8) Test Temperature, deg. C	20.4		20.6		20.3					
9) Temperature Correction, k	0.999912		0.999870		0.999934					
10) Specific Gravity @ 20 deg.C ((3 / 7) * k)	2.739		2.716		2.755					
Reported Average, G_s @ 20 deg.C	2.739		2.716		2.755					
Tare										
Dry Soil + tare, g	214.05		196.65		200.14					
Tare, g	131.42		117.99		117.77					

General Notes: Line 9, k, is determined by dividing the density of water at test temperature recorded, by the density of water at 20 deg. C.

Sample prep Method A: wet preparation

Sample prep Method B: dry preparation

Knight Piésold CONSULTING

Specific Gravity - Coarse Aggregate

ASTM C 127

Project	Casino	Project No.	VA101-325/18
Lab No.	L2014-099	Date of Test	10/15/2014
Tested By	DAB	Checked By	JDB

Run by / Date					
Sample No./ Depth	CL-02	CL-04	CL-06		
Sample Description	Plus No.4	Plus No. 4	Plus No. 4		
No. of +3 in. pcs.	0	0	0		
Tare No.	Dancers	69	3Kings		
Saturated Surface Dry Aggregate + Tare	3804.1	5059.8	3820.6		
Dry Aggregate + Tare	3666.1	4923.0	3713.9		
Tare	348.3	351.1	228.8		
Saturated Surface Dry Aggregate (B)	3455.8	4708.7	3591.8		
Dry Aggregate (A)	3317.8	4571.9	3485.1		
Basket Submerged					
Saturated Aggregate Submerged (C)	2101.7	2869.6	2190		
Temperature of Water	23	23	23		
Correction Factor	1	1	1		
Apparent Specific Gravity (A / (A-C))	2.73	2.69	2.69		
Bulk Specific Gravity , SSD (B / (B-C))	2.55	2.56	2.56		
Bulk Specific Gravity (A / (B-C))	2.45	2.49	2.49		
Absorption (%)	4.16	2.99	3.06		
Percent Retained #4	69.8	94.2	89.6		
Percent Passing #4	30.2	5.8	10.4		
Gs of Aggregate Passing #4	2.739	2.716	2.755		
Weighted Average Specific Gravity	2.731	2.687	2.698		

Remarks:

APPENDIX B

SATURATED HYDRAULIC CONDUCTIVITY TEST RESULTS

(Pages B-1 to B-7)

Knight Piésold CONSULTING

TABLE B.1

CASINO MINING CORPORATION
CASINO PROJECT

2014 AND 2015 GEOTECHNICAL TESTING OF LEACH ORE
SATURATED HYDRAULIC CONDUCTIVITY TESTING

Print Sep/23/15 15:00:42

Sample ID	Laboratory	Normal Stress	Dry Density	K_s	$K_{s,head\ corrected}$
		(kPa)	(tonne/m^3)	(cm/s)	(cm/s)
CL-01 & CL-02	KP Denver (8-inch cell)	200	1.75	2.0E-01	2.9E-01
CL-01 & CL-02	KP Denver (8-inch cell)	800	1.80	1.4E-01	1.8E-01
CL-01 & CL-02	KP Denver (8-inch cell)	2720	2.02	9.6E-03	9.6E-03
CL-03	KP Denver (8-inch cell)	200	1.41	4.2E-01	9.2E-01
CL-03	KP Denver (8-inch cell)	800	1.52	4.0E-01	9.0E-01
CL-03	KP Denver (8-inch cell)	2720	1.69	2.9E-01	5.2E-01
CL-05	KP Denver (8-inch cell)	200	1.38	5.3E-01	1.6E+00
CL-05	KP Denver (8-inch cell)	800	1.49	4.6E-01	1.2E+00
CL-05	KP Denver (8-inch cell)	2720	1.69	3.6E-01	8.3E-01

\\VAN11\Prj_file\1\01\00325\18\A\Report\1 - 2014&2015 Geotechnical Laboratory Testing of Leach Ore\Rev 0\Appendix B\[App. B Constant Head Permeability.xlsx]Summary (2014 All)

NOTES:

1. No oversize correction applied.
4. K_{sat} = saturated hydraulic conductivity, not corrected for head loss in testing apparatus.
5. $K_{sat,head\ corrected}$ = saturated hydraulic conductivity, corrected for head loss in testing apparatus.
6. Head loss correction based on Trial 1.

0	24SEP'15	ISSUED WITH REPORT VA101-325/18-1	SB	LJG	LJG
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D

Knight Piésold CONSULTING

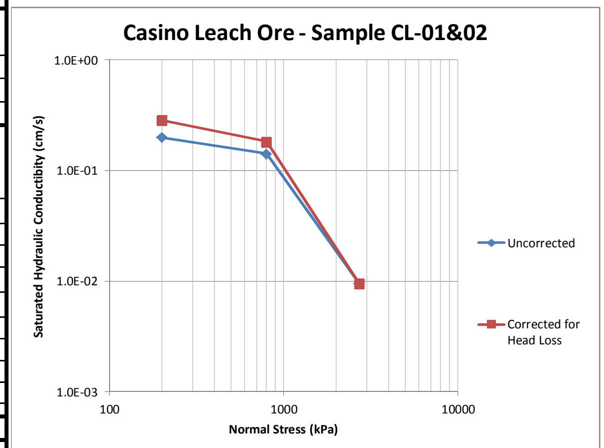
Constant Head Permeability
USBR 5605 - Amended

Project	*Casino*	*Project No.*	*VA101-326/18*
Lab No.	*L2014-099*	*Date of Test*	*10/29/18*
Sample No.	*Blend CL-01 & CL-02*	*Tested By*	*DAB*
	Crushed to minus 1.5"	*Checked By*	*JDB*

Specimen Data

Target Dry Density, pcf	NA	Wet Sample Wt. + Tare, lbs.	19.125
Target Density, t/m^3	NA	Tare, lbs.	0.000
Moisture Content, %	7.1	Wet Sample Wt., lbs.	19.125
Mold Diameter, in.	8.02	Sample Length, in.	6.820
Mold Area, in.^{2}	50.52	Sample Volume, in.^{3}	344.5
Mold Area, ft^2	0.3508	Sample Volume, ft^3	0.1994
Depth to Mold Bottom, in.	8.747	Wet Density, pcf	95.9
		Initial Depth to Plate, in.	1.927

Normal Stress Range, kPa 200 800 2720



Permeability Trial Data

Normal Stress, kPa 200 | Head, cm 1.5
Avg. Depth to Plate, in. 3.140 | Consolidated Length, in. 5.607 | Wet Density, pcf 116.7

Head Loss Correction

Trial No.	Q cc	Time sec	Flow cc/sec	Permeability k, cm/sec	Head Loss cm	Corrected Head cm	Permeability k, cm/sec
1	91.8	13.66	6.720	2.0E-01	0.45095	1.04905	0.27992
2	91.8	13.40	6.851	2.0E-01	0.45907	1.04093	0.28757
3	91.8	13.34	6.882	2.0E-01	0.46098	1.03902	0.28940
4	91.8	13.32	6.892	2.0E-01	0.46162	1.03838	0.29001
5	91.8	13.31	6.897	2.0E-01	0.46194	1.03806	0.29032
Averages			6.848	2.0E-01	0.45891	1.04109	0.28744

Permeability Trial Data

Normal Stress, kPa 800 | Head, cm 1.6
Avg. Depth to Plate, in. 3.310 | Consolidated Length, in. 5.437 | Wet Density, pcf 120.3

Trial No.	Q cc	Time sec	Flow cc/sec	Permeability k, cm/sec	Head Loss cm	Corrected Head cm	Permeability k, cm/sec
1	91.8	17.25	5.322	1.4E-01	0.36041	1.23959	0.18190
2	91.8	17.28	5.313	1.4E-01	0.35979	1.24021	0.18150
3	91.8	17.00	5.400	1.4E-01	0.36564	1.23436	0.18536
4	91.8	17.22	5.331	1.4E-01	0.36103	1.23897	0.18231
5	91.8	17.06	5.381	1.4E-01	0.36438	1.23562	0.18452
Averages			5.349	1.4E-01	0.362252016	1.237747984	0.183116586

Permeability Trial Data

Normal Stress, kPa 2720 | Head, cm 1.8
Avg. Depth to Plate, in. 3.910 | Consolidated Length, in. 4.837 | Wet Density, pcf 135.2

Trial No.	Q cc	Time sec	Flow cc/sec	Permeability k, cm/sec	Head Loss cm	Corrected Head cm	Permeability k, cm/sec
1	27.54	60.0	0.459	9.6E-03	-0.00308	1.80308	0.00960
2	27.54	60.0	0.459	9.6E-03	-0.00308	1.80308	0.00960
3	27.54	60.0	0.459	9.6E-03	-0.00308	1.80308	0.00960
4	27.54	60.0	0.459	9.6E-03	-0.00308	1.80308	0.00960
5	27.54	60.0	0.459	9.6E-03	-0.00308	1.80308	0.00960
Averages			0.459	9.6E-03	-0.00308	1.80308	0.00960

General Notes:

1) Tap water was used as permeant.
2) Flow conditions may vary depending on the particle distribution in the field.
3) The sample was placed in the mold in a loose condition.
4) Particles larger than 1.5" were crushed and added back to the blend prior to testing.

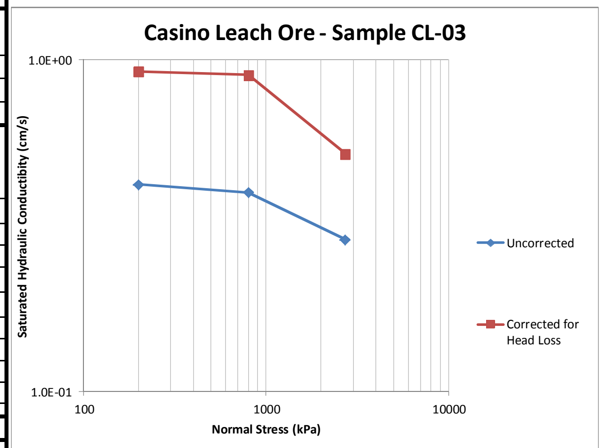
Knight Piésold CONSULTING

Constant Head Permeability
USBR 5605 - Amended

Project	*Casino*	*Project No.*	*VA101-326/18*
Lab No.	*L2014-099*	*Date of Test*	*11/06/14*
Sample No.	*CL-03*	*Tested By*	*DAB*
	Crushed to minus 1.5"	*Checked By*	*JDB*

Specimen Data

Target Dry Density, pcf	NA	Wet Sample Wt. + Tare, lbs.	18.272
Target Density, t/m^3	NA	Tare, lbs.	0.000
Moisture Content, %	6.4	Wet Sample Wt., lbs.	18.272
Mold Diameter, in.	8.02	Sample Length, in.	6.927
Mold Area, in.^{2}	50.52	Sample Volume, in.^{3}	349.9
Mold Area, ft^2	0.3508	Sample Volume, ft^3	0.2025
Depth to Mold Bottom, in.	8.700	Wet Density, pcf	90.2
		Initial Depth to Plate, in.	1.773
Normal Stress Range, kPa	200 800 2720		



Permeability Trial Data

Normal Stress, kPa: 200 | Head, cm: 0.7
Avg. Depth to Plate, in.: 2.020 | Consolidated Length, in.: 6.680 | Wet Density, pcf: 93.6

Head Loss Correction

Trial No.	Q cc	Time sec	Flow cc/sec	Permeability k, cm/sec	Head Loss cm	Corrected Head cm	Permeability k, cm/sec
1	93.6	16.81	5.568	4.1E-01	0.37682	0.32318	0.89688
2	93.6	16.53	5.662	4.2E-01	0.38304	0.31696	0.92999
3	93.6	16.32	5.735	4.3E-01	0.38783	0.31217	0.95642
4	93.6	16.65	5.622	4.2E-01	0.38035	0.31965	0.91552
5	93.6	16.34	5.728	4.3E-01	0.38737	0.31263	0.95384
Averages			5.663	4.2E-01	0.38308	0.31692	0.93053

Permeability Trial Data

Normal Stress, kPa: 800 | Head, cm: 0.7
Avg. Depth to Plate, in.: 2.500 | Consolidated Length, in.: 6.200 | Wet Density, pcf: 100.8

Trial No.	Q cc	Time sec	Flow cc/sec	Permeability k, cm/sec	Head Loss cm	Corrected Head cm	Permeability k, cm/sec
1	93.6	16.09	5.817	4.0E-01	0.39321	0.30679	0.91615
2	93.6	15.90	5.887	4.1E-01	0.39774	0.30226	0.94101
3	93.6	16.49	5.676	3.9E-01	0.38395	0.31605	0.86774
4	93.6	16.34	5.728	4.0E-01	0.38737	0.31263	0.88530
5	93.6	16.28	5.749	4.0E-01	0.38876	0.31124	0.89252
Averages			5.772	4.0E-01	0.39021	0.30979	0.90054

Permeability Trial Data

Normal Stress, kPa: 2720 | Head, cm: 0.7
Avg. Depth to Plate, in.: 3.133 | Consolidated Length, in.: 5.567 | Wet Density, pcf: 112.3

Trial No.	Q cc	Time sec	Flow cc/sec	Permeability k, cm/sec	Head Loss cm	Corrected Head cm	Permeability k, cm/sec
1	93.6	20.3	4.609	2.9E-01	0.31184	0.38816	0.51508
2	93.6	20.3	4.622	2.9E-01	0.31278	0.38722	0.51787
3	93.6	19.9	4.701	2.9E-01	0.31824	0.38176	0.53423
4	93.6	20.2	4.636	2.9E-01	0.31373	0.38627	0.52068
5	93.6	20.2	4.629	2.9E-01	0.31326	0.38674	0.51927
Averages			4.642	2.9E-01	0.31397	0.38603	0.52143

General Notes:
1) Tap water was used as permeant.
2) Flow conditions may vary depending on the particle distribution in the field.
3) The sample was placed in the mold in a loose condition.
4) Particles larger than 1.5" were crushed and added back to the blend prior to testing.
5) Audible crushing of rocks noted at 800 kPa.

Knight Piésold CONSULTING

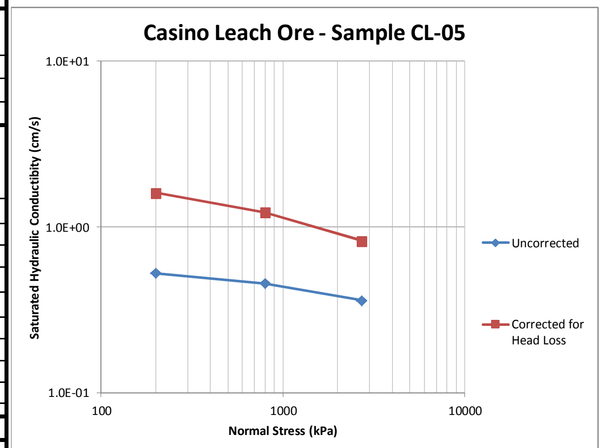
Constant Head Permeability
USBR 5605 - Amended

Project	*Casino*	*Project No.*	*VA101-326/18*
Lab No.	*L2014-099*	*Date of Test*	*11/06/14*
Sample No.	*CL-05*	*Tested By*	*DAB*
	Crushed to minus 1.5"	*Checked By*	*JDB*

Specimen Data

Target Dry Density, pcf	NA	Wet Sample Wt. + Tare, lbs.	18.198
Target Density, t/m^3	NA	Tare, lbs.	0.000
Moisture Content, %	6.2	Wet Sample Wt., lbs.	18.198
Mold Diameter, in.	8.02	Sample Length, in.	7.000
Mold Area, in.^{2}	50.52	Sample Volume, in.^{3}	353.6
Mold Area, ft^2	0.3508	Sample Volume, ft^3	0.2046
Depth to Mold Bottom, in.	8.700	Wet Density, pcf	88.9
		Initial Depth to Plate, in.	1.700

Normal Stress Range, kPa: 200 800 2720



Permeability Trial Data

Normal Stress, kPa: 200; Head, cm: 0.7
Avg. Depth to Plate, in.: 1.887; Consolidated Length, in.: 6.813; Wet Density, pcf: 91.4

Head Loss Correction

Trial No.	Q cc	Time sec	Flow cc/sec	Permeability k, cm/sec	Head Loss cm	Corrected Head cm	Permeability k, cm/sec
1	93.6	13.65	6.857	5.2E-01	0.45947	0.24053	1.51359
2	93.6	13.07	7.161	5.4E-01	0.47820	0.22180	1.71429
3	93.6	13.72	6.822	5.2E-01	0.45729	0.24271	1.49239
4	93.6	13.06	7.167	5.4E-01	0.47854	0.22146	1.71819
5	93.6	13.85	6.758	5.1E-01	0.45331	0.24669	1.45448
Averages			6.953	5.3E-01	0.46536	0.23464	1.57859

Permeability Trial Data

Normal Stress, kPa: 800; Head, cm: 0.7
Avg. Depth to Plate, in.: 2.400; Consolidated Length, in.: 6.300; Wet Density, pcf: 98.8

Trial No.	Q cc	Time sec	Flow cc/sec	Permeability k, cm/sec	Head Loss cm	Corrected Head cm	Permeability k, cm/sec
1	93.6	14.69	6.372	4.5E-01	0.42896	0.27104	1.15417
2	93.6	14.06	6.657	4.7E-01	0.44699	0.25301	1.29182
3	93.6	14.16	6.610	4.6E-01	0.44404	0.25596	1.26791
4	93.6	14.43	6.486	4.5E-01	0.43625	0.26375	1.20740
5	93.6	14.38	6.509	4.6E-01	0.43767	0.26233	1.21818
Averages			6.527	4.6E-01	0.43878	0.26122	1.22789

Permeability Trial Data

Normal Stress, kPa: 2720; Head, cm: 0.7
Avg. Depth to Plate, in.: 3.133; Consolidated Length, in.: 5.567; Wet Density, pcf: 111.8

Trial No.	Q cc	Time sec	Flow cc/sec	Permeability k, cm/sec	Head Loss cm	Corrected Head cm	Permeability k, cm/sec
1	93.6	16.62	5.632	3.5E-01	0.38102	0.31898	0.76596
2	93.6	15.47	6.050	3.7E-01	0.40836	0.29164	0.90005
3	93.6	16.09	5.817	3.6E-01	0.39321	0.30679	0.82261
4	93.6	16.08	5.821	3.6E-01	0.39344	0.30656	0.82376
5	93.6	16.12	5.806	3.6E-01	0.39250	0.30750	0.81919
Averages			5.830	3.6E-01	0.39371	0.30629	0.82631

General Notes:
1) Tap water was used as permeant.
2) Flow conditions may vary depending on the particle distribution in the field.
3) The sample was placed in the mold in a loose condition.
4) Particles larger than 1.5" were crushed and added back to the blend prior to testing.
5) Audible crushing of rocks noted at 800 kPa.

Knight Piésold
CONSULTING

Constant Head Permeability Test

Rigid Wall Permeameter - USBR Procedure 5600/5605 Modified

Project	HEAD LOSS	Project No.	
Sample No.	Mold D	Date Tested	18/09/2013
Sample ID		Tested By	DAB/JDB
Description		File No.	

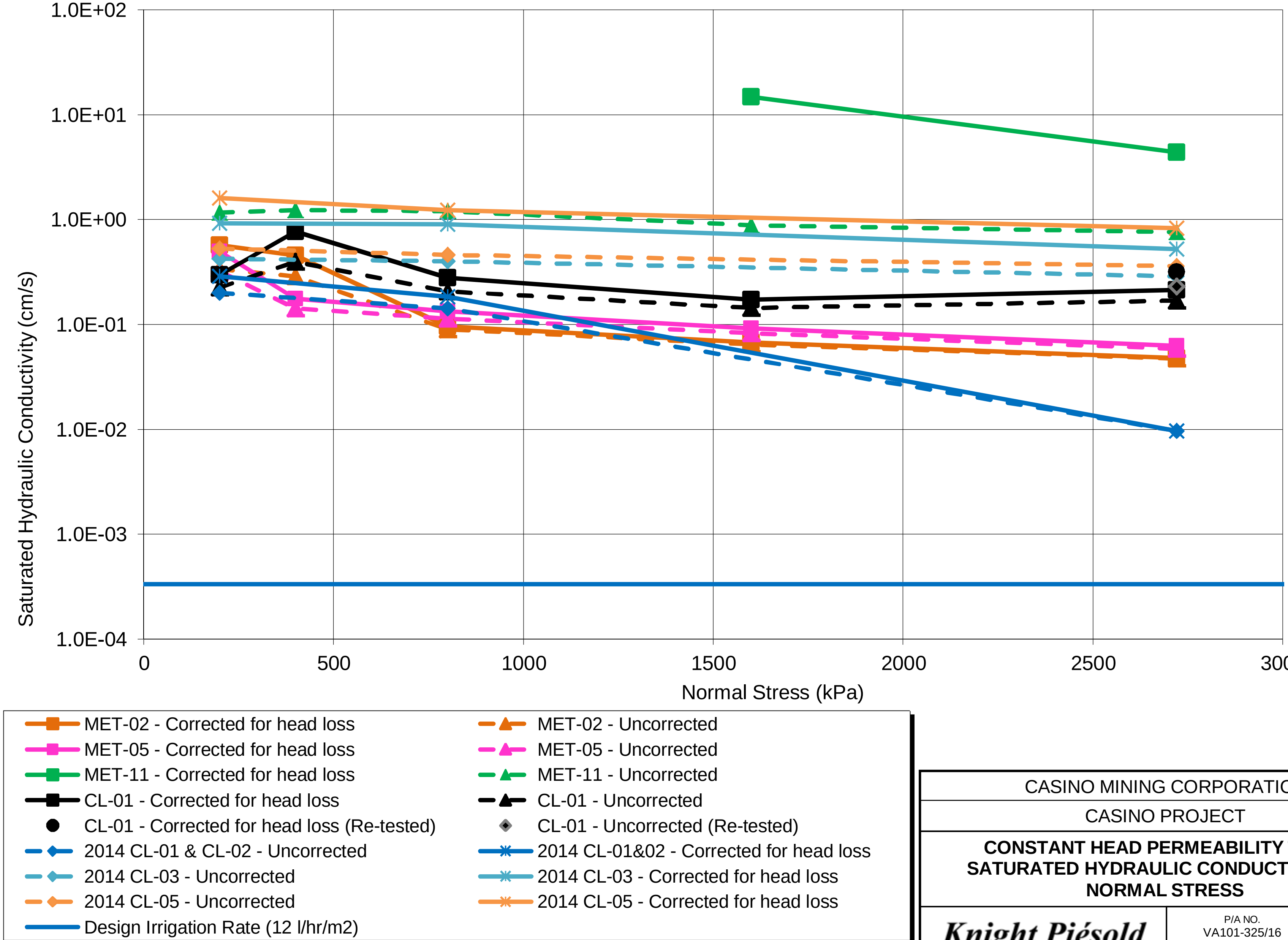
	US	Metric
Depth to Bot. of Mold, in./cm		
Depth to Plate, in./cm		
Sample Height, in./cm		
Initial Moisture Content, %		
Initial Sample Wet Wt., g/lbs.		
Dry Sample Wt., g/lbs.		

Moisture Content Data

	Initial	Final
Tare ID		
Wet Soil+Tare		
Dry Soil + Tare		
Tare		
Moist Content.%		

Mold Dia., in.	8.02
Mold Area, in^2	
Sample Vol., ft^3	
Buret Constant, a, ml/cm	45.9
Initial Wet Density, pcf	
Initial Dry Density, pcf	
Target Dry Density, pcf	

Date	Normal Load psf/gauge	Time Start	Time Stop	Elapsed Time min/sec.	Head Manometers: Inflow Height cm	Head Manometers: Outflow Height cm	Head Manometers: Average Head cm	Volume, cc: Initial Column Level cm	Volume, cc: Final Column Level cm	Volume, cc: Volume Change cc	Flow Rate CC/sec
18/09/2013	NA			43.72			0.05			45.9	1.050
				42.4						45.9	1.083
				43.15						45.9	1.064
				44.19						45.9	1.039
	Depth to plate measurements, in.:			1)	2)	3)	Avg.	L-			1.059
				24.34			0.1			45.9	1.886
				23.75						45.9	1.933
				25						45.9	1.836
				26.37						45.9	1.741
				49.68						91.8	1.848
				50.65						91.8	1.812
	Depth to plate measurements, in.:			1)	2)	3)	Avg.	L-			1.843
				15.63			0.2			45.9	2.937
				15.32						45.9	2.996
				15.38						45.9	2.984
				15.24						45.9	3.012
	Depth to plate measurements, in.:			1)	2)	3)	Avg.	L-			2.982
				8.16			0.4			45.9	5.625
				7.72						45.9	5.946
				7.87						45.9	5.832
				7.59						45.9	6.047
				7.53						45.9	6.096
				7.81						45.9	5.877
	Depth to plate measurements, in.:			1)	2)	3)	Avg.	L-			5.904
				12.44			0.5			91.8	7.379
				12.38						91.8	7.415
				12.07						91.8	7.606
				12.03						91.8	7.631
				12.47						91.8	7.362
	Depth to plate measurements, in.:			1)	2)	3)	Avg.	L-			7.479



REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D
0	24SEP'15	ISSUED WITH REPORT	SB	LJG	LJG

CASINO MINING CORPORATION

CASINO PROJECT

CONSTANT HEAD PERMEABILITY TESTS SATURATED HYDRAULIC CONDUCTIVITY VS NORMAL STRESS

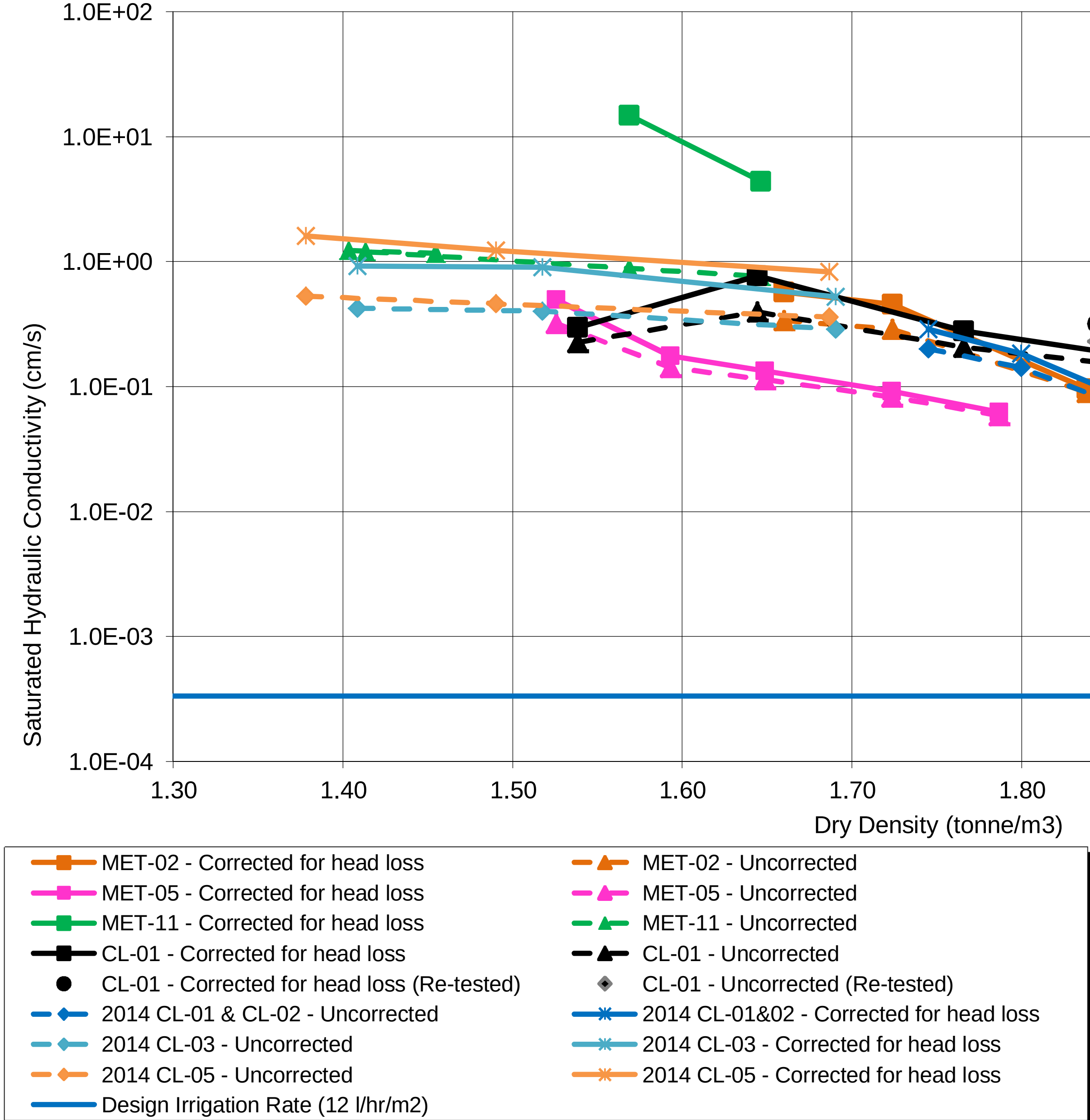
Knight Piésold CONSULTING

P/A NO. VA101-325/16

REF. NO. 1

FIGURE B.1

REV 0



CASINO MINING CORPORATION

CASINO PROJECT

CONSTANT HEAD PERMEABILITY TESTS SATURATED HYDRAULIC CONDUCTIVITY VS DRY DENSITY

Knight Piésold CONSULTING

P/A NO.	REF. NO.
VA101-325/18	1

FIGURE B.2 REV 0

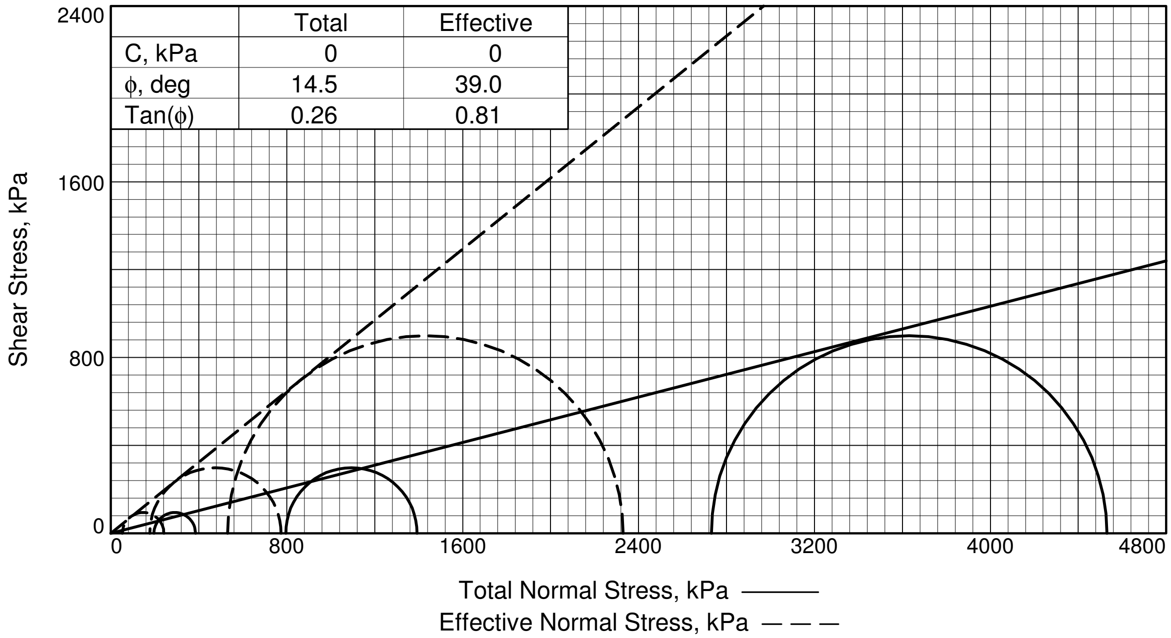
0	24SEP'15	ISSUED WITH REPORT	SB	LJG	LJG
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D

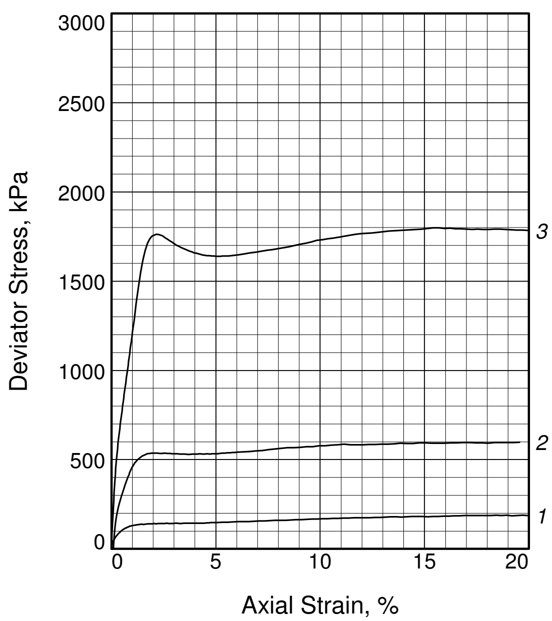
APPENDIX C

TRIAXIAL SHEAR STRENGTH TEST RESULTS

(Pages C-1 to C-35)

Cursory interpretations provided require review by a professional engineer. Knight Piesold accepts no responsibility in subsequent analyses.





Specimen No.		1	2	3
Initial	Water Content, %	7.3	7.3	7.3
	Dry Density, pcf	101.4	101.5	102.3
	Saturation, %	29.1	29.2	29.7
	Void Ratio	0.6813	0.6792	0.6674
	Diameter, in.	5.93	6.02	5.88
	Height, in.	12.00	11.65	12.10
At Test	Water Content, %	23.4	22.5	14.2
	Dry Density, pcf	103.9	105.6	122.7
	Saturation, %	100.0	100.0	100.0
	Void Ratio	0.6403	0.6149	0.3892
	Diameter, in.	5.88	5.94	5.53
	Height, in.	11.90	11.50	11.40
Strain rate, %/min.		0.02	0.03	0.03
Eff. Cell Pressure, kPa		197	796	2731
Fail. Stress, kPa		189	597	1799
Excess Pore Pr., kPa		144	619	2200
Strain, %		19.7	19.6	15.7
Ult. Stress, kPa				
Excess Pore Pr., kPa				
Strain, %				
$\bar{\sigma}_1$ Failure, kPa		241	774	2330
$\bar{\sigma}_3$ Failure, kPa		53	177	531

Type of Test:
CU with Pore Pressures

Sample Type: Remolded

Description:

Specific Gravity= 2.731

Remarks: Failure tangents drawn for large strain conditions. Particles larger than 1" were crushed to finer than 1" prior to testing.

Figure _______

Client: Casino Mining Corporation

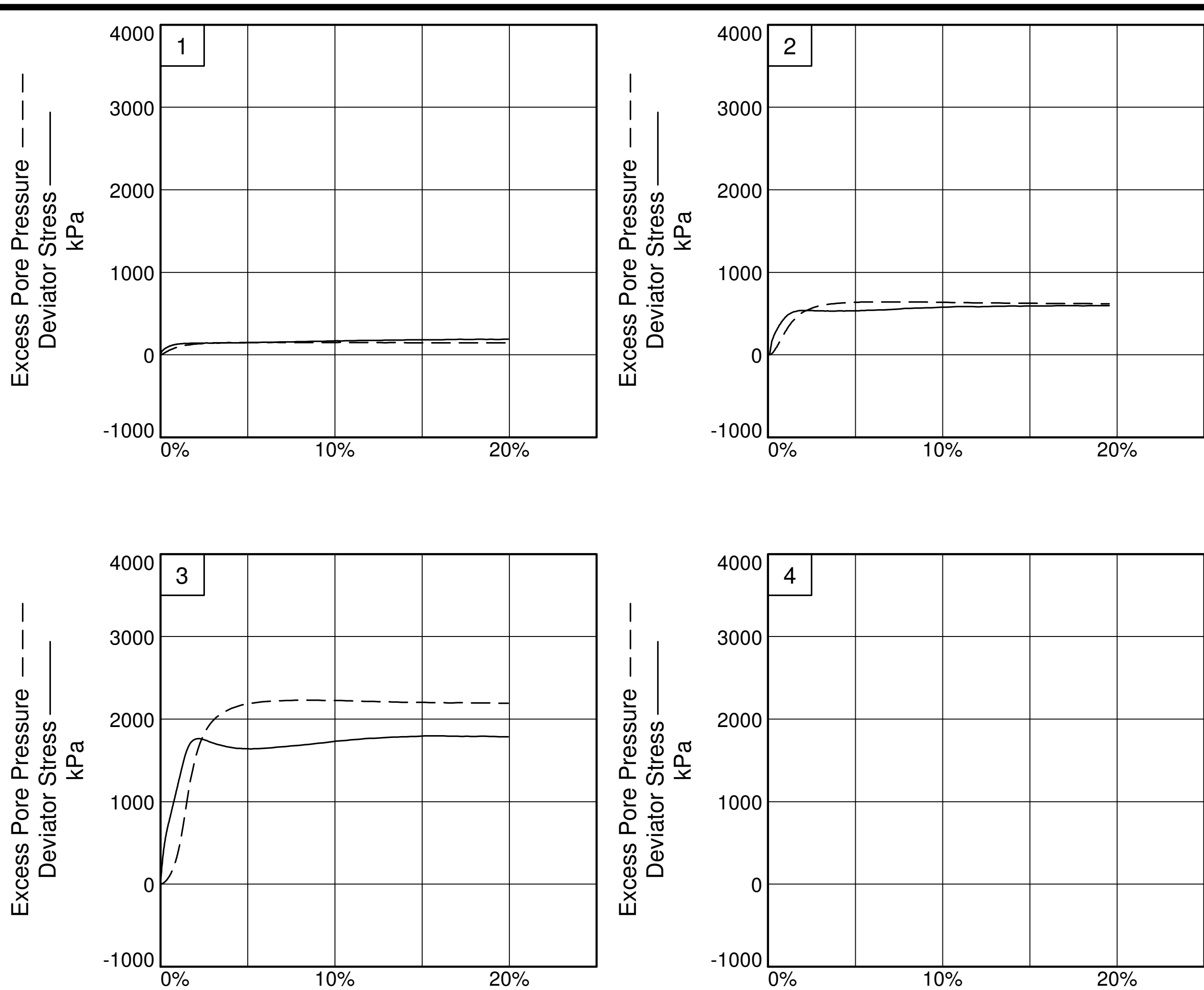
Project: Casino

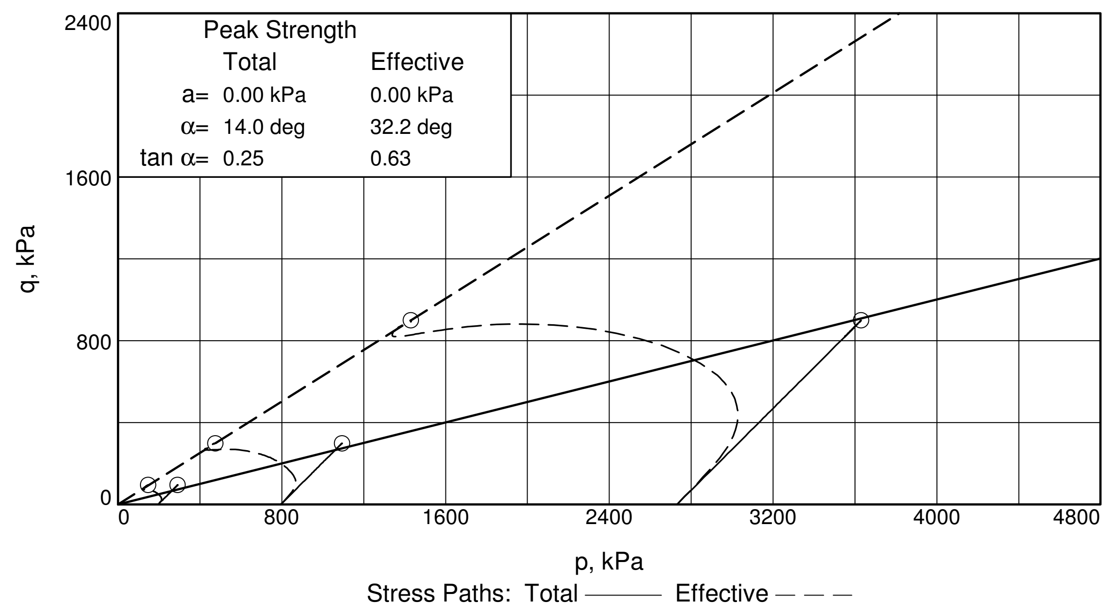
Sample Number: CL-01 & CL-02 Blend

Proj. No.: VA101-325/18 **Date Sampled:** 10/28/14

Knight Piésold
CONSULTING

Tested By: DAB **Checked By:** JDB





Client: Casino Mining Corporation
Project: Casino
Sample Number: CL-01 & CL-02 Blend
Project No.: VA101-325/18 **Figure** _______

Knight Piesold Geotechnical Lab.

Tested By: DAB **Checked By:** JDB

TRIAXIAL COMPRESSION TEST

CU with Pore Pressures

1/30/2015
9:35 AM

Date: 10/28/14
Client: Casino Mining Corporation
Project: Casino
Project No.: VA101-325/18
Sample Number: CL-01 & CL-02 Blend
Description:
Remarks: Failure tangents drawn for large strain conditions. Particles larger than 1" were crushed to finer than 1" prior to testing.
Type of Sample: Remolded
Specific Gravity=2.731 **LL=** **PL=** **PI=**
Test Method: COE uniform strain

Parameters for Specimen No. 1

Specimen Parameter	Initial	Saturated	Consolidated	Final
Moisture content: Moist soil+tare, gms.	1411.000			13370.500
Moisture content: Dry soil+tare, gms.	1343.340			11626.000
Moisture content: Tare, gms.	411.400			2779.000
Moisture, %	7.3	24.9	23.4	19.7
Moist specimen weight, gms.	9472.1			
Diameter, in.	5.93	5.93	5.88	
Area, in.²	27.65	27.65	27.19	
Height, in.	12.00	12.00	11.90	
Net decrease in height, in.		0.00	0.10	
Wet density, pcf	108.8	126.7	128.3	
Dry density, pcf	101.4	101.4	103.9	
Void ratio	0.6813	0.6813	0.6403	
Saturation, %	29.1	100.0	100.0	

Test Readings for Specimen No. 1

Membrane modulus = 0.124105 kN/cm²
Membrane thickness = 0.064 cm
Consolidation cell pressure = 58.48 psi (403.2 kPa)
Consolidation back pressure = 29.98 psi (206.7 kPa)
Consolidation effective confining stress = 196.5 kPa
Strain rate, %/min. = 0.02
Fail. Stress = 188.5 kPa **at reading no.** 139

Test Readings for Specimen No. 1

No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress kPa	Minor Eff. Stress kPa	Major Eff. Stress kPa	1:3 Ratio	Pore Press. psi	P kPa	Q kPa
0	0.0000	69.488	0.0	0.0	0.0	196.5	196.5	1.00	29.98	196.5	0.0
1	0.0030	146.712	77.2	0.0	19.6	195.2	214.8	1.10	30.17	205.0	9.8
2	0.0060	197.361	127.9	0.1	32.4	194.0	226.4	1.17	30.34	210.2	16.2
3	0.0090	226.068	156.6	0.1	39.7	192.0	231.7	1.21	30.63	211.8	19.8
4	0.0120	251.083	181.6	0.1	46.0	189.5	235.5	1.24	30.99	212.5	23.0
5	0.0150	273.084	203.6	0.1	51.6	186.9	238.4	1.28	31.38	212.6	25.8
6	0.0180	294.247	224.8	0.2	56.9	183.6	240.5	1.31	31.85	212.1	28.4
7	0.0210	314.086	244.6	0.2	61.9	180.4	242.3	1.34	32.32	211.3	31.0
8	0.0240	331.204	261.7	0.2	66.2	177.3	243.5	1.37	32.77	210.4	33.1
9	0.0270	347.264	277.8	0.2	70.3	174.0	244.2	1.40	33.25	209.1	35.1
10	0.0300	362.852	293.4	0.3	74.2	171.0	245.2	1.43	33.67	208.1	37.1
11	0.0330	377.603	308.1	0.3	77.9	168.0	245.9	1.46	34.11	207.0	39.0
12	0.0360	391.324	321.8	0.3	81.3	164.8	246.2	1.49	34.57	205.5	40.7
13	0.0390	402.957	333.5	0.3	84.3	161.6	245.9	1.52	35.04	203.8	42.1
14	0.0420	416.016	346.5	0.4	87.5	158.8	246.4	1.55	35.45	202.6	43.8
15	0.0450	429.561	360.1	0.4	90.9	155.7	246.6	1.58	35.90	201.2	45.5
16	0.0480	439.326	369.8	0.4	93.4	153.4	246.8	1.61	36.23	200.1	46.7
17	0.0510	448.547	379.1	0.4	95.7	150.5	246.2	1.64	36.65	198.4	47.8
18	0.0540	460.856	391.4	0.5	98.8	147.5	246.3	1.67	37.09	196.9	49.4
19	0.0570	469.915	400.4	0.5	101.0	145.0	246.1	1.70	37.44	195.6	50.5
20	0.0600	478.666	409.2	0.5	103.2	141.5	244.7	1.73	37.96	193.1	51.6
21	0.0630	488.063	418.6	0.5	105.6	139.4	244.9	1.76	38.26	192.2	52.8
22	0.0660	496.005	426.5	0.6	107.5	137.7	245.3	1.78	38.50	191.5	53.8
23	0.0690	502.961	433.5	0.6	109.3	135.1	244.4	1.81	38.88	189.8	54.6
24	0.0720	509.490	440.0	0.6	110.9	132.8	243.7	1.83	39.22	188.3	55.4
25	0.0750	516.858	447.4	0.6	112.7	130.6	243.3	1.86	39.54	186.9	56.4
26	0.0780	526.800	457.3	0.7	115.2	128.5	243.7	1.90	39.85	186.1	57.6
27	0.0810	533.535	464.0	0.7	116.9	126.1	243.0	1.93	40.19	184.5	58.4
28	0.0840	536.918	467.4	0.7	117.7	123.9	241.5	1.95	40.52	182.7	58.8
29	0.0870	545.374	475.9	0.7	119.8	121.9	241.7	1.98	40.80	181.8	59.9
30	0.0900	549.610	480.1	0.8	120.8	119.9	240.7	2.01	41.09	180.3	60.4
31	0.0930	557.257	487.8	0.8	122.7	118.0	240.7	2.04	41.36	179.4	61.3
32	0.0960	558.389	488.9	0.8	123.0	115.8	238.8	2.06	41.68	177.3	61.5
33	0.0990	564.566	495.1	0.8	124.5	112.5	237.0	2.11	42.16	174.8	62.2
34	0.1020	569.419	499.9	0.9	125.7	110.8	236.5	2.13	42.41	173.6	62.8
35	0.1050	575.317	505.8	0.9	127.1	109.6	236.7	2.16	42.59	173.1	63.6
36	0.1080	576.802	507.3	0.9	127.5	108.4	235.9	2.18	42.75	172.1	63.7
37	0.1110	580.508	511.0	0.9	128.4	106.5	234.9	2.20	43.03	170.7	64.2
38	0.1140	586.390	516.9	1.0	129.8	105.0	234.7	2.24	43.26	169.9	64.9
39	0.1170	588.317	518.8	1.0	130.2	103.1	233.3	2.26	43.53	168.2	65.1
40	0.1200	587.846	518.4	1.0	130.1	101.7	231.8	2.28	43.73	166.8	65.0
41	0.1230	592.155	522.7	1.0	131.1	100.0	231.1	2.31	43.98	165.6	65.6
42	0.1350	604.318	534.8	1.1	134.1	94.4	228.5	2.42	44.78	161.5	67.0
43	0.1470	607.906	538.4	1.2	134.8	89.2	224.0	2.51	45.55	156.6	67.4
44	0.1590	614.392	544.9	1.3	136.3	84.1	220.4	2.62	46.28	152.2	68.2
45	0.1710	620.745	551.3	1.4	137.8	81.7	219.5	2.69	46.63	150.6	68.9
46	0.1830	621.142	551.7	1.5	137.7	78.1	215.8	2.76	47.15	146.9	68.9

Test Readings for Specimen No. 1

No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress kPa	Minor Eff. Stress kPa	Major Eff. Stress kPa	1:3 Ratio	Pore Press. psi	P kPa	Q kPa
47	0.1950	626.789	557.3	1.6	139.0	75.5	214.5	2.84	47.53	145.0	69.5
48	0.2070	631.672	562.2	1.7	140.1	72.7	212.7	2.93	47.94	142.7	70.0
49	0.2190	636.157	566.7	1.8	141.0	70.1	211.1	3.01	48.31	140.6	70.5
50	0.2310	637.745	568.3	1.9	141.3	67.9	209.2	3.08	48.64	138.5	70.6
51	0.2430	638.848	569.4	2.0	141.4	66.4	207.8	3.13	48.85	137.1	70.7
52	0.2550	638.216	568.7	2.1	141.1	64.3	205.4	3.19	49.15	134.9	70.6
53	0.2670	643.863	574.4	2.2	142.4	62.7	205.1	3.27	49.38	133.9	71.2
54	0.2790	641.216	571.7	2.3	141.6	60.8	202.3	3.33	49.67	131.5	70.8
55	0.2910	647.569	578.1	2.4	143.0	59.6	202.6	3.40	49.83	131.1	71.5
56	0.3030	647.731	578.2	2.5	142.9	58.7	201.6	3.43	49.96	130.2	71.4
57	0.3150	650.378	580.9	2.6	143.4	57.5	200.9	3.49	50.14	129.2	71.7
58	0.3270	647.040	577.6	2.7	142.4	56.1	198.5	3.54	50.35	127.3	71.2
59	0.3390	647.849	578.4	2.8	142.5	55.0	197.5	3.59	50.50	126.2	71.2
60	0.3510	649.731	580.2	2.9	142.8	54.1	196.9	3.64	50.63	125.5	71.4
61	0.3631	653.849	584.4	3.1	143.6	53.4	197.0	3.69	50.74	125.2	71.8
62	0.3751	653.731	584.2	3.2	143.5	53.1	196.5	3.70	50.78	124.8	71.7
63	0.3871	651.202	581.7	3.3	142.7	52.2	194.9	3.73	50.90	123.6	71.3
64	0.3991	653.070	583.6	3.4	143.0	51.6	194.6	3.77	51.00	123.1	71.5
65	0.4111	656.555	587.1	3.5	143.7	51.1	194.8	3.81	51.06	123.0	71.8
66	0.4231	657.496	588.0	3.6	143.8	51.0	194.8	3.82	51.08	122.9	71.9
67	0.4351	656.261	586.8	3.7	143.3	50.3	193.7	3.85	51.18	122.0	71.7
68	0.4471	659.099	589.6	3.8	143.9	49.9	193.8	3.88	51.24	121.9	71.9
69	0.4591	657.143	587.7	3.9	143.2	49.4	192.7	3.90	51.31	121.1	71.6
70	0.4711	660.540	591.1	4.0	143.9	49.2	193.1	3.93	51.35	121.1	72.0
71	0.4831	658.452	589.0	4.1	143.3	48.6	191.8	3.95	51.43	120.2	71.6
72	0.4951	664.482	595.0	4.2	144.6	48.4	193.0	3.99	51.46	120.7	72.3
73	0.5071	665.805	596.3	4.3	144.7	48.0	192.8	4.01	51.51	120.4	72.4
74	0.5191	665.908	596.4	4.4	144.6	48.1	192.7	4.01	51.51	120.4	72.3
75	0.5311	666.570	597.1	4.5	144.6	47.4	192.0	4.05	51.61	119.7	72.3
76	0.5431	668.394	598.9	4.6	144.9	47.7	192.7	4.04	51.56	120.2	72.5
77	0.5551	674.379	604.9	4.7	146.2	47.2	193.4	4.10	51.64	120.3	73.1
78	0.5671	677.085	607.6	4.8	146.7	47.7	194.4	4.08	51.56	121.1	73.4
79	0.5791	678.512	609.0	4.9	146.9	47.2	194.1	4.11	51.64	120.6	73.4
80	0.5911	682.085	612.6	5.0	147.6	47.0	194.6	4.14	51.66	120.8	73.8
81	0.6031	683.968	614.5	5.1	147.9	47.0	194.9	4.15	51.67	120.9	73.9
82	0.6331	693.071	623.6	5.3	149.7	47.1	196.8	4.18	51.65	121.9	74.8
83	0.6631	695.218	625.7	5.6	149.8	47.0	196.8	4.19	51.66	121.9	74.9
84	0.6931	703.439	634.0	5.8	151.4	46.9	198.3	4.23	51.68	122.6	75.7
85	0.7231	708.498	639.0	6.1	152.2	46.4	198.5	4.28	51.76	122.4	76.1
86	0.7531	711.925	642.4	6.3	152.6	46.1	198.7	4.31	51.79	122.4	76.3
87	0.7831	711.969	642.5	6.6	152.2	45.5	197.7	4.34	51.88	121.6	76.1
88	0.8131	724.161	654.7	6.8	154.6	46.1	200.7	4.36	51.80	123.4	77.3
89	0.8431	734.382	664.9	7.1	156.6	46.3	202.9	4.38	51.76	124.6	78.3
90	0.8731	734.029	664.5	7.3	156.1	46.5	202.6	4.36	51.74	124.5	78.1
91	0.9031	743.102	673.6	7.6	157.8	46.5	204.3	4.40	51.74	125.4	78.9
92	0.9331	752.382	682.9	7.8	159.6	46.7	206.2	4.42	51.71	126.5	79.8
93	0.9631	754.029	684.5	8.1	159.5	46.5	206.1	4.43	51.73	126.3	79.8

Test Readings for Specimen No. 1

No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress kPa	Minor Eff. Stress kPa	Major Eff. Stress kPa	1:3 Ratio	Pore Press. psi	P kPa	Q kPa
94	0.9931	762.397	692.9	8.3	161.0	47.1	208.1	4.42	51.66	127.6	80.5
95	1.0231	769.868	700.4	8.6	162.3	47.3	209.6	4.43	51.62	128.5	81.2
96	1.0531	774.751	705.3	8.8	163.0	46.7	209.7	4.49	51.70	128.2	81.5
97	1.0831	778.192	708.7	9.1	163.3	46.9	210.2	4.48	51.68	128.5	81.7
98	1.1131	786.751	717.3	9.4	164.8	47.4	212.3	4.48	51.60	129.8	82.4
99	1.1431	796.678	727.2	9.6	166.7	47.7	214.4	4.49	51.56	131.0	83.3
100	1.1731	804.620	735.1	9.9	168.0	46.4	214.4	4.62	51.75	130.4	84.0
101	1.2031	812.738	743.2	10.1	169.4	46.1	215.5	4.67	51.79	130.8	84.7
102	1.2332	812.576	743.1	10.4	168.9	45.6	214.5	4.70	51.86	130.1	84.4
103	1.2632	821.620	752.1	10.6	170.5	46.7	217.2	4.65	51.70	132.0	85.2
104	1.2932	828.223	758.7	10.9	171.5	46.1	217.6	4.72	51.79	131.8	85.7
105	1.3232	831.856	762.4	11.1	171.8	46.6	218.4	4.68	51.72	132.5	85.9
106	1.3532	841.459	772.0	11.4	173.5	47.0	220.5	4.69	51.66	133.8	86.7
107	1.3832	846.930	777.4	11.6	174.2	46.7	220.9	4.73	51.70	133.8	87.1
108	1.4132	851.857	782.4	11.9	174.8	47.0	221.8	4.72	51.66	134.4	87.4
109	1.4432	852.916	783.4	12.1	174.5	46.8	221.3	4.73	51.69	134.1	87.3
110	1.4732	856.048	786.6	12.4	174.7	48.1	222.9	4.63	51.50	135.5	87.4
111	1.5032	864.210	794.7	12.6	176.0	49.4	225.5	4.56	51.31	137.4	88.0
112	1.5332	870.034	800.5	12.9	176.8	49.7	226.5	4.56	51.27	138.1	88.4
113	1.5632	878.167	808.7	13.1	178.1	48.2	226.3	4.70	51.49	137.2	89.0
114	1.5932	886.579	817.1	13.4	179.4	47.9	227.3	4.75	51.53	137.6	89.7
115	1.6232	889.152	819.7	13.6	179.5	47.8	227.3	4.76	51.55	137.5	89.7
116	1.6532	886.049	816.6	13.9	178.3	48.2	226.5	4.69	51.48	137.4	89.1
117	1.6832	897.756	828.3	14.1	180.3	50.3	230.6	4.58	51.18	140.5	90.1
118	1.7132	902.447	833.0	14.4	180.8	52.0	232.8	4.47	50.93	142.4	90.4
119	1.7432	907.682	838.2	14.6	181.4	50.4	231.8	4.60	51.17	141.1	90.7
120	1.7732	911.388	841.9	14.9	181.6	50.1	231.8	4.62	51.21	141.0	90.8
121	1.8032	908.859	839.4	15.2	180.6	50.7	231.2	4.56	51.13	141.0	90.3
122	1.8332	917.815	848.3	15.4	182.0	50.7	232.7	4.59	51.13	141.7	91.0
123	1.8632	921.271	851.8	15.7	182.1	50.4	232.5	4.61	51.17	141.5	91.1
124	1.8932	926.860	857.4	15.9	182.8	50.5	233.3	4.62	51.15	141.9	91.4
125	1.9232	932.875	863.4	16.2	183.5	50.6	234.1	4.63	51.14	142.4	91.8
126	1.9533	941.095	871.6	16.4	184.7	51.4	236.2	4.59	51.02	143.8	92.4
127	1.9832	945.110	875.6	16.7	185.0	51.6	236.6	4.59	51.00	144.1	92.5
128	2.0133	956.155	886.7	16.9	186.8	52.4	239.2	4.56	50.87	145.8	93.4
129	2.0433	963.979	894.5	17.2	187.8	53.2	241.1	4.53	50.76	147.1	93.9
130	2.0733	961.552	892.1	17.4	186.8	52.2	239.0	4.58	50.90	145.6	93.4
131	2.1033	961.920	892.4	17.7	186.3	52.2	238.5	4.57	50.91	145.3	93.1
132	2.1333	965.743	896.3	17.9	186.5	52.5	239.0	4.55	50.87	145.8	93.3
133	2.1633	974.523	905.0	18.2	187.8	52.7	240.4	4.57	50.84	146.5	93.9
134	2.1933	979.465	910.0	18.4	188.2	52.5	240.7	4.59	50.87	146.6	94.1
135	2.2233	978.288	908.8	18.7	187.4	52.9	240.3	4.54	50.80	146.6	93.7
136	2.2533	986.156	916.7	18.9	188.4	52.8	241.2	4.57	50.82	147.0	94.2
137	2.2833	976.862	907.4	19.2	185.9	52.2	238.1	4.56	50.91	145.2	93.0
138	2.3133	986.171	916.7	19.4	187.2	52.4	239.6	4.57	50.88	146.0	93.6
139	2.3433	995.406	925.9	19.7	188.5	52.5	241.1	4.59	50.86	146.8	94.3
140	2.3733	993.759	924.3	19.9	187.6	52.5	240.1	4.57	50.87	146.3	93.8

Parameters for Specimen No. 2

Specimen Parameter	Initial	Saturated	Consolidated	Final
Moisture content: Moist soil+tare, gms.	1411.000			13151.000
Moisture content: Dry soil+tare, gms.	1343.340			11691.000
Moisture content: Tare, gms.	411.400			2842.000
Moisture, %	7.3	24.9	22.5	16.5
Moist specimen weight, gms.	9472.1			
Diameter, in.	6.02	6.02	5.94	
Area, in.²	28.43	28.43	27.70	
Height, in.	11.65	11.65	11.50	
Net decrease in height, in.		0.00	0.15	
Wet density, pcf	108.9	126.8	129.3	
Dry density, pcf	101.5	101.5	105.6	
Void ratio	0.6792	0.6792	0.6149	
Saturation, %	29.2	100.0	100.0	

Test Readings for Specimen No. 2

Membrane modulus = 0.124105 kN/cm²
Membrane thickness = 0.064 cm
Consolidation cell pressure = 145.77 psi (1005.0 kPa)
Consolidation back pressure = 30.38 psi (209.5 kPa)
Consolidation effective confining stress = 795.6 kPa
Strain rate, %/min. = 0.03
Fail. Stress = 597.2 kPa **at reading no.** 126

No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress kPa	Minor Eff. Stress kPa	Major Eff. Stress kPa	1:3 Ratio	Pore Press. psi	P kPa	Q kPa
0	0.0000	139.785	0.0	0.0	0.0	795.6	795.6	1.00	30.38	795.6	0.0
1	0.0035	157.668	17.9	0.0	4.4	795.3	799.7	1.01	30.42	797.5	2.2
2	0.0069	165.830	26.0	0.1	6.5	795.6	802.1	1.01	30.38	798.8	3.2
3	0.0104	171.418	31.6	0.1	7.9	795.5	803.3	1.01	30.40	799.4	3.9
4	0.0138	299.438	159.7	0.1	39.7	794.6	834.3	1.05	30.53	814.4	19.8
5	0.0173	485.563	345.8	0.2	85.9	791.5	877.5	1.11	30.97	834.5	43.0
6	0.0208	642.731	502.9	0.2	124.9	787.6	912.6	1.16	31.54	850.1	62.5
7	0.0242	764.927	625.1	0.2	155.3	782.0	937.2	1.20	32.36	859.6	77.6
8	0.0277	859.283	719.5	0.2	178.6	775.4	954.0	1.23	33.31	864.7	89.3
9	0.0311	938.228	798.4	0.3	198.2	768.5	966.7	1.26	34.30	867.6	99.1
10	0.0346	1011.231	871.4	0.3	216.2	760.4	976.6	1.28	35.49	868.5	108.1
11	0.0380	1072.571	932.8	0.3	231.4	752.2	983.6	1.31	36.67	867.9	115.7
12	0.0415	1131.103	991.3	0.4	245.8	743.4	989.2	1.33	37.95	866.3	122.9
13	0.0450	1181.987	1042.2	0.4	258.4	734.0	992.3	1.35	39.32	863.1	129.2
14	0.0484	1233.180	1093.4	0.4	271.0	724.2	995.2	1.37	40.73	859.7	135.5
15	0.0519	1283.873	1144.1	0.5	283.5	714.6	998.0	1.40	42.13	856.3	141.7
16	0.0553	1333.772	1194.0	0.5	295.7	704.2	999.9	1.42	43.63	852.1	147.9
17	0.0588	1379.465	1239.7	0.5	307.0	693.8	1000.8	1.44	45.14	847.3	153.5
18	0.0622	1423.423	1283.6	0.5	317.7	683.3	1001.1	1.46	46.66	842.2	158.9
19	0.0657	1467.587	1327.8	0.6	328.6	672.0	1000.6	1.49	48.30	836.3	164.3
20	0.0692	1515.015	1375.2	0.6	340.2	661.4	1001.6	1.51	49.84	831.5	170.1
21	0.0726	1560.355	1420.6	0.6	351.3	650.9	1002.2	1.54	51.36	826.6	175.7
22	0.0761	1604.121	1464.3	0.7	362.0	639.5	1001.6	1.57	53.01	820.6	181.0
23	0.0796	1641.726	1501.9	0.7	371.2	628.0	999.3	1.59	54.68	813.7	185.6
24	0.0830	1686.772	1547.0	0.7	382.2	616.4	998.7	1.62	56.36	807.6	191.1

Test Readings for Specimen No. 2

No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress kPa	Minor Eff. Stress kPa	Major Eff. Stress kPa	1:3 Ratio	Pore Press. psi	P kPa	Q kPa
25	0.0865	1726.200	1586.4	0.8	391.9	605.5	997.4	1.65	57.95	801.4	195.9
26	0.0899	1765.907	1626.1	0.8	401.6	593.7	995.3	1.68	59.66	794.5	200.8
27	0.0934	1799.379	1659.6	0.8	409.7	582.6	992.3	1.70	61.27	787.5	204.8
28	0.0969	1829.351	1689.6	0.8	417.0	570.3	987.2	1.73	63.06	778.7	208.5
29	0.1003	1867.734	1727.9	0.9	426.3	560.1	986.4	1.76	64.53	773.3	213.2
30	0.1038	1902.383	1762.6	0.9	434.7	547.6	982.3	1.79	66.35	765.0	217.4
31	0.1072	1932.649	1792.9	0.9	442.1	537.2	979.3	1.82	67.85	758.3	221.0
32	0.1107	1960.797	1821.0	1.0	448.9	525.6	974.4	1.85	69.54	750.0	224.4
33	0.1141	1994.563	1854.8	1.0	457.0	514.7	971.8	1.89	71.12	743.2	228.5
34	0.1176	2014.446	1874.7	1.0	461.8	504.3	966.1	1.92	72.63	735.2	230.9
35	0.1210	2040.565	1900.8	1.1	468.1	494.1	962.2	1.95	74.10	728.2	234.0
36	0.1245	2066.507	1926.7	1.1	474.3	482.9	957.2	1.98	75.74	720.0	237.2
37	0.1280	2092.096	1952.3	1.1	480.5	472.9	953.4	2.02	77.18	713.2	240.2
38	0.1314	2109.332	1969.5	1.1	484.6	462.5	947.1	2.05	78.69	704.8	242.3
39	0.1349	2127.803	1988.0	1.2	489.0	453.7	942.7	2.08	79.97	698.2	244.5
40	0.1383	2145.025	2005.2	1.2	493.1	443.5	936.6	2.11	81.44	690.1	246.5
41	0.1418	2159.805	2020.0	1.2	496.6	435.2	931.8	2.14	82.65	683.5	248.3
42	0.1556	2216.263	2076.5	1.4	509.8	400.1	910.0	2.27	87.73	655.1	254.9
43	0.1694	2264.279	2124.5	1.5	521.0	372.2	893.2	2.40	91.78	632.7	260.5
44	0.1833	2290.560	2150.8	1.6	526.8	345.9	872.7	2.52	95.60	609.3	263.4
45	0.1971	2318.914	2179.1	1.7	533.1	323.2	856.2	2.65	98.90	589.7	266.5
46	0.2109	2330.914	2191.1	1.8	535.3	304.0	839.3	2.76	101.68	571.7	267.7
47	0.2247	2338.517	2198.7	2.0	536.5	286.2	822.7	2.87	104.27	554.4	268.3
48	0.2385	2340.385	2200.6	2.1	536.3	270.2	806.6	2.98	106.58	538.4	268.2
49	0.2523	2341.988	2202.2	2.2	536.1	257.8	793.9	3.08	108.37	525.9	268.0
50	0.2661	2340.635	2200.9	2.3	535.1	246.3	781.4	3.17	110.04	513.9	267.5
51	0.2800	2343.915	2204.1	2.4	535.2	235.7	770.9	3.27	111.59	503.3	267.6
52	0.2938	2349.283	2209.5	2.6	535.9	227.0	762.9	3.36	112.84	495.0	267.9
53	0.3076	2344.385	2204.6	2.7	534.0	218.7	752.7	3.44	114.05	485.7	267.0
54	0.3214	2348.974	2209.2	2.8	534.5	211.4	745.8	3.53	115.11	478.6	267.2
55	0.3353	2348.033	2208.2	2.9	533.6	204.8	738.4	3.61	116.07	471.6	266.8
56	0.3491	2348.091	2208.3	3.0	532.9	199.5	732.4	3.67	116.84	466.0	266.5
57	0.3629	2348.327	2208.5	3.2	532.3	194.2	726.6	3.74	117.60	460.4	266.2
58	0.3767	2344.974	2205.2	3.3	530.9	189.9	720.8	3.80	118.22	455.4	265.4
59	0.3905	2352.621	2212.8	3.4	532.0	185.5	717.5	3.87	118.87	451.5	266.0
60	0.4043	2350.386	2210.6	3.5	530.8	182.3	713.1	3.91	119.33	447.7	265.4
61	0.4181	2349.738	2210.0	3.6	530.0	178.3	708.3	3.97	119.91	443.3	265.0
62	0.4320	2353.165	2213.4	3.8	530.2	175.9	706.1	4.01	120.26	441.0	265.1
63	0.4458	2358.842	2219.1	3.9	530.9	173.3	704.2	4.06	120.63	438.8	265.4
64	0.4596	2364.680	2224.9	4.0	531.6	171.5	703.1	4.10	120.89	437.3	265.8
65	0.4734	2368.622	2228.8	4.1	531.9	169.5	701.3	4.14	121.19	435.4	265.9
66	0.4872	2374.460	2234.7	4.2	532.6	167.2	699.8	4.19	121.52	433.5	266.3
67	0.5011	2370.813	2231.0	4.4	531.1	165.4	696.5	4.21	121.78	430.9	265.5
68	0.5149	2374.813	2235.0	4.5	531.4	164.2	695.6	4.24	121.95	429.9	265.7
69	0.5287	2382.313	2242.5	4.6	532.5	162.6	695.0	4.28	122.19	428.8	266.2
70	0.5425	2381.872	2242.1	4.7	531.7	161.0	692.7	4.30	122.42	426.8	265.8
71	0.5563	2389.343	2249.6	4.8	532.8	160.3	693.1	4.32	122.52	426.7	266.4

Test Readings for Specimen No. 2

No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress kPa	Minor Eff. Stress kPa	Major Eff. Stress kPa	1:3 Ratio	Pore Press. psi	P kPa	Q kPa
72	0.5701	2394.696	2254.9	5.0	533.4	159.7	693.1	4.34	122.61	426.4	266.7
73	0.5840	2398.961	2259.2	5.1	533.7	158.7	692.4	4.36	122.76	425.5	266.9
74	0.5978	2404.697	2264.9	5.2	534.4	158.2	692.6	4.38	122.82	425.4	267.2
75	0.6116	2413.815	2274.0	5.3	535.9	157.0	692.9	4.41	123.00	424.9	267.9
76	0.6254	2421.079	2281.3	5.4	536.9	155.6	692.5	4.45	123.20	424.0	268.5
77	0.6392	2430.271	2290.5	5.6	538.4	155.7	694.1	4.46	123.18	424.9	269.2
78	0.6530	2436.551	2296.8	5.7	539.2	154.8	694.0	4.48	123.32	424.4	269.6
79	0.6669	2442.801	2303.0	5.8	540.0	154.5	694.5	4.49	123.36	424.5	270.0
80	0.6807	2445.286	2305.5	5.9	539.8	154.2	694.1	4.50	123.40	424.1	269.9
81	0.6945	2453.934	2314.1	6.0	541.2	154.2	695.4	4.51	123.41	424.8	270.6
82	0.7290	2473.111	2333.3	6.3	543.9	153.9	697.8	4.53	123.45	425.9	272.0
83	0.7636	2486.567	2346.8	6.6	545.3	153.7	699.0	4.55	123.48	426.3	272.7
84	0.7982	2509.406	2369.6	6.9	548.8	154.2	703.0	4.56	123.41	428.6	274.4
85	0.8327	2527.569	2387.8	7.2	551.3	154.6	705.9	4.57	123.35	430.2	275.6
86	0.8672	2556.217	2416.4	7.5	556.1	154.8	710.9	4.59	123.31	432.9	278.0
87	0.9018	2585.042	2445.3	7.8	560.9	155.6	716.5	4.60	123.20	436.1	280.4
88	0.9363	2607.351	2467.6	8.1	564.1	156.2	720.4	4.61	123.11	438.3	282.1
89	0.9708	2625.764	2486.0	8.4	566.5	156.9	723.4	4.61	123.01	440.1	283.3
90	1.0054	2633.808	2494.0	8.7	566.5	157.2	723.7	4.60	122.97	440.5	283.2
91	1.0399	2653.515	2513.7	9.0	569.1	156.9	726.0	4.63	123.01	441.4	284.5
92	1.0744	2673.575	2533.8	9.3	571.7	157.8	729.5	4.62	122.89	443.6	285.9
93	1.1090	2689.649	2549.9	9.6	573.4	158.4	731.8	4.62	122.80	445.1	286.7
94	1.1435	2715.047	2575.3	9.9	577.2	159.3	736.5	4.62	122.66	447.9	288.6
95	1.1781	2727.062	2587.3	10.2	578.0	160.2	738.2	4.61	122.54	449.2	289.0
96	1.2126	2748.651	2608.9	10.5	580.9	161.4	742.3	4.60	122.35	451.9	290.4
97	1.2472	2770.181	2630.4	10.8	583.7	162.3	745.9	4.60	122.24	454.1	291.8
98	1.2817	2789.741	2650.0	11.1	586.0	162.5	748.6	4.61	122.20	455.6	293.0
99	1.3162	2786.623	2646.8	11.4	583.4	163.7	747.0	4.56	122.03	455.4	291.7
100	1.3508	2796.638	2656.9	11.7	583.6	164.9	748.5	4.54	121.86	456.7	291.8
101	1.3853	2801.977	2662.2	12.0	582.8	165.1	747.9	4.53	121.82	456.5	291.4
102	1.4199	2821.169	2681.4	12.3	585.0	165.2	750.2	4.54	121.81	457.7	292.5
103	1.4544	2834.110	2694.3	12.6	585.8	166.7	752.5	4.51	121.59	459.6	292.9
104	1.4890	2851.523	2711.7	12.9	587.5	167.7	755.2	4.50	121.45	461.5	293.8
105	1.5235	2860.832	2721.0	13.2	587.5	168.2	755.8	4.49	121.37	462.0	293.8
106	1.5581	2876.421	2736.6	13.5	588.8	168.7	757.6	4.49	121.30	463.1	294.4
107	1.5926	2899.951	2760.2	13.8	591.9	169.4	761.2	4.49	121.20	465.3	295.9
108	1.6271	2903.701	2763.9	14.1	590.6	170.2	760.8	4.47	121.08	465.5	295.3
109	1.6617	2909.599	2769.8	14.4	589.8	170.6	760.3	4.46	121.03	465.4	294.9
110	1.6962	2936.658	2796.9	14.7	593.5	171.1	764.5	4.47	120.96	467.8	296.7
111	1.7307	2946.879	2807.1	15.0	593.5	171.2	764.7	4.47	120.94	467.9	296.8
112	1.7653	2949.071	2809.3	15.3	591.9	171.5	763.4	4.45	120.90	467.4	295.9
113	1.7998	2960.071	2820.3	15.6	592.1	173.0	765.1	4.42	120.68	469.0	296.0
114	1.8344	2974.527	2834.7	15.9	593.0	173.4	766.4	4.42	120.62	469.9	296.5
115	1.8689	2988.366	2848.6	16.2	593.8	173.0	766.8	4.43	120.68	469.9	296.9
116	1.9035	3002.529	2862.7	16.5	594.6	173.2	767.8	4.43	120.65	470.5	297.3
117	1.9380	3019.985	2880.2	16.8	596.1	173.7	769.8	4.43	120.57	471.8	298.0
118	1.9726	3026.721	2886.9	17.1	595.3	173.7	769.0	4.43	120.58	471.3	297.6

Test Readings for Specimen No. 2

No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress kPa	Minor Eff. Stress kPa	Major Eff. Stress kPa	1:3 Ratio	Pore Press. psi	P kPa	Q kPa
119	2.0071	3034.118	2894.3	17.4	594.7	173.7	768.3	4.42	120.58	471.0	297.3
120	2.0416	3042.765	2903.0	17.7	594.3	174.0	768.2	4.42	120.54	471.1	297.1
121	2.0762	3045.398	2905.6	18.0	592.6	173.7	766.3	4.41	120.58	470.0	296.3
122	2.1107	3073.943	2934.2	18.3	596.3	175.3	771.6	4.40	120.35	473.4	298.1
123	2.1452	3083.135	2943.3	18.6	595.9	176.1	772.1	4.38	120.22	474.1	298.0
124	2.1798	3097.547	2957.8	18.9	596.6	176.4	773.1	4.38	120.18	474.8	298.3
125	2.2143	3107.783	2968.0	19.3	596.5	176.1	772.6	4.39	120.22	474.4	298.2
126	2.2489	3122.298	2982.5	19.6	597.2	176.7	773.9	4.38	120.14	475.3	298.6

Parameters for Specimen No. 3

Specimen Parameter	Initial	Saturated	Consolidated	Final
Moisture content: Moist soil+tare, gms.	1411.000			12059.000
Moisture content: Dry soil+tare, gms.	1343.340			10972.000
Moisture content: Tare, gms.	411.400			2129.000
Moisture, %	7.3	24.4	14.2	12.3
Moist specimen weight, gms.	9472.1			
Diameter, in.	5.88	5.88	5.53	
Area, in.²	27.19	27.19	24.05	
Height, in.	12.10	12.10	11.40	
Net decrease in height, in.		0.00	0.70	
Wet density, pcf	109.7	127.2	140.2	
Dry density, pcf	102.3	102.3	122.7	
Void ratio	0.6674	0.6674	0.3892	
Saturation, %	29.7	100.0	100.0	

Test Readings for Specimen No. 3

Membrane modulus = 0.124105 kN/cm²

Membrane thickness = 0.064 cm

Consolidation cell pressure = 426.08 psi (2937.7 kPa)

Consolidation back pressure = 29.96 psi (206.6 kPa)

Consolidation effective confining stress = 2731.2 kPa

Strain rate, %/min. = 0.03

Fail. Stress = 1798.6 kPa **at reading no.** 120

No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress kPa	Minor Eff. Stress kPa	Major Eff. Stress kPa	1:3 Ratio	Pore Press. psi	P kPa	Q kPa
0	0.0000	364.852	0.0	0.0	0.0	2731.2	2731.2	1.00	29.96	2731.2	0.0
1	0.0030	627.319	262.5	0.0	75.2	2729.8	2805.1	1.03	30.15	2767.5	37.6
2	0.0060	864.210	499.4	0.1	143.1	2729.2	2872.3	1.05	30.24	2800.8	71.6
3	0.0090	1081.469	716.6	0.1	205.3	2728.0	2933.3	1.08	30.42	2830.6	102.7
4	0.0121	1285.418	920.6	0.1	263.7	2724.8	2988.5	1.10	30.88	2856.7	131.8
5	0.0151	1478.469	1113.6	0.1	318.9	2722.2	3041.1	1.12	31.26	2881.7	159.4
6	0.0181	1654.079	1289.2	0.2	369.1	2719.6	3088.6	1.14	31.64	2904.1	184.5
7	0.0211	1812.659	1447.8	0.2	414.4	2716.1	3130.5	1.15	32.14	2923.3	207.2
8	0.0242	1958.856	1594.0	0.2	456.1	2711.9	3168.0	1.17	32.75	2940.0	228.0
9	0.0272	2092.861	1728.0	0.2	494.3	2707.3	3201.6	1.18	33.41	2954.5	247.2
10	0.0302	2217.219	1852.4	0.3	529.7	2702.1	3231.8	1.20	34.18	2966.9	264.9
11	0.0333	2330.149	1965.3	0.3	561.9	2696.6	3258.5	1.21	34.97	2977.5	280.9
12	0.0363	2439.095	2074.2	0.3	592.9	2690.5	3283.3	1.22	35.86	2986.9	296.4

Test Readings for Specimen No. 3

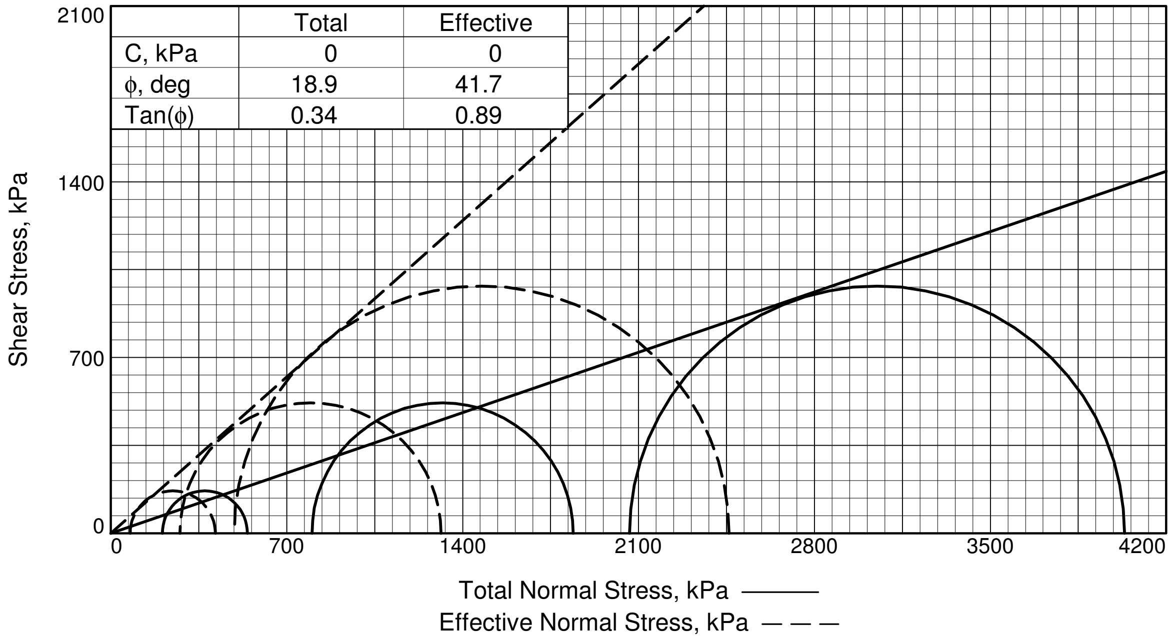
No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress kPa	Minor Eff. Stress kPa	Major Eff. Stress kPa	1:3 Ratio	Pore Press. psi	P kPa	Q kPa
13	0.0393	2538.981	2174.1	0.3	621.3	2684.0	3305.2	1.23	36.80	2994.6	310.6
14	0.0423	2630.455	2265.6	0.4	647.2	2677.0	3324.2	1.24	37.81	3000.6	323.6
15	0.0454	2718.106	2353.3	0.4	672.1	2669.7	3341.8	1.25	38.87	3005.8	336.0
16	0.0484	2808.948	2444.1	0.4	697.8	2662.3	3360.1	1.26	39.95	3011.2	348.9
17	0.0514	2898.113	2533.3	0.5	723.1	2654.2	3377.3	1.27	41.12	3015.7	361.6
18	0.0545	2984.072	2619.2	0.5	747.4	2645.6	3393.0	1.28	42.37	3019.3	373.7
19	0.0575	3070.899	2706.0	0.5	772.0	2636.4	3408.4	1.29	43.70	3022.4	386.0
20	0.0605	3154.358	2789.5	0.5	795.6	2626.6	3422.2	1.30	45.12	3024.4	397.8
21	0.0635	3235.008	2870.2	0.6	818.4	2616.8	3435.2	1.31	46.55	3026.0	409.2
22	0.0666	3317.850	2953.0	0.6	841.8	2606.3	3448.1	1.32	48.07	3027.2	420.9
23	0.0696	3400.368	3035.5	0.6	865.1	2595.1	3460.2	1.33	49.69	3027.7	432.5
24	0.0726	3482.680	3117.8	0.6	888.3	2583.6	3471.9	1.34	51.36	3027.8	444.2
25	0.0756	3567.786	3202.9	0.7	912.3	2571.3	3483.6	1.35	53.15	3027.4	456.2
26	0.0787	3645.921	3281.1	0.7	934.3	2558.2	3492.5	1.37	55.04	3025.4	467.2
27	0.0817	3725.042	3360.2	0.7	956.6	2544.7	3501.3	1.38	57.00	3023.0	478.3
28	0.0847	3805.795	3440.9	0.7	979.3	2530.6	3510.0	1.39	59.04	3020.3	489.7
29	0.0877	3888.342	3523.5	0.8	1002.5	2515.8	3518.4	1.40	61.19	3017.1	501.3
30	0.0908	3970.860	3606.0	0.8	1025.7	2500.7	3526.4	1.41	63.39	3013.5	512.9
31	0.0938	4055.408	3690.6	0.8	1049.5	2484.4	3533.9	1.42	65.75	3009.1	524.8
32	0.0969	4136.823	3772.0	0.8	1072.4	2467.2	3539.6	1.43	68.24	3003.4	536.2
33	0.0999	4218.885	3854.0	0.9	1095.4	2449.2	3544.7	1.45	70.85	2997.0	547.7
34	0.1029	4304.417	3939.6	0.9	1119.4	2430.8	3550.2	1.46	73.52	2990.5	559.7
35	0.1059	4388.877	4024.0	0.9	1143.1	2410.6	3553.8	1.47	76.45	2982.2	571.6
36	0.1089	4466.409	4101.6	1.0	1164.8	2389.9	3554.8	1.49	79.45	2972.3	582.4
37	0.1120	4552.707	4187.9	1.0	1189.0	2368.1	3557.1	1.50	82.62	2962.6	594.5
38	0.1150	4638.651	4273.8	1.0	1213.1	2345.2	3558.3	1.52	85.94	2951.7	606.6
39	0.1180	4727.699	4362.8	1.0	1238.0	2321.3	3559.3	1.53	89.41	2940.3	619.0
40	0.1210	4813.202	4448.3	1.1	1262.0	2296.3	3558.3	1.55	93.02	2927.3	631.0
41	0.1241	4893.499	4528.6	1.1	1284.4	2269.8	3554.2	1.57	96.87	2912.0	642.2
42	0.1362	5231.851	4867.0	1.2	1378.9	2155.2	3534.1	1.64	113.49	2844.7	689.4
43	0.1483	5551.172	5186.3	1.3	1467.8	2024.5	3492.3	1.73	132.45	2758.4	733.9
44	0.1604	5852.360	5487.5	1.4	1551.3	1883.0	3434.3	1.82	152.97	2658.7	775.7
45	0.1725	6099.708	5734.9	1.5	1619.5	1739.1	3358.6	1.93	173.85	2548.8	809.8
46	0.1846	6291.965	5927.1	1.6	1672.0	1599.8	3271.8	2.05	194.05	2435.8	836.0
47	0.1967	6435.368	6070.5	1.7	1710.6	1470.2	3180.8	2.16	212.84	2325.5	855.3
48	0.2088	6533.784	6168.9	1.8	1736.5	1354.0	3090.5	2.28	229.70	2222.2	868.2
49	0.2209	6596.036	6231.2	1.9	1752.1	1253.8	3005.9	2.40	244.24	2129.8	876.0
50	0.2330	6624.214	6259.4	2.0	1758.1	1167.2	2925.3	2.51	256.80	2046.2	879.1
51	0.2451	6646.141	6281.3	2.1	1762.4	1091.7	2854.0	2.61	267.75	1972.9	881.2
52	0.2572	6651.729	6286.9	2.3	1762.0	1027.0	2789.0	2.72	277.13	1908.0	881.0
53	0.2693	6643.964	6279.1	2.4	1757.9	970.9	2728.8	2.81	285.26	1849.9	879.0
54	0.2814	6629.596	6264.7	2.5	1752.0	921.7	2673.7	2.90	292.40	1797.7	876.0
55	0.2935	6606.684	6241.8	2.6	1743.7	879.7	2623.4	2.98	298.49	1751.6	871.8
56	0.3056	6587.624	6222.8	2.7	1736.5	840.7	2577.2	3.07	304.15	1708.9	868.2
57	0.3177	6561.799	6196.9	2.8	1727.4	807.7	2535.1	3.14	308.94	1671.4	863.7
58	0.3298	6540.666	6175.8	2.9	1719.6	778.3	2497.9	3.21	313.19	1638.1	859.8
59	0.3419	6520.210	6155.4	3.0	1712.0	753.2	2465.2	3.27	316.84	1609.2	856.0

Test Readings for Specimen No. 3

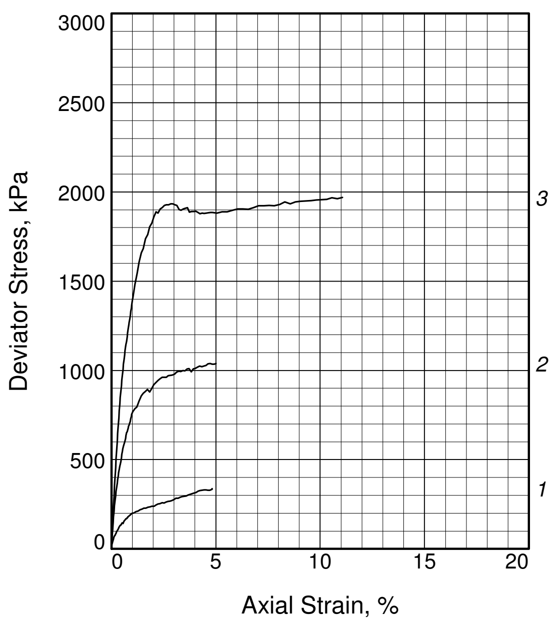
No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress kPa	Minor Eff. Stress kPa	Major Eff. Stress kPa	1:3 Ratio	Pore Press. psi	P kPa	Q kPa
60	0.3540	6493.561	6128.7	3.1	1702.8	729.8	2432.5	3.33	320.24	1581.1	851.4
61	0.3661	6479.605	6114.8	3.2	1697.0	708.6	2405.6	3.39	323.30	1557.1	848.5
62	0.3783	6456.604	6091.8	3.3	1688.8	690.4	2379.1	3.45	325.95	1534.7	844.4
63	0.3903	6448.074	6083.2	3.4	1684.6	673.5	2358.0	3.50	328.40	1515.8	842.3
64	0.4024	6434.383	6069.5	3.5	1678.9	659.2	2338.1	3.55	330.47	1498.7	839.5
65	0.4145	6420.735	6055.9	3.6	1673.3	645.2	2318.5	3.59	332.50	1481.8	836.7
66	0.4266	6408.132	6043.3	3.7	1668.0	633.3	2301.3	3.63	334.23	1467.3	834.0
67	0.4387	6399.323	6034.5	3.8	1663.7	622.3	2286.0	3.67	335.82	1454.2	831.9
68	0.4508	6392.602	6027.7	4.0	1660.0	612.3	2272.3	3.71	337.28	1442.3	830.0
69	0.4630	6386.793	6021.9	4.1	1656.6	603.1	2259.7	3.75	338.61	1431.4	828.3
70	0.4751	6381.542	6016.7	4.2	1653.3	594.6	2247.9	3.78	339.84	1421.3	826.7
71	0.4872	6375.483	6010.6	4.3	1649.8	586.2	2236.0	3.81	341.06	1411.1	824.9
72	0.4993	6372.248	6007.4	4.4	1647.1	578.9	2226.0	3.85	342.12	1402.4	823.6
73	0.5114	6370.910	6006.1	4.5	1644.9	571.4	2216.3	3.88	343.20	1393.9	822.5
74	0.5235	6373.660	6008.8	4.6	1643.8	564.9	2208.7	3.91	344.15	1386.8	821.9
75	0.5356	6376.822	6012.0	4.7	1642.9	558.5	2201.4	3.94	345.08	1379.9	821.4
76	0.5477	6378.366	6013.5	4.8	1641.5	554.0	2195.5	3.96	345.73	1374.7	820.7
77	0.5598	6386.248	6021.4	4.9	1641.8	549.1	2190.9	3.99	346.44	1370.0	820.9
78	0.5719	6387.616	6022.8	5.0	1640.3	545.9	2186.2	4.00	346.90	1366.1	820.2
79	0.5840	6391.896	6027.0	5.1	1639.7	542.3	2182.0	4.02	347.42	1362.2	819.8
80	0.5961	6396.558	6031.7	5.2	1639.1	539.0	2178.0	4.04	347.91	1358.5	819.5
81	0.6082	6411.529	6046.7	5.3	1641.3	535.9	2177.2	4.06	348.35	1356.6	820.7
82	0.6384	6425.897	6061.0	5.6	1640.6	526.8	2167.4	4.11	349.67	1347.1	820.3
83	0.6687	6456.854	6092.0	5.9	1644.3	521.0	2165.4	4.16	350.51	1343.2	822.2
84	0.6989	6487.605	6122.8	6.1	1648.0	516.1	2164.1	4.19	351.22	1340.1	824.0
85	0.7292	6527.475	6162.6	6.4	1654.0	512.9	2166.9	4.22	351.69	1339.9	827.0
86	0.7595	6561.741	6196.9	6.7	1658.5	510.5	2169.0	4.25	352.04	1339.7	829.3
87	0.7897	6592.977	6228.1	6.9	1662.1	508.4	2170.5	4.27	352.35	1339.4	831.1
88	0.8200	6634.611	6269.8	7.2	1668.5	505.3	2173.8	4.30	352.79	1339.6	834.2
89	0.8502	6673.333	6308.5	7.5	1674.0	505.7	2179.7	4.31	352.74	1342.7	837.0
90	0.8805	6705.982	6341.1	7.7	1677.8	503.5	2181.3	4.33	353.05	1342.4	838.9
91	0.9107	6738.909	6374.1	8.0	1681.7	501.3	2183.0	4.35	353.37	1342.2	840.8
92	0.9410	6784.161	6419.3	8.3	1688.7	500.7	2189.4	4.37	353.46	1345.0	844.4
93	0.9713	6821.104	6456.3	8.5	1693.5	501.5	2195.0	4.38	353.34	1348.3	846.8
94	1.0015	6867.444	6502.6	8.8	1700.7	502.8	2203.5	4.38	353.16	1353.1	850.4
95	1.0318	6911.901	6547.0	9.1	1707.4	503.4	2210.7	4.39	353.08	1357.0	853.7
96	1.0620	6953.874	6589.0	9.3	1713.3	504.2	2217.5	4.40	352.95	1360.9	856.7
97	1.0923	6998.346	6633.5	9.6	1719.8	504.8	2224.6	4.41	352.87	1364.7	859.9
98	1.1225	7050.524	6685.7	9.8	1728.3	503.9	2232.2	4.43	353.00	1368.0	864.1
99	1.1528	7088.276	6723.4	10.1	1732.9	504.5	2237.4	4.44	352.91	1370.9	866.5
100	1.1831	7127.704	6762.9	10.4	1737.9	506.7	2244.6	4.43	352.60	1375.6	869.0
101	1.2133	7165.470	6800.6	10.6	1742.5	508.2	2250.7	4.43	352.37	1379.5	871.2
102	1.2436	7204.413	6839.6	10.9	1747.2	510.5	2257.7	4.42	352.04	1384.1	873.6
103	1.2738	7242.105	6877.3	11.2	1751.6	512.7	2264.3	4.42	351.72	1388.5	875.8
104	1.3041	7285.048	6920.2	11.4	1757.3	514.8	2272.1	4.41	351.41	1393.5	878.6
105	1.3343	7327.520	6962.7	11.7	1762.8	515.7	2278.5	4.42	351.28	1397.1	881.4
106	1.3646	7364.522	6999.7	12.0	1766.8	518.1	2284.9	4.41	350.94	1401.5	883.4

Test Readings for Specimen No. 3

No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress kPa	Minor Eff. Stress kPa	Major Eff. Stress kPa	1:3 Ratio	Pore Press. psi	P kPa	Q kPa
107	1.3948	7389.126	7024.3	12.2	1767.7	517.5	2285.2	4.42	351.02	1401.4	883.8
108	1.4251	7421.892	7057.0	12.5	1770.6	519.0	2289.5	4.41	350.81	1404.3	885.3
109	1.4553	7457.834	7093.0	12.8	1774.2	520.0	2294.2	4.41	350.66	1407.1	887.1
110	1.4856	7489.468	7124.6	13.0	1776.7	521.0	2297.6	4.41	350.52	1409.3	888.3
111	1.5159	7527.999	7163.1	13.3	1780.8	522.8	2303.6	4.41	350.26	1413.2	890.4
112	1.5461	7559.824	7195.0	13.6	1783.3	525.5	2308.8	4.39	349.86	1417.2	891.6
113	1.5764	7588.707	7223.9	13.8	1784.9	526.5	2311.4	4.39	349.72	1418.9	892.5
114	1.6066	7617.841	7253.0	14.1	1786.6	527.7	2314.3	4.39	349.55	1421.0	893.3
115	1.6369	7649.474	7284.6	14.4	1788.9	528.0	2316.9	4.39	349.50	1422.4	894.4
116	1.6671	7677.475	7312.6	14.6	1790.2	528.7	2318.9	4.39	349.40	1423.8	895.1
117	1.6974	7709.535	7344.7	14.9	1792.4	528.5	2320.9	4.39	349.43	1424.7	896.2
118	1.7276	7745.301	7380.4	15.2	1795.5	528.4	2323.9	4.40	349.44	1426.2	897.8
119	1.7579	7779.259	7414.4	15.4	1798.2	529.7	2327.9	4.39	349.25	1428.8	899.1
120	1.7881	7804.539	7439.7	15.7	1798.6	531.2	2329.8	4.39	349.04	1430.5	899.3
121	1.8184	7818.319	7453.5	16.0	1796.3	530.9	2327.2	4.38	349.07	1429.1	898.1
122	1.8487	7846.202	7481.3	16.2	1797.3	532.9	2330.2	4.37	348.79	1431.5	898.7
123	1.8789	7855.673	7490.8	16.5	1793.9	533.9	2327.8	4.36	348.64	1430.9	896.9
124	1.9092	7879.660	7514.8	16.7	1793.9	534.6	2328.5	4.36	348.55	1431.5	897.0
125	1.9394	7893.557	7528.7	17.0	1791.5	532.2	2323.7	4.37	348.90	1427.9	895.8
126	1.9697	7913.087	7548.2	17.3	1790.4	532.7	2323.1	4.36	348.82	1427.9	895.2
127	2.0000	7943.206	7578.4	17.5	1791.8	533.5	2325.2	4.36	348.71	1429.4	895.9
128	2.0302	7962.898	7598.0	17.8	1790.7	534.0	2324.6	4.35	348.63	1429.3	895.3
129	2.0604	7986.840	7622.0	18.1	1790.5	535.2	2325.7	4.35	348.46	1430.4	895.3
130	2.0907	8015.253	7650.4	18.3	1791.4	535.7	2327.0	4.34	348.39	1431.3	895.7
131	2.1210	8040.328	7675.5	18.6	1791.4	535.4	2326.8	4.35	348.42	1431.1	895.7
132	2.1512	8061.078	7696.2	18.9	1790.4	536.7	2327.1	4.34	348.24	1431.9	895.2
133	2.1815	8078.373	7713.5	19.1	1788.5	536.9	2325.5	4.33	348.20	1431.2	894.3
134	2.2117	8093.609	7728.8	19.4	1786.2	537.5	2323.7	4.32	348.12	1430.6	893.1
135	2.2420	8119.845	7755.0	19.7	1786.3	537.7	2324.0	4.32	348.10	1430.8	893.2
136	2.2722	8136.449	7771.6	19.9	1784.3	537.6	2321.9	4.32	348.10	1429.8	892.1



	Total	Effective
C, kPa	0	0
ϕ, deg	18.9	41.7
Tan(ϕ)	0.34	0.89



Specimen No.		1	2	3
Initial	Water Content, %	0.8	0.8	0.8
	Dry Density, pcf	99.4	99.4	99.4
	Saturation, %	2.9	2.9	2.9
	Void Ratio	0.7151	0.7151	0.7151
	Diameter, in.	5.78	5.78	5.78
	Height, in.	12.10	12.10	12.10
At Test	Water Content, %	24.9	18.6	17.0
	Dry Density, pcf	101.5	113.1	116.4
	Saturation, %	100.0	100.0	100.0
	Void Ratio	0.6791	0.5073	0.4642
	Diameter, in.	5.73	5.67	5.76
	Height, in.	12.01	11.04	10.39
Strain rate, %/min.		0.02	0.02	0.02
Eff. Cell Pressure, kPa		205	800	2065
Fail. Stress, kPa		339	1039	1969
Excess Pore Pr., kPa		128	526	1574
Strain, %		4.8	4.7	11.1
Ult. Stress, kPa				
Excess Pore Pr., kPa				
Strain, %				
$\bar{\sigma}_1$ Failure, kPa		416	1314	2460
$\bar{\sigma}_3$ Failure, kPa		77	275	491

Type of Test:
CU with Pore Pressures

Sample Type: Remolded

Description: poorly graded gravel

LL= NP **PI=** NP

Specific Gravity= 2.73

Remarks: Failure tangents drawn for large strain conditions. Particles larger than 1" were crushed to minus 1" prior to testing. Single specimen multistage test.

Figure _______

Client: Casino Mining Corporation

Project: Casino

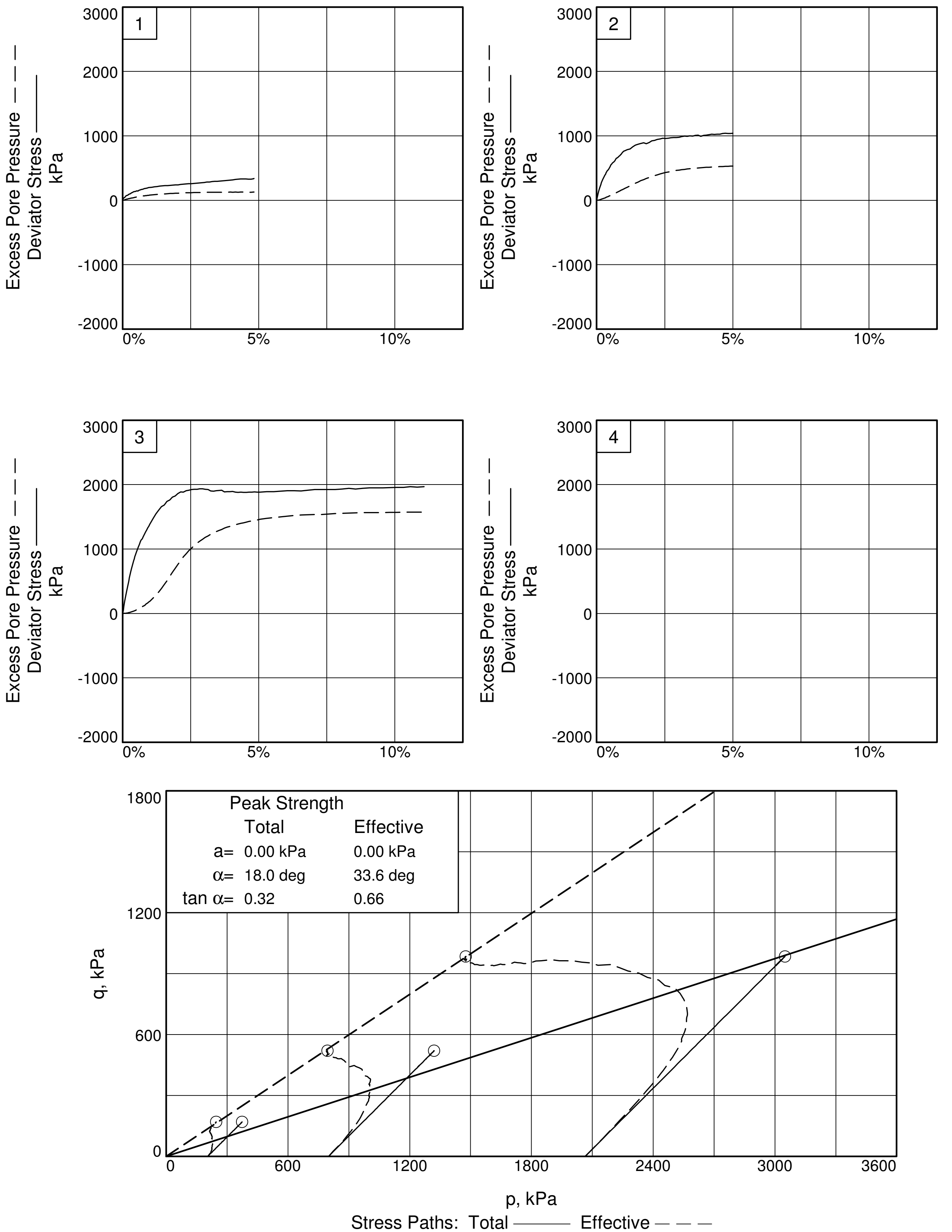
Sample Number: CL-03

Proj. No.: VA101-325/18 **Date Sampled:** 10/10/14

Knight Piésold
CONSULTING

Tested By: DAB **Checked By:** JDB

Cursory interpretations provided require review by a professional engineer. Knight Piesold accepts no responsibility in subsequent analyses.



Client: Casino Mining Corporation
Project: Casino
Sample Number: CL-03
Project No.: VA101-325/18

Figure _______

Knight Piesold Geotechnical Lab.

Tested By: DAB **Checked By:** JDB

TRIAXIAL COMPRESSION TEST

CU with Pore Pressures

1/30/2015
9:33 AM

Date: 10/10/14
Client: Casino Mining Corporation
Project: Casino
Project No.: VA101-325/18
Sample Number: CL-03
Description: poorly graded gravel
Remarks: Failure tangents drawn for large strain conditions. Particles larger than 1" were crushed to minus 1" prior to testing. Single specimen multistage test.
Type of Sample: Remolded
Specific Gravity=2.73 **LL=**NP **PL=** **PI=**NP
Test Method: COE uniform strain (staged method triaxial test)

Parameters for Specimen No. 1

Specimen Parameter	Initial	Saturated	Consolidated	Final
Moisture content: Moist soil+tare, gms.	10438.600			11306.000
Moisture content: Dry soil+tare, gms.	10360.000			10307.000
Moisture content: Tare, gms.	0.000			2126.500
Moisture, %	0.8	26.2	24.9	12.2
Moist specimen weight, gms.	8330.0			
Diameter, in.	5.78	5.78	5.73	
Area, in.²	26.19	26.19	25.83	
Height, in.	12.10	12.10	12.01	
Net decrease in height, in.		0.00	0.09	
Wet density, pcf	100.1	125.4	126.7	
Dry density, pcf	99.4	99.4	101.5	
Void ratio	0.7151	0.7151	0.6791	
Saturation, %	2.9	100.0	100.0	

Test Readings for Specimen No. 1

Membrane modulus = 0.124105 kN/cm²
Membrane thickness = 0.064 cm
Consolidation cell pressure = 50.29 psi (346.7 kPa)
Consolidation back pressure = 20.56 psi (141.8 kPa)
Consolidation effective confining stress = 205.0 kPa
Strain rate, %/min. = 0.02
Fail. Stress = 338.5 kPa **at reading no.** 82

Test Readings for Specimen No. 1

No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress kPa	Minor Eff. Stress kPa	Major Eff. Stress kPa	1:3 Ratio	Pore Press. psi	P kPa	Q kPa
0	0.0848	53.605	0.0	0.0	0.0	205.0	205.0	1.00	20.56	205.0	0.0
1	0.0876	142.256	88.7	0.0	23.7	203.0	226.6	1.12	20.85	214.8	11.8
2	0.0905	190.919	137.3	0.0	36.6	201.9	238.6	1.18	21.01	220.2	18.3
3	0.0934	219.509	165.9	0.1	44.3	198.6	242.9	1.22	21.48	220.8	22.1
4	0.0963	260.084	206.5	0.1	55.1	195.2	250.3	1.28	21.98	222.7	27.5
5	0.0992	291.394	237.8	0.1	63.4	192.4	255.8	1.33	22.39	224.1	31.7
6	0.1021	322.160	268.6	0.1	71.6	189.7	261.3	1.38	22.77	225.5	35.8
7	0.1050	337.616	284.0	0.2	75.7	187.0	262.7	1.40	23.17	224.8	37.8
8	0.1078	356.087	302.5	0.2	80.6	183.7	264.3	1.44	23.64	224.0	40.3
9	0.1107	377.324	323.7	0.2	86.2	181.4	267.6	1.48	23.98	224.5	43.1
10	0.1136	408.545	354.9	0.2	94.5	179.2	273.8	1.53	24.29	226.5	47.3
11	0.1165	424.340	370.7	0.3	98.7	176.8	275.5	1.56	24.65	226.1	49.4
12	0.1194	441.326	387.7	0.3	103.2	174.2	277.4	1.59	25.02	225.8	51.6
13	0.1223	459.224	405.6	0.3	108.0	172.2	280.2	1.63	25.31	226.2	54.0
14	0.1252	486.269	432.7	0.3	115.1	170.3	285.4	1.68	25.59	227.9	57.6
15	0.1281	504.623	451.0	0.4	120.0	168.3	288.2	1.71	25.89	228.2	60.0
16	0.1309	527.976	474.4	0.4	126.2	165.9	292.1	1.76	26.23	229.0	63.1
17	0.1338	544.404	490.8	0.4	130.5	164.0	294.5	1.80	26.50	229.3	65.2
18	0.1367	557.036	503.4	0.4	133.8	160.3	294.1	1.83	27.04	227.2	66.9
19	0.1396	557.228	503.6	0.5	133.8	158.6	292.4	1.84	27.29	225.5	66.9
20	0.1425	578.170	524.6	0.5	139.4	156.8	296.1	1.89	27.55	226.5	69.7
21	0.1453	594.200	540.6	0.5	143.6	155.3	298.9	1.92	27.77	227.1	71.8
22	0.1482	601.523	547.9	0.5	145.5	154.3	299.8	1.94	27.91	227.0	72.8
23	0.1511	587.111	533.5	0.6	141.6	152.6	294.3	1.93	28.16	223.4	70.8
24	0.1540	606.877	553.3	0.6	146.9	150.6	297.5	1.98	28.45	224.0	73.4
25	0.1569	635.569	582.0	0.6	154.4	149.4	303.8	2.03	28.63	226.6	77.2
26	0.1598	650.643	597.0	0.6	158.4	147.5	305.9	2.07	28.89	226.7	79.2
27	0.1627	663.099	609.5	0.6	161.7	145.7	307.3	2.11	29.16	226.5	80.8
28	0.1655	672.291	618.7	0.7	164.1	144.4	308.5	2.14	29.34	226.5	82.0
29	0.1684	691.277	637.7	0.7	169.1	143.1	312.1	2.18	29.54	227.6	84.5
30	0.1713	691.159	637.6	0.7	169.0	141.3	310.3	2.20	29.79	225.8	84.5
31	0.1742	702.410	648.8	0.7	171.9	139.9	311.9	2.23	29.99	225.9	86.0
32	0.1771	713.528	659.9	0.8	174.8	136.4	311.2	2.28	30.51	223.8	87.4
33	0.1799	732.867	679.3	0.8	179.9	135.4	315.4	2.33	30.65	225.4	90.0
34	0.1828	739.352	685.7	0.8	181.6	134.7	316.3	2.35	30.75	225.5	90.8
35	0.1857	749.926	696.3	0.8	184.3	133.4	317.7	2.38	30.95	225.5	92.2
36	0.1886	757.691	704.1	0.9	186.3	132.5	318.8	2.41	31.07	225.7	93.2
37	0.1915	765.986	712.4	0.9	188.5	131.4	319.9	2.43	31.24	225.6	94.2
38	0.1943	779.280	725.7	0.9	192.0	130.1	322.1	2.48	31.42	226.1	96.0
39	0.1972	788.810	735.2	0.9	194.4	129.0	323.4	2.51	31.58	226.2	97.2
40	0.2001	797.855	744.2	1.0	196.8	127.9	324.7	2.54	31.74	226.3	98.4
41	0.2030	805.752	752.1	1.0	198.8	126.7	325.5	2.57	31.92	226.1	99.4
42	0.2145	816.885	763.3	1.1	201.6	122.4	324.0	2.65	32.54	223.2	100.8
43	0.2260	847.298	793.7	1.2	209.4	118.6	328.0	2.77	33.09	223.3	104.7
44	0.2376	857.357	803.8	1.3	211.9	115.1	327.0	2.84	33.59	221.0	105.9
45	0.2491	885.711	832.1	1.4	219.1	111.6	330.8	2.96	34.10	221.2	109.6
46	0.2606	900.653	847.0	1.5	222.8	108.5	331.4	3.05	34.55	220.0	111.4

Knight Piesold Geotechnical Lab.

Test Readings for Specimen No. 1

No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress kPa	Minor Eff. Stress kPa	Major Eff. Stress kPa	1:3 Ratio	Pore Press. psi	P kPa	Q kPa
47	0.2721	921.462	867.9	1.6	228.1	105.0	333.1	3.17	35.06	219.1	114.0
48	0.2836	922.771	869.2	1.7	228.2	102.7	330.9	3.22	35.39	216.8	114.1
49	0.2951	941.831	888.2	1.8	233.0	99.7	332.7	3.34	35.83	216.2	116.5
50	0.3067	954.008	900.4	1.8	235.9	98.0	333.9	3.41	36.08	215.9	118.0
51	0.3182	966.523	912.9	1.9	239.0	95.9	334.9	3.49	36.38	215.4	119.5
52	0.3297	970.185	916.6	2.0	239.7	93.9	333.6	3.55	36.67	213.8	119.9
53	0.3412	997.995	944.4	2.1	246.7	90.2	337.0	3.73	37.20	213.6	123.4
54	0.3527	1017.098	963.5	2.2	251.5	91.0	342.5	3.76	37.09	216.7	125.7
55	0.3643	1022.054	968.4	2.3	252.5	89.7	342.2	3.82	37.28	216.0	126.3
56	0.3758	1043.938	990.3	2.4	258.0	88.1	346.1	3.93	37.51	217.1	129.0
57	0.3873	1041.702	988.1	2.5	257.2	86.5	343.7	3.97	37.74	215.1	128.6
58	0.3988	1060.938	1007.3	2.6	261.9	85.6	347.5	4.06	37.88	216.5	131.0
59	0.4104	1076.248	1022.6	2.7	265.6	84.6	350.2	4.14	38.03	217.4	132.8
60	0.4219	1084.042	1030.4	2.8	267.4	83.7	351.1	4.19	38.15	217.4	133.7
61	0.4334	1099.778	1046.2	2.9	271.2	83.2	354.4	4.26	38.22	218.8	135.6
62	0.4449	1119.485	1065.9	3.0	276.0	82.0	358.0	4.37	38.40	220.0	138.0
63	0.4565	1152.457	1098.9	3.1	284.3	81.9	366.2	4.47	38.41	224.1	142.1
64	0.4680	1150.957	1097.4	3.2	283.6	80.9	364.6	4.50	38.55	222.7	141.8
65	0.4795	1173.237	1119.6	3.3	289.1	80.0	369.1	4.62	38.69	224.5	144.5
66	0.4910	1189.223	1135.6	3.4	292.9	80.8	373.7	4.63	38.58	227.2	146.5
67	0.5025	1196.488	1142.9	3.5	294.5	81.0	375.5	4.64	38.54	228.3	147.3
68	0.5140	1204.944	1151.3	3.6	296.4	81.1	377.5	4.65	38.52	229.3	148.2
69	0.5256	1227.004	1173.4	3.7	301.8	80.2	382.0	4.76	38.65	231.1	150.9
70	0.5371	1240.887	1187.3	3.8	305.0	79.8	384.9	4.82	38.71	232.3	152.5
71	0.5486	1260.490	1206.9	3.9	309.8	79.5	389.3	4.90	38.76	234.4	154.9
72	0.5601	1269.726	1216.1	4.0	311.8	78.0	389.9	5.00	38.97	234.0	155.9
73	0.5716	1287.462	1233.9	4.1	316.1	79.2	395.3	4.99	38.80	237.2	158.0
74	0.5831	1316.360	1262.8	4.1	323.1	78.4	401.6	5.12	38.92	240.0	161.6
75	0.5946	1333.302	1279.7	4.2	327.1	79.2	406.3	5.13	38.81	242.7	163.6
76	0.6061	1343.082	1289.5	4.3	329.3	78.8	408.1	5.18	38.86	243.5	164.7
77	0.6177	1352.303	1298.7	4.4	331.3	79.0	410.3	5.20	38.84	244.6	165.7
78	0.6292	1349.435	1295.8	4.5	330.3	79.0	409.3	5.18	38.83	244.1	165.1
79	0.6407	1345.596	1292.0	4.6	329.0	79.6	408.5	5.13	38.75	244.1	164.5
80	0.6522	1347.729	1294.1	4.7	329.2	79.1	408.2	5.16	38.82	243.6	164.6
81	0.6637	1369.789	1316.2	4.8	334.5	76.7	411.2	5.36	39.16	243.9	167.2
82	0.6649	1385.892	1332.3	4.8	338.5	77.1	415.7	5.39	39.10	246.4	169.3

Parameters for Specimen No. 2

Specimen Parameter	Initial	Cum. for Test	Consolidated	Final
Moisture content: Moist soil+tare, gms.	10438.600			11306.000
Moisture content: Dry soil+tare, gms.	10360.000			10307.000
Moisture content: Tare, gms.	0.000			2126.500
Moisture, %	0.8		18.6	12.2
Moist specimen weight, gms.	8330.0			
Diameter, in.	5.78		5.67	
Area, in.²	26.19		25.22	
Height, in.	12.10		11.04	
Net decrease in height, in.		0.67	0.39	
Wet density, pcf	100.1		134.1	
Dry density, pcf	99.4		113.1	
Void ratio	0.7151		0.5073	
Saturation, %	2.9		100.0	

Test Readings for Specimen No. 2

Membrane modulus = 0.124105 kN/cm²

Membrane thickness = 0.064 cm

Consolidation cell pressure = 135.83 psi (936.5 kPa)

Consolidation back pressure = 19.75 psi (136.2 kPa)

Consolidation effective confining stress = 800.3 kPa

Strain rate, %/min. = 0.02

Fail. Stress = 1039.3 kPa **at reading no.** 78

No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress kPa	Minor Eff. Stress kPa	Major Eff. Stress kPa	1:3 Ratio	Pore Press. psi	P kPa	Q kPa
0	1.0572	109.740	0.0	0.0	0.0	800.3	800.3	1.00	19.75	800.3	0.0
1	1.0599	281.849	172.1	0.0	47.0	798.8	845.8	1.06	19.98	822.3	23.5
2	1.0627	463.842	354.1	0.0	96.8	797.9	894.6	1.12	20.11	846.2	48.4
3	1.0655	635.436	525.7	0.1	143.6	796.3	939.9	1.18	20.34	868.1	71.8
4	1.0682	767.295	657.6	0.1	179.6	793.3	972.9	1.23	20.77	883.1	89.8
5	1.0710	883.990	774.3	0.1	211.4	790.3	1001.7	1.27	21.21	896.0	105.7
6	1.0737	998.465	888.7	0.1	242.6	787.2	1029.8	1.31	21.66	908.5	121.3
7	1.0765	1101.234	991.5	0.2	270.6	784.0	1054.6	1.35	22.12	919.3	135.3
8	1.0793	1203.606	1093.9	0.2	298.5	780.2	1078.6	1.38	22.68	929.4	149.2
9	1.0820	1296.948	1187.2	0.2	323.8	776.9	1100.8	1.42	23.14	938.9	161.9
10	1.0848	1377.436	1267.7	0.3	345.7	772.9	1118.6	1.45	23.74	945.7	172.9
11	1.0876	1458.027	1348.3	0.3	367.6	768.8	1136.4	1.48	24.33	952.6	183.8
12	1.0903	1534.839	1425.1	0.3	388.4	764.2	1152.7	1.51	24.99	958.4	194.2
13	1.0931	1602.445	1492.7	0.3	406.8	759.7	1166.5	1.54	25.64	963.1	203.4
14	1.0958	1675.021	1565.3	0.4	426.4	755.4	1181.9	1.56	26.27	968.6	213.2
15	1.0986	1745.509	1635.8	0.4	445.5	750.4	1195.9	1.59	26.99	973.2	222.8
16	1.1014	1815.850	1706.1	0.4	464.6	746.8	1211.4	1.62	27.51	979.1	232.3
17	1.1041	1841.483	1731.7	0.4	471.4	741.1	1212.5	1.64	28.34	976.8	235.7
18	1.1069	1906.251	1796.5	0.5	488.9	736.3	1225.2	1.66	29.04	980.7	244.5
19	1.1096	1981.268	1871.5	0.5	509.2	732.1	1241.3	1.70	29.65	986.7	254.6
20	1.1124	2053.448	1943.7	0.5	528.7	727.1	1255.8	1.73	30.37	991.5	264.4
21	1.1152	2125.509	2015.8	0.5	548.2	723.1	1271.3	1.76	30.95	997.2	274.1
22	1.1179	2171.496	2061.8	0.6	560.6	717.7	1278.3	1.78	31.74	998.0	280.3
23	1.1207	2219.630	2109.9	0.6	573.5	713.1	1286.6	1.80	32.41	999.8	286.8
24	1.1234	2270.882	2161.1	0.6	587.3	708.3	1295.6	1.83	33.11	1001.9	293.6

Test Readings for Specimen No. 2

No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress kPa	Minor Eff. Stress kPa	Major Eff. Stress kPa	1:3 Ratio	Pore Press. psi	P kPa	Q kPa
25	1.1262	2292.030	2182.3	0.6	592.9	702.2	1295.1	1.84	33.98	998.7	296.4
26	1.1290	2334.473	2224.7	0.7	604.3	696.8	1301.1	1.87	34.77	998.9	302.1
27	1.1317	2390.343	2280.6	0.7	619.3	691.8	1311.0	1.90	35.50	1001.4	309.6
28	1.1345	2451.478	2341.7	0.7	635.7	686.7	1322.5	1.93	36.23	1004.6	317.9
29	1.1373	2508.053	2398.3	0.7	650.9	682.6	1333.5	1.95	36.82	1008.1	325.5
30	1.1400	2527.834	2418.1	0.8	656.1	677.2	1333.3	1.97	37.62	1005.2	328.1
31	1.1428	2555.776	2446.0	0.8	663.5	671.5	1335.1	1.99	38.43	1003.3	331.8
32	1.1455	2603.763	2494.0	0.8	676.4	666.8	1343.2	2.01	39.12	1005.0	338.2
33	1.1483	2644.485	2534.7	0.8	687.3	660.8	1348.1	2.04	39.99	1004.4	343.6
34	1.1511	2672.898	2563.2	0.9	694.8	655.4	1350.2	2.06	40.77	1002.8	347.4
35	1.1538	2722.003	2612.3	0.9	707.9	649.7	1357.6	2.09	41.60	1003.7	354.0
36	1.1566	2731.136	2621.4	0.9	710.2	643.6	1353.8	2.10	42.49	998.7	355.1
37	1.1594	2808.124	2698.4	0.9	730.9	638.9	1369.8	2.14	43.16	1004.4	365.4
38	1.1621	2852.111	2742.4	1.0	742.6	634.2	1376.8	2.17	43.84	1005.5	371.3
39	1.1649	2899.598	2789.9	1.0	755.3	629.0	1384.3	2.20	44.60	1006.6	377.6
40	1.1676	2928.599	2818.9	1.0	762.9	624.0	1386.9	2.22	45.33	1005.5	381.5
41	1.1704	2945.144	2835.4	1.0	767.2	617.5	1384.8	2.24	46.26	1001.1	383.6
42	1.1815	3018.662	2908.9	1.1	786.3	597.3	1383.7	2.32	49.20	990.5	393.2
43	1.1925	3056.487	2946.7	1.2	795.7	575.1	1370.9	2.38	52.42	973.0	397.9
44	1.2035	3179.741	3070.0	1.3	828.2	555.5	1383.7	2.49	55.26	969.6	414.1
45	1.2146	3289.143	3179.4	1.4	856.8	536.0	1392.8	2.60	58.09	964.4	428.4
46	1.2256	3349.616	3239.9	1.5	872.2	516.4	1388.6	2.69	60.94	952.5	436.1
47	1.2367	3389.955	3280.2	1.6	882.2	496.0	1378.2	2.78	63.89	937.1	441.1
48	1.2477	3437.854	3328.1	1.7	894.2	478.7	1372.9	2.87	66.40	925.8	447.1
49	1.2588	3387.264	3277.5	1.8	879.7	461.1	1340.8	2.91	68.95	900.9	439.8
50	1.2698	3454.326	3344.6	1.9	896.8	446.2	1342.9	3.01	71.12	894.5	448.4
51	1.2809	3548.697	3439.0	2.0	921.1	432.2	1353.4	3.13	73.14	892.8	460.6
52	1.2919	3587.095	3477.4	2.1	930.5	417.5	1348.0	3.23	75.27	882.8	465.2
53	1.3029	3637.686	3527.9	2.2	943.0	404.9	1348.0	3.33	77.10	876.4	471.5
54	1.3140	3679.570	3569.8	2.3	953.3	392.4	1345.7	3.43	78.91	869.1	476.6
55	1.3250	3715.983	3606.2	2.4	962.0	381.6	1343.7	3.52	80.48	862.6	481.0
56	1.3361	3715.748	3606.0	2.5	961.0	371.1	1332.1	3.59	82.00	851.6	480.5
57	1.3471	3723.571	3613.8	2.6	962.1	361.3	1323.4	3.66	83.42	842.4	481.0
58	1.3582	3757.220	3647.5	2.7	970.0	353.8	1323.8	3.74	84.52	838.8	485.0
59	1.3692	3770.411	3660.7	2.8	972.5	345.5	1318.1	3.81	85.72	831.8	486.3
60	1.3803	3779.588	3669.8	2.9	974.0	337.8	1311.8	3.88	86.83	824.8	487.0
61	1.3913	3803.177	3693.4	3.0	979.2	330.8	1310.1	3.96	87.84	820.5	489.6
62	1.4024	3845.811	3736.1	3.1	989.5	325.4	1314.9	4.04	88.64	820.1	494.7
63	1.4134	3871.180	3761.4	3.2	995.2	320.5	1315.6	4.11	89.35	818.1	497.6
64	1.4244	3867.827	3758.1	3.3	993.3	315.4	1308.6	4.15	90.09	812.0	496.6
65	1.4355	3896.887	3787.1	3.4	999.9	310.2	1310.1	4.22	90.84	810.2	500.0
66	1.4465	3892.004	3782.3	3.5	997.6	305.0	1302.6	4.27	91.59	803.8	498.8
67	1.4576	3934.065	3824.3	3.6	1007.6	301.6	1309.2	4.34	92.09	805.4	503.8
68	1.4686	3949.007	3839.3	3.7	1010.5	297.9	1308.5	4.39	92.62	803.2	505.3
69	1.4797	3882.533	3772.8	3.8	992.0	294.6	1286.6	4.37	93.10	790.6	496.0
70	1.4907	3945.771	3836.0	3.9	1007.6	291.8	1299.4	4.45	93.51	795.6	503.8
71	1.5018	3966.345	3856.6	4.0	1011.9	289.3	1301.2	4.50	93.87	795.3	506.0

Test Readings for Specimen No. 2

No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress kPa	Minor Eff. Stress kPa	Major Eff. Stress kPa	1:3 Ratio	Pore Press. psi	P kPa	Q kPa
72	1.5128	3996.567	3886.8	4.1	1018.8	286.7	1305.5	4.55	94.25	796.1	509.4
73	1.5238	4021.995	3912.3	4.2	1024.4	285.4	1309.8	4.59	94.44	797.6	512.2
74	1.5349	4010.465	3900.7	4.3	1020.3	283.0	1303.3	4.61	94.79	793.1	510.2
75	1.5459	4033.230	3923.5	4.4	1025.2	280.8	1306.0	4.65	95.10	793.4	512.6
76	1.5570	4045.069	3935.3	4.5	1027.2	277.7	1304.9	4.70	95.55	791.3	513.6
77	1.5680	4089.130	3979.4	4.6	1037.6	276.4	1314.0	4.75	95.74	795.2	518.8
78	1.5791	4099.777	3990.0	4.7	1039.3	274.7	1314.0	4.78	96.00	794.3	519.6
79	1.5901	4087.247	3977.5	4.8	1034.9	273.2	1308.2	4.79	96.20	790.7	517.5
80	1.6012	4095.659	3985.9	4.9	1036.0	270.6	1306.6	4.83	96.58	788.6	518.0
81	1.6094	4109.660	3999.9	5.0	1038.9	268.9	1307.8	4.86	96.83	788.3	519.4

Parameters for Specimen No. 3

Specimen Parameter	Initial	Cum. for Test	Consolidated	Final
Moisture content: Moist soil+tare, gms.	10438.600			11306.000
Moisture content: Dry soil+tare, gms.	10360.000			10307.000
Moisture content: Tare, gms.	0.000			2126.500
Moisture, %	0.8		17.0	12.2
Moist specimen weight, gms.	8330.0			
Diameter, in.	5.78		5.76	
Area, in.²	26.19		26.04	
Height, in.	12.10		10.39	
Net decrease in height, in.		1.61	0.10	
Wet density, pcf	100.1		136.2	
Dry density, pcf	99.4		116.4	
Void ratio	0.7151		0.4642	
Saturation, %	2.9		100.0	

Test Readings for Specimen No. 3

Membrane modulus = 0.124105 kN/cm²

Membrane thickness = 0.064 cm

Consolidation cell pressure = 318.60 psi (2196.7 kPa)

Consolidation back pressure = 19.15 psi (132.0 kPa)

Consolidation effective confining stress = 2064.6 kPa

Strain rate, %/min. = 0.02

Fail. Stress = 1969.4 kPa **at reading no.** 105

No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress kPa	Minor Eff. Stress kPa	Major Eff. Stress kPa	1:3 Ratio	Pore Press. psi	P kPa	Q kPa
0	1.5664	260.245	0.0	0.0	0.0	2064.6	2064.6	1.00	19.15	2064.6	0.0
1	1.5690	444.738	184.5	0.0	46.2	2065.1	2111.2	1.02	19.09	2088.2	23.1
2	1.5716	685.409	425.2	0.1	112.5	2063.8	2176.3	1.05	19.28	2120.0	56.3
3	1.5742	933.404	673.2	0.1	178.1	2063.3	2241.4	1.09	19.35	2152.3	89.1
4	1.5769	1165.531	905.3	0.1	239.5	2061.7	2301.2	1.12	19.58	2181.4	119.7
5	1.5795	1375.671	1115.4	0.1	295.0	2060.3	2355.4	1.14	19.77	2207.8	147.5
6	1.5821	1585.547	1325.3	0.2	350.4	2058.7	2409.2	1.17	20.00	2234.0	175.2
7	1.5847	1783.922	1523.7	0.2	402.8	2056.9	2459.7	1.20	20.27	2258.3	201.4
8	1.5873	1980.165	1719.9	0.2	454.6	2054.9	2509.5	1.22	20.56	2282.2	227.3
9	1.5899	2168.467	1908.2	0.2	504.2	2052.7	2556.8	1.25	20.89	2304.8	252.1
10	1.5925	2355.592	2095.3	0.3	553.5	2050.2	2603.7	1.27	21.24	2327.0	276.7

Test Readings for Specimen No. 3

No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress kPa	Minor Eff. Stress kPa	Major Eff. Stress kPa	1:3 Ratio	Pore Press. psi	P kPa	Q kPa
11	1.5951	2539.819	2279.6	0.3	602.0	2047.4	2649.4	1.29	21.65	2348.4	301.0
12	1.5977	2714.370	2454.1	0.3	647.9	2044.4	2692.4	1.32	22.08	2368.4	324.0
13	1.6003	2881.553	2621.3	0.3	691.9	2041.3	2733.2	1.34	22.54	2387.2	346.0
14	1.6029	3041.795	2781.5	0.4	734.0	2037.7	2771.7	1.36	23.06	2404.7	367.0
15	1.6056	3200.551	2940.3	0.4	775.7	2034.2	2809.9	1.38	23.57	2422.0	387.9
16	1.6082	3344.792	3084.5	0.4	813.6	2030.1	2843.6	1.40	24.17	2436.8	406.8
17	1.6108	3478.929	3218.7	0.4	848.7	2025.8	2874.6	1.42	24.78	2450.2	424.4
18	1.6134	3603.802	3343.6	0.5	881.4	2021.3	2902.8	1.44	25.43	2462.1	440.7
19	1.6160	3724.454	3464.2	0.5	913.0	2016.5	2929.5	1.45	26.13	2473.0	456.5
20	1.6186	3847.753	3587.5	0.5	945.3	2011.6	2956.9	1.47	26.84	2484.2	472.6
21	1.6212	3962.507	3702.3	0.5	975.3	2006.9	2982.2	1.49	27.52	2494.5	487.6
22	1.6238	4076.820	3816.6	0.6	1005.1	2002.0	3007.1	1.50	28.23	2504.6	502.6
23	1.6264	4190.957	3930.7	0.6	1034.9	1996.9	3031.8	1.52	28.98	2514.3	517.5
24	1.6290	4280.240	4020.0	0.6	1058.2	1991.3	3049.5	1.53	29.78	2520.4	529.1
25	1.6317	4392.774	4132.5	0.6	1087.5	1985.7	3073.2	1.55	30.61	2529.4	543.8
26	1.6343	4479.424	4219.2	0.7	1110.0	1979.6	3089.6	1.56	31.49	2534.6	555.0
27	1.6369	4576.560	4316.3	0.7	1135.3	1973.4	3108.7	1.58	32.38	2541.1	567.6
28	1.6395	4622.312	4362.1	0.7	1147.0	1966.1	3113.1	1.58	33.44	2539.6	573.5
29	1.6421	4684.094	4423.8	0.7	1163.0	1959.1	3122.1	1.59	34.45	2540.6	581.5
30	1.6447	4778.362	4518.1	0.8	1187.5	1952.3	3139.8	1.61	35.44	2546.0	593.7
31	1.6473	4864.086	4603.8	0.8	1209.7	1945.8	3155.5	1.62	36.38	2550.7	604.8
32	1.6499	4955.928	4695.7	0.8	1233.5	1939.0	3172.5	1.64	37.37	2555.7	616.8
33	1.6525	5042.873	4782.6	0.8	1256.0	1931.5	3187.5	1.65	38.46	2559.5	628.0
34	1.6551	5097.860	4837.6	0.9	1270.2	1923.3	3193.5	1.66	39.64	2558.4	635.1
35	1.6578	5169.686	4909.4	0.9	1288.7	1914.9	3203.5	1.67	40.87	2559.2	644.3
36	1.6604	5256.396	4996.2	0.9	1311.1	1907.2	3218.3	1.69	41.99	2562.7	655.6
37	1.6630	5332.796	5072.6	0.9	1330.8	1898.4	3229.3	1.70	43.26	2563.9	665.4
38	1.6656	5402.004	5141.8	1.0	1348.6	1889.8	3238.4	1.71	44.51	2564.1	674.3
39	1.6682	5476.169	5215.9	1.0	1367.8	1880.9	3248.7	1.73	45.80	2564.8	683.9
40	1.6708	5573.408	5313.2	1.0	1392.9	1872.6	3265.5	1.74	47.00	2569.1	696.4
41	1.6734	5644.940	5384.7	1.0	1411.3	1863.1	3274.4	1.76	48.38	2568.8	705.6
42	1.6838	5919.598	5659.4	1.1	1481.8	1822.9	3304.7	1.81	54.21	2563.8	740.9
43	1.6943	6168.093	5907.8	1.2	1545.3	1778.5	3323.7	1.87	60.65	2551.1	772.6
44	1.7047	6408.146	6147.9	1.3	1606.4	1729.5	3336.0	1.93	67.75	2532.8	803.2
45	1.7151	6614.963	6354.7	1.4	1658.8	1676.6	3335.4	1.99	75.43	2506.0	829.4
46	1.7256	6711.158	6450.9	1.5	1682.2	1616.5	3298.6	2.04	84.15	2457.5	841.1
47	1.7360	6931.108	6670.9	1.6	1737.7	1557.9	3295.6	2.12	92.65	2426.8	868.9
48	1.7464	7028.421	6768.2	1.7	1761.3	1490.7	3252.0	2.18	102.40	2371.3	880.6
49	1.7569	7200.133	6939.9	1.8	1804.1	1427.2	3231.4	2.26	111.60	2329.3	902.1
50	1.7673	7288.548	7028.3	1.9	1825.3	1362.5	3187.8	2.34	120.98	2275.1	912.6
51	1.7777	7428.421	7168.2	2.0	1859.7	1303.1	3162.8	2.43	129.60	2233.0	929.8
52	1.7882	7545.661	7285.4	2.1	1888.2	1247.0	3135.2	2.51	137.73	2191.1	944.1
53	1.7986	7528.366	7268.1	2.2	1881.7	1186.8	3068.5	2.59	146.47	2127.6	940.9
54	1.8091	7623.488	7363.2	2.3	1904.4	1138.8	3043.2	2.67	153.43	2091.0	952.2
55	1.8195	7659.063	7398.8	2.4	1911.6	1092.1	3003.7	2.75	160.21	2047.9	955.8
56	1.8299	7715.330	7455.1	2.5	1924.2	1048.9	2973.1	2.83	166.47	2011.0	962.1
57	1.8404	7735.683	7475.4	2.6	1927.5	1008.6	2936.1	2.91	172.31	1972.4	963.7

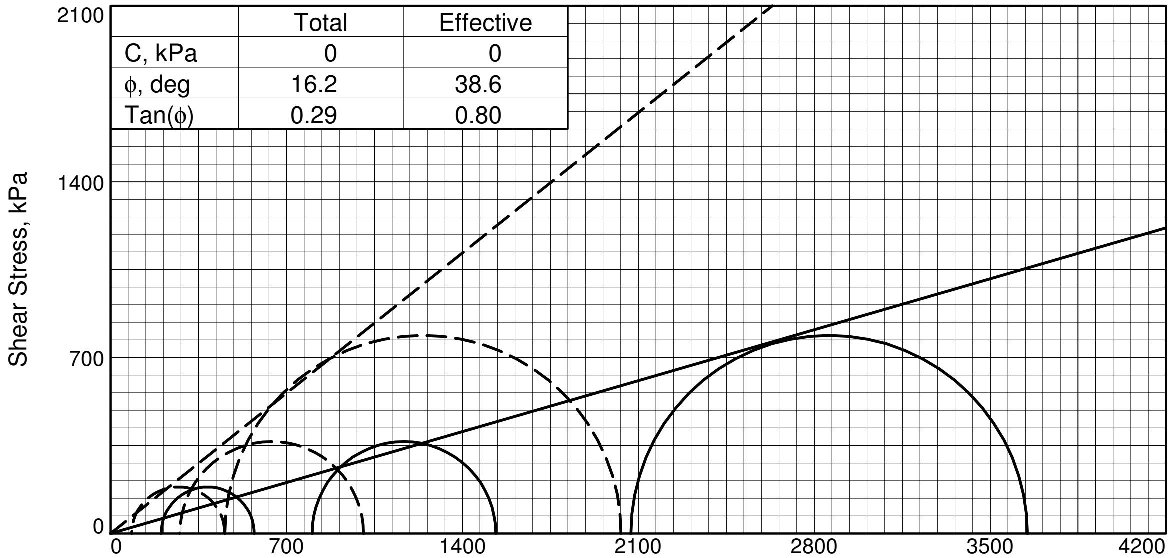
Test Readings for Specimen No. 3

No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress kPa	Minor Eff. Stress kPa	Major Eff. Stress kPa	1:3 Ratio	Pore Press. psi	P kPa	Q kPa
58	1.8508	7744.419	7484.2	2.7	1927.7	973.4	2901.1	2.98	177.42	1937.3	963.9
59	1.8612	7774.626	7514.4	2.8	1933.5	943.9	2877.4	3.05	181.70	1910.6	966.8
60	1.8717	7784.141	7523.9	2.9	1934.0	914.7	2848.6	3.11	185.94	1881.7	967.0
61	1.8821	7767.626	7507.4	3.0	1927.7	885.3	2813.0	3.18	190.20	1849.1	963.9
62	1.8925	7759.964	7499.7	3.1	1923.8	859.9	2783.6	3.24	193.89	1821.8	961.9
63	1.9030	7680.137	7419.9	3.2	1901.3	835.8	2737.1	3.27	197.38	1786.5	950.7
64	1.9134	7674.681	7414.4	3.3	1897.9	814.0	2712.0	3.33	200.54	1763.0	949.0
65	1.9238	7709.506	7449.3	3.4	1904.9	794.5	2699.4	3.40	203.37	1746.9	952.4
66	1.9343	7733.389	7473.1	3.5	1909.0	776.5	2685.5	3.46	205.98	1731.0	954.5
67	1.9447	7754.861	7494.6	3.6	1912.5	760.4	2672.9	3.52	208.31	1716.7	956.2
68	1.9551	7662.151	7401.9	3.7	1886.9	741.1	2627.9	3.55	211.12	1684.5	943.4
69	1.9656	7682.843	7422.6	3.8	1890.2	726.4	2616.5	3.60	213.25	1671.5	945.1
70	1.9760	7690.432	7430.2	3.9	1890.1	712.4	2602.6	3.65	215.27	1657.5	945.1
71	1.9864	7710.256	7450.0	4.0	1893.2	701.0	2594.2	3.70	216.92	1647.6	946.6
72	1.9969	7683.446	7423.2	4.1	1884.4	688.4	2572.8	3.74	218.75	1630.6	942.2
73	2.0073	7667.019	7406.8	4.2	1878.2	675.6	2553.8	3.78	220.62	1614.7	939.1
74	2.0178	7687.005	7426.8	4.3	1881.3	666.6	2548.0	3.82	221.91	1607.3	940.7
75	2.0282	7689.446	7429.2	4.4	1880.0	656.7	2536.7	3.86	223.35	1596.7	940.0
76	2.0386	7701.197	7441.0	4.5	1881.0	645.9	2526.9	3.91	224.92	1586.4	940.5
77	2.0491	7715.800	7455.6	4.6	1882.7	637.0	2519.7	3.96	226.21	1578.4	941.3
78	2.0595	7731.977	7471.7	4.7	1884.8	627.9	2512.7	4.00	227.53	1570.3	942.4
79	2.0699	7741.787	7481.5	4.8	1885.3	619.6	2504.9	4.04	228.73	1562.2	942.6
80	2.0804	7741.198	7481.0	4.9	1883.1	612.3	2495.5	4.08	229.79	1553.9	941.6
81	2.0908	7743.669	7483.4	5.0	1881.8	604.2	2486.0	4.11	230.97	1545.1	940.9
82	2.1169	7793.803	7533.6	5.3	1889.4	588.0	2477.4	4.21	233.32	1532.7	944.7
83	2.1430	7811.216	7551.0	5.5	1888.7	575.1	2463.9	4.28	235.18	1519.5	944.4
84	2.1690	7867.277	7607.0	5.8	1897.7	565.0	2462.7	4.36	236.65	1513.9	948.8
85	2.1951	7914.749	7654.5	6.0	1904.4	554.0	2458.4	4.44	238.25	1506.2	952.2
86	2.2212	7936.574	7676.3	6.3	1904.8	545.3	2450.0	4.49	239.51	1497.7	952.4
87	2.2473	7948.045	7687.8	6.6	1902.5	537.2	2439.7	4.54	240.69	1488.4	951.2
88	2.2734	8006.694	7746.4	6.8	1911.9	531.3	2443.1	4.60	241.55	1487.2	955.9
89	2.2995	8074.035	7813.8	7.1	1923.3	528.9	2452.2	4.64	241.90	1490.5	961.6
90	2.3256	8090.227	7830.0	7.3	1922.1	527.4	2449.4	4.64	242.11	1488.4	961.0
91	2.3516	8119.169	7858.9	7.6	1924.0	520.3	2444.3	4.70	243.13	1482.3	962.0
92	2.3777	8137.817	7877.6	7.8	1923.3	513.9	2437.2	4.74	244.06	1475.6	961.6
93	2.4038	8185.627	7925.4	8.1	1929.7	511.8	2441.5	4.77	244.36	1476.7	964.8
94	2.4299	8266.395	8006.1	8.3	1944.0	508.4	2452.4	4.82	244.87	1480.4	972.0
95	2.4560	8241.527	7981.3	8.6	1932.7	503.2	2435.9	4.84	245.62	1469.5	966.3
96	2.4821	8309.162	8048.9	8.8	1943.7	498.8	2442.5	4.90	246.25	1470.7	971.9
97	2.5082	8349.693	8089.4	9.1	1948.1	498.6	2446.7	4.91	246.29	1472.7	974.1
98	2.5342	8378.061	8117.8	9.3	1949.6	498.6	2448.2	4.91	246.29	1473.4	974.8
99	2.5603	8405.062	8144.8	9.6	1950.6	497.6	2448.2	4.92	246.43	1472.9	975.3
100	2.5864	8443.990	8183.7	9.8	1954.5	497.3	2451.9	4.93	246.47	1474.6	977.3
101	2.6125	8473.359	8213.1	10.1	1956.1	493.9	2450.0	4.96	246.96	1472.0	978.0
102	2.6386	8504.360	8244.1	10.3	1958.0	493.3	2451.2	4.97	247.06	1472.2	979.0
103	2.6647	8569.686	8309.4	10.6	1968.0	493.4	2461.4	4.99	247.04	1477.4	984.0
104	2.6907	8565.230	8305.0	10.8	1961.4	492.3	2453.7	4.98	247.20	1473.0	980.7

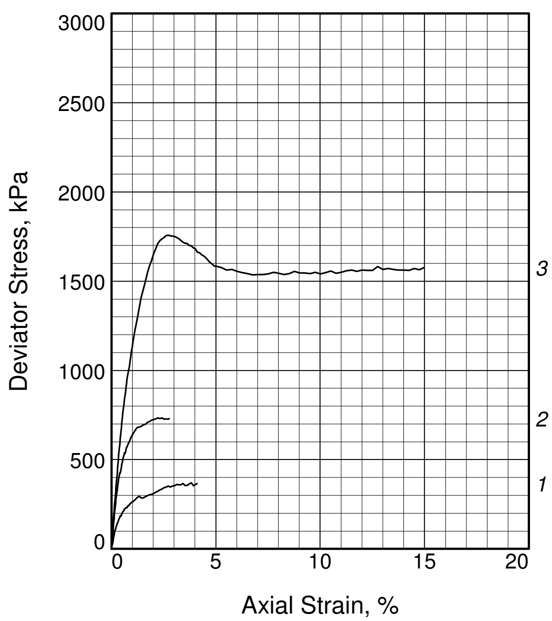
Test Readings for Specimen No. 3

No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress kPa	Minor Eff. Stress kPa	Major Eff. Stress kPa	1:3 Ratio	Pore Press. psi	P kPa	Q kPa
105	2.7168	8622.821	8362.6	11.1	1969.4	490.9	2460.3	5.01	247.41	1475.6	984.7

Knight Piesold Geotechnical Lab.



	Total	Effective
C, kPa	0	0
ϕ, deg	16.2	38.6
Tan(ϕ)	0.29	0.80



	Specimen No.	1	2	3
Initial	Water Content, %	2.5	2.5	2.5
	Dry Density, pcf	96.3	96.3	96.3
	Saturation, %	9.1	9.1	9.1
	Void Ratio	0.7494	0.7494	0.7494
	Diameter, in.	6.00	6.00	6.00
	Height, in.	12.00	12.00	12.00
At Test	Water Content, %	26.8	25.8	24.8
	Dry Density, pcf	97.8	99.3	101.0
	Saturation, %	100.0	100.0	100.0
	Void Ratio	0.7237	0.6971	0.6695
	Diameter, in.	5.97	6.06	6.12
	Height, in.	11.94	11.39	11.02
	Strain rate, %/min.	0.02	0.02	0.02
	Eff. Cell Pressure, kPa	201	802	2070
	Fail. Stress, kPa	370	731	1577
	Excess Pore Pr., kPa	117	527	1616
	Strain, %	3.8	2.8	15.0
	Ult. Stress, kPa			
	Excess Pore Pr., kPa			
	Strain, %			
	$\bar{\sigma}_1$ Failure, kPa	454	1006	2032
	$\bar{\sigma}_3$ Failure, kPa	84	275	454

Type of Test:
CU with Pore Pressures

Sample Type: Remolded

Description: poorly graded gravel

LL= NP **PI=** NP

Specific Gravity= 2.7

Remarks: Failure tangents drawn for large strain conditions. Particles larger than 1" were crushed to minus 1" prior to testing. Single specimen multistage test.

Figure _______

Client: Casino Mining Corporation

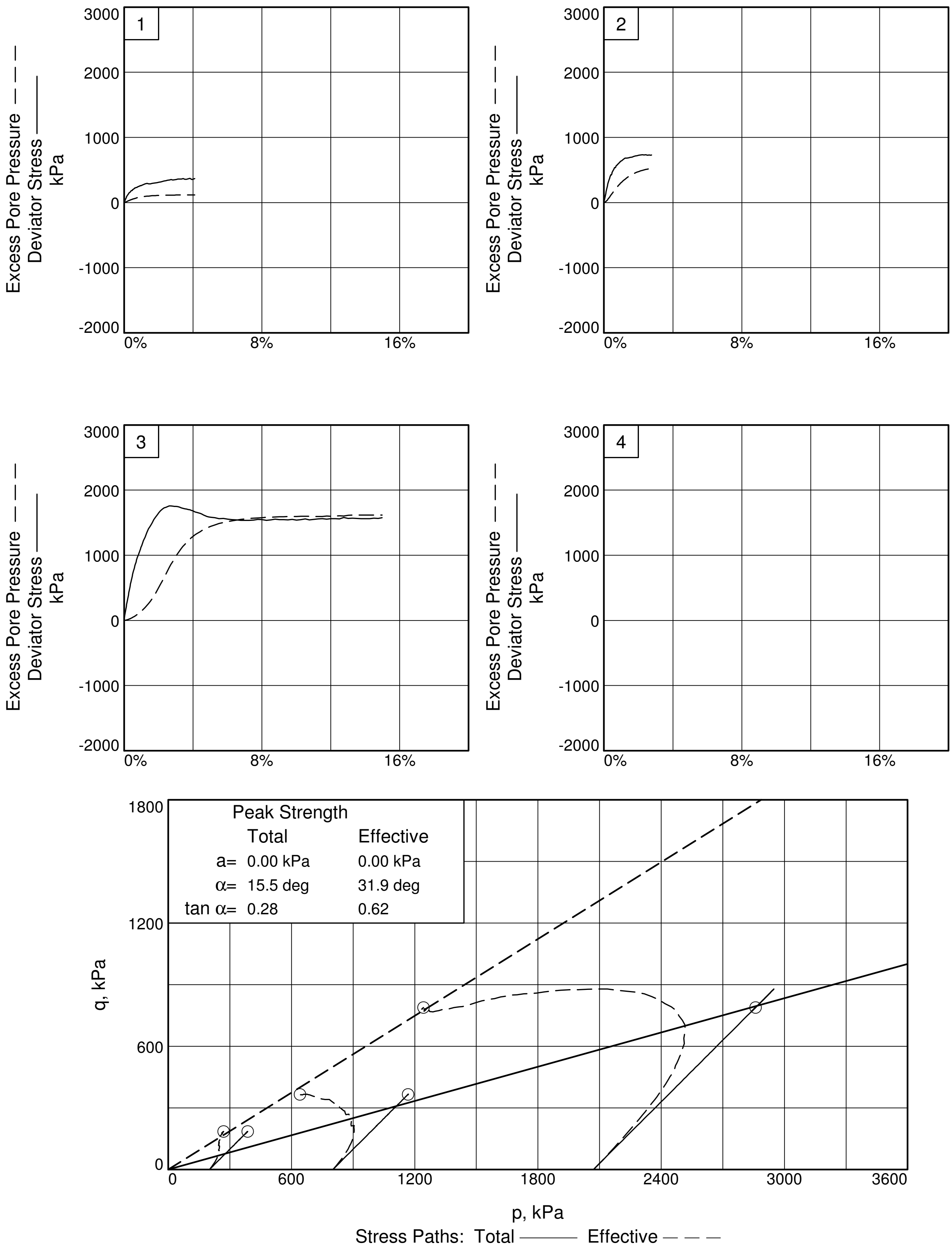
Project: Casino

Sample Number: CL-05

Proj. No.: VA101-325/18 **Date Sampled:** 10/10/14

Knight Piésold CONSULTING

Tested By: DAB **Checked By:** JDB



Client: Casino Mining Corporation
Project: Casino
Sample Number: CL-05
Project No.: VA101-325/18

Figure _______

Knight Piesold Geotechnical Lab.

Tested By: DAB **Checked By:** JDB

TRIAXIAL COMPRESSION TEST

CU with Pore Pressures

1/30/2015
9:40 AM

Date: 10/10/14
Client: Casino Mining Corporation
Project: Casino
Project No.: VA101-325/18
Sample Number: CL-05
Description: poorly graded gravel
Remarks: Failure tangents drawn for large strain conditions. Particles larger than 1" were crushed to minus 1" prior to testing. Single specimen multistage test.
Type of Sample: Remolded
Specific Gravity=2.7 **LL=**NP **PL=** **PI=**NP
Test Method: COE uniform strain (staged method triaxial test)

Parameters for Specimen No. 1

Specimen Parameter	Initial	Saturated	Consolidated	Final
Moisture content: Moist soil+tare, gms.	9300.000			12475.500
Moisture content: Dry soil+tare, gms.	9071.800			11330.000
Moisture content: Tare, gms.	0.000			2841.500
Moisture, %	2.5	27.8	26.8	13.5
Moist specimen weight, gms.	8797.0			
Diameter, in.	6.00	6.00	5.97	
Area, in.²	28.27	28.27	28.00	
Height, in.	12.00	12.00	11.94	
Net decrease in height, in.		0.00	0.06	
Wet density, pcf	98.8	123.1	124.0	
Dry density, pcf	96.3	96.3	97.8	
Void ratio	0.7494	0.7494	0.7237	
Saturation, %	9.1	100.0	100.0	

Test Readings for Specimen No. 1

Membrane modulus = 0.124105 kN/cm²
Membrane thickness = 0.064 cm
Consolidation cell pressure = 58.42 psi (402.8 kPa)
Consolidation back pressure = 29.23 psi (201.5 kPa)
Consolidation effective confining stress = 201.3 kPa
Strain rate, %/min. = 0.02
Fail. Stress = 370.3 kPa **at reading no.** 69

Test Readings for Specimen No. 1

No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress kPa	Minor Eff. Stress kPa	Major Eff. Stress kPa	1:3 Ratio	Pore Press. psi	P kPa	Q kPa
0	0.0588	63.605	0.0	0.0	0.0	201.3	201.3	1.00	29.23	201.3	0.0
1	0.0618	141.182	77.6	0.0	19.1	199.3	218.4	1.10	29.51	208.9	9.6
2	0.0648	167.198	103.6	0.1	25.5	198.6	224.1	1.13	29.62	211.3	12.7
3	0.0678	245.848	182.2	0.1	44.8	195.9	240.7	1.23	30.01	218.3	22.4
4	0.0708	314.674	251.1	0.1	61.8	193.0	254.8	1.32	30.42	223.9	30.9
5	0.0738	374.073	310.5	0.1	76.4	190.0	266.4	1.40	30.86	228.2	38.2
6	0.0768	427.708	364.1	0.2	89.5	187.6	277.2	1.48	31.20	232.4	44.8
7	0.0797	480.739	417.1	0.2	102.5	183.9	286.5	1.56	31.75	235.2	51.3
8	0.0827	522.800	459.2	0.2	112.9	181.0	293.9	1.62	32.16	237.5	56.4
9	0.0857	561.742	498.1	0.2	122.4	177.6	300.0	1.69	32.66	238.8	61.2
10	0.0887	603.921	540.3	0.3	132.7	174.9	307.6	1.76	33.06	241.2	66.4
11	0.0917	642.790	579.2	0.3	142.2	172.2	314.5	1.83	33.44	243.4	71.1
12	0.0947	668.158	604.6	0.3	148.4	169.1	317.5	1.88	33.90	243.3	74.2
13	0.0977	692.145	628.5	0.3	154.3	166.2	320.5	1.93	34.32	243.3	77.1
14	0.1006	719.807	656.2	0.4	161.0	163.5	324.6	1.98	34.70	244.0	80.5
15	0.1036	759.677	696.1	0.4	170.8	160.7	331.5	2.06	35.12	246.1	85.4
16	0.1066	780.501	716.9	0.4	175.8	158.3	334.2	2.11	35.46	246.3	87.9
17	0.1096	817.988	754.4	0.4	185.0	156.1	341.1	2.18	35.77	248.6	92.5
18	0.1126	814.341	750.7	0.5	184.1	153.5	337.6	2.20	36.15	245.5	92.0
19	0.1156	831.400	767.8	0.5	188.2	151.3	339.5	2.24	36.48	245.4	94.1
20	0.1186	869.578	806.0	0.5	197.5	148.6	346.1	2.33	36.87	247.3	98.7
21	0.1215	890.049	826.4	0.5	202.5	146.8	349.3	2.38	37.13	248.0	101.2
22	0.1245	908.991	845.4	0.6	207.1	145.2	352.2	2.43	37.37	248.7	103.5
23	0.1275	929.404	865.8	0.6	212.0	141.9	353.9	2.49	37.84	247.9	106.0
24	0.1305	947.934	884.3	0.6	216.5	140.8	357.3	2.54	37.99	249.1	108.2
25	0.1335	973.729	910.1	0.6	222.7	138.7	361.4	2.61	38.30	250.1	111.4
26	0.1365	984.524	920.9	0.7	225.3	136.9	362.2	2.65	38.56	249.6	112.7
27	0.1395	1000.642	937.0	0.7	229.2	134.6	363.9	2.70	38.89	249.3	114.6
28	0.1425	1007.627	944.0	0.7	230.9	132.8	363.6	2.74	39.17	248.2	115.4
29	0.1454	1011.289	947.7	0.7	231.7	130.6	362.3	2.77	39.48	246.4	115.8
30	0.1484	1012.686	949.1	0.8	232.0	129.4	361.4	2.79	39.65	245.4	116.0
31	0.1514	1039.805	976.2	0.8	238.5	126.3	364.9	2.89	40.10	245.6	119.3
32	0.1544	1049.585	986.0	0.8	240.9	126.0	366.8	2.91	40.15	246.4	120.4
33	0.1574	1064.218	1000.6	0.8	244.4	124.8	369.2	2.96	40.31	247.0	122.2
34	0.1604	1067.174	1003.6	0.9	245.1	122.7	367.8	3.00	40.62	245.2	122.5
35	0.1634	1088.028	1024.4	0.9	250.1	121.4	371.4	3.06	40.82	246.4	125.0
36	0.1664	1098.455	1034.8	0.9	252.6	120.4	373.0	3.10	40.96	246.7	126.3
37	0.1693	1115.117	1051.5	0.9	256.6	119.3	375.8	3.15	41.12	247.6	128.3
38	0.1723	1132.323	1068.7	1.0	260.7	117.8	378.4	3.21	41.34	248.1	130.3
39	0.1753	1123.970	1060.4	1.0	258.6	116.3	374.9	3.22	41.55	245.6	129.3
40	0.1783	1138.162	1074.6	1.0	262.0	115.9	377.9	3.26	41.61	246.9	131.0
41	0.1813	1144.706	1081.1	1.0	263.5	113.8	377.3	3.32	41.91	245.6	131.8
42	0.1932	1192.767	1129.2	1.1	275.0	110.1	385.1	3.50	42.45	247.6	137.5
43	0.2052	1244.519	1180.9	1.2	287.3	107.1	394.3	3.68	42.89	250.7	143.6
44	0.2171	1277.770	1214.2	1.3	295.1	104.7	399.8	3.82	43.23	252.3	147.5
45	0.2291	1243.872	1180.3	1.4	286.5	102.2	388.7	3.80	43.60	245.5	143.3
46	0.2410	1243.240	1179.6	1.5	286.1	98.9	385.0	3.89	44.07	242.0	143.0

Test Readings for Specimen No. 1

No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress kPa	Minor Eff. Stress kPa	Major Eff. Stress kPa	1:3 Ratio	Pore Press. psi	P kPa	Q kPa
47	0.2529	1274.653	1211.0	1.6	293.4	97.0	390.4	4.02	44.35	243.7	146.7
48	0.2649	1299.345	1235.7	1.7	299.1	95.5	394.6	4.13	44.57	245.0	149.5
49	0.2768	1317.698	1254.1	1.8	303.2	94.5	397.7	4.21	44.71	246.1	151.6
50	0.2888	1330.243	1266.6	1.9	305.9	93.4	399.3	4.28	44.88	246.3	153.0
51	0.3007	1353.464	1289.9	2.0	311.2	92.4	403.6	4.37	45.02	248.0	155.6
52	0.3127	1383.054	1319.4	2.1	318.0	90.9	408.9	4.50	45.24	249.9	159.0
53	0.3246	1408.364	1344.8	2.2	323.8	90.5	414.3	4.58	45.30	252.4	161.9
54	0.3365	1436.526	1372.9	2.3	330.3	89.8	420.0	4.68	45.40	254.9	165.1
55	0.3485	1464.116	1400.5	2.4	336.5	89.1	425.7	4.78	45.49	257.4	168.3
56	0.3604	1491.234	1427.6	2.5	342.7	88.9	431.6	4.86	45.53	260.2	171.4
57	0.3724	1508.309	1444.7	2.6	346.5	88.3	434.7	4.92	45.61	261.5	173.2
58	0.3843	1531.177	1467.6	2.7	351.6	87.4	439.0	5.02	45.74	263.2	175.8
59	0.3963	1512.471	1448.9	2.8	346.7	87.4	434.2	4.97	45.74	260.8	173.4
60	0.4082	1533.060	1469.5	2.9	351.3	87.1	438.4	5.03	45.78	262.8	175.7
61	0.4202	1541.942	1478.3	3.0	353.1	86.1	439.1	5.10	45.94	262.6	176.5
62	0.4321	1577.767	1514.2	3.1	361.2	85.7	446.9	5.22	45.99	266.3	180.6
63	0.4440	1572.017	1508.4	3.2	359.5	85.0	444.5	5.23	46.09	264.7	179.7
64	0.4560	1575.194	1511.6	3.3	359.9	85.0	444.9	5.23	46.09	264.9	179.9
65	0.4679	1603.195	1539.6	3.4	366.2	85.6	451.8	5.28	46.00	268.7	183.1
66	0.4799	1560.590	1497.0	3.5	355.7	84.4	440.1	5.21	46.18	262.2	177.8
67	0.4918	1565.429	1501.8	3.6	356.4	84.2	440.6	5.23	46.21	262.4	178.2
68	0.5038	1599.371	1535.8	3.7	364.1	84.0	448.1	5.34	46.24	266.0	182.1
69	0.5157	1627.078	1563.5	3.8	370.3	84.1	454.4	5.40	46.22	269.3	185.2
70	0.5276	1557.590	1494.0	3.9	353.5	83.6	437.1	5.23	46.29	260.4	176.7
71	0.5396	1590.282	1526.7	4.0	360.8	84.3	445.2	5.28	46.19	264.8	180.4
72	0.5479	1616.710	1553.1	4.1	366.8	85.0	451.8	5.32	46.10	268.4	183.4

Parameters for Specimen No. 2

Specimen Parameter	Initial	Cum. for Test	Consolidated	Final
Moisture content: Moist soil+tare, gms.	9300.000			12475.500
Moisture content: Dry soil+tare, gms.	9071.800			11330.000
Moisture content: Tare, gms.	0.000			2841.500
Moisture, %	2.5		25.8	13.5
Moist specimen weight, gms.	8797.0			
Diameter, in.	6.00		6.06	
Area, in.²	28.27		28.89	
Height, in.	12.00		11.39	
Net decrease in height, in.		0.55	0.06	
Wet density, pcf	98.8		125.0	
Dry density, pcf	96.3		99.3	
Void ratio	0.7494		0.6971	
Saturation, %	9.1		100.0	

Test Readings for Specimen No. 2

Membrane modulus = 0.124105 kN/cm²

Membrane thickness = 0.064 cm

Consolidation cell pressure = 146.14 psi (1007.6 kPa)

Consolidation back pressure = 29.84 psi (205.7 kPa)

Consolidation effective confining stress = 801.9 kPa

Strain rate, %/min. = 0.02

Fail. Stress = 731.2 kPa **at reading no.** 59

No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress kPa	Minor Eff. Stress kPa	Major Eff. Stress kPa	1:3 Ratio	Pore Press. psi	P kPa	Q kPa
0	0.5064	150.079	0.0	0.0	0.0	801.9	801.9	1.00	29.84	801.9	0.0
1	0.5093	297.938	147.9	0.0	35.3	799.6	834.9	1.04	30.17	817.2	17.6
2	0.5121	433.473	283.4	0.0	67.6	796.6	864.2	1.08	30.60	830.4	33.8
3	0.5150	575.258	425.2	0.1	101.4	793.5	894.9	1.13	31.05	844.2	50.7
4	0.5178	721.043	571.0	0.1	136.1	788.7	924.9	1.17	31.74	856.8	68.1
5	0.5207	845.386	695.3	0.1	165.7	782.4	948.2	1.21	32.66	865.3	82.9
6	0.5235	979.391	829.3	0.2	197.6	776.4	974.1	1.25	33.53	875.2	98.8
7	0.5264	1105.999	955.9	0.2	227.7	768.6	996.3	1.30	34.67	882.4	113.9
8	0.5292	1223.474	1073.4	0.2	255.7	761.7	1017.4	1.34	35.66	889.5	127.8
9	0.5321	1341.817	1191.7	0.2	283.8	753.6	1037.4	1.38	36.84	895.5	141.9
10	0.5349	1450.718	1300.6	0.3	309.6	745.4	1055.1	1.42	38.02	900.3	154.8
11	0.5378	1538.545	1388.5	0.3	330.5	736.6	1067.1	1.45	39.31	901.8	165.2
12	0.5406	1632.902	1482.8	0.3	352.8	727.0	1079.8	1.49	40.70	903.4	176.4
13	0.5435	1716.640	1566.6	0.3	372.7	718.2	1090.8	1.52	41.98	904.5	186.3
14	0.5463	1796.188	1646.1	0.4	391.5	709.4	1100.8	1.55	43.26	905.1	195.7
15	0.5492	1871.205	1721.1	0.4	409.2	699.0	1108.2	1.59	44.76	903.6	204.6
16	0.5520	1948.664	1798.6	0.4	427.5	690.6	1118.2	1.62	45.97	904.4	213.8
17	0.5549	1936.428	1786.3	0.4	424.5	679.1	1103.6	1.63	47.65	891.3	212.3
18	0.5577	2000.313	1850.2	0.5	439.6	670.0	1109.6	1.66	48.97	889.8	219.8
19	0.5606	2082.684	1932.6	0.5	459.0	661.4	1120.5	1.69	50.21	890.9	229.5
20	0.5634	2152.496	2002.4	0.5	475.5	653.8	1129.3	1.73	51.31	891.6	237.8
21	0.5663	2207.027	2056.9	0.5	488.3	643.5	1131.8	1.76	52.81	887.7	244.2
22	0.5691	2263.265	2113.2	0.6	501.6	634.8	1136.4	1.79	54.07	885.6	250.8
23	0.5720	2318.031	2168.0	0.6	514.4	626.4	1140.8	1.82	55.29	883.6	257.2
24	0.5748	2369.754	2219.7	0.6	526.6	618.3	1144.9	1.85	56.46	881.6	263.3

Test Readings for Specimen No. 2

No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress kPa	Minor Eff. Stress kPa	Major Eff. Stress kPa	1:3 Ratio	Pore Press. psi	P kPa	Q kPa
25	0.5777	2422.344	2272.3	0.6	538.9	609.8	1148.7	1.88	57.70	879.2	269.5
26	0.5805	2397.329	2247.2	0.7	532.8	598.8	1131.6	1.89	59.29	865.2	266.4
27	0.5834	2441.874	2291.8	0.7	543.3	590.7	1134.0	1.92	60.46	862.4	271.6
28	0.5862	2498.112	2348.0	0.7	556.5	581.9	1138.4	1.96	61.74	860.1	278.2
29	0.5891	2547.805	2397.7	0.7	568.1	574.9	1143.0	1.99	62.75	859.0	284.0
30	0.5919	2568.394	2418.3	0.8	572.8	566.4	1139.2	2.01	63.99	852.8	286.4
31	0.5948	2602.292	2452.2	0.8	580.7	559.4	1140.1	2.04	65.01	849.7	290.4
32	0.5976	2628.941	2478.9	0.8	586.9	550.5	1137.3	2.07	66.30	843.9	293.4
33	0.6005	2663.471	2513.4	0.8	594.9	544.6	1139.5	2.09	67.15	842.0	297.4
34	0.6033	2684.693	2534.6	0.9	599.8	535.8	1135.5	2.12	68.43	835.7	299.9
35	0.6062	2718.106	2568.0	0.9	607.5	529.6	1137.1	2.15	69.33	833.3	303.8
36	0.6090	2733.812	2583.7	0.9	611.1	521.7	1132.8	2.17	70.47	827.3	305.5
37	0.6119	2783.535	2633.5	0.9	622.7	516.4	1139.0	2.21	71.25	827.7	311.3
38	0.6147	2809.242	2659.2	1.0	628.6	508.0	1136.6	2.24	72.46	822.3	314.3
39	0.6175	2830.301	2680.2	1.0	633.4	502.1	1135.5	2.26	73.32	818.8	316.7
40	0.6204	2845.228	2695.1	1.0	636.8	495.2	1131.9	2.29	74.32	813.6	318.4
41	0.6232	2869.538	2719.5	1.0	642.4	488.7	1131.1	2.31	75.26	809.9	321.2
42	0.6346	2959.306	2809.2	1.1	662.9	464.9	1127.8	2.43	78.71	796.4	331.5
43	0.6460	3038.015	2887.9	1.2	680.8	443.9	1124.7	2.53	81.76	784.3	340.4
44	0.6574	3043.427	2893.3	1.3	681.4	422.5	1103.9	2.61	84.86	763.2	340.7
45	0.6688	3068.355	2918.3	1.4	686.5	404.1	1090.6	2.70	87.54	747.3	343.3
46	0.6802	3101.665	2951.6	1.5	693.7	388.0	1081.7	2.79	89.86	734.9	346.8
47	0.6916	3124.063	2974.0	1.6	698.2	372.1	1070.3	2.88	92.17	721.2	349.1
48	0.7030	3172.785	3022.7	1.7	708.9	358.3	1067.2	2.98	94.18	712.7	354.5
49	0.7144	3200.257	3050.2	1.8	714.7	346.7	1061.4	3.06	95.85	704.0	357.3
50	0.7258	3228.479	3078.4	1.9	720.5	335.2	1055.7	3.15	97.53	695.5	360.3
51	0.7372	3253.774	3103.7	2.0	725.7	326.2	1051.9	3.22	98.83	689.1	362.9
52	0.7486	3272.598	3122.5	2.1	729.4	317.3	1046.7	3.30	100.12	682.0	364.7
53	0.7600	3294.849	3144.8	2.2	733.8	308.6	1042.4	3.38	101.38	675.5	366.9
54	0.7714	3282.378	3132.3	2.3	730.2	301.6	1031.8	3.42	102.40	666.7	365.1
55	0.7828	3301.320	3151.2	2.4	733.8	294.5	1028.3	3.49	103.43	661.4	366.9
56	0.7942	3270.421	3120.3	2.5	725.9	288.6	1014.5	3.51	104.28	651.6	362.9
57	0.8056	3287.363	3137.3	2.6	729.1	282.8	1011.9	3.58	105.12	647.3	364.5
58	0.8169	3280.186	3130.1	2.7	726.7	276.8	1003.5	3.63	105.99	640.1	363.3
59	0.8217	3300.893	3150.8	2.8	731.2	275.1	1006.3	3.66	106.24	640.7	365.6

Parameters for Specimen No. 3

Specimen Parameter	Initial	Cum. for Test	Consolidated	Final
Moisture content: Moist soil+tare, gms.	9300.000			12475.500
Moisture content: Dry soil+tare, gms.	9071.800			11330.000
Moisture content: Tare, gms.	0.000			2841.500
Moisture, %	2.5		24.8	13.5
Moist specimen weight, gms.	8797.0			
Diameter, in.	6.00		6.12	
Area, in.²	28.27		29.39	
Height, in.	12.00		11.02	
Net decrease in height, in.		0.92	0.06	
Wet density, pcf	98.8		126.0	
Dry density, pcf	96.3		101.0	
Void ratio	0.7494		0.6695	
Saturation, %	9.1		100.0	

Test Readings for Specimen No. 3

Membrane modulus = 0.124105 kN/cm²
Membrane thickness = 0.064 cm
Consolidation cell pressure = 329.71 psi (2273.3 kPa)
Consolidation back pressure = 29.41 psi (202.8 kPa)
Consolidation effective confining stress = 2070.5 kPa
Strain rate, %/min. = 0.02
Fail. Stress = 1577.3 kPa **at reading no.** 121

No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress kPa	Minor Eff. Stress kPa	Major Eff. Stress kPa	1:3 Ratio	Pore Press. psi	P kPa	Q kPa
0	0.8916	285.849	0.0	0.0	0.0	2070.5	2070.5	1.00	29.41	2070.5	0.0
1	0.8944	481.725	195.9	0.0	45.9	2069.9	2115.9	1.02	29.49	2092.9	23.0
2	0.8971	674.512	388.7	0.0	91.1	2069.1	2160.2	1.04	29.62	2114.6	45.6
3	0.8999	846.856	561.0	0.1	131.5	2067.9	2199.4	1.06	29.79	2133.6	65.8
4	0.9026	1017.098	731.2	0.1	171.4	2066.7	2238.1	1.08	29.96	2152.4	85.7
5	0.9054	1179.237	893.4	0.1	209.3	2065.0	2274.4	1.10	30.20	2169.7	104.7
6	0.9081	1331.522	1045.7	0.1	245.0	2063.4	2308.4	1.12	30.44	2185.9	122.5
7	0.9109	1485.072	1199.2	0.2	280.9	2061.5	2342.4	1.14	30.71	2201.9	140.4
8	0.9136	1638.490	1352.6	0.2	316.7	2059.5	2376.2	1.15	31.01	2217.8	158.4
9	0.9164	1791.143	1505.3	0.2	352.4	2057.1	2409.5	1.17	31.35	2233.3	176.2
10	0.9191	1939.781	1653.9	0.2	387.1	2054.8	2441.9	1.19	31.68	2248.4	193.5
11	0.9219	2092.081	1806.2	0.3	422.6	2052.6	2475.2	1.21	32.01	2263.9	211.3
12	0.9246	2240.396	1954.5	0.3	457.2	2050.0	2507.2	1.22	32.39	2278.6	228.6
13	0.9274	2385.637	2099.8	0.3	491.0	2047.3	2538.3	1.24	32.78	2292.8	245.5
14	0.9301	2535.805	2250.0	0.3	526.0	2044.4	2570.4	1.26	33.20	2307.4	263.0
15	0.9329	2681.104	2395.3	0.4	559.8	2041.5	2601.4	1.27	33.61	2321.5	279.9
16	0.9356	2800.947	2515.1	0.4	587.7	2038.3	2626.0	1.29	34.09	2332.1	293.9
17	0.9384	2932.011	2646.2	0.4	618.2	2034.9	2653.1	1.30	34.57	2344.0	309.1
18	0.9411	3070.781	2784.9	0.4	650.4	2031.6	2682.0	1.32	35.05	2356.8	325.2
19	0.9439	3205.551	2919.7	0.5	681.7	2028.4	2710.2	1.34	35.51	2369.3	340.9
20	0.9466	3326.085	3040.2	0.5	709.7	2024.8	2734.5	1.35	36.04	2379.6	354.9
21	0.9494	3446.311	3160.5	0.5	737.6	2020.9	2758.5	1.36	36.61	2389.7	368.8
22	0.9521	3557.859	3272.0	0.5	763.4	2017.2	2780.7	1.38	37.13	2398.9	381.7
23	0.9549	3660.451	3374.6	0.6	787.2	2013.1	2800.3	1.39	37.73	2406.7	393.6
24	0.9577	3768.220	3482.4	0.6	812.1	2009.0	2821.1	1.40	38.33	2415.1	406.1

Test Readings for Specimen No. 3

No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress kPa	Minor Eff. Stress kPa	Major Eff. Stress kPa	1:3 Ratio	Pore Press. psi	P kPa	Q kPa
25	0.9604	3863.268	3577.4	0.6	834.1	2004.8	2838.9	1.42	38.94	2421.9	417.0
26	0.9632	3966.978	3681.1	0.6	858.0	2000.8	2858.8	1.43	39.52	2429.8	429.0
27	0.9659	4060.746	3774.9	0.7	879.7	1996.3	2875.9	1.44	40.18	2436.1	439.8
28	0.9687	4156.515	3870.7	0.7	901.7	1991.8	2893.6	1.45	40.82	2442.7	450.9
29	0.9714	4267.225	3981.4	0.7	927.3	1987.5	2914.8	1.47	41.45	2451.1	463.7
30	0.9742	4365.302	4079.5	0.7	949.9	1983.1	2933.0	1.48	42.09	2458.0	475.0
31	0.9769	4452.409	4166.6	0.8	969.9	1978.2	2948.1	1.49	42.80	2463.1	485.0
32	0.9797	4531.426	4245.6	0.8	988.1	1973.2	2961.3	1.50	43.52	2467.2	494.0
33	0.9824	4580.516	4294.7	0.8	999.3	1968.0	2967.3	1.51	44.27	2467.7	499.6
34	0.9852	4646.431	4360.6	0.8	1014.3	1962.9	2977.3	1.52	45.01	2470.1	507.2
35	0.9879	4743.420	4457.6	0.9	1036.6	1957.5	2994.1	1.53	45.80	2475.8	518.3
36	0.9907	4830.379	4544.5	0.9	1056.6	1952.4	3009.0	1.54	46.54	2480.7	528.3
37	0.9934	4919.324	4633.5	0.9	1077.0	1947.0	3024.0	1.55	47.33	2485.5	538.5
38	0.9962	4999.547	4713.7	0.9	1095.4	1941.4	3036.8	1.56	48.13	2489.1	547.7
39	0.9989	5089.257	4803.4	1.0	1116.0	1935.8	3051.8	1.58	48.95	2493.8	558.0
40	1.0017	5164.569	4878.7	1.0	1133.2	1929.8	3063.0	1.59	49.81	2496.4	566.6
41	1.0044	5234.483	4948.6	1.0	1149.1	1924.0	3073.1	1.60	50.66	2498.6	574.6
42	1.0154	5568.099	5282.2	1.1	1225.3	1899.7	3125.0	1.65	54.18	2512.4	612.7
43	1.0264	5795.711	5509.9	1.2	1276.9	1872.3	3149.2	1.68	58.15	2510.8	638.4
44	1.0374	6100.414	5814.6	1.3	1346.1	1843.6	3189.7	1.73	62.32	2516.6	673.1
45	1.0484	6367.557	6081.7	1.4	1406.5	1812.5	3219.0	1.78	66.84	2515.7	703.3
46	1.0594	6573.329	6287.5	1.5	1452.6	1776.6	3229.2	1.82	72.04	2502.9	726.3
47	1.0704	6761.204	6475.4	1.6	1494.5	1739.2	3233.7	1.86	77.47	2486.4	747.3
48	1.0814	6994.213	6708.4	1.7	1546.7	1700.2	3246.9	1.91	83.12	2473.6	773.4
49	1.0924	7163.529	6877.7	1.8	1584.2	1657.6	3241.7	1.96	89.30	2449.7	792.1
50	1.1034	7306.284	7020.4	1.9	1615.4	1611.1	3226.5	2.00	96.04	2418.8	807.7
51	1.1144	7474.997	7189.1	2.0	1652.5	1563.5	3216.0	2.06	102.94	2389.8	826.3
52	1.1254	7616.311	7330.5	2.1	1683.3	1514.0	3197.3	2.11	110.13	2355.6	841.6
53	1.1364	7740.066	7454.2	2.2	1710.0	1463.5	3173.4	2.17	117.45	2318.5	855.0
54	1.1474	7822.201	7536.4	2.3	1727.0	1411.7	3138.8	2.22	124.95	2275.3	863.5
55	1.1584	7869.439	7583.6	2.4	1736.1	1360.6	3096.7	2.28	132.38	2228.6	868.0
56	1.1694	7916.426	7630.6	2.5	1745.1	1309.2	3054.2	2.33	139.83	2181.7	872.5
57	1.1804	7975.781	7689.9	2.6	1756.8	1259.8	3016.7	2.39	146.99	2138.3	878.4
58	1.1914	7984.958	7699.1	2.7	1757.1	1210.6	2967.8	2.45	154.12	2089.2	878.6
59	1.2024	7980.266	7694.4	2.8	1754.3	1165.3	2919.5	2.51	160.70	2042.4	877.1
60	1.2134	7977.384	7691.5	2.9	1751.8	1120.5	2872.3	2.56	167.20	1996.4	875.9
61	1.2245	7983.031	7697.2	3.0	1751.3	1078.3	2829.6	2.62	173.31	1954.0	875.6
62	1.2355	7963.148	7677.3	3.1	1745.0	1039.3	2784.3	2.68	178.97	1911.8	872.5
63	1.2465	7943.544	7657.7	3.2	1738.7	1002.2	2740.9	2.73	184.35	1871.6	869.4
64	1.2575	7907.190	7621.3	3.3	1728.7	967.4	2696.1	2.79	189.40	1831.7	864.3
65	1.2685	7871.424	7585.6	3.4	1718.8	933.1	2651.9	2.84	194.37	1792.5	859.4
66	1.2795	7856.615	7570.8	3.5	1713.6	903.6	2617.2	2.90	198.66	1760.4	856.8
67	1.2905	7852.673	7566.8	3.6	1711.0	874.9	2585.9	2.96	202.81	1730.4	855.5
68	1.3015	7815.260	7529.4	3.7	1700.8	847.9	2548.6	3.01	206.74	1698.3	850.4
69	1.3125	7817.378	7531.5	3.8	1699.5	823.6	2523.1	3.06	210.25	1673.4	849.7
70	1.3235	7771.361	7485.5	3.9	1687.3	798.7	2486.1	3.11	213.86	1642.4	843.7
71	1.3345	7746.081	7460.2	4.0	1679.9	778.3	2458.2	3.16	216.83	1618.2	839.9

Test Readings for Specimen No. 3

No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress kPa	Minor Eff. Stress kPa	Major Eff. Stress kPa	1:3 Ratio	Pore Press. psi	P kPa	Q kPa
72	1.3455	7680.828	7395.0	4.1	1663.5	757.2	2420.7	3.20	219.89	1588.9	831.7
73	1.3565	7671.298	7385.4	4.2	1659.6	739.6	2399.2	3.24	222.44	1569.4	829.8
74	1.3675	7631.723	7345.9	4.3	1649.0	722.7	2371.6	3.28	224.90	1547.1	824.5
75	1.3785	7607.237	7321.4	4.4	1641.8	706.7	2348.5	3.32	227.21	1527.6	820.9
76	1.3895	7571.824	7286.0	4.5	1632.1	691.6	2323.7	3.36	229.40	1507.7	816.1
77	1.4005	7517.954	7232.1	4.6	1618.4	679.2	2297.5	3.38	231.20	1488.4	809.2
78	1.4115	7468.702	7182.9	4.7	1605.7	665.5	2271.2	3.41	233.18	1468.4	802.8
79	1.4225	7431.171	7145.3	4.8	1595.6	651.9	2247.5	3.45	235.16	1449.7	797.8
80	1.4335	7394.523	7108.7	4.9	1585.7	639.2	2224.9	3.48	237.00	1432.1	792.9
81	1.4445	7390.758	7104.9	5.0	1583.2	626.0	2209.2	3.53	238.91	1417.6	791.6
82	1.4720	7381.949	7096.1	5.3	1577.1	603.2	2180.3	3.61	242.23	1391.7	788.6
83	1.4995	7334.535	7048.7	5.5	1562.4	583.5	2145.9	3.68	245.08	1364.7	781.2
84	1.5270	7371.625	7085.8	5.8	1566.5	568.0	2134.6	3.76	247.32	1351.3	783.3
85	1.5545	7340.889	7055.0	6.0	1555.6	554.0	2109.6	3.81	249.36	1331.8	777.8
86	1.5820	7321.888	7036.0	6.3	1547.3	542.3	2089.6	3.85	251.05	1316.0	773.6
87	1.6095	7318.005	7032.2	6.5	1542.3	531.3	2073.6	3.90	252.65	1302.5	771.2
88	1.6370	7306.946	7021.1	6.8	1535.8	520.4	2056.1	3.95	254.24	1288.2	767.9
89	1.6645	7330.300	7044.5	7.0	1536.8	510.8	2047.5	4.01	255.63	1279.2	768.4
90	1.6920	7347.889	7062.0	7.3	1536.5	505.7	2042.2	4.04	256.36	1273.9	768.2
91	1.7195	7388.596	7102.7	7.5	1541.2	500.6	2041.8	4.08	257.10	1271.2	770.6
92	1.7470	7444.893	7159.0	7.8	1549.2	496.3	2045.5	4.12	257.73	1270.9	774.6
93	1.7745	7446.231	7160.4	8.0	1545.3	493.5	2038.8	4.13	258.14	1266.1	772.6
94	1.8020	7426.054	7140.2	8.3	1536.7	488.0	2024.8	4.15	258.93	1256.4	768.4
95	1.8295	7477.012	7191.2	8.5	1543.5	485.4	2028.9	4.18	259.30	1257.2	771.7
96	1.8571	7547.426	7261.6	8.8	1554.4	482.9	2037.2	4.22	259.67	1260.1	777.2
97	1.8845	7526.543	7240.7	9.0	1545.6	479.8	2025.4	4.22	260.12	1252.6	772.8
98	1.9121	7552.250	7266.4	9.3	1546.9	477.8	2024.7	4.24	260.41	1251.2	773.4
99	1.9396	7555.367	7269.5	9.5	1543.3	477.1	2020.4	4.23	260.51	1248.7	771.6
100	1.9671	7609.134	7323.3	9.8	1550.4	475.4	2025.8	4.26	260.76	1250.6	775.2
101	1.9946	7585.427	7299.6	10.0	1541.1	474.1	2015.2	4.25	260.95	1244.7	770.6
102	2.0221	7634.356	7348.5	10.3	1547.1	473.3	2020.5	4.27	261.06	1246.9	773.6
103	2.0496	7702.373	7416.5	10.5	1557.1	472.7	2029.9	4.29	261.15	1251.3	778.6
104	2.0771	7665.004	7379.2	10.8	1544.9	473.6	2018.6	4.26	261.01	1246.1	772.5
105	2.1046	7706.020	7420.2	11.0	1549.2	475.4	2024.6	4.26	260.76	1250.0	774.6
106	2.1321	7770.670	7484.8	11.3	1558.3	476.7	2035.0	4.27	260.57	1255.9	779.2
107	2.1596	7811.613	7525.8	11.5	1562.4	474.1	2036.5	4.30	260.95	1255.3	781.2
108	2.1871	7798.715	7512.9	11.8	1555.3	468.6	2023.9	4.32	261.75	1246.2	777.7
109	2.2146	7855.850	7570.0	12.0	1562.7	470.9	2033.6	4.32	261.42	1252.2	781.4
110	2.2421	7865.071	7579.2	12.3	1560.2	468.7	2028.9	4.33	261.74	1248.8	780.1
111	2.2696	7884.145	7598.3	12.5	1559.7	465.0	2024.6	4.35	262.27	1244.8	779.8
112	2.2971	8013.268	7727.4	12.8	1581.7	466.5	2048.1	4.39	262.05	1257.3	790.8
113	2.3246	7961.795	7675.9	13.0	1566.6	456.9	2023.5	4.43	263.45	1240.2	783.3
114	2.3521	8004.723	7718.9	13.3	1570.9	453.6	2024.5	4.46	263.92	1239.1	785.4
115	2.3796	8002.914	7717.1	13.5	1566.0	452.4	2018.4	4.46	264.10	1235.4	783.0
116	2.4071	8010.503	7724.7	13.8	1563.0	454.2	2017.2	4.44	263.84	1235.7	781.5
117	2.4346	8030.548	7744.7	14.0	1562.5	454.1	2016.6	4.44	263.85	1235.3	781.3
118	2.4621	8047.151	7761.3	14.3	1561.3	453.4	2014.7	4.44	263.95	1234.1	780.7

Test Readings for Specimen No. 3

No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress kPa	Minor Eff. Stress kPa	Major Eff. Stress kPa	1:3 Ratio	Pore Press. psi	P kPa	Q kPa
119	2.48968	115.904	7830.1	14.5	1570.6	452.8	2023.3	4.47	264.04	1238.1	785.3
120	2.51718	103.918	7818.1	14.8	1563.6	454.4	2018.0	4.44	263.80	1236.2	781.8
121	2.54178	193.275	7907.4	15.0	1577.3	454.3	2031.6	4.47	263.83	1242.9	788.7

APPENDIX D

DURABILITY TEST RESULTS

APPENDIX D1

SLAKE DURABILITY TEST RESULTS

(Pages D1-1 to D1-10)

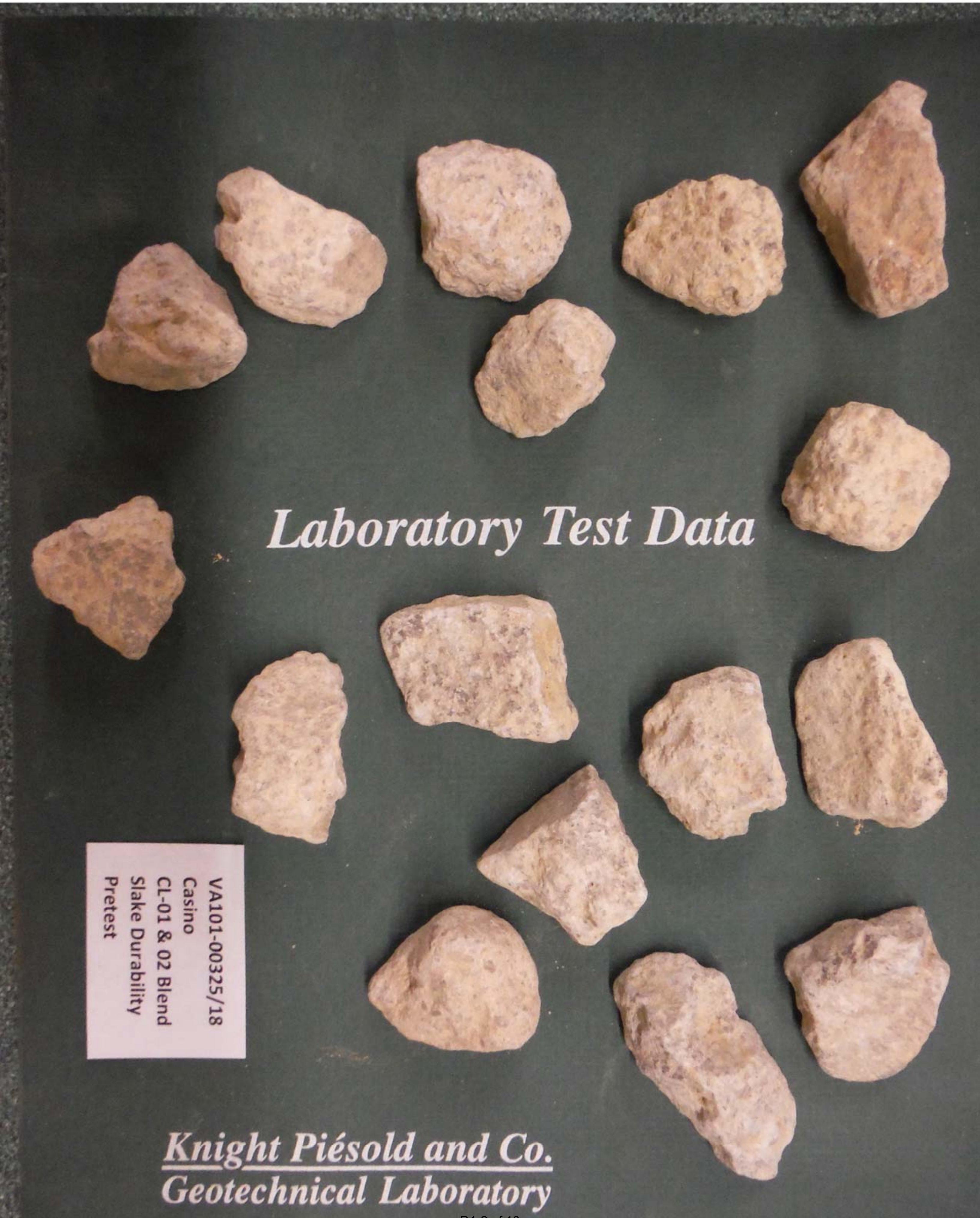
Knight Piésold CONSULTING

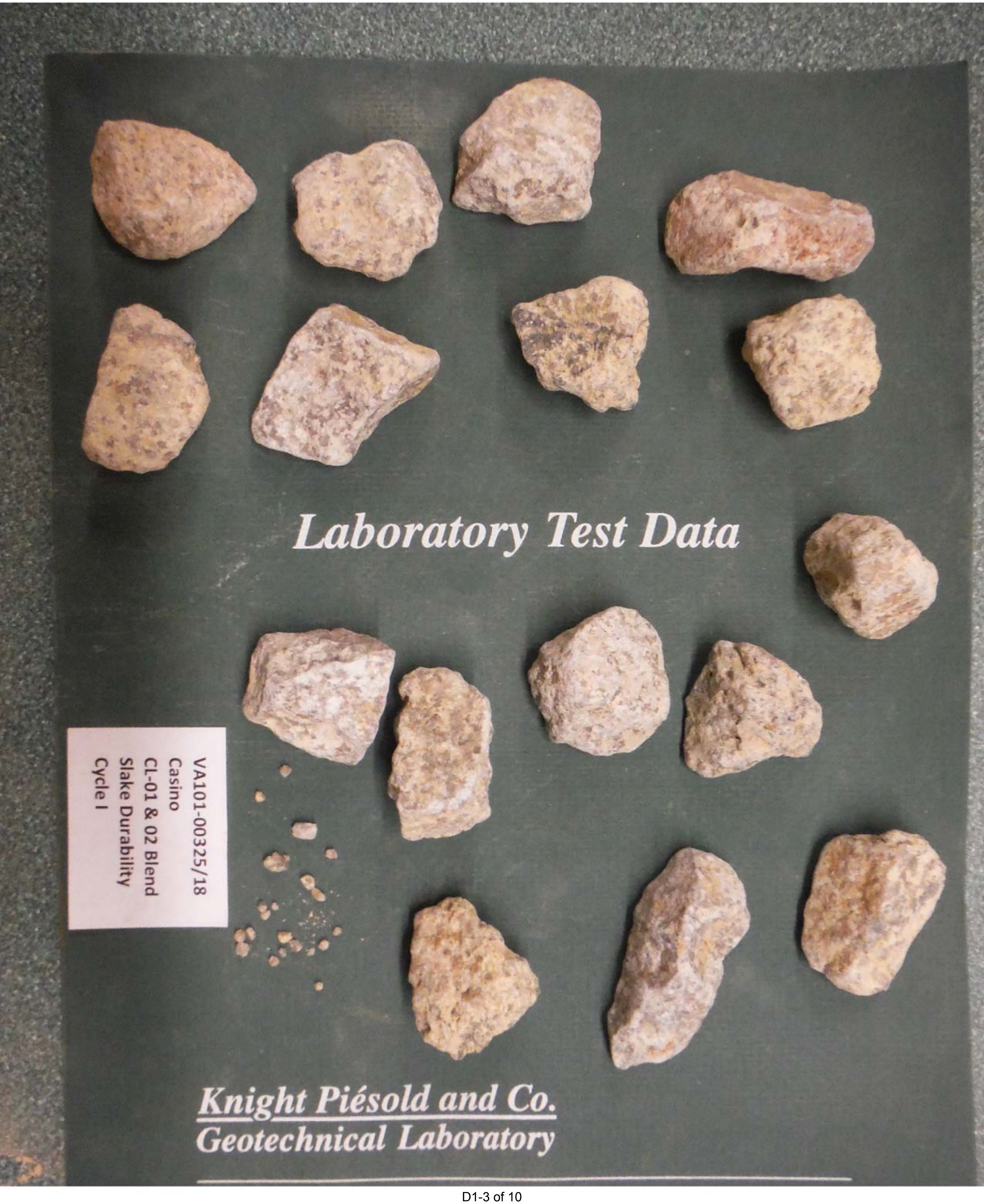
Slake Durability
ASTM D 4644

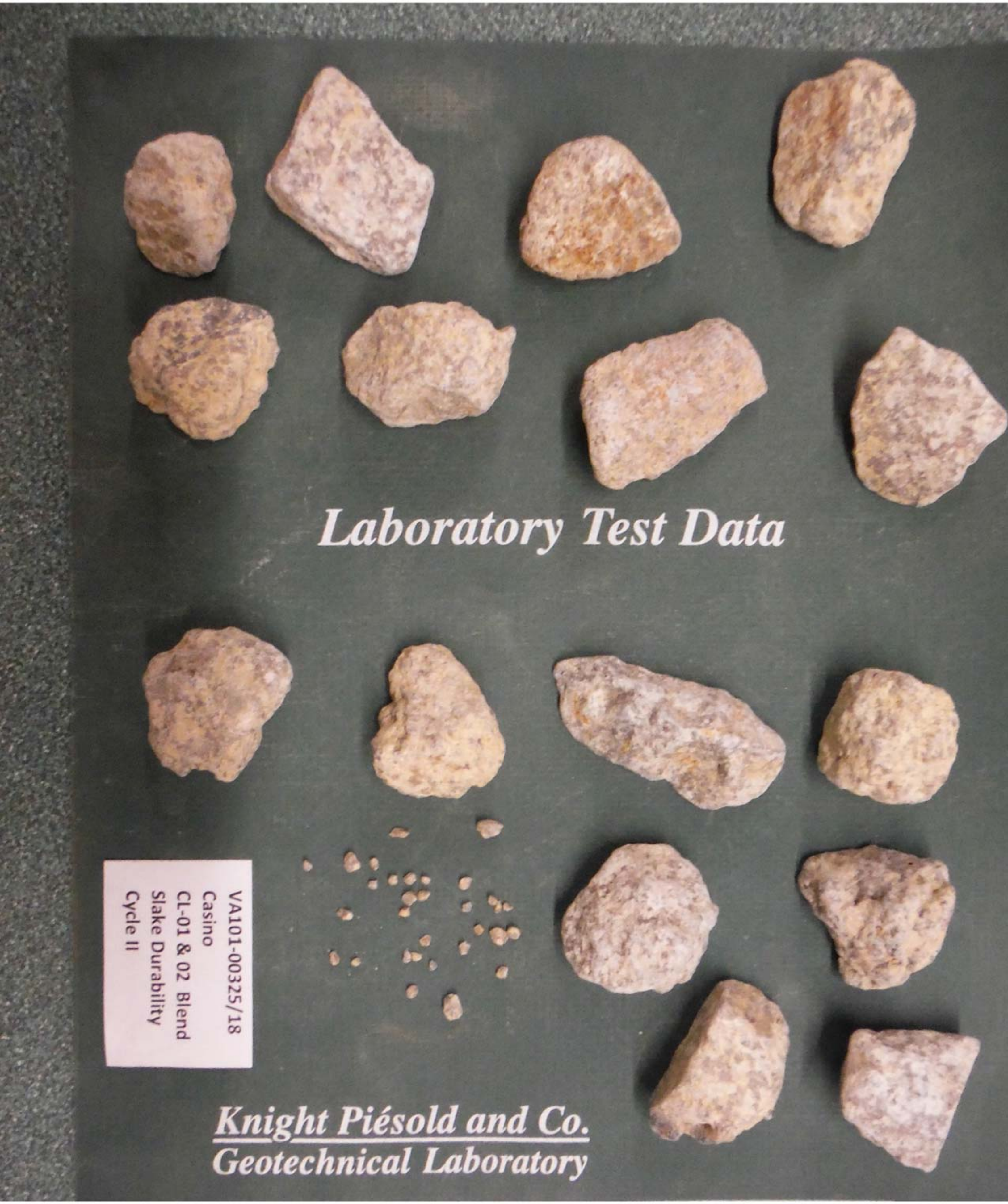
Project	Casino Gold		PA Number	VA101-325/18
Client	Casino Mining Corporation		Task	
Sample Location			Lab No.	L2014-099
Tested By	JHK		Checked By	JDB

		Specimen Data		
Sample No.	CL-01&CL-02 Blend	CL-03	CL-05	
Date	2/2/2015	2/2/2015	2/2/2015	
Tare ID				
Wet Sample Wt. + Tare, g				
Dry Sample Wt. + Tare, g				
Tare, g				
Wt. of Water, g				
Dry Sample Wt., g	469.63	491.00	484.68	
Moisture Content, %	NA	NA	NA	
		Cycle I		
Date In	**2/2/2015**	**2/2/2015**	**2/2/2015**	
No. of Pieces	16	10	10	
Total Dry Wt., g	469.63	491.00	484.68	
Time In	14:40	14:40	14:55	
Time Out	14:50	14:50	15:05	
Elapsed Time, min.	10	10	10	
Tested By	JHK	JHK	JHK	
H2O Temp.	19.7	19.8	19.9	
		Cycle II		
Date In	**2/4/2015**	**2/4/2015**	**2/4/2015**	
No. of Pieces	16	10	10	
Total Dry Wt., g	464.6	489.4	482.3	
Time In	9:34	9:34	9:49	
Time Out	9:44	9:44	9:59	
Elapsed Time, min.	10	10	10	
Tested By	JHK	JHK	JHK	
H2O Temp.	19.0	19.0	18.9	
		Post Test Condition		
No.of Pieces	16	10	10	
Total Dry Wt.	462.2	488.5	480.9	
Slake Index, %	98.4	99.5	99.2	
	Type I	Type I	Type I	
Photos Taken (Y or N)	Y	Y	Y	

General Notes


Laboratory Test Data
VA101-00325/18
Casino
CL-01 & 02 Blend
Slake Durability
Pretest
Knight Piésold and Co.
Geotechnical Laboratory


Laboratory Test Data
VA101-00325/18
Casino
CL-01 & 02 Blend
Slake Durability
Cycle I
Knight Piésold and Co.
Geotechnical Laboratory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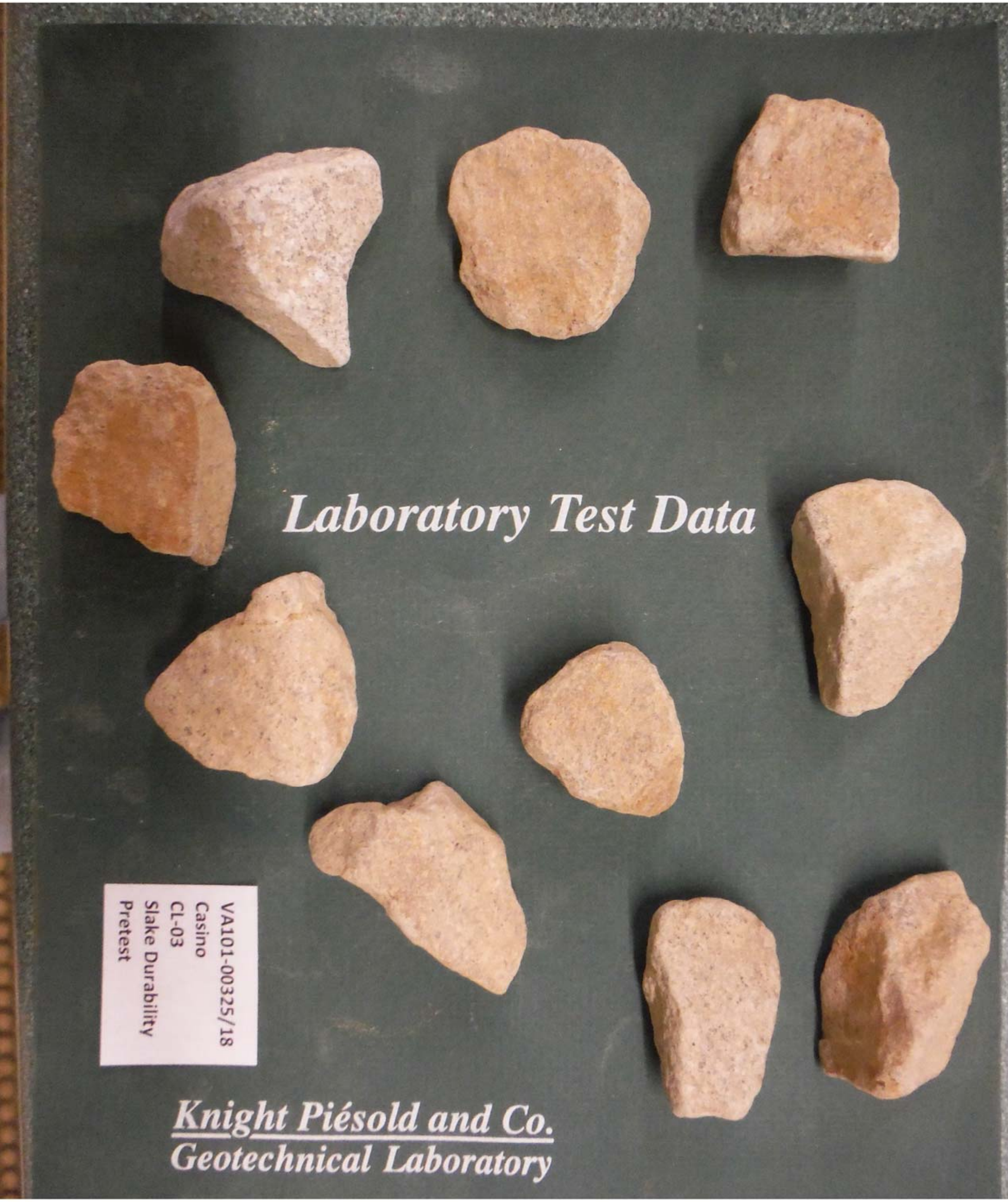
Casino
CL-01 & 02 Blend
Slake Durability
Cycle II
Knight Piésold and Co.
Geotechnical Laboratory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Slake Durability
Pretest
Knight Piésold and Co.
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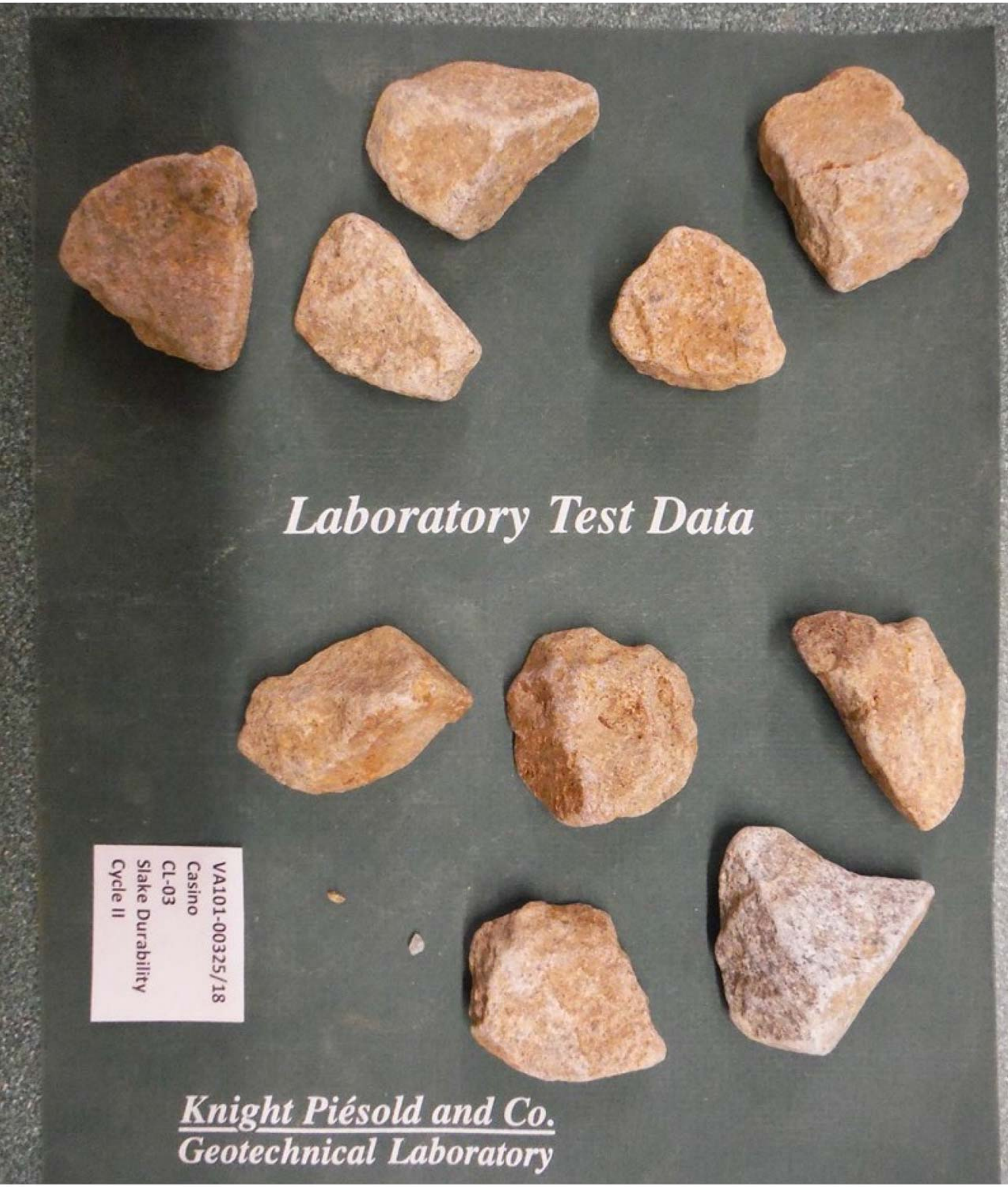
Casino
CL-03
Slake Durability
Cycle I
Knight Piésold and Co.
Geotechnical Laboratory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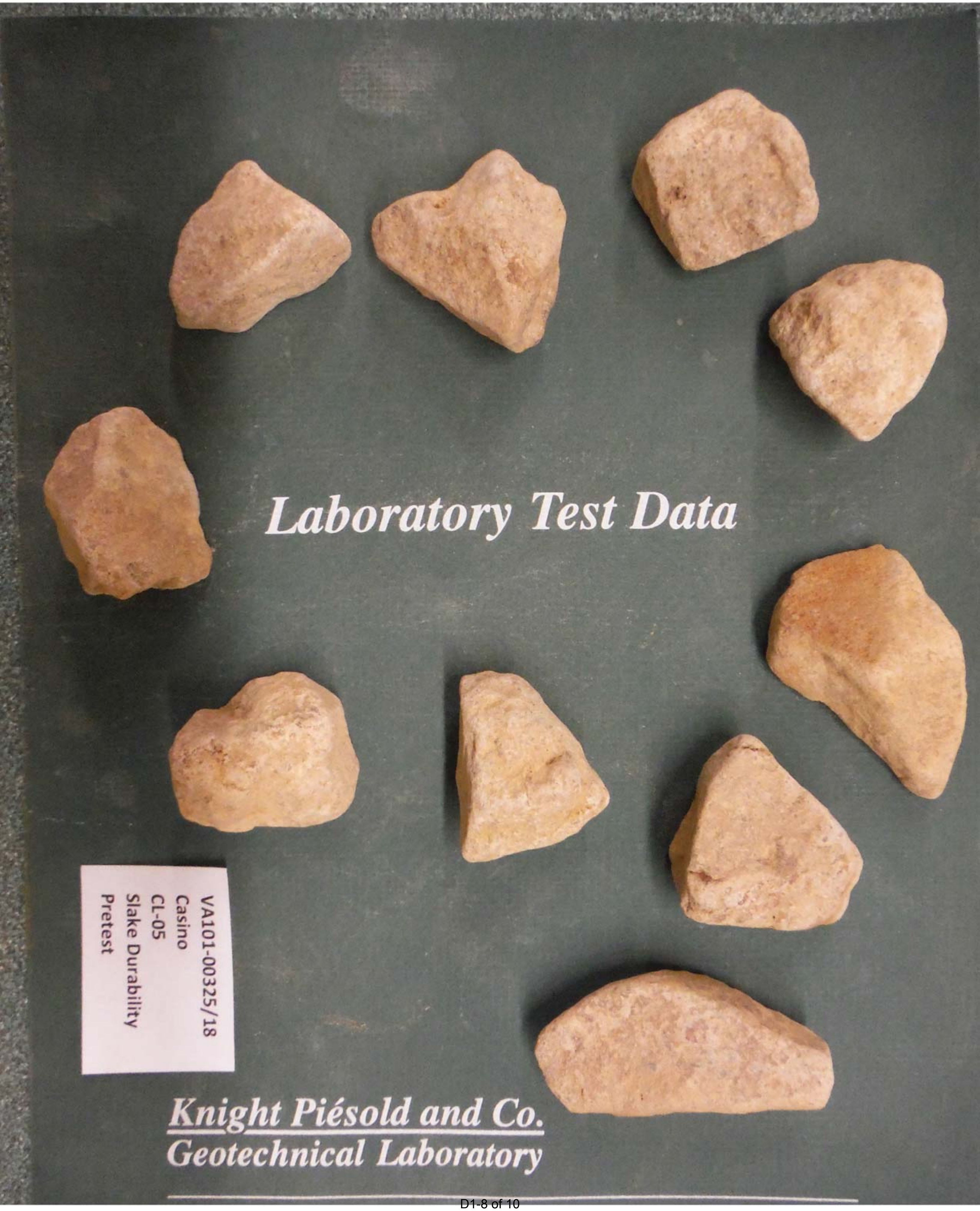
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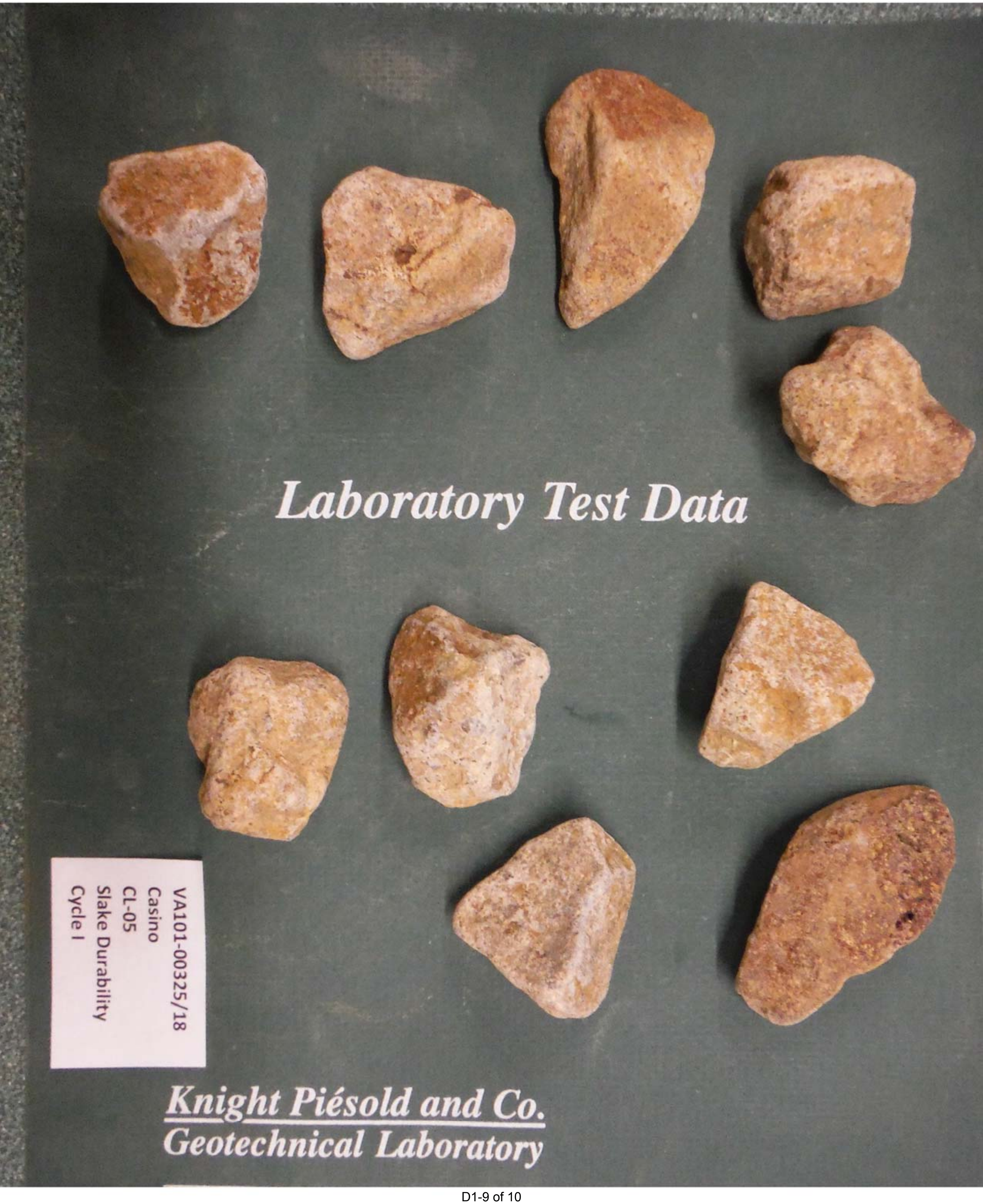
Knight Piésold and Co.
Geotechnical Laboratory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Cycle I
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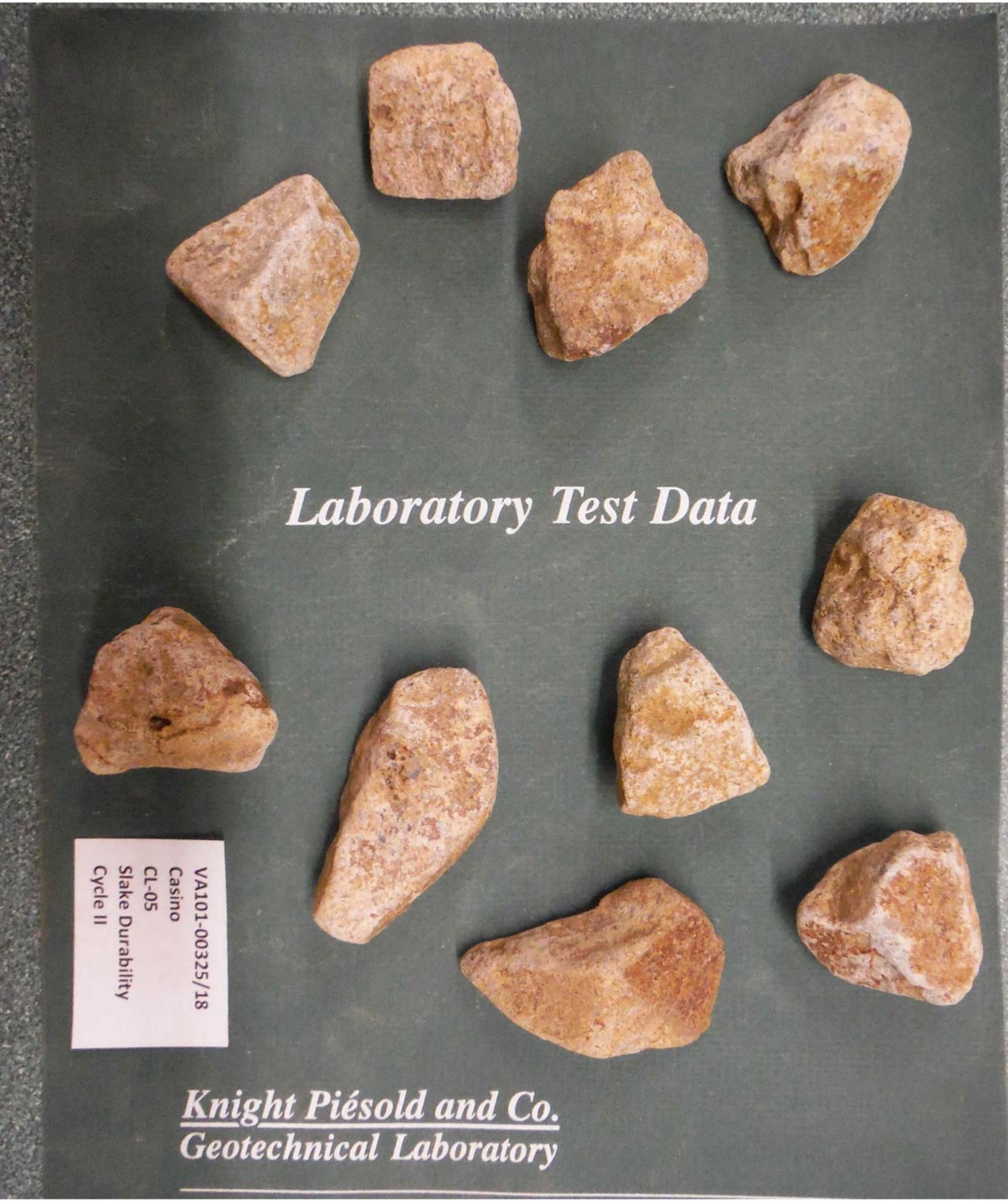
Laboratory Test Data
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Casino
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Slake Durability
Cycle II
Knight Piésold and Co.
Geotechnical Laboratory

APPENDIX D2

FREEZE-THAW TEST RESULTS

(Pages D2-1 to D2-20)

2014 CASINO GOLD PROJECT
PROJECT NO. DV101-VA101-00325/18

SUMMARY OF LABORATORY TEST RESULTS
FREEZE-THAW RESISTANCE - AASHTO T 103

Sample No. **CL-01 & CL-02 Coarse**

Sieve Size	Grading of Original Sample, % Pass.	Grading, Indiv. % Retained	Mass of Test Fractions Before Test	Mass of Test Fractions After Test	Percent Loss After Test	Weighted Percent Loss
2"	100.0					
1.5"	100.0					
1"	87.9	20.8	0.0	0.0	49.01	10.19
.75"	80.0	13.7	703.9	358.9	49.01	6.71
0.5	70.0	17.2	679.5	345.9	49.09	8.44
3/8"	62.7	12.6	334.9	228.8	31.68	3.99
No.4	42.0	35.7	302.1	219.3	27.41	9.78
Total		**100**				**39.13**

Sample No. **CL-01 & CL-02 Fine**

Sieve Size	Grading of Original Sample, Percent	Recomputed Grading, Indiv. % Retained	Mass of Test Fractions Before Test	Mass of Test Fractions After Test	Percent Loss After Test	Weighted Percent Loss
No.8	27.2	35.2	161.3	132.0	18.1	6.40
No.16	16.4	25.7	131.8	116.7	11.4	2.94
No.30	10.0	15.2	122.6	114.8	6.4	0.97
No.50	7.2	6.7	119.7	112.3	6.2	0.41
Minus 50	0.0	17.1	0.0	0.0	0.0	0.00
Total		**100**				**10.72**

Test Notes: Method utilized: Method A, Total Immersion in water.
No. of Cycles: 25

2014 CASINO GOLD PROJECT
PROJECT NO. DV101-VA101-00325/18

SUMMARY OF LABORATORY TEST RESULTS
FREEZE-THAW RESISTANCE - AASHTO T 103

Sample No. **CL-03 Coarse**

Sieve Size	Grading of Original Sample, % Pass.	Grading, Indiv. % Retained	Mass of Test Fractions Before Test	Mass of Test Fractions After Test	Percent Loss After Test	Weighted Percent Loss
2"	100.0					
1.5"	78.1	25.5	0.0	0.0	0.28	0.07
1"	50.8	31.9	1035.0	1032.1	0.28	0.09
.75"	37.4	15.5	711.9	707.9	0.56	0.09
0.5	26.9	12.3	677.6	671.9	0.84	0.10
3/8"	22.2	5.6	333.3	324.6	2.60	0.15
No.4	14.2	9.2	304.4	290.8	4.47	0.41
Total		**100**				**0.91**

Sample No. **CL-03 Fine**

Sieve Size	Grading of Original Sample, Percent	Recomputed Grading, Indiv. % Retained	Mass of Test Fractions Before Test	Mass of Test Fractions After Test	Percent Loss After Test	Weighted Percent Loss
No.8	10.7	23.6	170.0	151.9	10.7	2.51
No.16	7.9	20.0	139.3	126.6	9.1	1.83
No.30	5.7	15.7	122.6	115.2	6.0	0.95
No.50	4.2	10.7	108.5	101.2	6.6	0.71
Minus 50	0.0	30.0	0.0	0.0	0.0	0.00
Total		**100**				**6.00**

Test Notes: Method utilized: Method A, Total Immersion in water.
No. of Cycles: 25

2014 CASINO GOLD PROJECT
PROJECT NO. DV101-VA101-00325/18

SUMMARY OF LABORATORY TEST RESULTS
FREEZE-THAW RESISTANCE - AASHTO T 103

Sample No. **CL-05 Coarse**

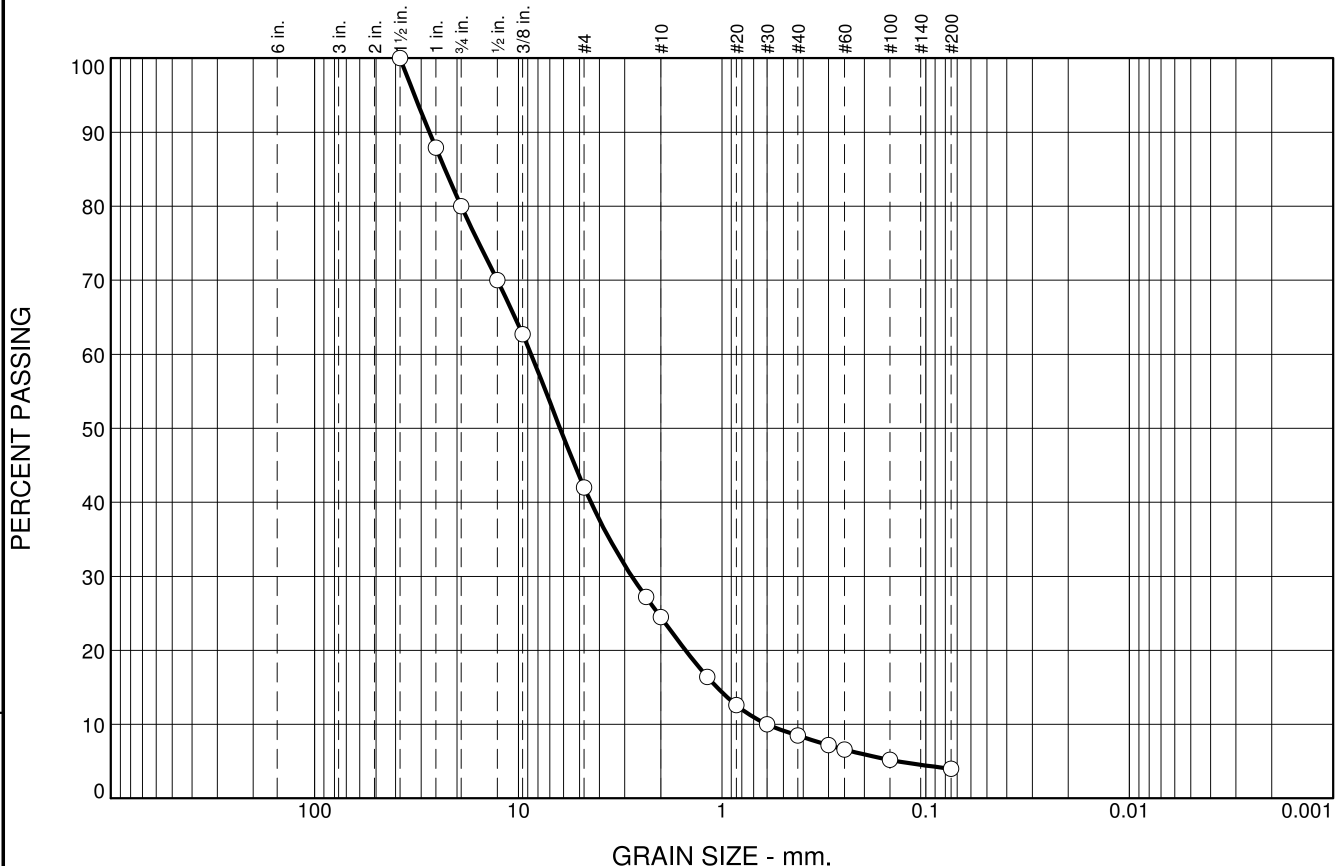
Sieve Size	Grading of Original Sample, % Pass.	Grading, Indiv. % Retained	Mass of Test Fractions Before Test	Mass of Test Fractions After Test	Percent Loss After Test	Weighted Percent Loss
3"	100					
2"	95.7	4.7	0.0	0.0	1.13	0.05
1.5"	75.5	21.8	0.0	0.0	1.13	0.25
1"	38.1	40.4	1002.7	991.4	1.13	0.46
.75"	24.3	14.9	721.3	712.4	1.23	0.18
0.5	15.7	9.4	673.8	653.5	3.02	0.28
3/8"	11.7	4.2	334.5	310.9	7.05	0.30
No.4	7.5	4.6	304.5	264.3	13.20	0.61
Total		**100**				**2.13**

Sample No. **CL-05 Fine**

Sieve Size	Grading of Original Sample, Percent	Recomputed Grading, Indiv. % Retained	Mass of Test Fractions Before Test	Mass of Test Fractions After Test	Percent Loss After Test	Weighted Percent Loss
No.8	5.6	25.3	133.8	99.4	25.7	6.52
No.16	4.5	14.7	161.0	145.8	9.5	1.39
No.30	3.7	10.7	134.7	123.2	8.5	0.91
No.50	3.0	9.3	110.0	98.8	10.2	0.96
Minus 50	0.0	40.0	0.0	0.0	0.0	0.00
Total		**100**				**9.77**

Test Notes: Method utilized: Method A, Total Immersion in water.
No. of Cycles: 25

Particle Size Distribution Report



The USCS classification pertains only to the portion of sample that passes the 3" sieve as per ASTM D2487.

% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	20.0	38.0	17.5	16.0	4.5	4.0	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1.5	100.0		
1	87.9		
.75	80.0		
.5	70.0		
.375	62.7		
#4	42.0		
#8	27.2		
#10	24.5		
#16	16.4		
#20	12.6		
#30	10.0		
#40	8.5		
#50	7.2		
#60	6.6		
#100	5.2		
#200	4.0		

* (no specification provided)

Material Description

well-graded gravel with sand

Atterberg Limits

PL= NP LL= NP PI= NP

Classification

USCS= GW AASHTO= A-1-a

Remarks

Source of Sample: Freeze Thaw
Sample Number: CL-01 & CL-02 Blend

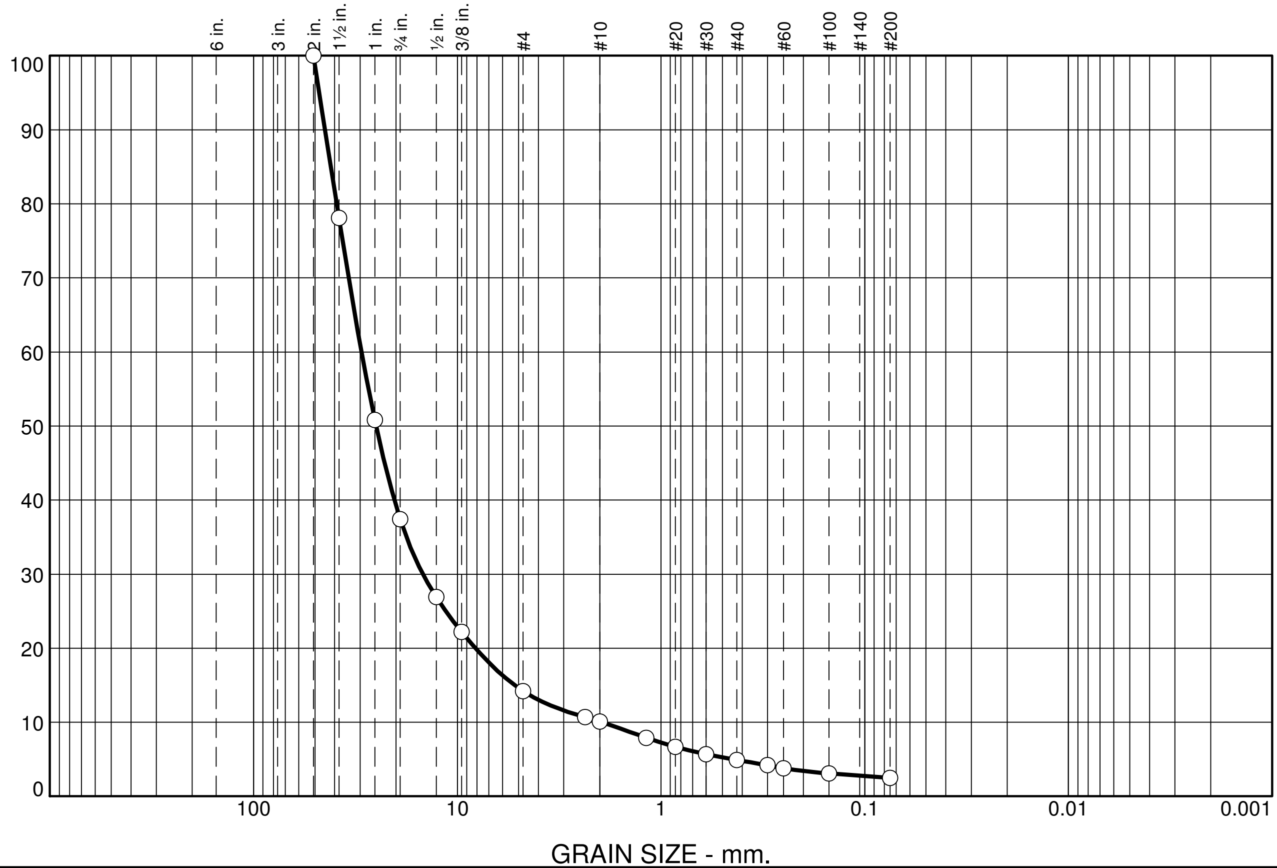
Date: 3/10/15

Knight Piésold CONSULTING

Client: Casino Mining Corporation
Project: Casino
Project No: VA101-325/18 **Figure**

Tested By: DAB **Checked By:** JDB

Particle Size Distribution Report



The USCS classification pertains only to the portion of sample that passes the 3" sieve as per ASTM D2487.

% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	62.6	23.2	4.1	5.2	2.4	2.5	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
2	100.0		
1.5	78.1		
1	50.8		
.75	37.4		
.5	26.9		
.375	22.2		
#4	14.2		
#8	10.7		
#10	10.1		
#16	7.9		
#20	6.7		
#30	5.7		
#40	4.9		
#50	4.2		
#60	3.8		
#100	3.1		
#200	2.5		

* (no specification provided)

Material Description

poorly graded gravel

Atterberg Limits

PL= NP LL= NP PI= NP

Classification

USCS= GP AASHTO= A-1-a

Remarks

Source of Sample: Freeze Thaw
Sample Number: CL-03

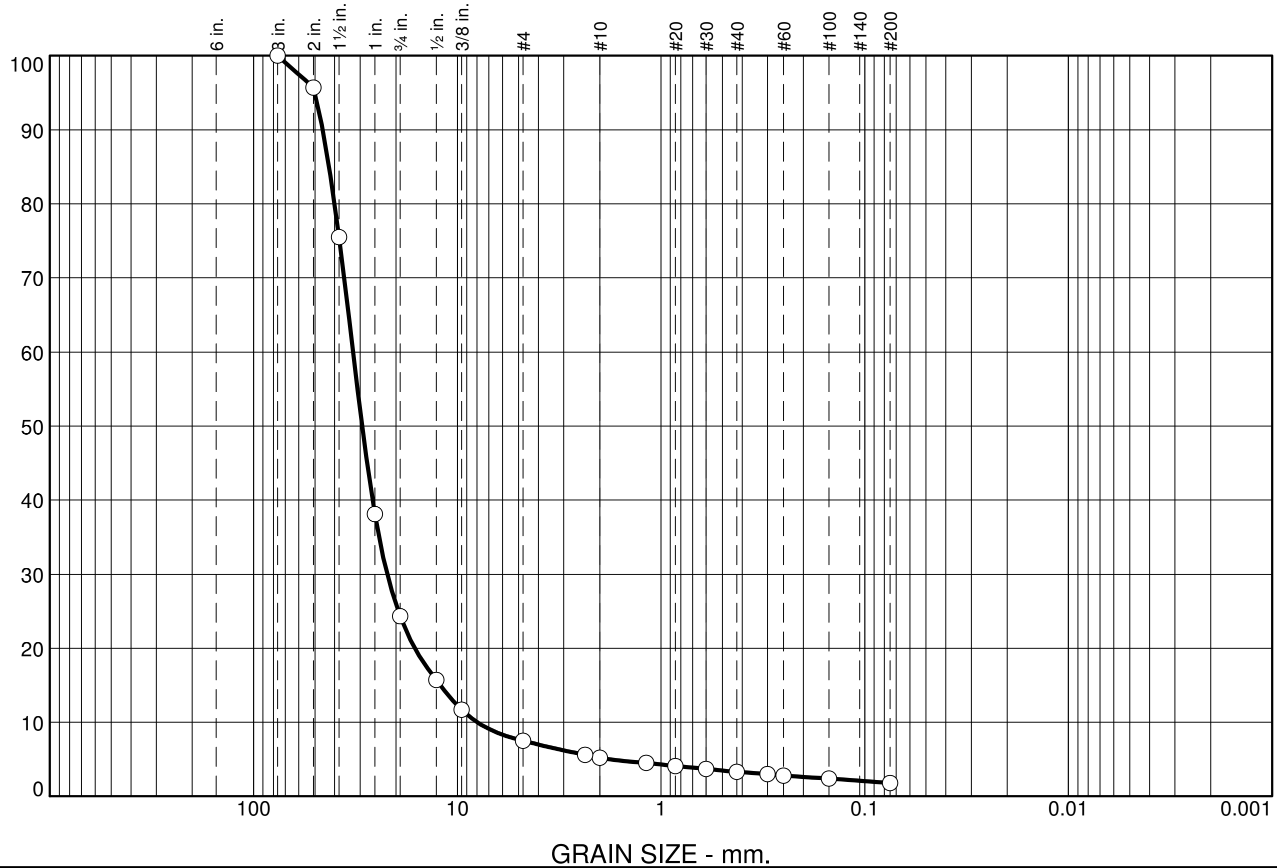
Date: 3/10/15

Knight Piésold CONSULTING

Client: Casino Mining Corporation
Project: Casino
Project No: VA101-325/18 **Figure**

Tested By: DAB **Checked By:** JDB

Particle Size Distribution Report



The USCS classification pertains only to the portion of sample that passes the 3" sieve as per ASTM D2487.

% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	75.7	16.8	2.3	1.9	1.5	1.8	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3	100.0		
2	95.7		
1.5	75.5		
1	38.1		
.75	24.3		
.5	15.7		
.375	11.7		
#4	7.5		
#8	5.6		
#10	5.2		
#16	4.5		
#20	4.1		
#30	3.7		
#40	3.3		
#50	3.0		
#60	2.8		
#100	2.4		
#200	1.8		

* (no specification provided)

Material Description

well-graded gravel

Atterberg Limits

PL= NP LL= NP PI= NP

Classification

USCS= GW AASHTO= A-1-a

Remarks

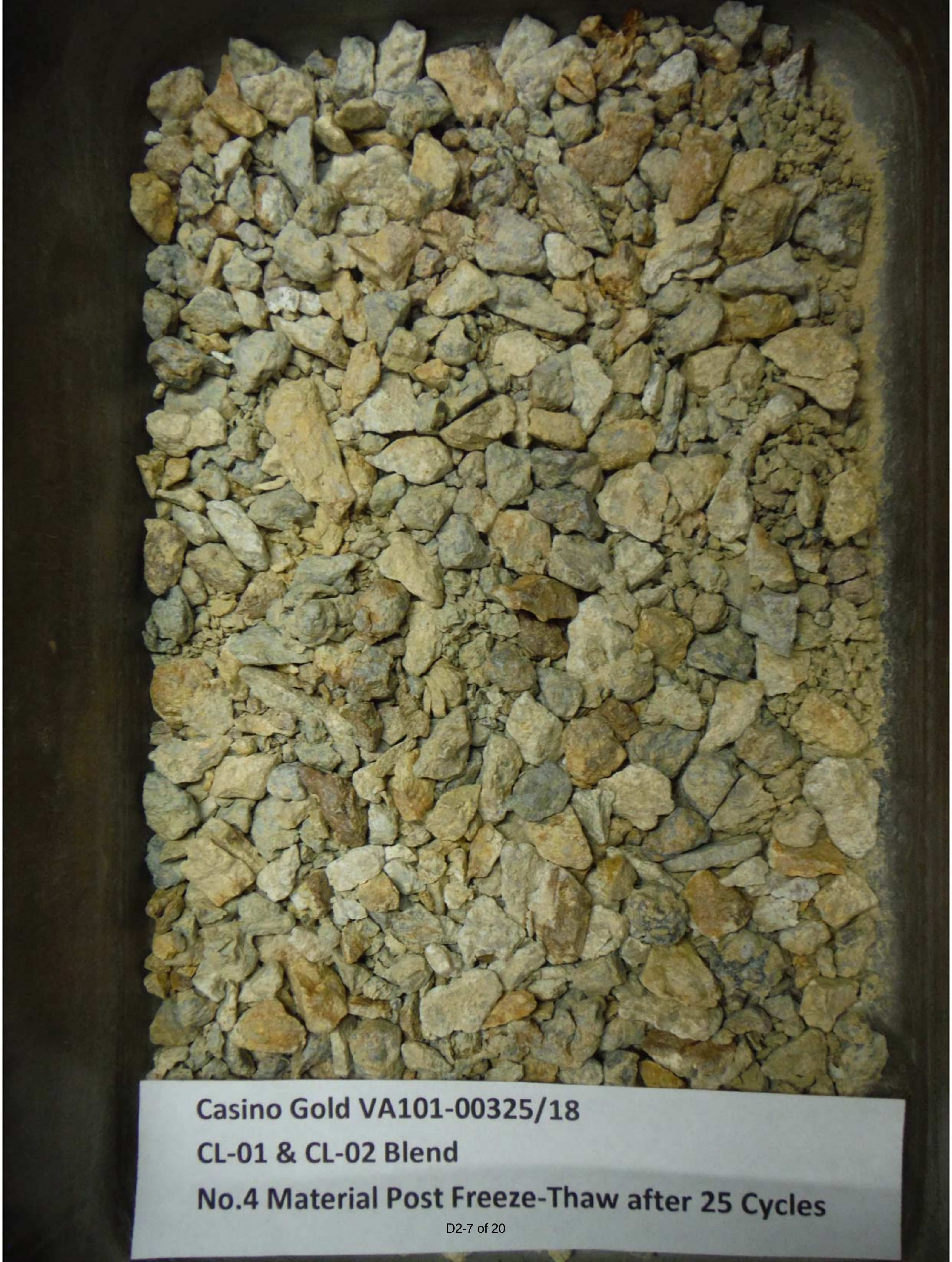
Source of Sample: Freeze Thaw
Sample Number: CL-05

Date: 3/10/15

Knight Piésold CONSULTING

Client: Casino Mining Corporation
Project: Casino
Project No: VA101-325/18 **Figure**

Tested By: DAB **Checked By:** JDB


Casino Gold VA101-00325/18
CL-01 & CL-02 Blend
No.4 Material Post Freeze-Thaw after 25 Cycles


Casino Gold VA101-00325/18
CL-01 & CL-02 Blend
3/8" Material Post Freeze-Thaw after 25 Cycles


Casino Gold VA101-00325/18
CL-01 & CL-02 Blend
1/2" Material Post Freeze-Thaw after 25 Cycles


Casino Gold VA101-00325/18
CL-01 & CL-02 Blend
3/4” Material Post Freeze-Thaw after 25 Cycles


Casino Gold VA101-00325/18
CL-03 No.4 Material Post Freeze-Thaw after 25 Cycles


Casino Gold VA101-00325/18
CL-03 3/8" Material Post Freeze-Thaw after 25 Cycles


Casino Gold VA101-00325/18
CL-03 1/2" Material Post Freeze-Thaw after 25 Cycles


Casino Gold VA101-00325/18
CL-03 3/4" Material Post Freeze-Thaw after 25 Cycles


Casino Gold VA101-00325/18
CL-03 1" Material Post Freeze-Thaw after 25 Cycles


Casino Gold VA101-00325/18
CL-05 No.4 Material Post Freeze-Thaw after 25 Cycles


Casino Gold VA101-00325/18
CL-05 3/8" Material Post Freeze-Thaw after 25 Cycles


Casino Gold VA101-00325/18
CL-05 1/2" Material Post Freeze-Thaw after 25 Cycles


Casino Gold VA101-00325/18
CL-05 3/4" Material Post Freeze-Thaw after 25 Cycles


Casino Gold VA101-00325/18
CL-05 1" Material Post Freeze-Thaw after 25 Cycles

APPENDIX B.4F: Ore Characterization

VOLUME B.I: PROJECT INTRODUCTION & OVERVIEW

CASINO PROJECT

ORE CHARACTERIZATION

REVISION 2

PREPARED FOR:

Western Copper & Gold Corporation

JANUARY 22, 2015

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FIGURES

EXECUTIVE SUMMARY

Hydrodynamic characterization of two Casino head samples was undertaken to define the physical and hydraulic response of the ore. The samples included Composites Met 02-05 and Met 11-17 which represent 1:1 blends of the individual samples Met 02 and Met 05; and Met 11 and Met 17, respectively.

The metallurgical data indicate average head grades of the metals of interest; Au (0.32 ppm & 0.50 ppm), Ag (1.0 ppm & 3.0 ppm), Cu (0.01% and 0.053%) for composites Met 02-05 and Met 11-17, respectively. These samples show high levels of Al (6.9% & 6.7%), Fe (2.3% & 2.6%), K (3.3% & 4.6%), and S (0.4% & 0.6%). Some trace elements are present; Ba (1,187 ppm & 1,614 ppm), Bi (3 ppm & 2 ppm), Mo (61 ppm & 181 ppm), Ti (1500 ppm & 972 ppm), Pb (20 ppm & 123 ppm), and Th (16 ppm & 17 ppm) which could have some influence in gold extraction. The grade by size data indicate that Au and Ag are not uniformly distributed along the PSD of these composites. Met 02-05 has most of its metal value (35%) on the size fractions smaller than 1.7 mm. In contrast, Met 11-17 has most of its metal value (>25%) on rock fragments larger than 25.4 mm.

The mineralogical characterization indicates that Au occurs primarily as sub-microscopic native gold. Potential cyanide consuming minerals include metal sulfides including copper, iron, arsenic and zinc; iron oxide-hydroxides such as Limonite and Jarosite which can also act as preg-robbing; and secondary alumino-silicates and swelling clays. Shake leach tests conducted by FL Smidth leads us to believe that: the increased recovery on composites Met 11-17 (and Met 19-20) at very high CN-concentrations results from the dissolution of sulfide minerals (sulfide encapsulation due to, but not exclusively, copper sulfides) which may be coating the Au minerals and dissolve at high CN concentrations. On the other hand, the ultimate Au recovery in Met 02-05 is likely associated to silica encapsulation.

A few key findings from the hydrodynamic characterization are as follows:

- Agglomeration of individual composites and blending produce improved hydrodynamic performance which increases the range of heap heights supported by these samples. For instance, 2:1 blend of Met 02-05 and Met 11-17 sample agglomerated to a Level 3 (L3) could support a heap height close to 140 m. The more competent composite Met 11-17 would support percolation leaching to heights up to 140 m even without agglomeration.
- The Casino head samples are competent and show limited compaction and loss of percolation capacity along a 140-m heap profile. Notwithstanding the strong nature of the Casino samples, it appears that the key considerations for the adequate leaching of the **non-agglomerated** Casino ore include:
    - The permeability for Composite Met 02-05 or a blend thereof as the heap height increases beyond 70 m, and
    - Effective solution-to-ore contact for Composite Met 11-17 if not blended.
- As a result of the very competent nature of the Met 11-17 and its low content of fines, the void space is dominated by macro-porosity. This macro-porosity provides, on the one hand, high solution percolation capacity, but in the other limits wettability of the ore. The large component of the macro-porosity translates into gravity-dominated flow where limited horizontal movement of solution occurs leading to inefficient wetting and hence limited metallurgical performance. Typically, this type of flow

condition combined with non-agglomerated ore leads to reduced metal extraction, inefficient reagent (cyanide and lime) utilization and protracted leach cycles. Blending with Met 02-05 will improve the wettability of composite Met 11-17.

- The results from the Hydrodynamic Column Tests (HCTs) confirm that composites Met 02-05 and Met 11-17 will effectively support percolation leaching during the initial stages of the operation as shown by the results of the Hydrodynamic Column Tests (HCTs) for a 32-m heap with a solution application rate of 10 L/h/m^2.
- According to the results from the HCTs, the best performing sample is Met 02-05 as it produces a good solution-to-ore contact which should promote efficient gold dissolution and recovery.
- Blending and agglomeration leads to improved hydrodynamic performance of these two composites which is expected to also improve their metallurgical performance.

As part of its characterization technology HGS has developed the Integrated Column Test (ICT), a procedure that allows simultaneous determination of hydrodynamic and metallurgical performance). Application of this procedure, at no cost to WCG, on the Casino samples shows that:

- Preliminary gold recoveries of about 70% for Composite Met 02-05 and 30% for Met 11-17.
- These results seem to be in good agreement with the conclusions arising from the available physical, hydrodynamic, metallurgical and mineralogical data.
- Based on the metallurgical data, gold recovery on composite Met 11-17 may be hindered due to coating by sulfide minerals (sulfide encapsulation due to, but not exclusively, copper sulfides) while ultimate recovery from Met 02-05 is likely associated to silica encapsulation.

The work conducted as part of this study and other available data show that:

1) There are significant physical, hydrodynamic, metallurgical and mineralogical differences between the two composites evaluated on this study.
2) Ore preparation practices (crushing, blending, and agglomeration) would have a significant impact on the metallurgical performance of the ore. Operational design should consider agglomeration, blending or both to improve the hydrodynamic properties of these composites.
3) For composite Met 02-05, the optimal solution application rate would be equal to or smaller than 10 L/h/m^2 to balance between reagent delivery and air-percolation capacity.
4) For composite Met 11-17, the optimal solution application rate would be equal to or smaller than 6 L/h/m^2 to balance between reagent delivery and solution-to-ore contact.
5) A 2:1 blend of Met 02-05 and Met 11-17 may perform better than the each of the individual composites. Agglomeration of this blend would allow leaching this material to the 140-m design height.
6) The distance between drip points should not be larger than 30 cm.
7) The irrigation for both of these composites should follow a ramp-up irrigation scheme (RUI).

A fact that needs to be considered in the interpretation of the results presented in this report is that all the samples tested to date represent fresh ore. A multi-lift heap is susceptible to weathering, slumping, differential settlement, and for oxide-gold to chemical-induced decrepitation to a lesser extent. All of these mechanisms negatively impact the hydrodynamic properties of the ore and increase the potential solution and metal inventory. Therefore, it is critical that hydrodynamic properties of the leached residue be determined to optimize the design and operational conditions of the heap. Additional HCTs for process optimization are recommended at heap design heights once the mine operation starts and the ore has been exposed to at least three leaching cycles.

Section 4.0 of this document presents additional discussion of the results and recommendations aimed to improve the design and eventual performance of the heap leaching process of the Casino project.

1.0 TEST PROGRAM AND BASIC METALLURGICAL DATA

1.1 Characterization Program

WCG provided two different composite head samples, namely Composite Met 02-05 and Composite Met 11-17. It is understood that these composites represent a one-to-one blend of the individual samples by the same name (i.e., Met 02, Met 05, Met 11, and Met 17). A total of 89 kg already separated into eight size fractions was supplied by SGS/Metcon (Metcon). As indicated on the test matrix presented in Figure 2.1, each of the samples was subjected to the Stacking Test procedure under three different conditions:

- As-received dry ore mixed with 2.93 kg of pebble lime per ton of ore (kg/t) per Metcon results from their bottle role tests and the value used on the recent metallurgical columns;
- As-received dry ore mixed with powder lime at 2.93 kg/t per Metcon recipe used on the ongoing metallurgical columns;
- A sample mixed with 2.93 kg/t of powder lime and agglomerated with alkalinity amended tap water with a pH of 11.3.

The non-agglomerated samples represent a benchmark to assess the potential benefits from agglomeration. After these tests, it was recommended that for practical purposes the use of pebble lime be discontinued and any future work use only powder lime.

The characterization program consisted of:

a) Review of available particle size distribution (PSD) information,

b) Agglomeration trials to define the optimal moisture content for each PSD,

c) Review of metallurgical and mineralogical data,

d) Stacking Tests to determine the potential hydrodynamic behavior of the samples to select the most promising agglomeration conditions, and

e) Hydrodynamic Column Tests on three PSD to determine the potential operation conditions for these samples for a 32-m heap.

The following paragraphs provide a summary of the data reviewed as part of this study, testing methods and the most relevant results from the application of these tests to the Casino ore. The last section of this document presents a number of recommendations on the basis of these findings.

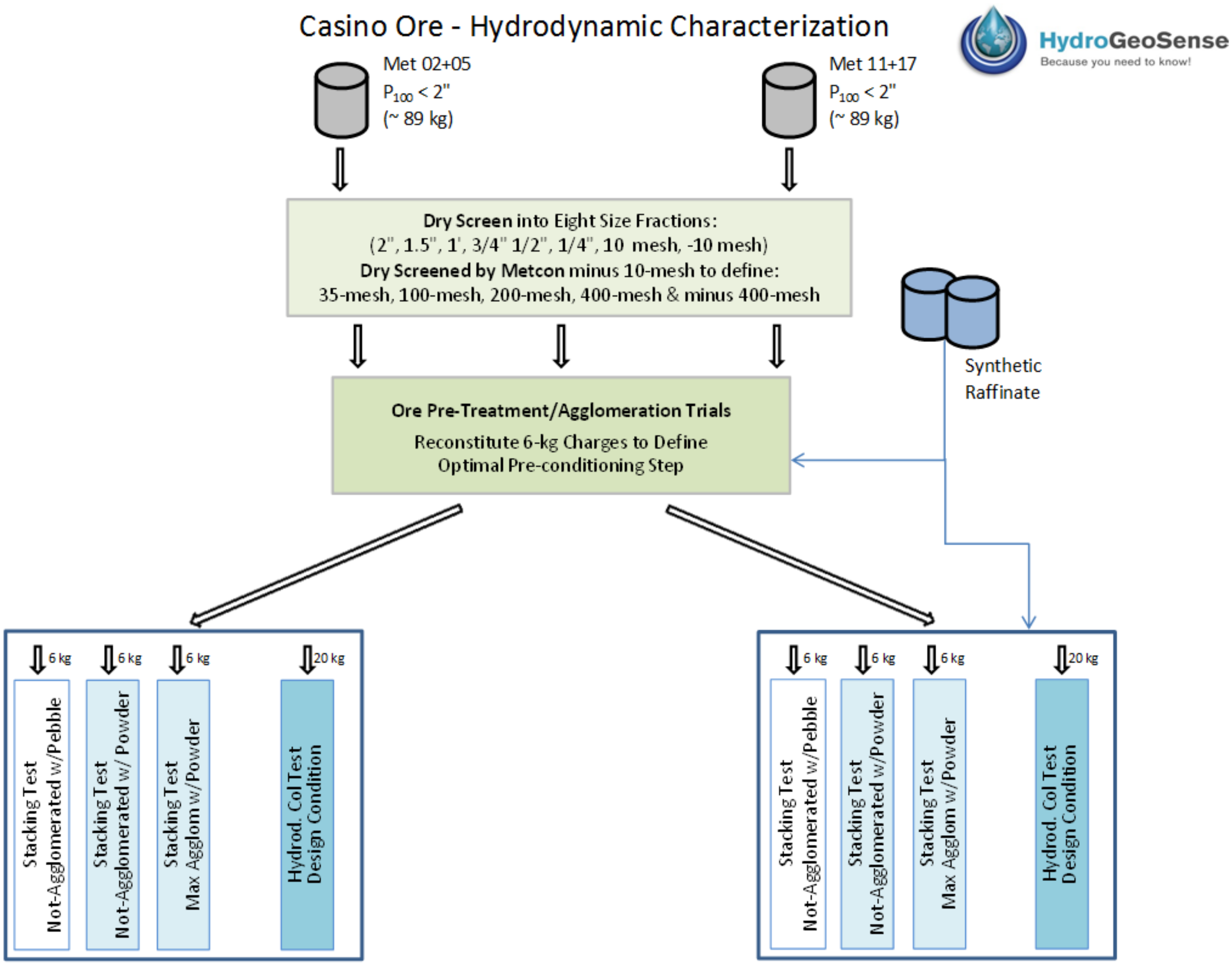

Figure 1.1 Casino – Final Test Matrix

1.2 Particle Size Distribution

The particle size distribution (PSD) for the head ore samples was determined by Metcon and is summarized in Figure 1.1. For comparison, HGS used the PSD of the individual ore samples determined by ALS Metallurgy to determine the PSD of the 1:1 composites also presented as in Figure 1.1. It is noted that none of the ALS' PSD showed particle sizes larger than 5.cm (2") while the two composites received from Metcon (M 02-05 and M 11-17) contained particle sizes larger than 5 cm. Overall, the PSD for the 1:1 composites determined from ALS' PSDs are similar to those reported by Metcon, indicating good consistency between the procedures used by these laboratories.

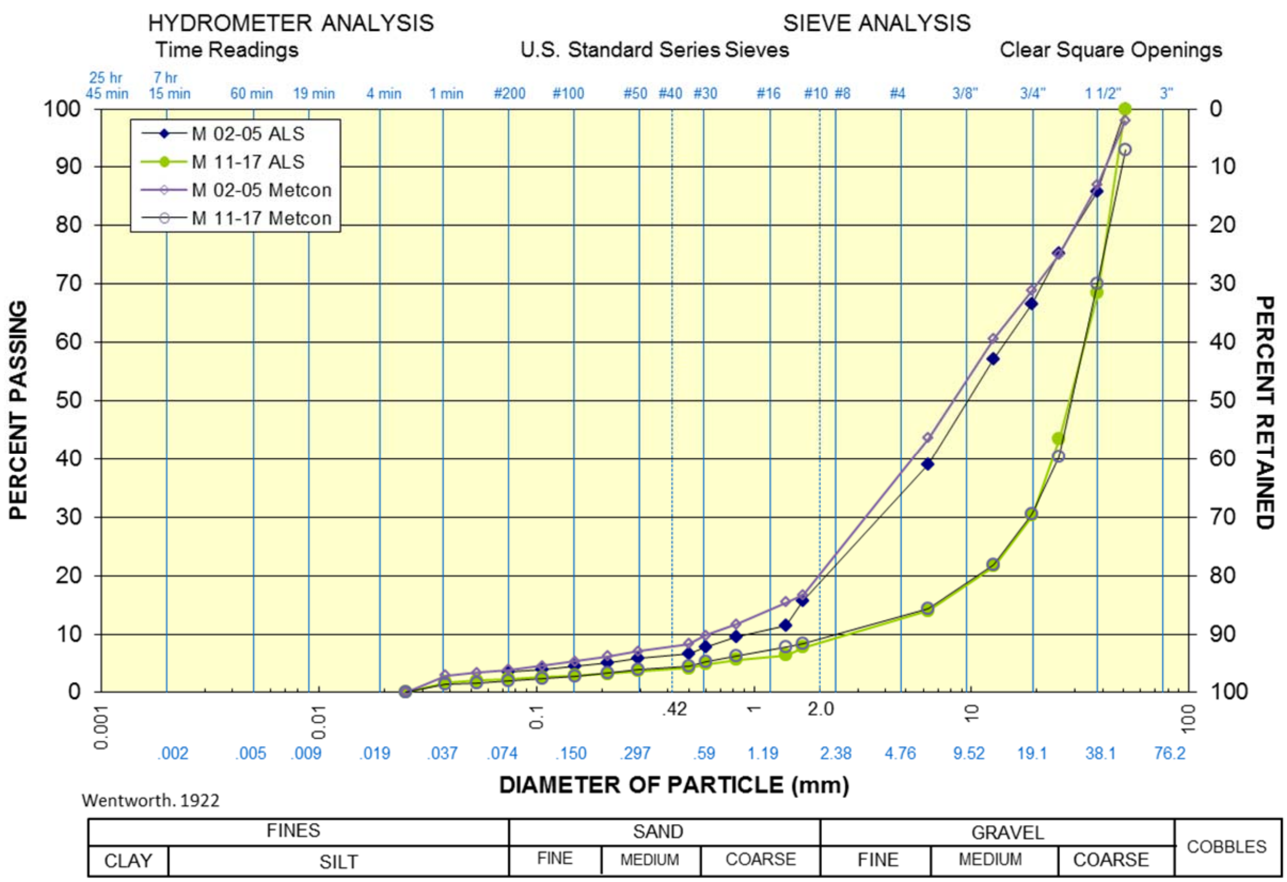

Figure 1.2 Particle size distribution TMC Fresh ore

From the PSD of each composite the P_{80} (the particle size larger than 80% of the rock fragments) and the main size fractions (gravel, sand and fines) can be determined (Table 1.1). These data show that:

- The $\mathbf{P_{80}}$ of M 02-05 is 30.6 mm while that for the M 11-17 composite is 43.6 mm.
- The fines:sand:gravel partition of the Casino ore is: 3.9:12.8:83.3 for the M 02-05 composite and 2.0:6.3:91.7 for the composite M 11-17. This partition of the main size fractions indicates that as long as the rock fragments are stable, these composites should be permeable to allow percolation through the heap of a significant height.
- However, it is noted that the large gravel content (more so for composite M 11-17) could promote solution channelization and low wetting efficiency.
- The Stacking and Hydrodynamic Column Tests described below provide additional insight in this potential issue.

Table 1.1 Particle size distribution from Metcon				
Sample ID	**P_{80} (mm)**	**Gravel (%)**	**Sand (%)**	**Fines (%)**
M 02-05	30.6	83.3	12.8	3.9
M 11-17	43.6	91.7	6.3	2.0

1.3 Ore Specific Gravity

The Casino samples were tested to determine the Specific Gravity (SG) of the solids on each of the main size fractions (gravel, sand and fines). An accurate determination of the porosity (void ratio) of the sample requires an accurate value of the SG. Difference in the SG on the main fractions indicates potential differences on the alteration type and extent of the rock mass. In the case of alteration differences between the size fractions, these data also provide a better estimate of the overall specific gravity of the sample. The average SG for the Casino is estimated at 2.660 for M 02-05 and 2.632 for M 11-17.

Table 1.2 Specific Gravity		
	Specific Gravity	
Fraction	**M 02-05**	**M 11-17**
Gravel	2.673	2.641
Sand	2.575	2.529
Fines	2.678	2.556
Overall	**2.660**	**2.632**

The difference in specific gravity of the gravel, sand, and the fines may be indicative of varying degrees of alteration among these fractions, and in this particular case, also between the two composites.

1.4 Head Assay Determination

In order to get an understanding of the relationship between the hydrodynamic behavior and the potential metallurgical performance of the Casino samples the data presented by ALS and Metcon are briefly summarized in this section.

ALS assayed each size fraction of samples M 02, M 05, M 11, and M 17 for total copper, iron, sulfur, and gold as well as for multi-element ICP analysis. Metcon performed head assays for gold and silver on the two composites delivered (M 02-05 and M 11-17) to HGS.

HGS recommended mineralogical characterization (QEMSCAN or Quantitative XRD and optical microscopy) of the Casino composites to better understand the mineral species responsible for the occurrence of the Au/Ag values. A one kilogram test charge was prepared for each of these composites (including M19-20) and submitted for mineralogical analysis to FL Smidth during the first week of August 2014. The results of this characterization are summarized below in section 1.4.3.

Table 1.3 summarizes the total copper, iron, sulfur, gold, and silver of the individual samples (Met 02, Met 05, Met 11, Met 17) based on the ICP analysis by ALS and composite samples (Met 02-05 and Met 11-17) determined by Metcon. These data show that:

- Sample Met 05 contains less copper, iron, gold and silver than any of the other individual samples summarized on Table 3.1. It is noted from the individual PSD of this sample that 95% of the rock fragments are smaller than 38.1 mm (1.5") while the average of the other (including Met 19 and 20) is only about 72% (Met 11 has only 63.3% of its mass smaller than 38.1 mm). This information suggests that Met 05 may represent a more altered zone of the deposit.

- M 11-17 has the highest Au and Ag content, although it also has the highest Cu content (530 ppm) of the two composites. Depending on the copper solubility, this higher Cu content might promote CN consumption and interfere with Au/Ag absorption.

- The calculated head assays from the ALS data are similar to those reported by Metcon for copper and gold but the calculated silver content is slightly larger than the values reported by Metcon. Overall, the agreement between these two independent evaluations is quite good.

Table 1.3 Summary of Head Assays

Lab	ALS					Metcon		
Sample ID	**Cu (%)**	**Fe (%)**	**S (%)**	**Au (ppm)**	**Ag (ppm)**	**Cu (%)**	**Au (ppm)**	**Ag (ppm)**
Met 02	0.018	3.2	0.64	0.52	1.59			
Met 05	0.002	1.4	0.18	0.20	0.52			
Met 11	0.022	3.2	0.94	0.42	4.62			
Met 17	0.083	2.1	0.31	0.64	2.15			
Met 02-05*	0.010	2.30	0.41	0.36	1.06	0.009	0.32	0.8
Met 11-17*	0.053	2.65	0.63	0.53	3.39	0.051	0.55	2.7

*Composite assays calculated from individual assays assuming a 1:1 mix

- The S content would indicate that the iron on the Casino sample occurs mostly as oxides rather than sulfide minerals. If this is correct, there would be some potential for the iron-oxides to encapsulate or coat the gold minerals and the reaction of sulfides minerals to consume oxygen and lower the pH.

1.4.1 ICP Elemental Analysis

ALS (2013) reports the results from a 48-element ICP scan on seven size fractions which provides a general indication of the geochemical composition of the samples. The results from ALS AR-ICP analysis were combined with the percent of each of the particle size fraction to determine the elemental composition for each of the samples and the two composites of interest for this evaluation. The resulting calculations are summarized in tabular form in Table 1.4 and graphically in Figure 1.2.

Inspection of the data summarized in Table 1.4 and Figure 1.2 indicates that:

- Only three elements are reported with concentration larger than 1% (10,000 ppm), namely: Al (ranging from 6.2% in Met 05 to 7.6% in Met 02), Fe (ranging from 1.4% in Met 05 to 3.2% in Met 02), and K (ranging from 3.0% in Met 05 to 5.1% in Met 17). All of these are highlighted in Table 1.4.
- Similarly, Calcium (ranging from 0.019% in Met 05 to 0.058% in Met 11) and Magnesium (ranging from 0.22% in Met 05 to 0.39% in Met 02) are also present. To the extent that these minerals are associated to Dolomite or Calcite they could reduce the alkalinity requirements of the leaching process.
- The concentrations of the metals of interest (in blue font in Table 1.3) are as follows: Ag (ranging from 0.5 ppm in Met 05 to 4.6 ppm in Met 02), and Cu (ranging from 0.01% in Met 05 to 0.08% in Met 02). As mentioned before, at the higher concentrations (>100 ppm) copper, if sufficiently soluble, has the potential to promote CN consumption and interfere with Au/Ag absorption.
- Several trace metals are reported to be present, namely; As, Ba, Cd, Pb, Rb, Ti, V and Zr although only Ba and Ti are reported to have concentrations of about or larger than 1,000 ppm.
- There is a good agreement between the Cu and S concentrations derived from the ICP analysis and the head assays reported above.
- Similarly, there is good agreement between the Cu and Ag grades estimated from the ICP with those reported by Metcon for both composites.
- Based on the results from the ICP characterization, it can be concluded that the chemical composition for composites M 02-05 and M 11-17 is quite similar with the exception of the concentrations of Ag, Cu, Mo, Sr, U and Zn (see Figure 1.2).

1.4.2 Mineral distribution as a function of particle size

Both ALS (2013) and Metcon (2014[1]) reported Au and Ag head grades as a function of particle size. The Au and Ag grade and the percent retained for each size fraction is summarized in Figure 1.3 and Table 1.5. These data show that:

- The overall trend depicted by these two sets of data for the Au and Ag head grades is consistent.
- The gold and silver content vary in proportion to each other. For Met 02-05 the average ratio of Au to Ag is about 0.33 while for Met 11-17 is about 0.19 which remain fairly constant over the various size fractions. As such, it would be expected that Met 02-05 would leach more efficiently than Met 11-17.
- For Met 02-05, the gold and silver content shows a consistent reduction from the coarsest to the 1.7 mm fraction and then a noticeable increase on the minus 1.7 mm fraction. This type of metal distribution requires good solution-to ore contact in order to efficiently leach the coarse fractions.
- For M 11-17, the gold and silver content is relatively constant over the size fraction although, similar to that observed for Met 02-05, it shows a noticeable increase (a factor of two) in the minus 1.7 mm fraction. Given the coarse nature of this composite, efficient leaching of the Au/Ag from both the coarse and fine fractions will require careful selection of the irrigation scheme.

[1] Metcon 2014. Email communication from Narsagdorj Gatumur, July 12, 2014.

Table 1.4 ICP Elemental Analysis (After ALS, 2013)						
Element	**Met 02 (ppm)**	**Met 05 (ppm)**	**Met 11 (ppm)**	**Met 17 (ppm)**	**Met 02-05 (ppm)**	**Met 11-17 (ppm)**
Ag	1.6	0.5	4.6	2.2	1.1	3.4
Al	75,540	61,784	66,419	67,115	68,662	66,767
As	85.1	14.6	82.4	38.7	49.8	60.5
Ba	1,178	1,196	1,666	1,561	1,187	1,614
Be	1.4	0.4	1.0	1.0	0.9	1.0
Bi	2.8	3.3	2.2	1.3	3.1	1.7
Ca	450	194	576	264	322	420
Cd	0.1	0.0	0.4	0.1	0.1	0.2
Ce	60.6	47.0	73.1	98.2	53.8	85.6
Co	1.6	0.6	2.8	1.7	1.1	2.3
Cr	164	165	192	188	165	190
Cs	7.5	1.0	5.5	4.7	4.2	5.1
Cu	183.9	18.5	224.6	827.2	101.2	525.9
Fe	32,043	13,731	31,703	20,814	22,887	26,258
Ga	15.4	15.6	13.8	12.0	15.5	12.9
Ge	0.2	0.2	0.2	0.2	0.2	0.2
Hf	0.8	1.3	0.9	1.0	1.0	1.0
In	0.2	0.0	0.2	0.1	0.1	0.2
K	35,185	30,356	42,142	50,782	32,770	46,462
La	35.1	28.5	40.5	67.0	31.8	53.7
Li	11.4	5.2	11.8	10.8	8.3	11.3
Mg	3,871	2,222	2,733	2,365	3,047	2,549
Mn	60	20	76	39	40	37
Mo	81.3	20.0	68.9	293.5	50.6	181.2
Na	1,045	918	1,311	2,388	982	1,850
Nb	2.8	3.5	2.8	2.8	3.1	2.8
Ni	5.4	3.8	5.0	7.4	4.6	6.2
P	1,141	112	590	558	626	574
Pb	27.8	11.6	211.7	34.3	19.7	123.0
Rb	175.4	130.3	171.8	185.2	152.9	178.5
Re	0.004	0.002	0.006	0.005	0.003	0.005
S	6,412	1,788	9,381	3,139	4,100	6,260
Sb	7.8	2.5	16.0	6.9	5.1	11.5
Sc	13.4	9.8	6.3	8.1	11.6	7.2
Se	2	6	4	3	4	4
Sn	5.9	12.6	5.4	4.6	9.2	5.0
Sr	26.8	21.9	80.5	92.5	24.3	86.5
Ta	0.3	0.4	0.2	0.2	0.3	0.2
Te	0.3	0.7	1.1	0.1	0.5	0.6
Th	22.9	8.5	20.6	12.4	15.7	16.5
Ti	1,624	1,310	926	1,018	1,467	972
Tl	1.9	0.9	1.9	1.7	1.4	1.8
U	1.9	1.2	2.1	11.6	1.5	6.9
V	87	72	46	62	80	54
W	32.2	57.3	33.1	69.1	44.8	51.1
Y	6.1	3.3	5.1	5.5	4.7	5.3
Zn	24	4	45	30	14	37
Zr	18.3	29.7	24.8	29.8	24.0	27.3

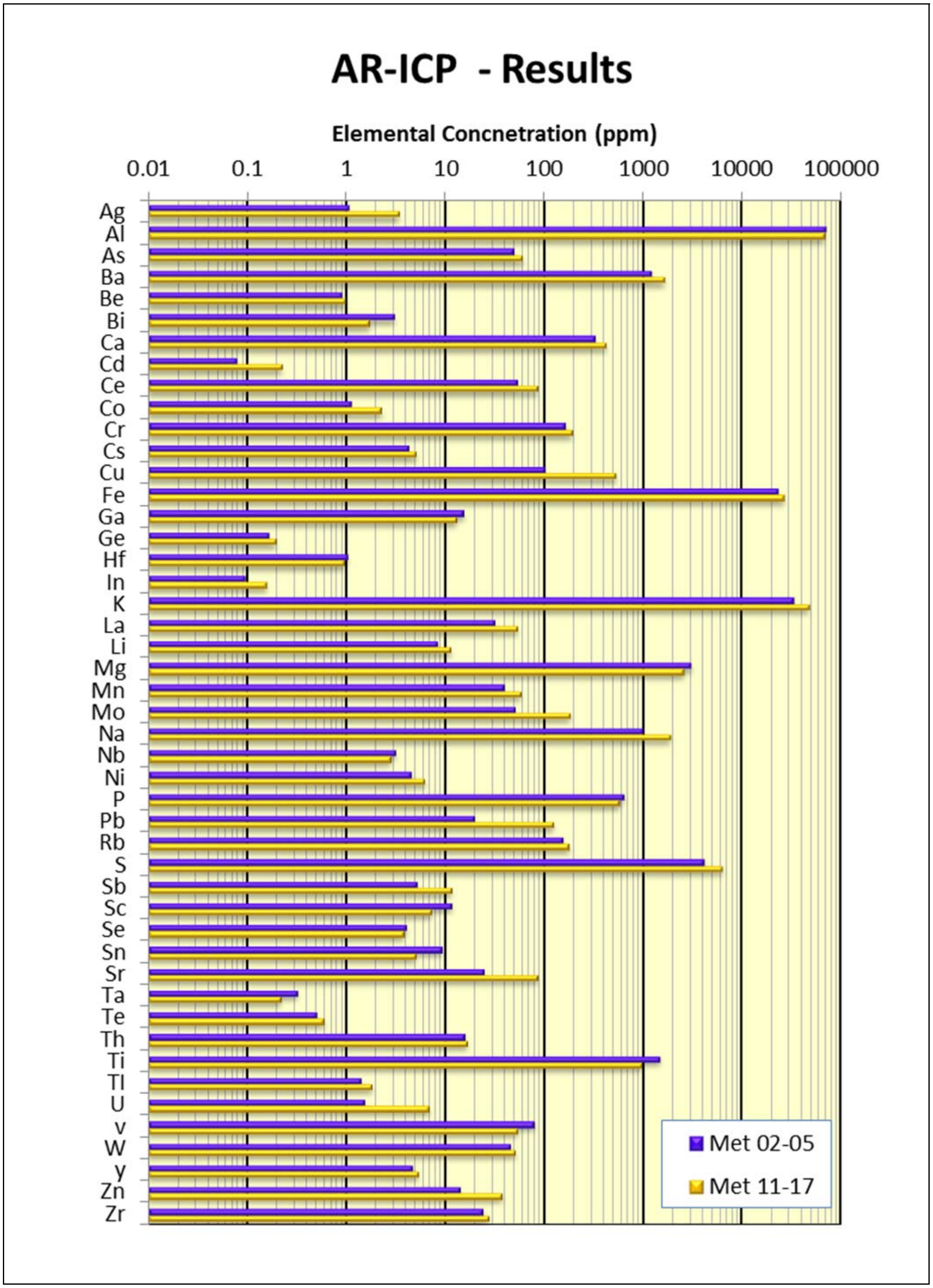

Figure 1.2 AR-ICP on pulps of Casino composites

Table 1.5 Gold and Silver content by size fraction						
Size Fraction	ALS (2013)			Metcon (2014)		
	W. Retained (%)	Au (ppm)	Ag (ppm)	W. Retained (%)	Au (ppm)	Ag (ppm)
Met 02-05						
2"	0			2.03	0.46	1.20
+1.5"	14.15	0.65	1.72	10.91	0.31	1.00
+1"	10.55	0.37	1.17	11.99	0.26	0.90
+3/4"	8.85	0.29	1.03	6.18	0.24	0.70
+1/2"	9.35	0.22	0.76	8.23	0.23	0.70
+1/4"	18.05	0.20	0.66	17.06	0.17	0.50
+10 mesh	23.40	0.20	0.70	26.91	0.14	0.50
-10 mesh	15.7	0.64	1.55	16.69	0.57	1.70
Met 11-17						
2"	0			7.06	0.46	2.70
+1.5"	31.60	0.28	2.70	22.89	0.54	2.20
+1"	25.00	0.47	2.93	29.64	0.51	2.60
+3/4"	13.15	0.70	3.34	9.92	0.44	2.60
+1/2"	8.70	0.52	3.04	8.67	0.46	2.20
+1/4"	7.60	0.56	3.45	7.48	0.43	3.50
+10 mesh	6.30	0.52	4.00	6.04	0.52	2.80
-10 mesh	7.75	1.53	7.53	8.29	1.00	4.30

- According to the Metcon data, for Met 02-05 about 16% of the Au and about 16% of the Ag occurs in the size fractions larger than 25.4 mm (1") in size. For Met 11-17 about 29% of the Au and more than 25% of the Ag occur on these coarse fractions.
- Similarly, Metcon's data show that for Met 02-05 35% of the Au and about 34% of the Ag are present in the minus 1.7 mm fraction. For Met 11-17 these numbers are 15.4% and 13.2%, respectively. These data suggest that everything else being equal, Met 02-05 should leach better than Met 11-17.
- A comparison between the data generated by ALS with the assays determined by Metcon shows that these data sets produce similar results lending confidence to the head assay values.

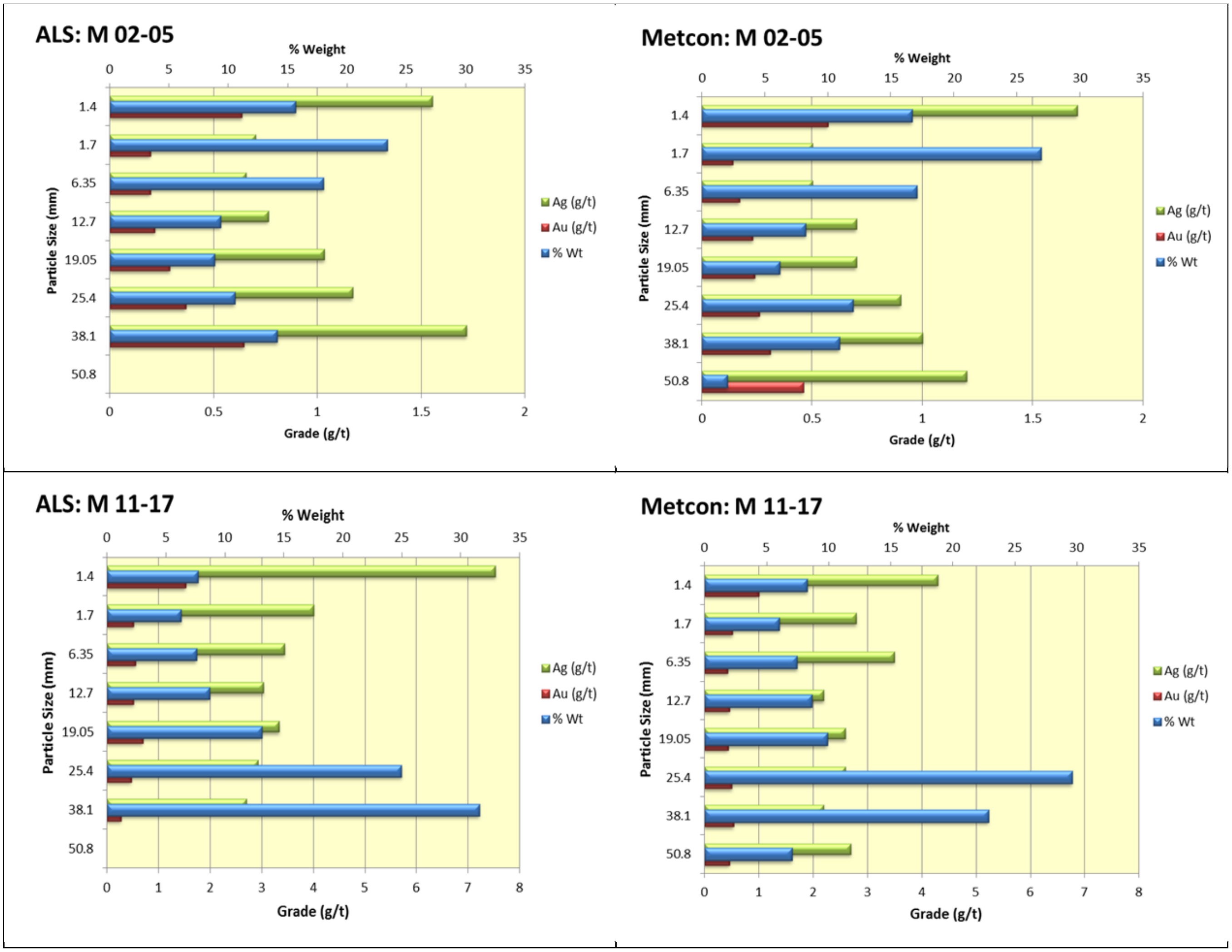

Figure 1.3 Gold and silver grade distributions by size fraction and percent retained

1.4.3 Mineralogical characterization

HGS recommended to WCG to undertake mineralogical characterization of the samples in an attempt to understand the mineral assemblage responsible for the mineralization. HGS coordinated with SGS personnel to deliver a one-kilogram split of each of the three Casino composites to FL Smidth to determine: the gangue mineralogy, abundance of clay minerals, potential cyanide consuming minerals, and mode of gold occurrence. In addition, WCG undertook QEMSCAN of the composites.

For completeness and to help with the interpretation of the data derived during this characterization effort, the following paragraphs provide a brief discussion of the findings by FLS for the two composites of interest, namely;

Met 02-05 and Met 11-17. For a complete analysis and discussion of the procedures used to generate these data the interested reader is refer to the FLS report (FLS, 2014)[2].

Gangue mineralogy

The bulk gangue mineralogy determined by FLS is summarized graphically in Figure 1.4. These data show:

- The gangue is composed predominantly by quartz ($Si0_2$) and alumino-silicate minerals; K-feldspar ($2KAlSi_3O_8$) and Muscovite ($KAl_2(AlSi_3)O_{10}(OH)_2$). Chlorite ($(Mg,Fe)_3(Si,Al)_4O_{10}(OH)_2{\bullet}(Mg,Fe)_3(OH)_6$) is present in a minor amount in Met 19-20. These minerals make up about 88%, 85% and 81% of the gangue minerals in Met 02-05, Met 11-17 and Met 19-20, respectively.
- The quartz fraction is quite different from each of the composites, 55.5% for Met 02-05, 41.7% for Met 11-17 and 36.8% for Met 190-20.
- The secondary alumino-silicate minerals include Kaolinite ($Al_2Si_2O_5(OH)$), with some swelling clays representing 5.5%, 6.0% and 7.7% for Met 02-05, Met 11-17 and Met 19-20, respectively.
- Iron oxides include Jarosite ($KFe^{3+}{}_3(OH)_6(SO_4)_2$) and Hematite ($Fe_2O_3$). The presence of these minerals confirms the conclusion reached from the ICP data regarding iron in the Casino samples being indeed representative of oxide minerals.
- The concentrations of Ti identified by the ICP analysis are explained by the presence of Rutile (TiO_2) in all three composites.
- Met 11-17 and Met 19-20 are similar except for the presence of Plagioclase (a transition feldspar), Chlorite, and Hematite on the latter.

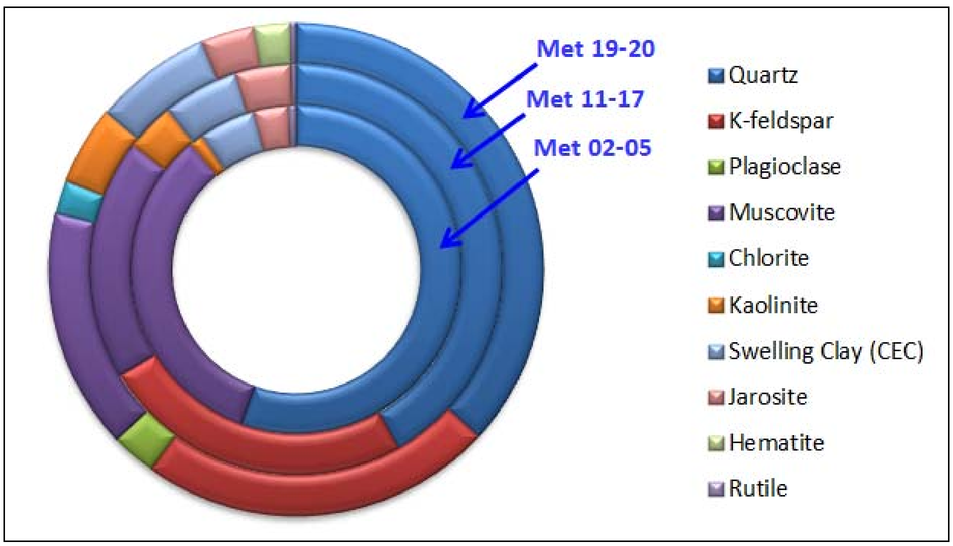

Figure 1.4 Casino – Bulk gangue mineralogy (After FLS, 2014)

[2] FLSmidth 2014. Draft Technical Report, M-14085 Western Copper & Gold Casino Samples.

Potential Cyanide Consuming Minerals

Based on the mineralogical characterization from FLS and other mineralogical data, the potential CN consuming minerals include:

- Metal sulfides including copper, iron, arsenic and zinc;
- Iron oxide-hydroxides such as Limonite and Jarosite which can also act as preg-robbing. Further, Jarosite as well as other acidic materials may also induce lower pH values which may promote CN destruction; and
- Secondary alumino-silicates and swelling clays to a minor extent.

Mode of Gold Occurrence and Potential Solubility

The FLS report indicates that:

- Given the low grades of the material it is extremely difficult to mineralogically characterize the occurrence of gold and further characterization was recommended by FLS.
- From the fact that no visible gold was observed in the received composites or in their gravity concentrates, and the results of the cyanide solubility, FLS conclude that the gold occurs primarily as sub-microscopic native gold.
- Shake leach tests at various concentrations of CN were used to determine the potential solubility of gold. These tests were conducted on 10 g with a P_{95} of minus 106 micron and show that:
    - Au recoveries increase with increased CN concentrations. A CN concentration of 3 g/L results in an average Au recovery of about 61% for all the three composites;
    - Increasing CN concentration produces additional Au recovery for composites Met 11-17 and Met 19-20 but not for composite Met 02-05. Even at a CN concentration of 50 g/L at which the other composites yielded an Au recovery greater than 97%, the recovery for the latter was only 75%.
    - It is our contention that the additional recovery on the first two composites results from the dissolution of sulfide minerals (sulfide encapsulation due to, but not exclusively, copper sulfides) which may be coating the Au minerals and dissolve in the presence of higher CN concentrations. On the other hand, the limited Au recovery in Met 02-05 is likely associated to silica encapsulation.

The available head grade for composites Met 02-05 and Met 11-17 for copper, Au and Ag are summarized in Table 1.6. These data show a good correspondence between these three data sets lending confidence in the sample preparation and analytical methods as well as on the values of the head assays.

Given the low Au grade on these composites, it would be important to understand the minerals responsible for the copper values. FL Smidth recommended and conducted QEMSCAN analysis to try to identify the copper minerals present on these samples. However, FLS indicated that given the low concentration of Cu (< 5%) and the accuracy of this method (0.1% by weight), only a small fraction of the Cu (33% for M 02-05 and ~8% for M11-17 and M 19-20) was detected which prevented full determination of Cu deportment. Notwithstanding these limitations, the QEMSCAN characterization shows that Chalcopyrite is the dominant Cu-sulfide and that some Cu bearing Iron Oxides are present in M 11-17 and M 19-20 but not in M 02-05. The results from the FLS study reinforce our conclusion that Met 02-05 would metallurgically outperform the other two composites.

Table 1.6 Head Grades for Casino Composites

Lab	ALS*			FLS			Metcon		
Sample ID	Cu (%)	Au (ppm)	Ag (ppm)	Cu (%)	Au (ppm)	Ag (ppm)	Cu (%)	Au (ppm)	Ag (ppm)
Met 02-05	0.010	0.36	1.06	0.01	0.32	<2.0	0.009	0.32	0.8
Met 11-17	0.053	0.53	3.39	0.06	0.47	2.9	0.051	0.55	2.7

*Composite assays calculated from individual assays assuming a 1:1 mix

2.0 HYDRODYNAMIC CHARACTERIZATION

Over the years, the leaching community has bought into the false precept that as long as an ore is very permeable it is good for a leaching process and therefore standard geotechnical characterization is typically limited to the measurement of the saturated hydraulic conductivity. ROM ore and crushed ore devoid of fines are good illustrations of the falsehood of this assertion. In these materials, the leaching solution will indeed move quickly through the ore bed but it will do so with minimal solution-to-ore contact resulting in an inefficient leaching process. Solution bypass through the coarse fractions and pooling on the fines fractions is a common occurrence in ROM heaps which leads to inefficient metal recovery. As discussed in the following paragraphs, a leaching material must not only be permeable but should satisfy a number of other physical and hydraulic requirements.

Industrial experience worldwide shows that the lack of ore preparation standards, in general, and of agglomeration standards, in specific, results in significant variability from day to day and from operation to operation. Improved agglomeration significantly enhances hydrodynamic performance of the ore and hence the metallurgical performance of the process. With this in mind, HGS developed the following scale to qualify the condition of the ore delivered to a heap; a non-agglomerated sample is assigned a Level 0 (L0), while a sample that has been fully agglomerated is assigned a Level 5 (L5). Most crushed, agglomerated ore leaching operations are working with an intermediate agglomerated product with a quality below L3. Recent experience shows that attaining higher levels of agglomeration (L3 to L5) is feasible once the necessary conditions have been identified and operators have been properly trained[3]. It is important to recognize that low levels of agglomeration and ROM ore placement result in particle size segregation along the heap profile, which in turn promotes solution segregation (channeling), protracted leach cycles and overall poor leaching efficiency.

[3] Guzman, A., R.E. Scheffel and S. Flaherty 2006. *Geochemical Profiling of a sulfide leaching operation: A case study*. SME 2006 Spring Meeting. March 2006 St. Louis, Mo

Application of the above agglomeration scale helps explain the discrepancies often encountered amongst metallurgical tests as well as the difference between lab-scale tests and industrial leaching operations. We have concluded[4] that optimal agglomeration needs to satisfy the following specifications:

1.0 Bind all the dispersed fines to minimize their negative effect on the percolation and solution-retention capacity of the ore;

 1.1 The percolation capacity of the ore should be at least 100 times larger than the typical application rate (10^{-4} cm/s) for a dynamic heap, and at least 1,000 times larger than this rate for a multi-lift heap.

 1.2 The maximum solution retention capacity during irrigation should result in a liquid degree of saturation smaller than or equal to 75% for an oxide-leaching operation or 60% for a sulfide leaching operation.

 1.3 Air conductivity should remain larger than 10^{-3} cm/s.

2.0 The resulting porous structure yields at the maximum lift/heap height a total porosity larger than 30% which is partitioned between macro- and micro-porosity of about 50:50 to facilitate bulk solution movement and intimate contact between solution and ore;

3.0 The porous structure is sufficiently resilient to withstand deformation and physical stress resulting from the design heap-height;

4.0 The agglomeration product is sufficiently resilient to chemical decrepitation;

5.0 The agglomeration product and resulting porous structure is able to withstand flooding without major loss of structural integrity; and

6.0 Produce an agglomeration product which promotes leaching bed homogeneity, uniform flow distribution and equal opportunity-leaching for all the size fractions.

All these specifications are more critical in the case of a multi-lift heap where the material will be exposed to the cumulative effect chemical decrepitation and compaction resulting from multiple leaching cycles. In general, alkaline leaching conditions (as those used in the leaching of Au and Ag) produce less decrepitation than that observed in acidic leaching conditions (as those used in the leaching of Cu, Zn and Ni) so the conditions specified on item 1) above may be relaxed slightly.

With these requirements in mind, two testing procedures (the Stacking Test and the Hydrodynamic Column Test) were developed based on experience from the hydrological sciences and observations in more than 50 leaching operations worldwide. **These test procedures provide the most complete characterization of the physical and hydrodynamic properties of an ore-for-leach available to the mining industry.**

[4] A. Guzman, S. Robertson and B. Calienes, Constitutive relationships for the representation of a heap leach process, in The **Heap Leach** Solutions 2013 Proceedings Vancouver, Canada, September 22-25, 2013.

Extensive experience with the application of these procedures to the leaching processes on a variety of minerals including crushed-agglomerated ore and ROM ore indicates that:

- Ore bulk density controls the hydrodynamic performance of the ore;
- Bulk density varies in a non-linear fashion along the heap profile and strongly depends on ore preparation practices (particle size distribution, crushing approach, agglomeration and additives, and stacking mode);
- Hydrodynamic performance controls operational conditions, metallurgical performance as well as geotechnical performance of the ore mass; and
- As such, it is critical to recognize that operational conditions for a given ore sample depend on ore preparation techniques, method of stacking and equally important, the bulk density of the ore.

In practical terms, a large difference between the Stacking Test results from Level 0 and Level 5 material indicates a strong sensitivity of the hydrodynamic properties of the ore and highlights the need for optimizing the agglomeration process. On the other hand, a relatively small gap between L0 and L5 STs suggests that the ore is robust enough and that a sub-optimal agglomeration product would not greatly impact the performance of the leaching process.

The following sections provide a brief overview of these procedures, test conditions, and the results from their application to the Casino head composites.

2.1 Testing Solution

Testing with a representative solution (density, viscosity, and bulk chemistry) is a key procedural practice that has been overlooked during the measurement of hydrodynamic properties in the context of the design of many heap leaching operations. This oversight typically results on erroneous conclusions regarding the hydraulic performance of the ore. With this in mind, the tests requiring solution were conducted as follows:

- Tap water with 0.13 g of lime per liter of water to obtain a pH close to 11.3 for the agglomerating solution and Stacking Tests.
- The HCTs used tap water with 0.10 g/L of lime, a pH of 11.2 plus 0.5 g/L of NaCN for the irrigating solution.

Saturated hydraulic conductivity tests were conducted using synthetic raffinate to make the results from these tests as representative as possible. The moisture content values represented in Table 2.1 represent the optimal moisture required to achieve an agglomeration level of L3 (the typical attainable at an industrial scale without much difficulty).

Hydraulic conductivity is directly proportional to the solution density and inversely proportional to the viscosity of the solution. The specific gravity (S.G.) of the synthetic raffinate was measured at 1.00. It is noted that all values of saturated hydraulic conductivity reported on this document have been normalized to a temperature of 20°C to account for the variation of solution viscosity as a function of temperature.

2.2 Stacking Tests

A Stacking Test[5] (ST) simulates the lithostatic load resulting from the weight of the ore as the height of the heap increases. A ST is performed by placing an ore sample into a test cell and mechanically increasing the confining load to simulate the effect of heap height on the bulk density of the ore. The load is increased in a stepwise fashion, allowing for height stabilization during each of the loading steps. The density and permeability of the ore are measured at each step and then the load is increased to simulate additional lithostatic loading. The maximum load for a stacking test is selected to represent either the maximum lift height in the case of a dynamic heap or the maximum heap height in the case of a permanent (multi-lift) heap[6]. A soft-ore produces a steep density profile indicative of a rapidly changing hydraulic conductivity profile while a competent ore produces relatively flat density and conductivity profiles. The stacking test is conducted under partially saturated conditions, containing only the moisture of agglomeration (or as-drained moisture in some cases), as opposed to fully saturated conditions typically employed in similar studies conducted by geotechnical practitioners. The results from a Stacking Test include:

- *Density profile* – defines the relationship between the ore density and heap height. This profile provides a direct measurement of the physical integrity of the ore sample under load and, as such, it quantifies the robustness of the pore structure resulting from the selected ore-preparation practice;
- *Hydraulic conductivity profile* – defines the relationship between the ore conductivity and heap height. These data represent a direct measurement of the integrity of the porous structure and its resilience under various heap heights and determines the effect of physical and chemical decrepitation (when using a leached sample) on the percolation capacity of the ore;
- *The minimum hydraulic conductivity of the sample* – By design, the results from a Stacking Test represent the bulk density, ore permeability and, at the end of the test, the saturated hydraulic conductivity of unit volume of ore located at the bottom of the heap. Therefore, the saturated hydraulic conductivity value at the end of the load-sequence indicates whether the heap is sufficiently permeable at its ultimate height to allow free drainage of the pregnant leach solution (PLS) to the collection system;
- *Preliminary estimates of total-, micro- and macro-porosity* – these preliminary estimates provide a direct indication of the capacity of the sample to support percolation leaching. Ample data from industrial operations indicate that a total porosity of at least 30% is required for proper solution and air percolation. In addition, a 50:50 portioning of the porosity into micro- and macro-components has been determined to provide a good balance between advection and diffusion controlled solution movement.

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[5] A. Guzman and R.E. Scheffel, The Fundamentals of Physical Characterization of Ore for Leach, in International Symposium Hydrometallurgy (6th: 2008 Phoenix, AZ). Edited by C.A. Young et al., SME.

[6] A. Guzman, S. Robertson and B. Calienes, Constitutive relationships for the representation of a heap leach process, in The **Heap Leach** Solutions 2013 Proceedings Vancouver, Canada, September 22-25, 2013.

- *The maximum lift and heap height* – Data from the density and permeability profiles provide a direct measurement of the lift and heap height at which the leaching process will allow unimpeded percolation of solution.

As described above, two composites from the Casino ore body were subjected to the ST procedure under different conditions of agglomeration. To accommodate the coarser nature of Met 11-17, the STs were conducted on 8" diameter cells. The agglomerated samples were targeted to an optimal condition (L5), however, due to the high proportion of gravel size fragments agglomeration for Met 02-05 reached an intermediate level of agglomeration (L3) while the coarser composite Met 11-17 reached a low level of agglomeration (L2). In addition, to fulfilling the tests the test matrix (Figure 2.1), we also tested a 1:1 blend of Met 02-05 and Met 11-17 under a non-agglomerated condition and a 2:1 blend of these composites under a L# agglomeration level. A total of 8 STs were conducted as summarized in Table 2.1.

Figures 2.1a and 2.1b present a visual record of the samples used during this characterization; non-agglomerated (L0) and agglomerated (L2 and L3). As indicated by the contrast in porous structure between the L0 and L3 samples, despite the low level of fines on the Casino samples, it seems likely that agglomeration has a positive impact on the hydrodynamic performance of the ore – more so for sample Met 02-05 with smaller top size and larger amount of fines. Agglomeration of the 2:1 blend of M 02-05 and M 11-17 (Figure 2.1b) produces a significant improvement of the porous structure when compared with the agglomerated samples of either one of these composites (Figure 2.1a).

Table 2.1 presents the sample identification (ID) together with the conditions for each of the STs. The sample ID contains information about the Composite (M-02-05, M-11-17 or Blend of these two), type of lime mixed with the initial non-agglomerated sample (Peb for Pebble and Pow for Powder), and the level of agglomeration (L0, L2 or L3). Powder lime was used for the remaining tests (agglomerated samples, blended non-agglomerated sample and the samples used on the HCTs described below). Also included are the Specific Gravity, the moisture content, maximum test height, minimum and maximum bulk density, minimum and maximum air conductivity, and minimum saturated hydraulic conductivity.

As indicated in Table 2.1, a 1:1 blend of composites Met 02-05 and Met 11-17 was prepared and tested under non-agglomerated conditions to evaluate the potential benefit of mixing these two samples. An additional 2:1 blend of these samples was prepared and tested under a L3 agglomeration level to document the beneficial impact of agglomeration on the Casino composites.

The samples were initially tested to a maximum heap height of about 70 m for the initial, then to about 140 m to simulate the range of heap heights considered within the current heap design. As discussed below, the load sequence was selected to generate sufficient detail over the range of heap heights relevant to the current multi-lift heap. It is noted that the slope of all the density profiles generated to date seem to steepen once the simulated heap height increases beyond twenty meters.

By design a Stacking Test determines the effect of lithostatic load on the degree of compaction of a sample. These results are presented on and X-Y semi-log plot where the Y-axis represents the bulk density (dry mass of ore per unit volume) and the X-axis represents the lithostatic load expressed in terms of the associated heap height. The shape of the density profile is in general diagnostic of the physical competence (strength) of the ore such that a "soft" or "weak" ore is characterized by a steep density profile while a competent, strong sample is described by a flatter density profile. It is noted, however, that the slope of the density profile is also affected by the initial porous structure of the sample such that the density profile of a fully agglomerated sample might be steeper than that from the corresponding non-agglomerated sample. Notwithstanding, this stepper density profile, the fully agglomerated samples invariably have a much higher percolation capacity than the non-agglomerated sample due to its more organized porous structure.

As such, interpretation of the results from a ST requires combined analysis of the density and conductivity profiles as well as the preliminary estimates of the total porosity and its partition into macro and micro. The following sections present a summary of the results in graphical form for the density and the conductivity profile as well as the partition of porosity into its micro- and macro-components to facilitate evaluation of the impact of the various testing conditions.

Appendix A at the end this document presents the laboratory report for each of the STs conducted as part of this investigation.

Sample	L0 w/ Pebble Lime	L0 w/ Powder Lime	Agglomerated w/ Powder Lime
M 02-05			
M 12-17			

Figure 2.1a Photographs of Casino samples

	Test Charge	Close-up	Detailed View
L0			
L3			

Figure 2.1b Photographs of Casino M02-05 & M11-17 blend 2:1 agglomerated

Table 2.1 Stacking Tests Conditions and Results										
Test ID	SG ( )	Agglomeration Level	Agglomeration Moisture	H_{Max} (m)	Bulk Density Min (t/m^3)	Bulk Density Max (t/m^3)		Ks min (cm/s)	Ka min (cm/s)	Ka max (cm/s)
M-02-05-Peb-L0	2.660	L0	0.4%	70.6	1.68	1.84	!	1.1E-01	1.6E-02	2.3E-02
M-02-05-Pow-L0	2.660	L0	0.4%	71.2	1.65	1.84	!	9.9E-02	1.2E-02	1.5E-02
M-02-05-L3	2.660	L3	5.7%	129.2	1.51	1.91	!	1.0E-01	2.4E-02	5.8E-01
M-11-17-Peb-L0	2.632	L0	0.3%	82.5	1.40	1.57	✓	2.3E-01	6.1E-01	7.5E-01
M-11-17-Pow-L0	2.632	L0	0.3%	120.3	1.36	1.56	!	7.7E-02	1.4E-01	2.4E-01
M-11-17-L2	2.632	L2	2.4%	147.7	1.43	1.73	✓	2.0E-01	4.2E-01	2.6E+00
M02-05+M11-17 1:1-L0	2.645	L0	0.3%	138.1	1.51	1.88	!	1.4E-01	3.6E-02	1.1E-01
M02-05/M11-17 2:1-L3	2.651	L3	5.5%	130.7	1.43	1.89	!	1.5E-01	2.7E-02	7.2E-01

2.2.1 STs on Casino Composite Met 02-05

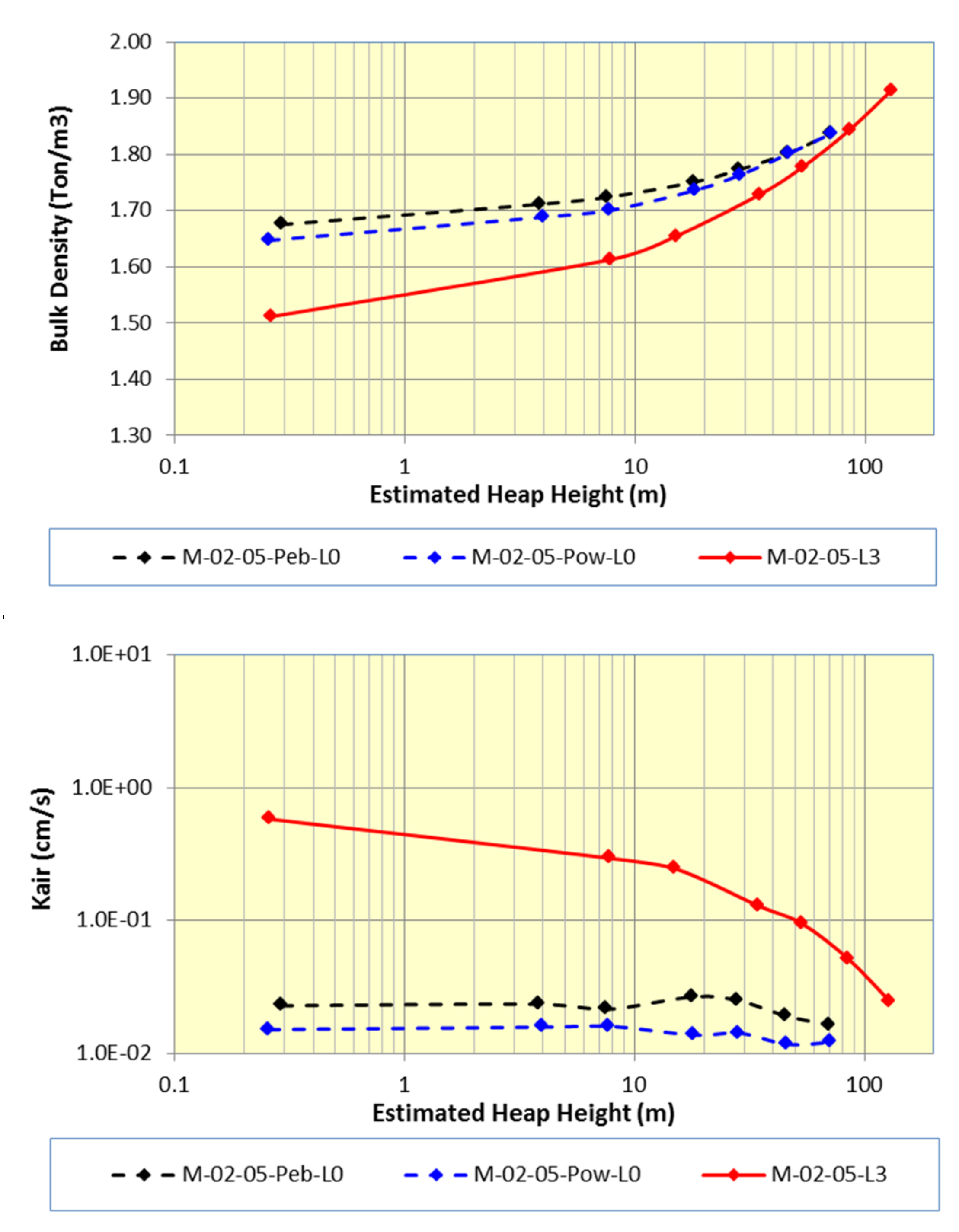


Figure 2.2 Density and conductivity profiles for Composite Met 02-05

2.2.2 STs on Casino Composite Met 11-17

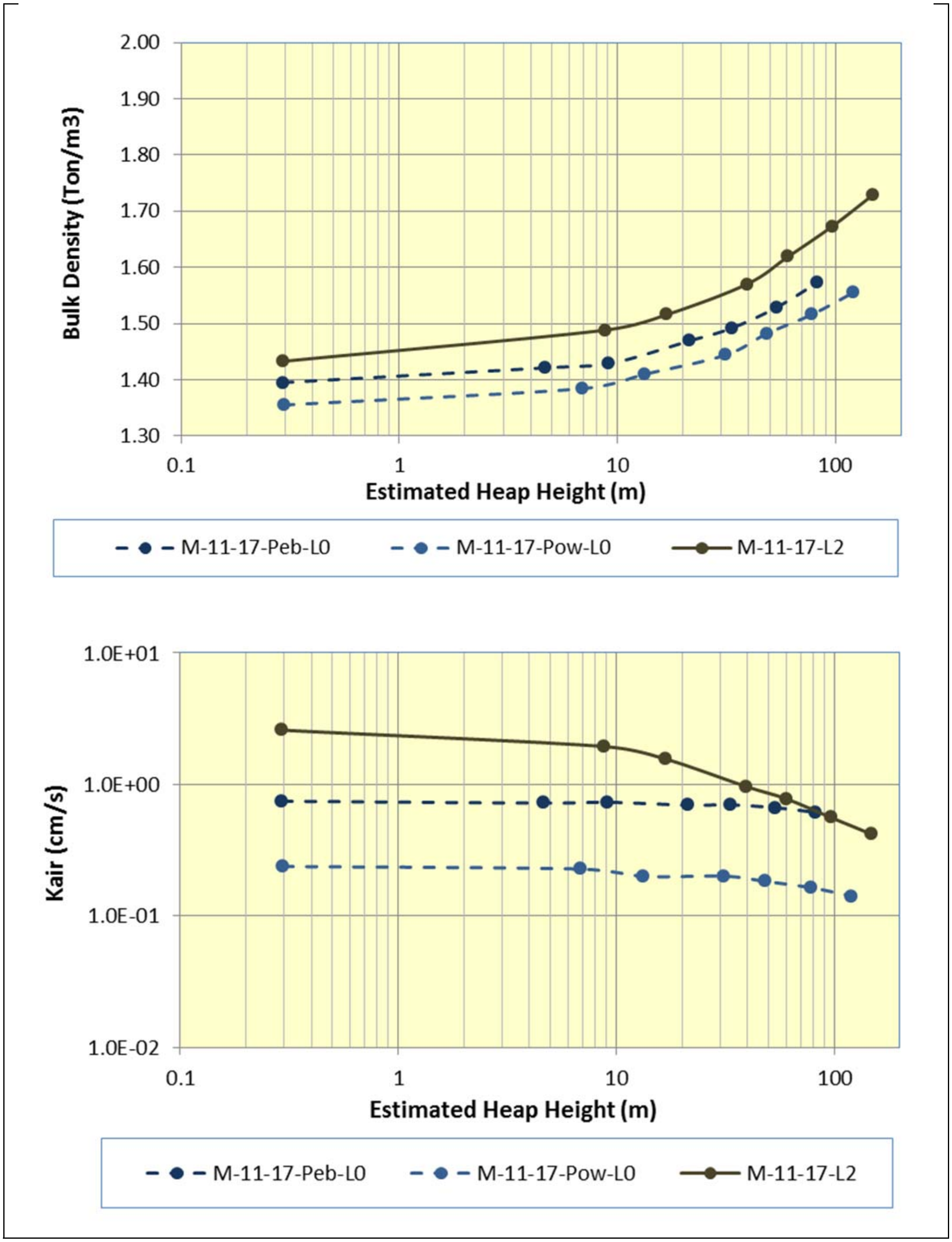


Figure 2.3 Density and conductivity profiles for Met 11-17

2.2.3 Comparison of STs Results for Blended Casino Composite

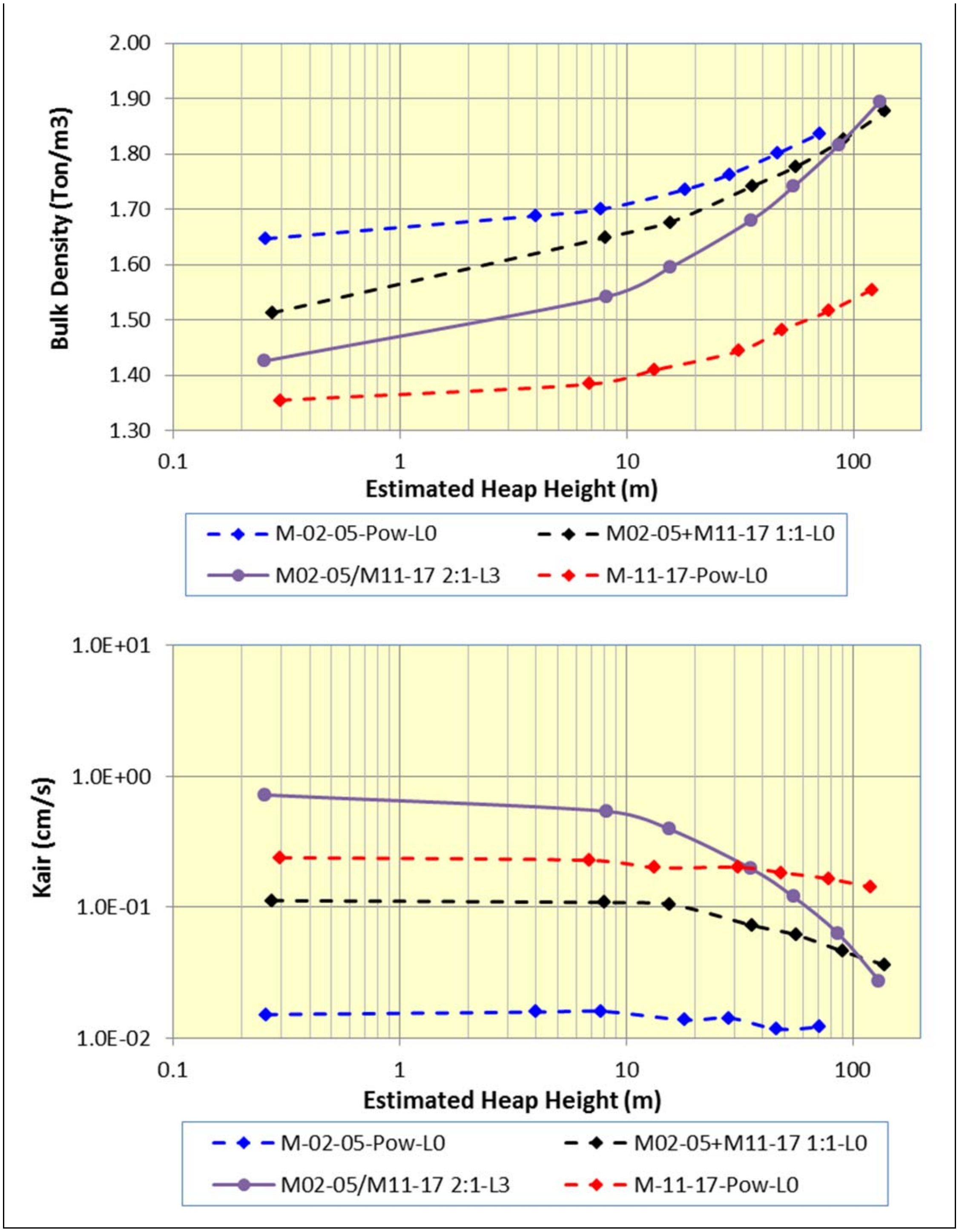


Figure 2.4 Comparison of Density and conductivity profiles for Blended Composite

2.2.5 Preliminary values of porosity partitioning

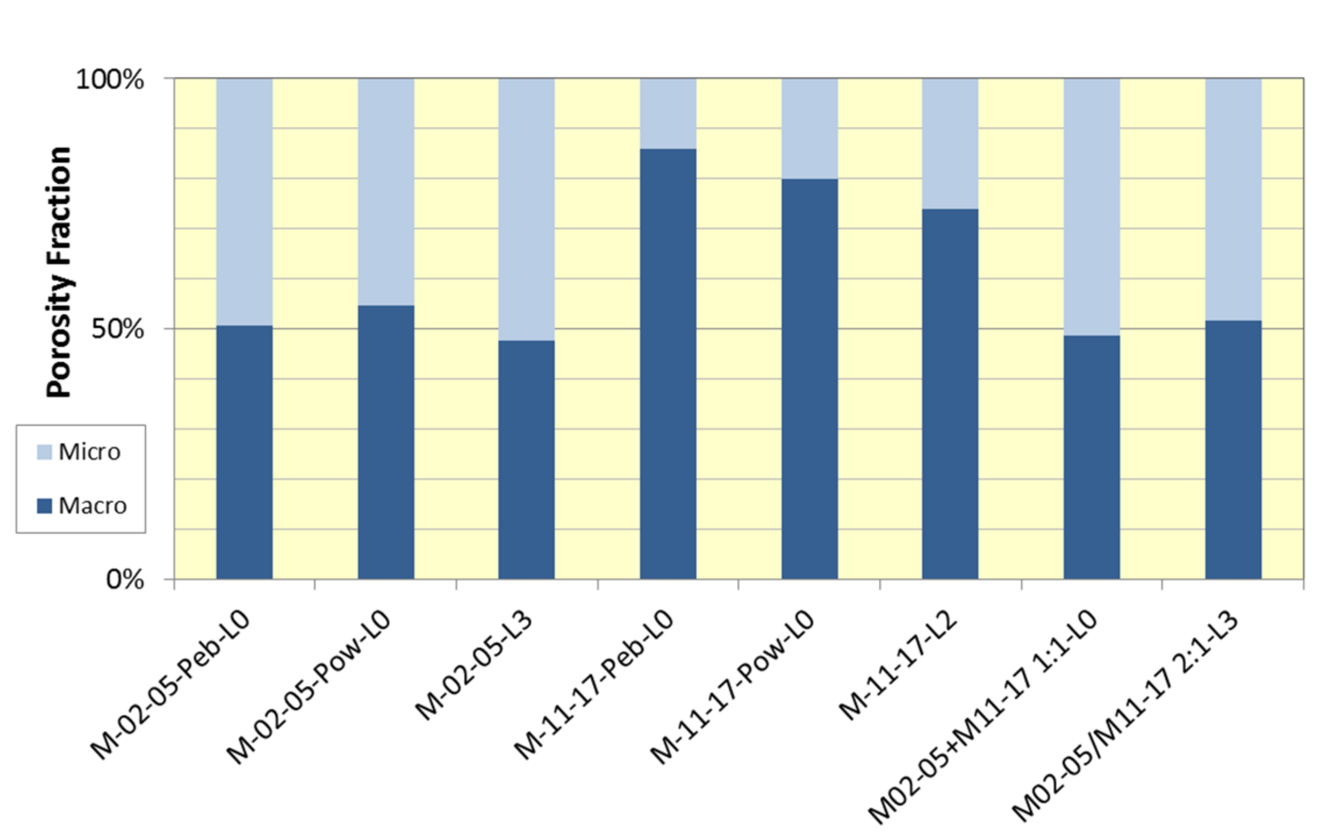


Figure 2.7 Partition of total porosity

2.2.6 Discussion of Stacking Tests Results

The results from the STs for the Casino samples are presented in Figures 2.2 to 2.4. Inspection of these data shows that:

- The bulk density and conductivity of all the samples are a function of the heap height. As the heap height increases the density increases and the conductivity (percolation capacity) decreases in a non-linear fashion. The change in these properties is relatively minor over the range of heap heights evaluated on this study (h < 145 m) indicating that the Casino composites are mechanically competent.
- The type of lime used for alkalinity amendment has an effect on both the density and conductivity profiles. This is interesting in that the alkalinity dosage was identical (2.93 kg/t) on these samples and the only difference was the texture of the lime; pebble or powder.
- The results from the STs show that alkalinity amendment with pebble lime slightly increases the density and the conductivity of these two composites. Although, the industrial significance of these difference is minor because using pebble lime would not be practical, they highlight some very important technical details:

  - The texture of the fines (dispersed versus clumped in this particular case) has a measurable effect on the hydrodynamic response of a sample;
  - The shape and actual values of the density and conductivity profiles are able to identify changes as small as 0.3% in the pore structure; and
  - Designing optimal conditions by controlling the PSD, ore preparation practices (as shown below) and measuring the impact of these changes via the Stacking Tests are attainable.
- Agglomeration (although not optimal due to the level of fines present on the Casino samples used for this evaluation; < 4% minus 200-mesh) provides a noticeable improvement on both the density and conductivity profiles with respect to those of the non-agglomerated samples even for the very coarse composite (Met 11-17).
- The conductivity profiles (bottom frames on Figures 2.2 to 2.3) confirm the beneficial effect of agglomeration showing an increase in conductivity of one order of magnitude (a factor of 10) for both composites (Met 02-05 and Met 11-17).
- Similarly, blending and agglomeration (Figure 2.4) produce a significant improvement on both the density and conductivity profiles. **These results show that ore preparation practices are therefore critical for an improved performance of the process.**
- Blending and agglomeration of Met 02-05 and Met 11-17 produced an improved sample from the hydrodynamic point of view, namely:
  - The density profile of the blended samples fall between those from the two original composites showing the incremental benefit of blending alone (M02-05+M11-17 1:1 L-0) and blending and agglomeration (M02-05/M11-17 2:1 L-3). The density of the agglomerated sample is smaller than that of the blended, non-agglomerated sample.
  - The conductivity profile of the blended samples is higher than that from the original M02-05-Pow-L0 composite showing the incremental benefit of blending alone (M02-05+M11-17 1:1 L-0) and blending and agglomeration (M02-05/M11-17 2:1 L-3) which produce conductivity values larger than those measured for the original M11-17-Pow-L0 composite. The conductivity of the agglomerated sample is larger than that of the blended, non-agglomerated sample.
  - These data indicate that blending all these samples would be beneficial for both composites from the point of view of their hydrodynamic performance (increasing conductivity for Met 02-05 and reducing the negative effect of the high gravel content for Met 11-17). Agglomeration further increase the benefit of blending.
  - Depending of the location of these composites with respect to the mining plan, blending all of these samples may be advantageous for the metallurgical process.
- Overall, the heap height has a small effect on the conductivity of the ore. As part of the ST procedure, each sample is fully saturated with synthetic raffinate, allowed to drain under the influence of gravity, and then reloaded to the maximum heap height simulated during the tests (~140 m). This portion of the ST determines the physical stability of the ore and its potential compaction at residual liquid saturation (typically larger than the optimal moisture of agglomeration) as expected to occur during the life of the multi-lift heap. The maximum compaction during reload was observed for the agglomerated samples. However, even **these values are smaller than 4.8% indicating a competent ore whose porous**

structure is able to withstand flooded conditions and the full lithostatic stress at its residual saturation.

Industrial experience on several different ore types (oxide and sulfide minerals) suggests that:

- For a dynamic (on and off) heap, a minimum saturated hydraulic conductivity of 100 times the application rate is required. For the recommended application rate of 6 L/h/m^2 (1.67 x 10^{-4} cm/s), this requirement translates into a minimum saturated hydraulic conductivity of 600 L/h/m^2 (1.67 x10^{-2} cm/s). For a multiple-lift (permanent) heap, the minimum saturated hydraulic conductivity requirement is 1,000 times the application rate to account for potential decrepitation, slumping and compaction. This requirement translates into a minimum saturated hydraulic conductivity of 6,000 L/h/m^2 (1.67 x10^{-1} cm/s) for a permanent heap.
    - As indicated in Table 2.1, all the samples tested during this program satisfy the requirement for a dynamic heap but some samples fall short of the requirement for the permanent heap. Of the samples prepared with powder lime, the non-agglomerated Composite Met 11-17 has the smallest K_s value (7.7 x 10^{-2} cm/s - 46% of the required value) while the projected minimum K_s for Composite Met 02-05 (9.9 x 10^{-2} cm/s) would be about 60% of the required hydraulic conductivity.
    - The minimum K_s value for the blend of these composites is 1.4 x 10^{-1} cm/s, interestingly higher than that for each of the composites. This improvement is attributed in the one hand to contribution of the coarser material from Met 11-17 and the beneficial effect of the sand fraction from Met 02-05 which prevents the migration of fines from Met 11-17. The fines tend to migrate and deposit along the heap profile forming low permeability layers.
    - Agglomeration increases the minimum saturated hydraulic conductivity of Composite Met 11-17 by a factor of three to 2.0 x 10^{-1} cm/s (120% of the required Ks) and has a smaller, though still positive, effect on Composite Met 05-02 (1.0 x 10^{-1} cm/s; 60% of the required K_s).
    - Blending produces a saturated hydraulic conductivity which essentially meets the 1,000 larger than the application rate requirement (1.4 x10^{-1} cm/s for M02-05+M11-17 1:1 L0) while the blended and agglomerated sample slight improves on the hydraulic conductivity (1.5 x10^{-1} cm/s for M02-05+M11-17 2:1 L3).
- As the total porosity approaches a value of 30% the ability of the ore to support percolation leaching is diminished. In addition, an optimal partition of the pore space consists of 50% micro-pores and 50% macro-pores to provide a good balance between advection and diffusion controlled solution movement. Inspection of the preliminary estimates of porosity and its partition into micro- and macro-components summarized in Table 2.2 below and Figure 2.7 shows that for the samples prepared with powder lime:
    - The total porosity of the agglomerated samples is smaller than that of the non-agglomerated samples; 31% versus 29% for Met 02-05 and 41% versus 35% for Met 11-17.

- The partitioning of the pore space of the Met 02-05 samples is close to the optimal; a macro/micro ratio of 55/45 for the non-agglomerated sample and slightly improved (48/52) for the agglomerated sample.
- However, the partitioning of the pore space for the Met 11-17 samples is dominated by macro-porosity (80/20 for the non-agglomerated and 74/26 for the agglomerated sample. The smaller improvement on composite Met 11-17 is due to its low fines content (2.0%) and its high gravel component (91.7%).
- Interestingly, the blended composite has a slightly lower total porosity (30%) but a macro- to micro-porosity partition of 49/51which is very close to the optimal (50/50).
- Similarly, the agglomerated 2:1 blend of M 02-05 and M 11-17 produces a micro to macro partition of 50:50.

- **The large component of the macro-porosity of the Met 11-17 non-agglomerated composite would translate into gravity-dominated flow where limited horizontal movement of solution occurs leading to inefficient wetting and limited metallurgical performance.** This type of flow conditions leads to poor metal extraction, inefficient reagent utilization and protracted leach cycles.
- In other words, an ore sample can be too permeable to be efficiently leached and more so if the irrigation scheme is not properly designed and operated to counteract the gravity-dominated flow.
- Composite Met 02-05 when not agglomerated may be able to support a percolation leaching process in heap with heights up to 70 m. An L3 level of agglomeration improves the percolation of this sample such that a heap as tall as 100 m may be supported.
- Notwithstanding the potential complications resulting from flow channelization, composite Met 11-17 may support percolation leaching in a heap with heights up to 140 m.
- Blending would lead to improved hydrodynamic and metallurgical performance of these two composites. The ST data from the agglomerated 2:1 blend of M 02-05 and M 11-17 indicate that this sample could support a heap height close to 140 m.

Table 2.2 Preliminary Estimates of Porosity

Test ID	SG	Agglomeration		H_{Max}	Minimum Porosity			Fraction (%)	
	( )	Level	Moisture	(m)	Total	Macro	Micro	Macro	Micro
M-02-05-Peb-L0	2.660	L0	0.4%	70.6	0.31	0.16	0.15	50.6	49.4
M-02-05-Pow-L0	2.660	L0	0.4%	71.2	0.31	0.17	0.14	54.6	45.4
M-02-05-L3	2.660	L3	5.7%	129.2	0.29	0.14	0.15	47.6	52.4
M-11-17-Peb-L0	2.632	L0	0.3%	82.5	0.40	0.35	0.06	85.9	14.1
M-11-17-Pow-L0	2.632	L0	0.3%	120.3	0.41	0.33	0.08	80.0	20.0
M-11-17-L2	2.632	L2	2.4%	147.7	0.35	0.26	0.09	73.9	26.1
M02-05+M11-17 1:1-L0	2.645	L0	0.3%	138.1	0.30	0.14	0.15	48.6	51.4
M02-05/M11-17 2:1-L3	2.651	L3	5.5%	130.7	0.30	0.15	0.14	51.6	48.4

- An important fact that needs to be considered in the analysis and interpretation of the results of the Stacking Tests is that all the samples tested to date represent fresh ore. Leaching typically results in chemical-induced decrepitation (more so under acidic conditions than alkaline conditions) which in turn negatively impacts the hydrodynamic properties of the ore. **Given that the Casino heap leaching process is designed as a multi-lift operation, it would be important that hydrodynamic properties of the leached residue after a three to four leach cycles be determined to define the potential impact of decrepitation on the long term operation of the heap. Given the favorable response of the blended, agglomerated samples it is expected that this long term condition could be easily managed.**

2.3 Hydrodynamic Column Tests

The hydrodynamic column test procedure provides the most complete characterization of the physical and hydrodynamic properties of an ore-for-leach at given bulk density. A Hydrodynamic Column Test (HCT) is performed by placing an ore sample into a column and subjecting the sample to a confining pressure equivalent to desired lift or heap height. The diameter of the test cell is selected to minimize potential wall effects on the determination of hydrodynamic parameters of the ore sample. Once the sample has been placed onto the test cell, the irrigation rate is varied over several orders of magnitude to evaluate the corresponding degree of saturation and the resiliency of the porous structure as the ore becomes increasingly wet. Each irrigation rate period is extended until steady state flow conditions are developed at which point the corresponding degree of saturation is measured. The maximum solution application rate is determined by the value at which the surface of the column becomes saturated (flooded). Once the ore is flooded, a saturated hydraulic conductivity test is conducted to quantify the maximum flow capacity of the ore (K_s). The relationship between irrigation rate and degree of liquid saturation (solution retention) varies from sample to sample and is strongly influenced by the ore preparation practice.

The parameters obtained from a HCT include: a) saturated hydraulic conductivity, b) hydraulic conductivity as a function of solution content (hydraulic conductivity curve), c) the moisture retention curve (the relationship between degree of saturation and pore pressure), d) the air permeability as a function of solution content (air conductivity curve), e) the drain down curve, and f) total, macro-, micro- and residual-porosity. As such, **the HCT provides a complete characterization of the potential hydrodynamic response of an ore sample under a percolation leaching process.** A description of each of the parameters obtained from the HCT test is as follows:

a) *Saturated hydraulic conductivity* – defines the maximum capacity of the ore to allow percolation of leaching solution. A saturated hydraulic conductivity (K_s) greater than or equal to 10^{-2} cm/s is a necessary but not sufficient condition to ensure an adequate metallurgical performance of an ore under percolation leaching at an industrial scale. As indicated above, the actual criteria for an adequate K_s is different for a dynamic heap (initial K_s greater than 100 times the application rate) than for a multi-lift, permanent heap (initial K_s greater than 1,000 times the application rate);

b) *Moisture retention curve* – provides the degree of saturation (moisture content) of the sample as a function of capillary (pore) pressure and hence defines the energy state of the solution within the pore space. This parameter is critical if numerical modeling of the flow process would be pursued but not critical from a practical point of view of design of the leaching process;

c) *Hydraulic conductivity curve* – indicates the degree of liquid saturation resulting from a steady-state solution application rate. This is the critical parameter in the design of the leaching/bio-oxidation process since the liquid saturation not only defines the ability of the ore to allow solution and air movement (from the air permeability curve described below) through an ore sample, but also determines the mechanical stability of the ore;

d) *Air permeability curve* – provides the air flow capacity of the ore as a function of degree of liquid saturation (solution application rate). This is a fundamental design parameter for forced or natural aeration system, which has not been traditionally considered;

e) *Drain down curve* – provides an idea of the rate of solution drainage due to the action of gravity. It represents a critical parameter necessary to estimate residual solution (and metal) inventory, required rest time before over-stacking (for a permanent heap) or removal of the leached residue (for a dynamic heap), as well as the potential discharge volume and rate during closure and post-closure conditions;

f) *Total-, micro-, macro-, and residual-porosity* – the total porosity indicates the pore space per unit volume of the sample. For a given ore sample, in general, and in an agglomerated ore in particular, the macro porosity is associated with the pore space between rock particles/agglomerates while the micro-porosity represents the pore space within rock particles/agglomerates themselves. The residual porosity is the fraction of the pore space which will remain saturated even after a prolonged drain down period. Optimal agglomeration process produces a 50:50 micro to macro partition and minimizes the residual porosity.

By design a sample subjected to HCT represents a unit volume of ore located at the bottom of the lift (heap) – the target bulk density is selected from the results of a Stacking Test on the same sample. This location experiences the most stringent conditions since it is exposed to the maximum lithostatic load and to the maximum degree of liquid saturation along the heap profile. If the hydraulic performance of this portion of the heap/lift is adequate, it is reasonable to conclude that the rest of the heap/lift profile will perform just as well or better.

The results from an HCT provide all the necessary information to understand movement of solution and air under a percolation leaching process. In other words, the HCT generates all the parameters required in the context of numerical representation (Computational Fluid Dynamics, CFD) of the leaching process. **From the more practical point of view, the HCT answers the key question for the design of a heap – the degree of saturation resulting from a given application rate.** Experience shows that for an oxide leach the maximum liquid saturation should be kept below 85% and ideally below 75% to accommodate the natural variability associated with the heap stacking process. Leaching of a sulphide ore typically requires that the degree of saturation remains below 60% to ensure that forced (or natural) aeration is properly supported. **As such, the operating degree of saturation is the critical design parameter as it controls solution-ore contact, aeration capacity of heap, and mechanical stability of the heap.**

From the point of view of the design of a leaching operation, hydrodynamic characterization provides a way to quantify the benefits from alternative ore preparation approaches (from mining methods, to crushing, to agglomeration and stacking) so these results can be used to select the most favorable ore preparation techniques and maximum bulk density for a given ore sample. In addition, this type of information can be used to select optimal operational conditions, including maximum lift height, maximum heap height, irrigation and aeration schemes and schedule as well as to determine the operation moisture content, drain-down moisture and maximum air intake among others.

As indicated by the Test Matrix (Figure 1.1) a HCT was conducted on each of the composites Met 02-05 and Met 11-17. The conditions for the HCTs were selected per WCG personnel to represent non-agglomerated ore. Table 2.3 summarizes the conditions used during the HCTs. The density of the samples, a critical variable which is in many cases overlooked on standard metallurgical column tests, was selected to represent a 32-m heap to ensure proper operation for the first several lifts.

Table 2.3 Hydrodynamic Column - Test matrix

Sample ID	Top Size (mm)	P_{80} (mm)	Bulk Density (t/m^3)	Agglomerate Level
Met 02-05	~50	30.6	1.770	L0
Met 11-17	~55	43.6	1.530	L0

One of the key pieces of information derived from a HCT is the hydraulic conductivity curve; the relationship between solution application rate and degree of liquid saturation (or saturation). In general, the shape of the hydraulic conductivity curve is influenced by the particle size distribution, ore conditioning/curing and moisture content, the blending ratio of the ore type, the type of solution used during the agglomeration process, the quality of agglomeration and the bulk density. All these parameters can be changed as part of the design of an operation so they constitute the **ore preparation practices**. As such, the shape of the curve is diagnostic of the effect of the ore preparation practices on the hydraulic response of an ore sample. The hydraulic conductivity curves derived for the Casino fresh ore samples are summarized in graphical form on the top frame of Figure 2.8.

A hydraulic conductivity curve can be read in two different ways:

1. To obtain the operational saturation associated to a given solution application rate (equivalent to the hydraulic conductivity); enter the plot along the y-axis, move horizontally to intercept the conductivity curve and then move downward to find the corresponding degree of saturation on the x-axis; or
2. To obtain the solution application rate (hydraulic conductivity) able to be sustained by a given degree of saturation enter the plot along the x-axis, move upward to intercept the curve and then horizontally to intercept the y-axis to find the corresponding solution application rate.

It is noted that in the context of the HCT and specifically for the hydraulic conductivity curve, because of the conditions imposed during this test, under steady-state flow conditions the solution application rate is closely equivalent to the hydraulic conductivity of the ore. Hence, we refer to these variables interchangeably throughout the rest of this document.

In addition to defining the relationship between irrigation rate and degree of liquid saturation (moisture content), the HCT procedure allows for the simultaneous determination of the air conductivity of an ore sample. The air conductivity is a critical parameter in the design of an aeration system that is typically overlooked. The lower frame of Figure 2.8 presents a graphical summary of the measurements of air for the two Casino non-agglomerated composites. The lab reports included in Appendix B present the numerical results from these tests.

From the operational point of view, the results from the HCTs on these TMC samples indicate that near the bottom of a 32-m heap:

- For the application rate (10 L/h/m^2) used by Metcon on their recent metallurgical columns, the Casino samples would operate at a degree of saturation below 56% for Composite Met 02-05, and 23.2% for Composite Met 11-17.
- It is noted that the degree of saturation obtained for Met 11-17 is one of the lowest of all samples tested by HGS to date. This low operational degree of saturation arises from the fact that nearly 74% of the void space of this composite is macro-porosity.
- These results confirm the preliminary determination obtained from the STs; **from the hydraulic point of view the Casino samples, even when not agglomerated, would easily support percolation leaching of a 32-m heap (lift).**
- It is important to note that slumping during initial irrigation of the lifts, potential decrepitation during leaching and destruction of the pore structure due to increase overburden stress will necessarily increase the density and degree of saturation as depicted in Figure 2.8. **Based on the results from the STs presented above, it is expected that these effects would be relatively minor for heap heights below 70 m.**
- **It is recommended, however, that leached residue from the recent Metcon columns or from the first lift once the operation is started be tested under the ST procedure to assess the potential impact of one leach cycle on the density and conductivity profiles of these two composites. If these results show a significant difference from the tests on the head samples, HCTs should be conducted to better assess the impact of leaching on the hydrodynamic properties of the Casino ore and the potential changes to the current heap design.**

As described in the previous section, the total porosity and its partition into macro and micro components are important parameters for the design of a heap leach process. Experience shows that a 50:50 partition between micro and macro porosity produces optimal hydrodynamic performance. Table 2.4 below summarizes the estimated total porosity, macro-, micro- and micro-residual porosity derived from the analysis of the drain down curves derived from the HCTs. The sum of the micro-drainable porosity and the micro-residual yields the micro-porosity.

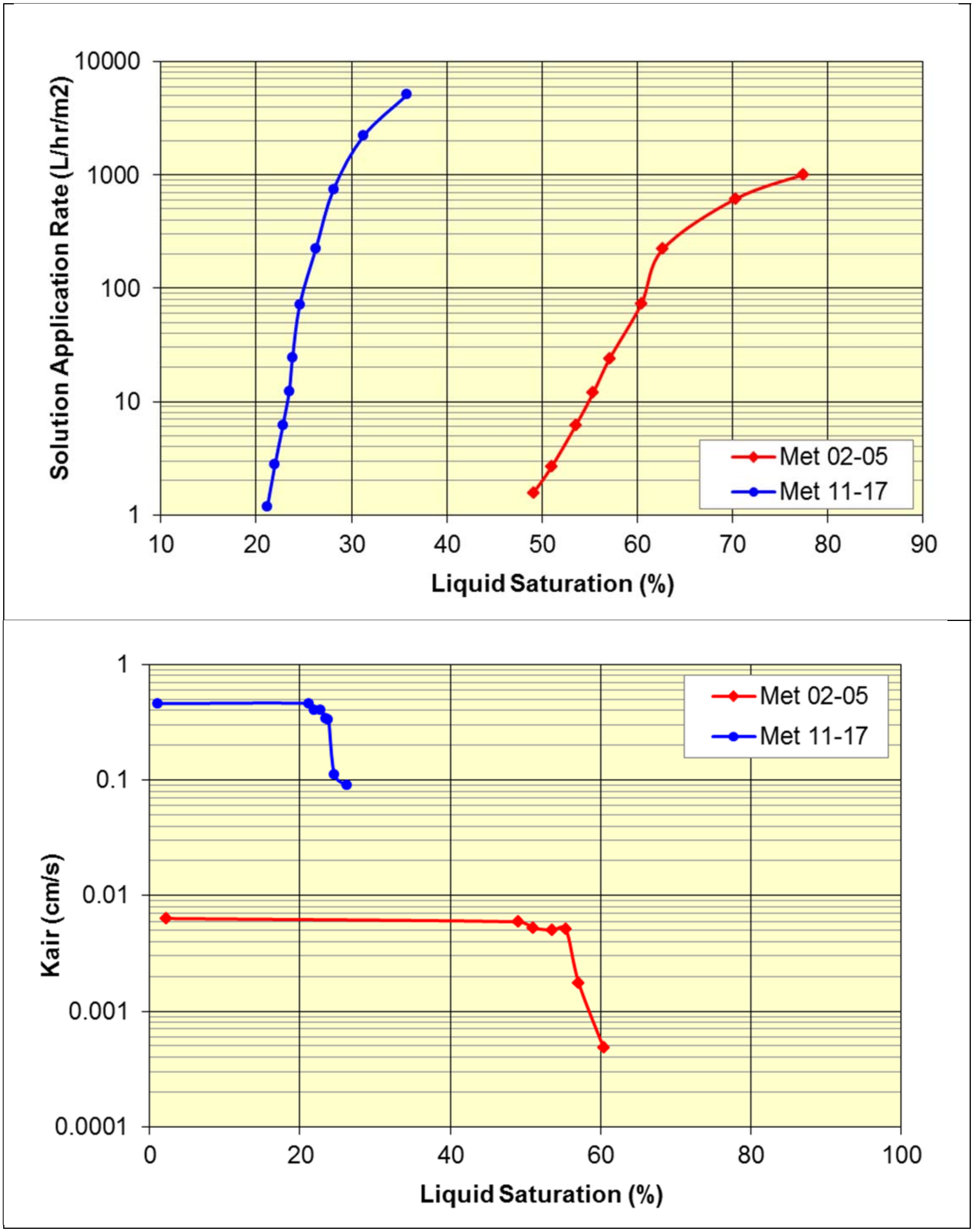


Figure 2.8 TMC – Conductivity Curves

Table 2.4 – Porosity Values					
Sample	**Total**	**Drainable**	**Macro**	**Micro Drainable**	**Micro Residual**
Met 02-05-L0	0.331	0.197	0.137	0.059	0.134
Met 11-17-L0	0.409	0.347	0.302	0.045	0.063

These data show that the Composite Met 02-05 has a macro-micro porosity partition of 42:58, while for the Composite Met 11-17 this partition is 74:26. These ratios suggest that Met 02-25 may be most suitable for the leaching process. It is important to note that the ST results on the 1:1 and 2:1 blend of these two composites resulted on improved hydrodynamic properties for both of the individual composites.

The air conductivity curve presented in the bottom frame of Figure 2.8 highlights a number of important aspects of two-phase flow associated to the porous structure in the context of natural and/or forced aeration:

- In general, air conductivity is a strong function of the PSD, degree of saturation and bulk density. In this particular case the spread on between the curves arises from the differences in the PSD of the samples.
- Typically, at low degree of liquid saturation (low moisture values) the air conductivity is nearly constant. The conductivity decreases slightly with increased saturation to the point when the degree of saturation reaches a threshold saturation value (S*) beyond which the conductivity drops rapidly.
- In this particular case, both composites follow this pattern but with significant different magnitudes – the initial air conductivity of Met 11-17 is almost 100 larger than that of Met 02-05.
- In general, the threshold saturation value at which air conductivity begins its rapid reduction is a function of the ore and the ore management practice (degree of agglomeration, top crush size, agglomeration additives, bulk density of the ore as placed, etc.). This saturation threshold corresponds to the moisture content at which the air-filled porosity starts to become discontinuous which greatly increases the resistance for air flow.
- It is important to note that this saturation threshold is, for most of the ore samples we have tested, far from full saturation (i.e., air flow is impaired much before all the pore space is occupied by solution). For most ores, the ability of a sample to allow air flow is, for all practical purposes, lost as the liquid saturation reaches a value of about 65%. For the Casino samples, the threshold saturation value for which the air permeability becomes smaller than that require to allow unimpeded air flow varies significantly for each of the composites:
    - For the Met 02-05, the air conductivity starts its rapid reduction at a saturation value of about S* = 55.4%;
    - For the Met 11-17, the saturation threshold occurs at about 22% despite the otherwise very permeable sample.
- Under natural aeration, air enters the heap through the top surface of the heap and its slopes. This air flow results from density differences due to thermal gradients between the heap and the atmosphere

and changes in atmospheric pressure. The force gradients resulting from these processes are small, so efficient aeration requires high air permeability values (> 10^{-3} cm/s).

- Table 2.5 below summarizes the operational conditions in terms of the liquid degree of saturation and corresponding air conductivity for the each of the non-agglomerated Casino samples under a nominal application rate of 10 L/h/m² (2.8 x10^{-4} cm/s). Also included in Table 2.5 is the threshold saturation (S*) for each of the samples. For this solution application rate:
  - The operational liquid saturation of the Casino samples is: 55% for Met 02-05, and 23.2% for the Met 11-17.
  - The operational degree of saturation is about the same as the saturation threshold for these composites which may limit the effectiveness of natural aeration (under irrigation rate of 10 L/h/m²). A smaller irrigation rate will improve the natural aeration on these composites.
  - It is noted that the operational degree of saturation is basically the same as the threshold saturation value at which the air conductivity starts its rapid reduction – which indicates that any upset condition (strong precipitation, variability in the irrigation rate, increased level of fines, localized compaction, etc.) resulting in increased saturation would produce a marked reduction in the air conductivity**.** Empirical evidence shows that the rate of dissolution decreases by more than a factor of two as oxygen decreases by a factor of two.
  - Given the Au and Ag as well as the Cu grades, it is expected that the oxygen demand associated to cyanide leaching will be small. The available information indicates that aeration requirements may be larger for Met 11-17 given its higher Cu content than for composite Met 02-05.

Table 2.5 – Operational conditions at 10 L/h/m²			
Sample	**S* (%)**	**S (%)**	**K_a (cm/s)**
Met 02-05-L0	55.4	55.0	5.0 x 10^{-3}
Met 11-17-L0	22.0	23.2	4.5 x 10^{-1}

A couple of additional remarks arising from the HCT results are as follows:

- The degree of saturation resulting from the solution irrigation rate combined with the residual porosity presented above provide an estimate of the dynamic moisture for each sample for a given solution application rate. For instance, for a solution irrigation rate of 10 L/h/m² the dynamic moisture for Composite Met 02-15 is: 48 liters of solution per cubic meter of ore (L/m³), and 32 L/m³ for the coarser composite (**Met 11-17**).
- Industrial experience from many different ore types and various minerals shows that, in most instances, the hydrodynamic performance controls the metallurgical performance of a percolation leaching process. In this particular case, **it appears that the key considerations for the adequate leaching of the non-agglomerated Casino ore are:**
  - The permeability for Composite Met 02-05 or a blend thereof, and

  - o Effective solution-to-ore contact for Composite Met 11-17 if not blended.

Accurate numerical modeling of the solution and gas movement through a heap leach requires, as a minimum, knowledge of:

- The relationship between hydraulic conductivity and the degree of saturation (top frame of Figure 2.8),
- The relationship between the air conductivity and the degree of liquid saturation (bottom frame of Figure 2.8) – not critical for the Casino composites evaluated as part of this effort; and
- The relationship between degree of saturation and the pore pressure (Figure 2.9), known in the hydrological community as the moisture characteristic curve.

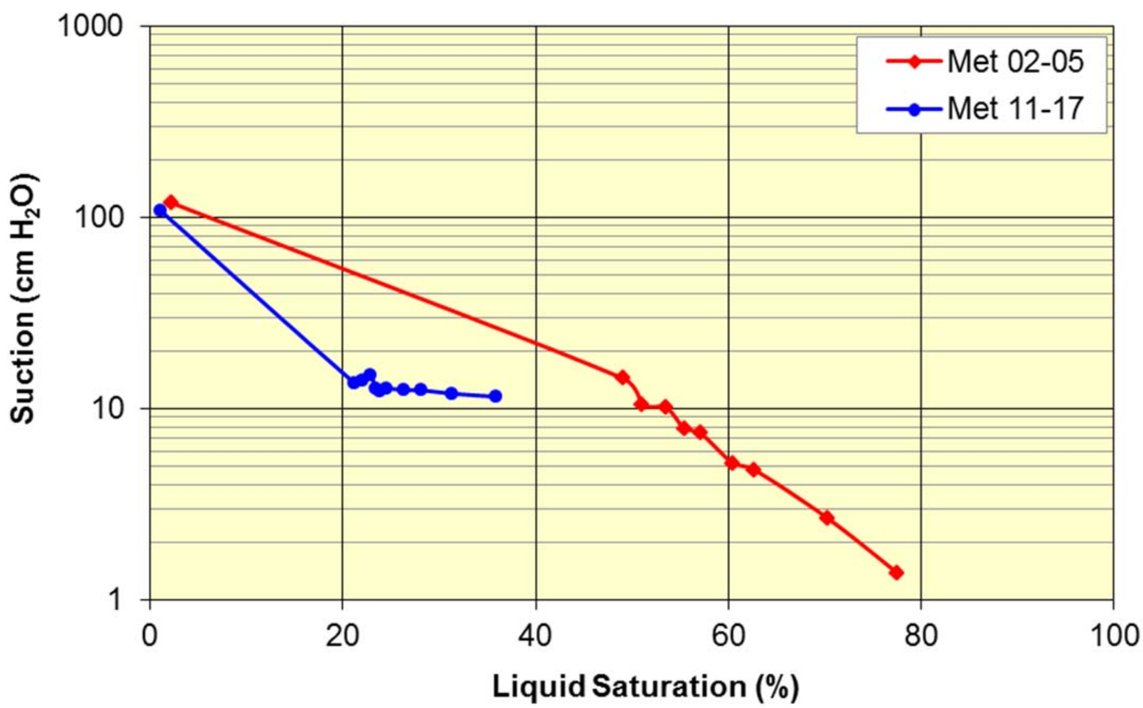


Figure 2.9 Casino – Moisture retention curve

It is noted that **the HCT is the only procedure that allows direct measurement of these properties concurrently and in a single sample in the context of multi-phase flow for the mining industry or otherwise.**

Because numerical analysis is not the focus of this characterization effort, the relationship between liquid saturation and pore pressure is not further discussed. However, it is worthwhile noting that the operational pore pressure for the Casino is 30 cm for Met 02-05 and about 12 cm for Met 11-17 at a solution application rate of 10 L/h/m^2. Availability of these data greatly facilitates modeling solution movement (wetting and draining) and reactive transport of the heap leach process.

3.0 PRELIMINARY METALLURGICAL PERFORMANCE

HGS continues to develop testing procedures for the optimal characterization of ore for leach. As part of this development, the HCT has been modified to included chemical testing of the feed and discharge solution to obtain a preliminary evaluation of the potential metallurgical performance of a sample. The resulting procedure is termed the Integrated Column Test (ICT) as it provides, for the first time in the history of leaching, all the hydrodynamic and critical metallurgical data on a single sample. It is our contention this integrated approach will greatly enhance our ability interpret the results of metallurgical tests, scale-up laboratory data, and build comprehensive numerical models of the leaching process.

The ICT procedure was applied to the Casino samples in order to generate a first estimate of metal extraction. Solution samples were collected and assayed for Au, Ag, Cu, NaCN and CaO in addition to the HCTs included on the original Scope of Work. It is noted, that this activity was undertaken as part of HGS development work therefore at no expense to WCG. As such, the results presented below are strictly preliminary and for information purpose only. It is noted however that the metallurgical data derived from the ICTs is in complete agreement with the conclusions derived from the physical, metallurgical, mineralogical and hydrodynamic characterization data presented in the above paragraphs.

The overall solution balance summarizing the metallurgical performance of composites Met 02-05 and Met 11-17 is presented in Figures 3.1 and 3.2, respectively. Table 3.1 presents the total metal recovery and reagent consumption. All the laboratory data and calculations of recovery could be made available to WCG in the future if necessary. The following paragraphs present a brief discussion of the more relevant findings from these data.

Table 3.1 – Preliminary metallurgical performance

	Recovery (%)			Consumption (kg/t)	
Sample ID	**Au**	**Ag**	**Cu**	**NaCN**	**CaO**
Met 02-05-L0	80.3	18.3	6.8	0.21	3.03
Met 11-17-L0	42.0	17.5	19.0	0.32	2.96

Inspection of the metal recovery and reagent consumption record for each of the composites indicates the following:

- As expected, Met 02-05 out performs the Au recovery of Met 11-17. It is noted that the Au recovery of Met 02-05 is quite fast (nearly 65% recovery in the first four days of operation) compared to that of Met 11-17 (25% recovery in seven days). The faster kinetics are likely associated to the finer size distribution of the former.
- The percent gold recovery for Met 02-05 is almost twice as high as that of Met 11-17 while the silver recovery for these composites is about the same (~18%).

- The last two days on the operation of the ICTs represent the flushing stage which in this particular case is shown to contribute about 10% of the Au recovery.
- It is noted, that copper extraction is higher in Met 11-17 (19.0% versus 6.8% in Met 02-05) which may explain the lower Au recovery of the former. Higher copper extraction can result in cyanide and oxygen consumption which tends to slow down the rate of gold dissolution. It would be important to completely determine the mineral composition of the copper species present in Met 11-17 to understand their potential impact on the performance of this composite at the industrial scale.
- The reagent utilization efficiency (g of Au dissolved by kg of NaCN) is 1.05 g/kg for Met 02-05 and 0.72 g/kg for Met 11-17 which indicates a more favorable leaching condition for the former.
- The reagent utilization efficiency of lime is 0.073 g/Kg for Met 02-05 and 0.078 g/Kg for Met 11-17.

Based on the conditions of the HCT it is concluded that leaching of these composites on a heap leach setting could result in Au recoveries of about 70% for Met 02-05 and about 30% for Met 11-17. **It is recommended that these preliminary results be compared to the larger scale column tests recently completed by Metcon in order to:**

a) Compare the calculated extractions, and more importantly;
b) Evaluate the potential scale-up factors required for the design of the industrial scale process.

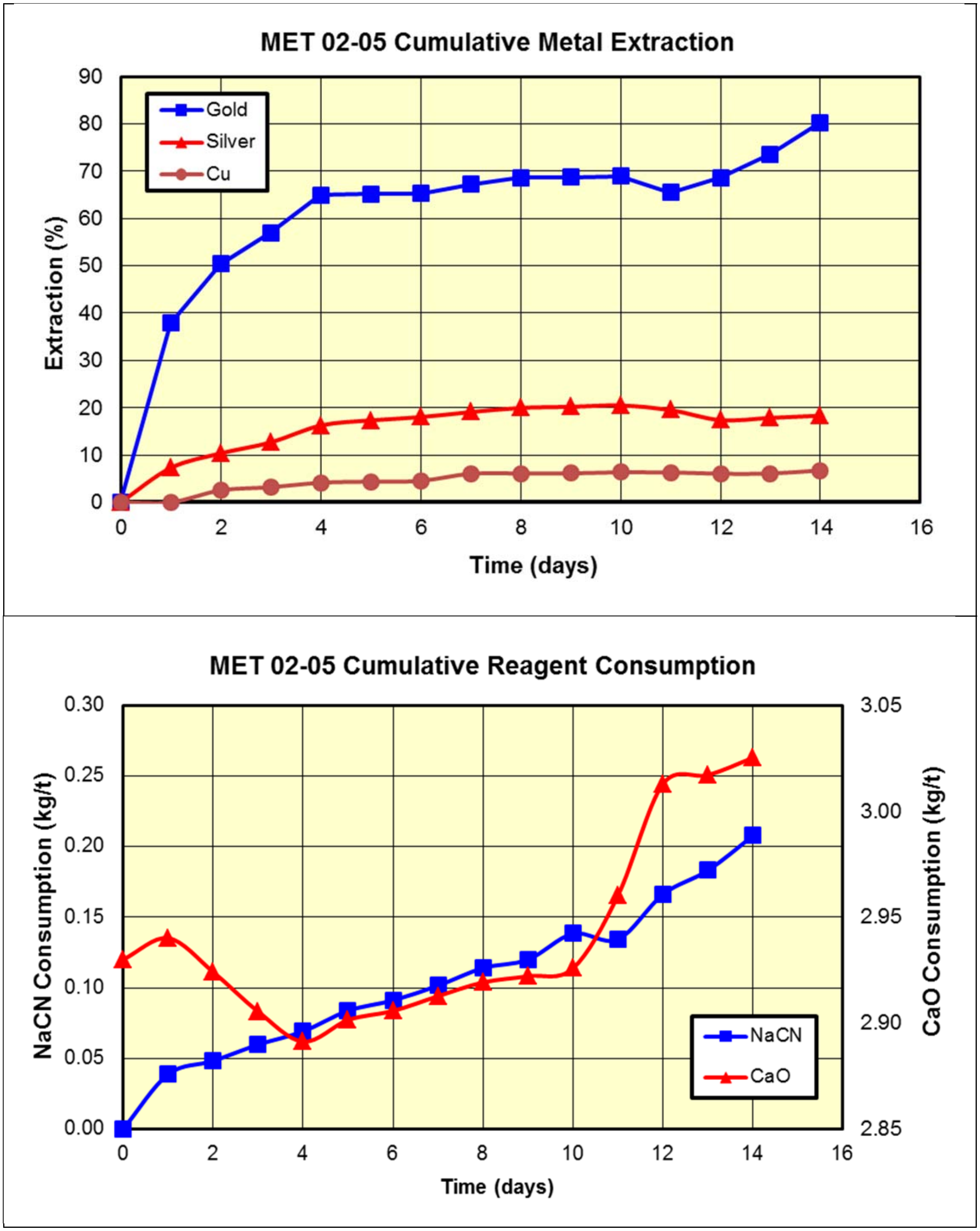


Figure 3.1 Met 02-05 – Preliminary metallurgical performance

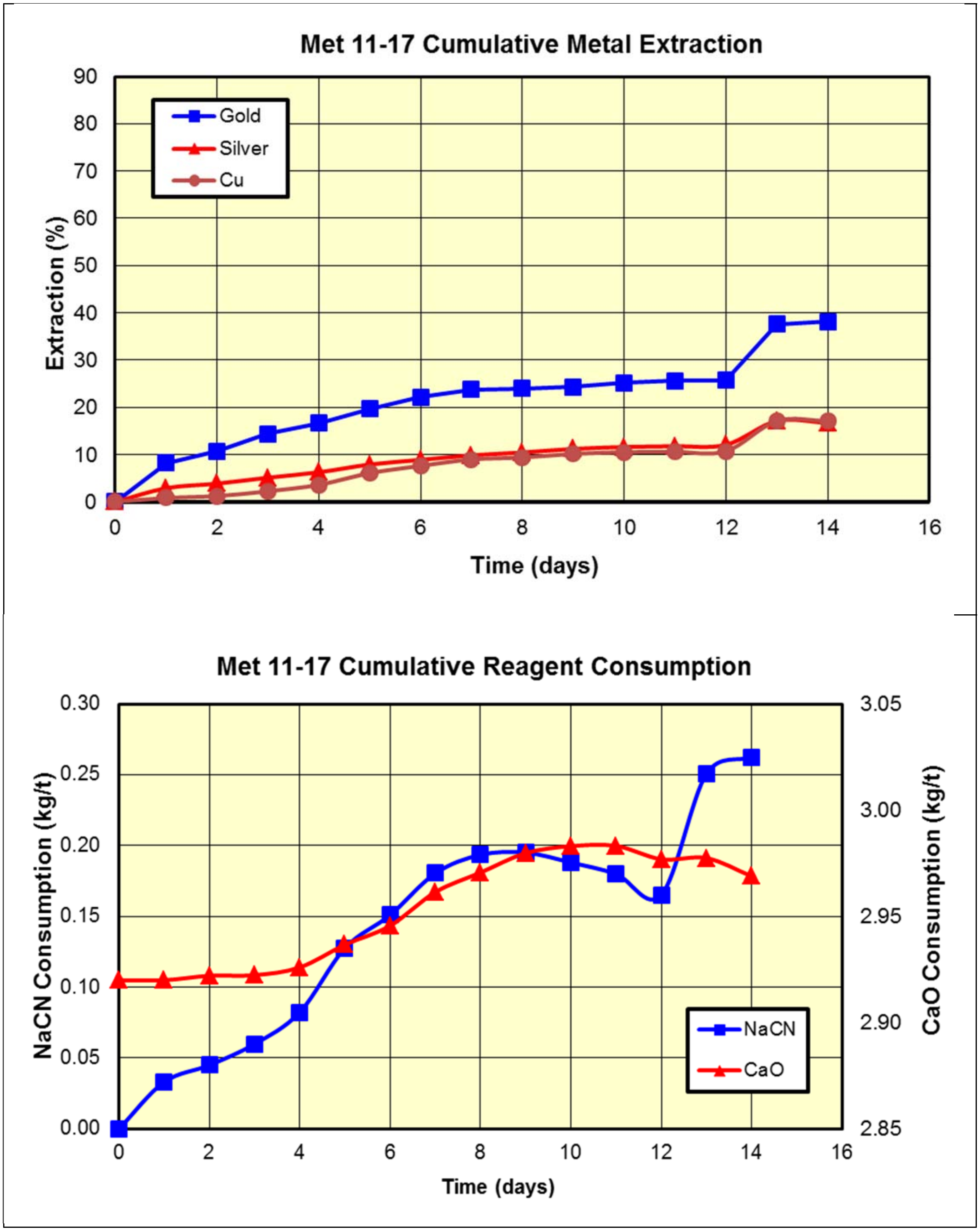


Figure 3.2 Met 11-17 – Preliminary metallurgical performance

4.0 CONCLUSIONS AND RECOMMEDATIONS

4.1 Conclusions

By necessity, the volume of rock analyzed by the work summarized on this document is small compared to the ore deposit. It is therefore critical that WCG develop a good understanding of the representativeness of these samples with respect to the ore body and the spatial distribution of the metallurgical composites with respect to the mine plan. This understanding will provide the basis for planning the mining sequence and identifying the opportunities for ore blending.

The main findings from the characterization activities and the data review presented in this document are as follows:

- There are significant physical, hydrodynamic, metallurgical and mineralogical differences between the two composites evaluated on this study. It is therefore important that a good understanding of their relative contribution and occurrence (location and timing) with respect to the mine plan be developed to assist with the conceptual design of the leaching process.
- Au and Ag are not uniformly distributed along the PSD of these composites. Met 02-05 has most of its metal value (35%) on the size fractions smaller than 1.7 mm and thus should be quite leachable. In contrast, Met 11-17 has most of its metal value (>25%) on rock fragments larger than 25.4 mm.
- The mineralogical characterization indicates that Au occurs primarily as sub-microscopic native gold.
- In addition bulk mineralogy indicates the gangue is composed predominantly by quartz and alumino-silicate minerals. The quartz fraction is quite different from each of the composites, 55.5% for Met 02-05, 41.7% for Met 11-17 and 36.8% for Met 19-20. Secondary minerals include Kaolinite ($Al_2Si_2O_5(OH)$) and swelling clays representing 5.5%, 6.0% and 7.7% for Met 02-05, Met 11-17 and Met 19-20, respectively.
- The competent nature of the Casino samples and their hydrodynamic performance would suggest that the bulk of the swelling clays are present within the crystalline structure of the feldspars and are not present as dispersed clays which tend to reduce he percolation capacity.
- Potential CN consuming minerals include metal sulfides including copper, iron, arsenic and zinc; iron oxide-hydroxides such as Limonite and Jarosite which can also act as preg-robbing; and secondary alumino-silicates and swelling clays.
- Shake leach tests conducted by FL Smidth leads us to believe that: the additional recovery on composites Met 11-17 and Met 19-20 at very high CN-concentrations results from the dissolution of sulfide minerals (sulfide encapsulation due to, but not exclusively, copper sulfides) which may be coating the Au minerals and dissolve in the presence of higher CN concentrations. On the other hand, the limited Au recovery in Met 02-05 is likely associated to silica encapsulation.
- The Casino ore is competent and contains a relatively low level of fines (< 4% minus 200-mesh) which results in a high percolation capacity and physically competent samples for the crush sizes (P_{100} 50 mm with a $\mathbf{P_{80}}$ of 30.6 mm for Met 02-05 and 43.6 mm for Met 11-17) evaluated in this study.
- This low level of fines (minus 200-mesh) is in contrast with the amount of swelling clays reported by the mineralogical characterization. The competent nature of the Casino samples and their hydrodynamic

performance would suggest that the bulk of the swelling clays are present within the crystalline structure of the feldspars. In other words, only small portion of the swelling clays are present in a dispersed fines which minimizes their negative impact on the hydrodynamic properties of these samples.

- The ST results show that heap height has a minimal effect on both the density and the conductivity of either composite which is indicative of a stiff, competent ore whose porous structure is able to withstand flooded conditions and the full lithostatic stress (up to 140 m) at its residual saturation.
- Notwithstanding the strong nature of the Casino samples;
    - Met 11-17 has a large macro-porosity which translates into gravity-dominated flow with limited horizontal movement of solution which typically leads to inefficient wetting and hence reduced metallurgical performance. This type of flow condition is responsible for lower metal extraction, inefficient reagent (CN, CaO and oxygen) utilization and protracted leach cycles.
    - At the 140-m lift height, only composite Met 11-17 satisfies the requirement that the minimum saturated hydraulic conductivity be larger than 1,000 times the application rate (assumed for this study as 6 $L/h/m^2$ based on the results from the hydrodynamic characterization presented in this document). The rationale behind the minimum K_s value of 1.7×10^{-1} cm/s considers the negative effect of slumping, decrepitation (weathering) of the ore during the life of the heap on the hydrodynamic properties of the ore.
    - The total porosity of the non-agglomerated Met 02-05 at a heap height of 71 m is 31% which compared to the minimal requirement of 30% may indicate that this particular condition may not support a heap height beyond 80 m.
    - For Met 11-17, the data suggest that it would support percolation leaching in a heap up to 140 m in height, but it may do so with significant solution channelization.
- **The results from the STs suggests that blending of the two composites (Met 02-05 and Met 11-17) even without agglomeration will improve the hydrodynamic (and potentially the metallurgical performance) of both composites.**
- **Similarly, despite the coarse nature and the limited amount of fines in the Casino ore, the results from the STs suggest that agglomerating these composites will result in a noticeable improvement of their hydrodynamic properties even for the very coarse Met 11-17.** Another important benefit from agglomeration with leaching solution (alkaline cyanide) is that the reagents are uniformly delivered to all the ore and the dissolution of minerals kick-started. This mode of reagent delivery is a significant improvement with respect to that attained on a typical ROM operation.
- **The ST data from the 2:1 blend of M 02-05 and M 11-17 indicate that this sample when agglomerated could support a heap height close to 140 m. These results show that ore preparation practices are therefore critical for an improved performance of the process.**
- An important fact that needs to be considered in the analysis and interpretation of the results is that all the samples considered in this report represent fresh ore. Leaching typically results in chemical-induced decrepitation (more so under acidic conditions than alkaline conditions) and exposure to ambient conditions lead to weathering both which negatively impact the hydrodynamic properties of the ore. **Given that the Casino heap leaching process is designed as a multi-lift operation, it would be important that hydrodynamic properties of the leached residue after three to four leach**

cycles be determined to define the potential impact of decrepitation to the long term operation of the heap.

- The results from the Hydrodynamic Column Tests (HCTs) show that composite Met 02-05 and Met 11-17 will easily support percolation leaching on the first several lifts (a 32-m heap was evaluated during this effort) with a solution application rate of up to 10 L/h/m^2. This conclusion is based on the following observations:
  - The data generated indicate that the degree of saturation associated to a 10 L/h/m^2 solution application rate would be below 56% for Composite Met 02-05, and 23.2% for Composite Met 11-17.
  - The macro-micro porosity partition for Composite Met 02-05 is 42:58, while that for Composite Met 11-17 is 74:26.
- It appears that the key considerations for the adequate leaching of the Casino ore **when not agglomerated** could be:
  - The permeability for Composite Met 02-05 or a blend thereof as the heap height increases beyond 70 m, and
  - Effective solution-to-ore contact for Composite Met 11-17 if not blended.
- The preliminary metallurgical performance of these two composites confirms that the conclusions based on the physical, hydrodynamic, metallurgical and mineralogical information regarding the potential metal recovery from the Casino composites are correct;
  - The metallurgical data show that gold recoveries of about 80% for Met 02-05 and 42% for Met 11-17. The corresponding silver recovery is about 18% for either of these composites. When the conditions of the HCTs are analyzed in the context of a heap leach operation, it is expected that Met 02-05 could yield gold recoveries of about 70% while Met 11-17 could produce gold recoveries of about 30%.
  - The better metallurgical performance of Met 02-05 compared to that of Met 11-17 is also confirmed by the better cyanide utilization efficiency (1.05 g/kg for Met 02-05 and 0.72 g/kg for Met 11-17).
- It is our contention, based on all the information presented in this document, that gold recovery from composite Met 11-17 **when not blended and agglomerated** may be hindered by gravity dominated flow and potentially by coatings of sulfide minerals (sulfide encapsulation due to, but not exclusively, copper sulfides) while ultimate recovery from Met 02-05 is likely associated to silica encapsulation.

4.2 Recommendations

- Given the difference in the properties of the composites, the design of the leaching process should consider the opportunities for segregation and/or blending of the materials delivered to the heap to ensure the best operational conditions. A clear understanding of abundance and location of the various composites with respect to the mining plan would be a critical piece of information for this task.

- The understanding of the abundance and location of the individual composites (02, 05, 11, 117, 19 and 20) would be critical for the design of the leaching process. For instance, in composite Met 02-05, sample Met 05 has about 40% of the Au and Fe, 30% of the Ag and S, and 11% of the Cu than values reported for Met 02. Selection of blending should consider the hydrodynamic performance and the mineralogical characteristics of the individual samples to enhance the potential leaching performance of the composite.
- QEMSCAN results on the Casino composites show that Chalcopyrite is the dominant Cu-sulfide and that some Cu bearing Iron Oxides are present in M 11-17 and Met 19-20 but not in Met 02-05, which may explain the limited gold recovery on composite Met 11-17. The impact of copper mineralization on Met 11-17 on Au dissolution and cyanide consumption should be carefully considered during the selection of blending options.
- Given the competent nature of the Casino samples tested during this study, Met 11-17 in particular, it is recommended that additional hydrodynamic and metallurgical tests be conducted on this sample under the following conditions:
    - Crushed ore with a top size between 1.25" to 1.5" to be evaluated under the ST procedure to select the best candidate for Integrated Column Tests (ICTs). Given the amount of gold on the coarser fraction, this may result in better gold liberation – albeit the potential issue with the interference from the copper minerals.
- Given the more permeable and very coarse nature of Met 11-17, blending it with Met 02-05 even under a non-agglomerated condition increases the heap height supported by the latter composite. As indicated by the ST results, agglomeration of a 2:1 blend produces a much improved condition from the point of view of solution percolation and likely air movement.
- Future metallurgical testing of the blend (Met 02-05+Met 11-17) should focus on determining the potential negative impact of the copper minerals on the performance of Met 02-05.
- Even though the non-agglomerated Casino composites would support heap heights between 70 m to 140 m, the hydrodynamic characterization indicates that substantial benefits could be derived from blending and proper agglomeration of the samples. In addition to the improved hydrodynamic performance, agglomeration has the added benefits of uniform reagent delivery and kick-starting of the leaching process. It is recommended that agglomeration of the Casino composites be further considered.
- Another important parameter that needs to be considered is the moisture of the ore as-mined and during stacking. The moisture content of stacking determines the potential for compaction and particle size segregation. If the decision is made that the ore will not be agglomerated, it is recommended that some additional STs be conducted once the material is being placed on the heap at the *in situ* moisture content to confirm that no over-compaction of the ore would occur.
- Industrial experience shows that a permanent (multi-lift) heap design can be strongly impacted by excessive solution inventory. Although the Casino ore is quite permeable and shows favorable drainage characteristics, a trade-off study should be conducted comparing the financial benefits of a dynamic heap versus the multi-lift heap currently considered. Elevated solution and metal inventory would be more significant for Met 02-05 than for Met 11-17, so it should be explicitly considered in the context of the recommended trade-off study.

- The data presented in this document shows that the hydrodynamic performance of composites Met 02-05 and Met 11-17 would be more than adequate during the initial stages of the operation as clearly shown by the results of the HCTs for a heap height of 32 m; (i.e., four lifts of 8 m). Although the optimal irrigation schedule and application rate would be best determined via a three-dimensional numerical model which includes all the geometric characteristics of the Casino heap, the hydrodynamic and metallurgical properties of the ore presented in this document, the following design specifications are recommended:
    - o Given the current crush size (**P_{100}** ~50 mm), a maximum distance between drippers of 30 cm and the solution application rate no larger than 10 L/h/m^2 for Composite Met 02-05 and no larger than 6 L/h/m^2 for Composite Met 11-17 are recommended.
    - o The irrigation for both of these composites should follow a ramp-up irrigation scheme (RUI) whereby the average application rate for the first few days is 25% of the target rate and is maintained until solution discharge is equal to the solution application; the second flow step is 50% of the target and is continued until steady state flow (in=out) is achieved; the third flow step is 75% of the target flow rate and is continued to steady state flow at which point the full target application is applied on a continuous basis.
    - o A rinsing period at the end of the leaching should be designed and instituted. Again, this is best done using the information presented in this document in combination of a 3-D flow model, however, based on the analysis so far it seems that the duration of the rinse cycle should be at least 10 days and at an irrigation rate of 200% the target irrigation.
- Given that the Casino is designed as a multi-heap leaching process, it is critical that the hydrodynamic properties of the leached residue be determined to define the potential impact of weathering, slumping and potential leaching-induced decrepitation to the long-term performance of the heap. It is recommended that leached residue, either from the recently completed columns at Metcon or from the future operation after three or four leach-cycles, be used for this purpose. If these results show a significant difference from the tests on the head samples, HCTs to be conducted to better assess the impact of leaching on the hydrodynamic properties of the Casino ore and the potential changes to the current heap design.
- Finally, It is recommended that the preliminary metallurgical results be compared to the larger scale column tests recently completed by Metcon in order to:
    - i) Compare the calculated extractions, and more importantly;
    - ii) Evaluate the potential scale-up factors required for the design of the industrial scale process.

APPENDIX A

STACKING TESTS

LABORATORY REPORTS

HYDRODYNAMIC LABORATORY REPORT

HydroGeoSense
Because you need to know!

STACKING TEST - Density and Permeability Profiles

SAMPLE DESCRIPTION

Client/Project: WCG

Date Tested: 6/25/2014

Sample ID: M-02-05-Peb

Mine/Project Site: Casino

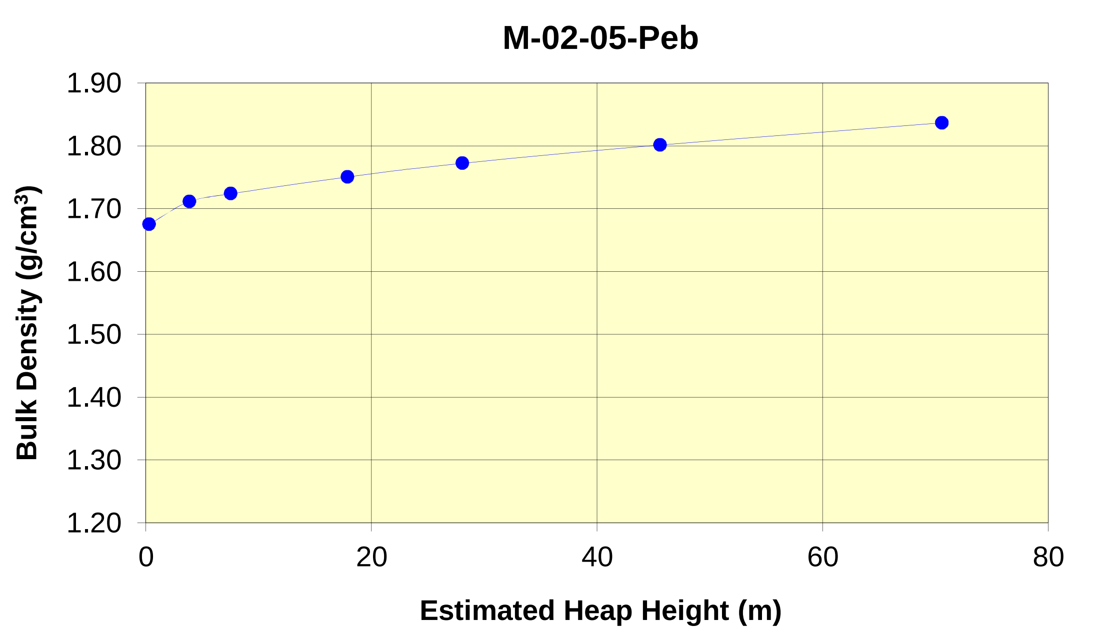
Description: Fresh ore non-agglomerated w/None

Cell Diameter: 15.55 cm S.G.: 2.66 Grav.M.C.: 0.4% Agglomeration. Level: L0

NUMERICAL RESULTS

Est Heap Height (m)	Dry Bulk Density (g/cm^3)	Permeability (cm^2)	Porosity ( )
0.3	1.68	3.6E-06	0.37
3.9	1.71	3.7E-06	0.36
7.5	1.72	3.4E-06	0.35
17.9	1.75	4.2E-06	0.34
28.1	1.77	3.9E-06	0.33
45.6	1.80	3.0E-06	0.32
70.6	1.84	2.6E-06	0.31

GRAPHICAL RESULTS



HYDRODYNAMIC LABORATORY REPORT

HydroGeoSense
Because you need to know!

STACKING TEST - Hydraulic Conductivity versus dry bulk density

SAMPLE DESCRIPTION

Client/Project: WCG

Date Tested: 6/25/2014

Sample ID: M-02-05-Peb

Mine/Project Site: Casino

Description: Fresh ore non-agglomerated w/None

Cell Diameter: 15.55 cm S.G.: 2.66 Grav.M.C.: 0.4% Agglomeration. Level: L0

NUMERICAL RESULTS

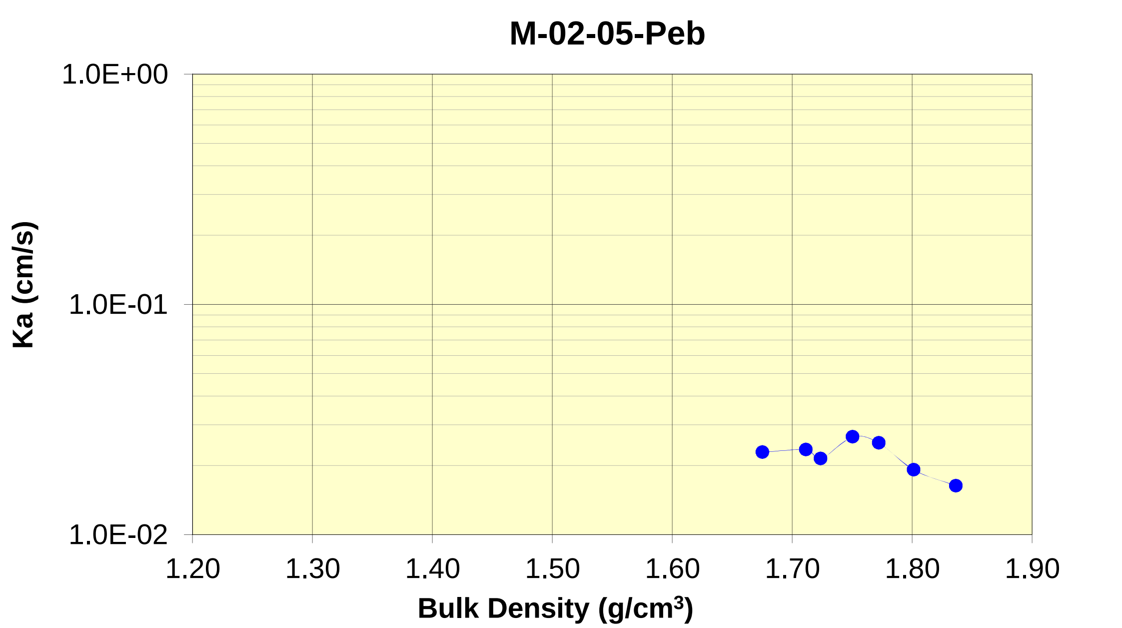
Est Heap Height (m)	Dry Bulk Density (g/cm3)	Ka (cm/s)	Kw (cm/s)
0.3	1.68	2.3E-02	1.5E-01
3.9	1.71	2.3E-02	1.5E-01
7.5	1.72	2.1E-02	1.4E-01
17.9	1.75	2.7E-02	1.7E-01
28.1	1.77	2.5E-02	1.6E-01
45.6	1.80	1.9E-02	1.2E-01
70.6	1.84	1.6E-02	1.1E-01

Final Ks available? 1.1E-01 cm/s

Ks/Ka = 6.51

Two Flow Meters in Parallel? No

GRAPHICAL RESULTS



CONSTANT HEAD - HYDRAULIC CONDUCTIVITY TEST

HydroGeoSense
Because you need to know!

Client: WCG **Date:** 6/25/2014 **Time:** 15:14

Sample ID: M-02-05-Peb **Operator(s):** ACS

Wet Ore Mass (g): 6,036.0 **Initial Grav. Moist. Content:** 0.4 % **T:** 28.5 C

Bottom of ore (cm): 31.4 (from collar to top of grid) **Initial Head Space (cm):** 14.2

Cell Diameter (in): 6.0 **Cell Area (cm^2):** 189.81 **Final Head Space (cm):** 14.0

Reservoir Area (cm^2): 42.85 **Bubble Inlet Elev (cm):** 54.0 **Discharge Elevation(cm):** 45

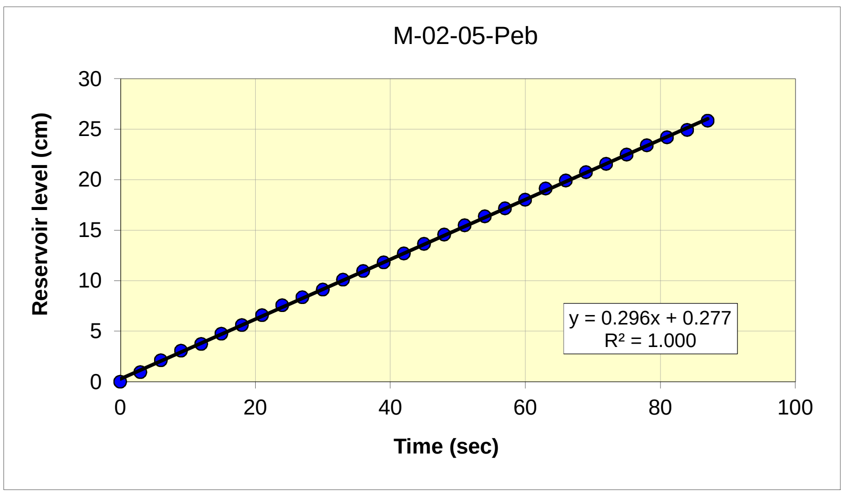
Test - Data

dt (s):	3
Time	Reservoir Level (cm)
0	0.00
3	0.93
6	2.10
9	3.05
12	3.73
15	4.75
18	5.60
21	6.57
24	7.55
27	8.35
30	9.10
33	10.08
36	10.95
39	11.80
42	12.70
45	13.64
48	14.55
51	15.47
54	16.35
57	17.15
60	18.00
63	19.12
66	19.90
69	20.74
72	21.55
75	22.47
78	23.38
81	24.17
84	24.90
87	25.83

Ks Data Analysis

First Row: 20 Last Row: 49.00 Q (cm^3/s): 12.68

Sample Height: 17.3 cm dh (cm): 9.0



ρ_b = 1.83 g/cm^3

K_s = 1.3E-01 cm/s at T = 28.5 C

Standard Temperature = 20.0 C

	Viscosity (mPa S)	Density (g/cm^3)
at T °C	0.824	9.954E-01
at Standard Temperature (°C)	1.002	9.974E-01

$K_{s\ Standard\ T}$ = 1.1E-01

10-Min Drain Down Analysis

Preliminary Volumetric porosity partitioning estimates				
Total	**Macro**	**Fraction**	**Micro**	**Fraction**
0.31	0.16	0.51	0.15	0.49
Preliminary Gravimetric porosity partitioning estimates				
	0.16	0.51	0.15	0.49

HYDRODYNAMIC LABORATORY REPORT

HydroGeoSense
Because you need to know!

STACKING TEST - Density and Permeability Profiles

SAMPLE DESCRIPTION

Client/Project: Casino

Date Tested: 6/25/2014

Sample ID: M-02-05-Pow

Mine/Project Site: WCG

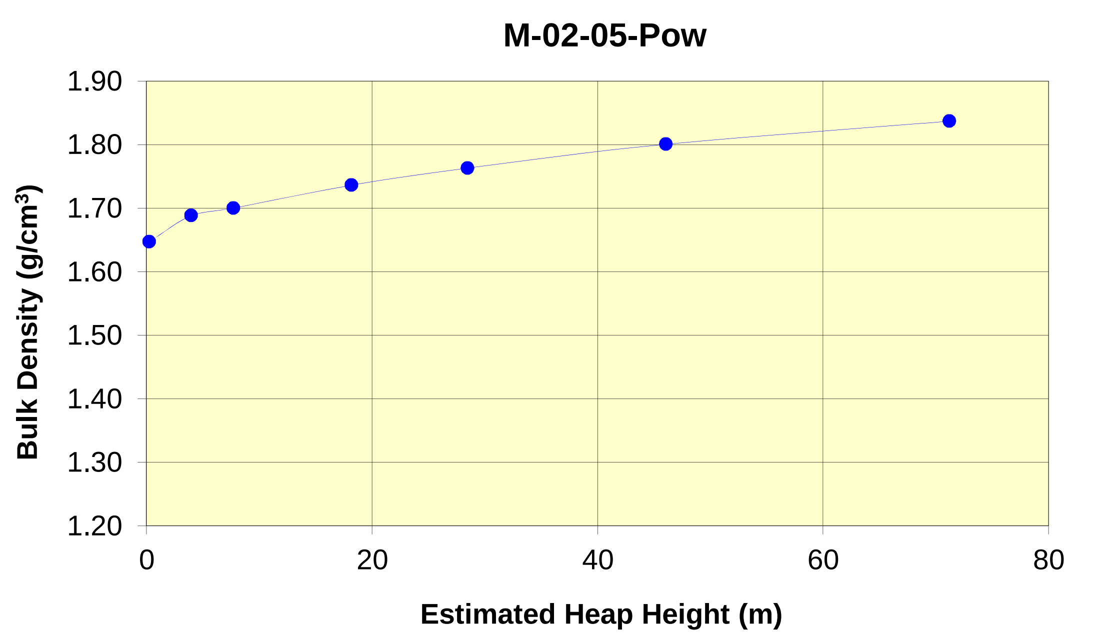
Description: Fresh ore non-agglomerated w/None

Cell Diameter: 15.48 cm S.G.: 2.66 Grav.M.C.: 0.4% Agglomeration. Level: L0

NUMERICAL RESULTS

Est Heap Height (m)	Dry Bulk Density (g/cm^3)	Permeability (cm^2)	Porosity ( )
0.3	1.65	2.4E-06	0.38
4.0	1.69	2.5E-06	0.37
7.7	1.70	2.5E-06	0.36
18.2	1.74	2.2E-06	0.35
28.5	1.76	2.2E-06	0.34
46.1	1.80	1.8E-06	0.32
71.2	1.84	1.9E-06	0.31

GRAPHICAL RESULTS



HYDRODYNAMIC LABORATORY REPORT

HydroGeoSense
Because you need to know!

STACKING TEST - Hydraulic Conductivity versus dry bulk density

SAMPLE DESCRIPTION

Client/Project: Casino Date Tested: 6/25/2014

Sample ID: M-02-05-Pow Mine/Project Site: WCG

Description: Fresh ore non-agglomerated w/None

Cell Diameter: 15.48 cm S.G.: 2.66 Grav.M.C.: 0.4% Agglomeration. Level: L0

NUMERICAL RESULTS

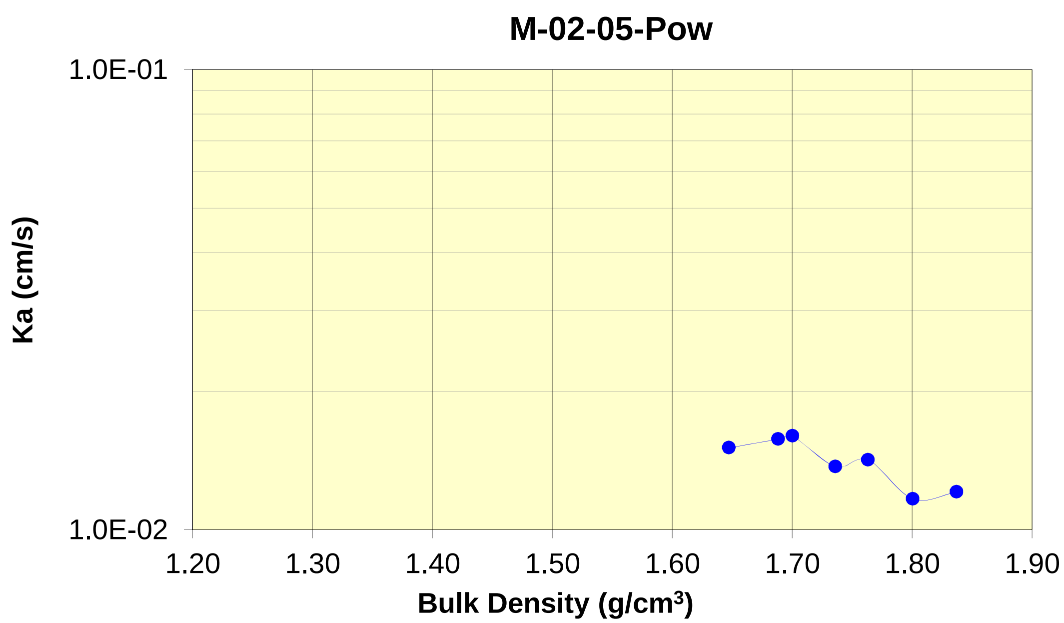
Est Heap Height (m)	Dry Bulk Density (g/cm3)	Ka (cm/s)	Kw (cm/s)
0.3	1.65	1.5E-02	1.2E-01
4.0	1.69	1.6E-02	1.3E-01
7.7	1.70	1.6E-02	1.3E-01
18.2	1.74	1.4E-02	1.1E-01
28.5	1.76	1.4E-02	1.2E-01
46.1	1.80	1.2E-02	9.5E-02
71.2	1.84	1.2E-02	9.9E-02

Final Ks available? 9.9E-02 cm/s

Ks/Ka = 8.18

Two Flow Meters in Parallel? No

GRAPHICAL RESULTS



CONSTANT HEAD - HYDRAULIC CONDUCTIVITY TEST

HydroGeoSense
Because you need to know!

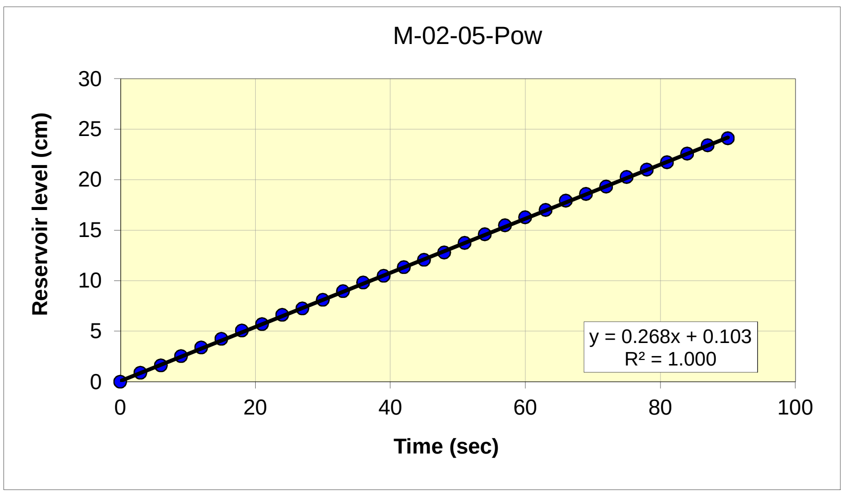
Client:	Casino	**Date:**	6/25/2014	**Time:**	16:47
Sample ID:	M-02-05-Pow			**Operator(s):**	RGS
Wet Ore Mass (g):	6,069.0	**Initial Grav. Moist. Content:**	0.4 %	**T:**	28.1 C
Bottom of ore (cm):	31.0 (from collar to top of grid)			**Initial Head Space (cm):**	13.5
Cell Diameter (in):	6.0	**Cell Area (cm^2):**	188.10	**Final Head Space (cm):**	13.4
Reservoir Area (cm^2):	42.85	**Bubble Inlet Elev (cm):**	54.0	**Discharge Elevation(cm):**	45

Test - Data

dt (s):	3
Time	Reservoir Level (cm)
0	0.00
3	0.88
6	1.60
9	2.52
12	3.37
15	4.23
18	5.05
21	5.70
24	6.62
27	7.25
30	8.10
33	8.95
36	9.80
39	10.48
42	11.32
45	12.07
48	12.80
51	13.75
54	14.60
57	15.47
60	16.27
63	17.00
66	17.90
69	18.57
72	19.30
75	20.25
78	21.00
81	21.70
84	22.56
87	23.40
90	24.10

Ks Data Analysis

First Row:	20	Last Row:	50.00	Q (cm^3/s):	11.47
Sample Height:	17.5 cm			dh (cm):	9.0



ρ_b = 1.83 g/cm^3

K_s = 1.2E-01 cm/s at T = 28.1 C

Standard Temperature = 20.0 C

	Viscosity (mPa S)	Density (g/cm^3)
at T °C	0.831	9.955E-01
at Standard Temperature (°C)	1.002	9.974E-01

$K_{s\ Standard\ T}$ = 9.9E-02

10-Min Drain Down Analysis

Preliminary Volumetric porosity partitioning estimates				
Total	**Macro**	**Fraction**	**Micro**	**Fraction**
0.31	0.17	0.55	0.14	0.45
Preliminary Gravimetric porosity partitioning estimates				
	0.17	0.55	0.14	0.45

HYDRODYNAMIC LABORATORY REPORT

HydroGeoSense
Because you need to know!

STACKING TEST - Density and Permeability Profiles

SAMPLE DESCRIPTION

Client/Project: WCG

Date Tested: 6/27/2014

Sample ID: M-02-05

Mine/Project Site: Casino

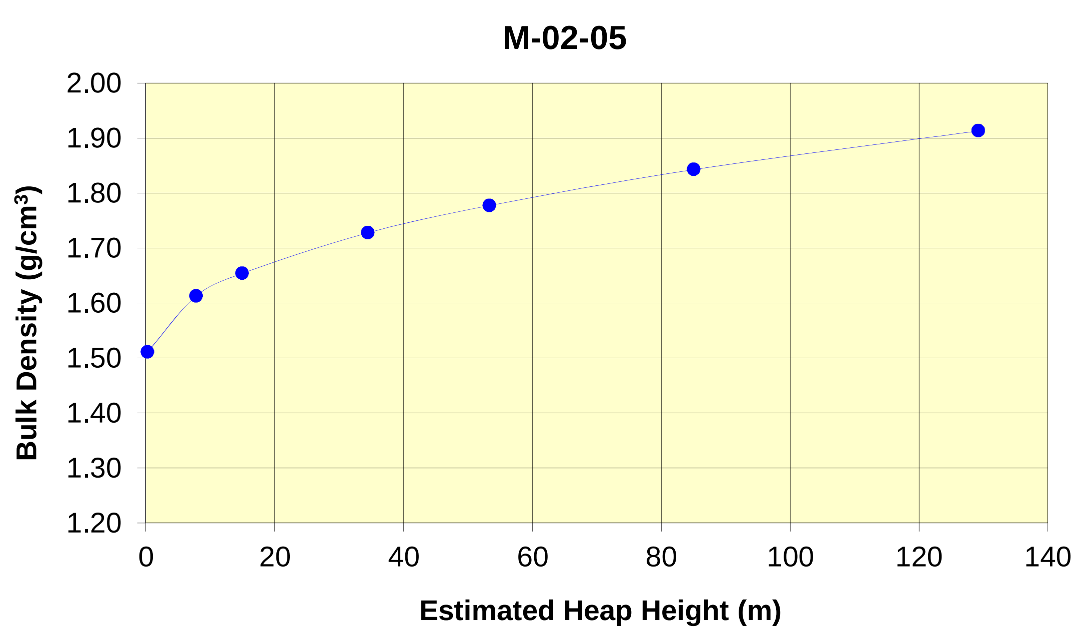
Description: Fresh ore agglomerated w/H2O w/Lime at a pH 11.0

Cell Diameter: 20.30 cm S.G.: 2.66 Grav.M.C.: 5.7% Agglomeration Level: L3

NUMERICAL RESULTS

Est Heap Height (m)	Dry Bulk Density (g/cm^3)	Permeability (cm^2)	Porosity ( )
0.3	1.51	9.1E-05	0.43
7.8	1.61	4.6E-05	0.39
15.0	1.65	3.9E-05	0.38
34.5	1.73	2.0E-05	0.35
53.3	1.78	1.5E-05	0.33
85.1	1.84	8.0E-06	0.31
129.2	1.91	3.8E-06	0.28

GRAPHICAL RESULTS



HYDRODYNAMIC LABORATORY REPORT

HydroGeoSense
Because you need to know!

STACKING TEST - Hydraulic Conductivity versus dry bulk density

SAMPLE DESCRIPTION

Client/Project: WCG

Date Tested: 6/27/2014

Sample ID: M-02-05

Mine/Project Site: Casino

Description: Fresh ore agglomerated w/H2O w/Lime at a pH 11.0

Cell Diameter: 20.30 cm   S.G.: 2.66   Grav.M.C.: 5.7%   Agglomeration. Level: L3

NUMERICAL RESULTS

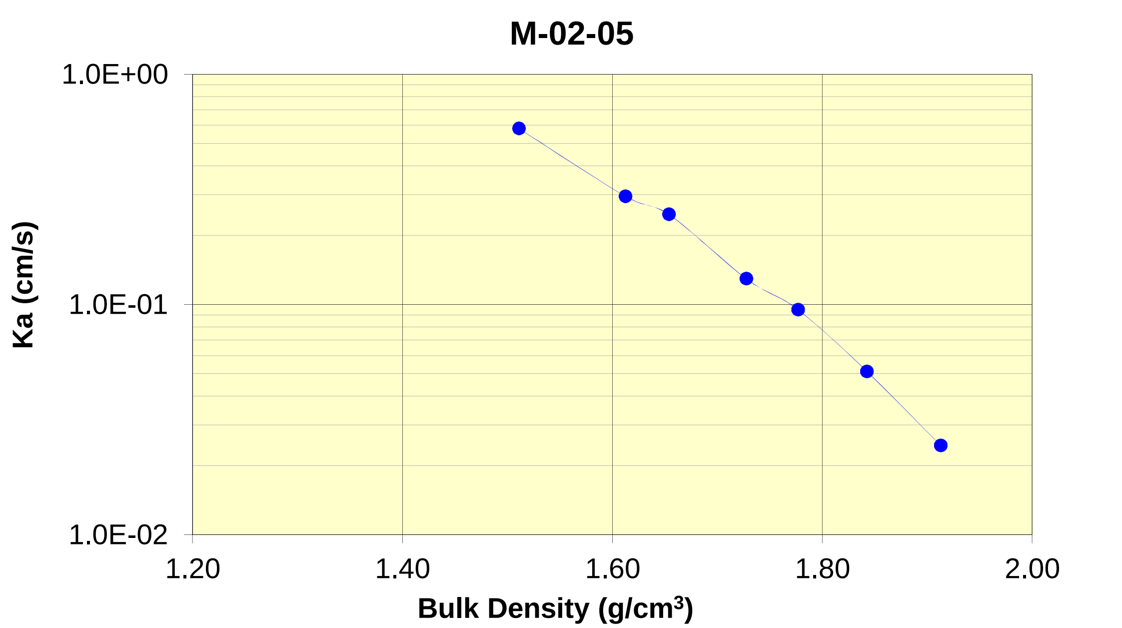
Est Heap Height (m)	Dry Bulk Density (g/cm3)	Ka (cm/s)	Kw (cm/s)
0.3	1.51	5.8E-01	2.5E+00
7.8	1.61	2.9E-01	1.3E+00
15.0	1.65	2.5E-01	1.1E+00
34.5	1.73	1.3E-01	5.5E-01
53.3	1.78	9.5E-02	4.1E-01
85.1	1.84	5.1E-02	2.2E-01
129.2	1.91	2.4E-02	1.0E-01

Final Ks available? 1.0E-01 cm/s

Ks/Ka = 4.28

Two Flow Meters in Parallel? Yes

GRAPHICAL RESULTS



CONSTANT HEAD - HYDRAULIC CONDUCTIVITY TEST

HydroGeoSense
Because you need to know!

Client: WCG **Date:** 6/27/2014 **Time:** 17:32

Sample ID: M-02-05 **Operator(s):** RGS

Wet Ore Mass (g): 11,252.0 **Initial Grav. Moist. Content:** 5.7 % **T:** 38.1 C

Bottom of ore (cm): 28.0 (from collar to top of grid) **Initial Head Space (cm):** 10.8

Cell Diameter (in): 8.0 **Cell Area (cm^2):** 323.79 **Final Head Space (cm):** 10.5

Reservoir Area (cm^2): 42.85 **Bubble Inlet Elev (cm):** 54.0 **Discharge Elevation(cm):** 45

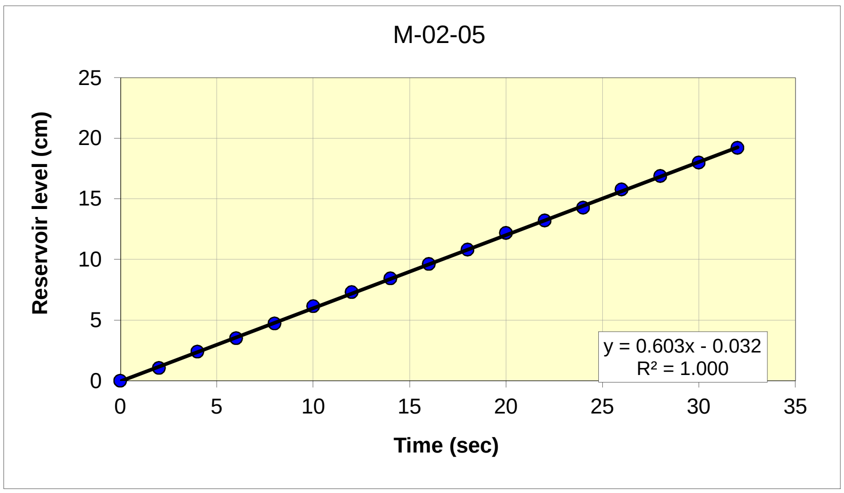
Test - Data

dt (s):	2
Time	Reservoir Level (cm)
0	0.00
2	1.05
4	2.40
6	3.50
8	4.72
10	6.13
12	7.30
14	8.45
16	9.62
18	10.80
20	12.18
22	13.22
24	14.28
26	15.78
28	16.88
30	18.00
32	19.20

Ks Data Analysis

First Row: 20 Last Row: 36.00 Q (cm^3/s): 25.84

Sample Height: 17.3 cm dh (cm): 9.0



ρ_b = 1.90 g/cm³

K_s = 1.5E-01 cm/s at T = 38.1 C

Standard Temperature = 20.0 C

	Viscosity (mPa S)	Density (g/cm^3)
at T °C	0.676	9.925E-01
at Standard Temperature (°C)	1.002	9.974E-01

$K_{s\ Standard\ T}$ = 1.0E-01

10-Min Drain Down Analysis

Preliminary Volumetric porosity partitioning estimates				
Total	**Macro**	**Fraction**	**Micro**	**Fraction**
0.29	0.14	0.48	0.15	0.52
Preliminary Gravimetric porosity partitioning estimates				
	0.14	0.48	0.15	0.52

HYDRODYNAMIC LABORATORY REPORT

HydroGeoSense
Because you need to know!

STACKING TEST - Density and Permeability Profiles

SAMPLE DESCRIPTION

Client/Project: WGC

Date Tested: 6/26/2014

Sample ID: M-11-17-Peb

Mine/Project Site: Casino

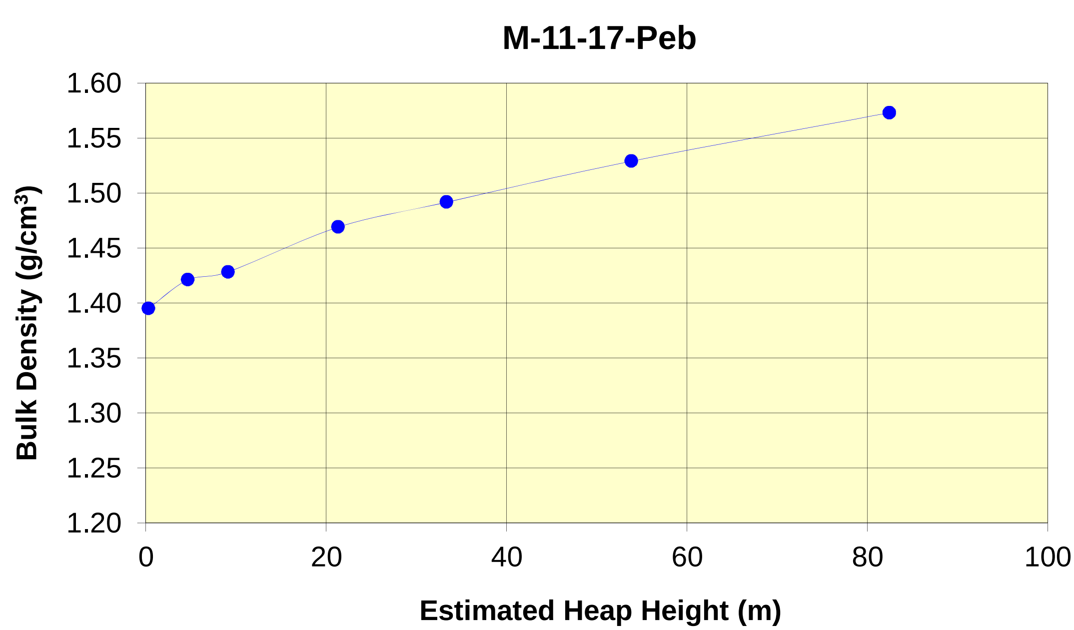
Description: Fresh ore non-agglomerated w/None

Cell Diameter: 15.55 cm S.G.: 2.63 Grav.M.C.: 0.3% Agglomeration Level: L0

NUMERICAL RESULTS

Est Heap Height (m)	Dry Bulk Density (g/cm^3)	Permeability (cm^2)	Porosity ( )
0.3	1.40	1.2E-04	0.47
4.7	1.42	1.1E-04	0.46
9.1	1.43	1.2E-04	0.46
21.3	1.47	1.1E-04	0.44
33.4	1.49	1.1E-04	0.43
53.8	1.53	1.0E-04	0.42
82.5	1.57	9.6E-05	0.40

GRAPHICAL RESULTS



HYDRODYNAMIC LABORATORY REPORT

HydroGeoSense
Because you need to know!

STACKING TEST - Hydraulic Conductivity versus dry bulk density

SAMPLE DESCRIPTION

Client/Project: WGC

Date Tested: 6/26/2014

Sample ID: M-11-17-Peb

Mine/Project Site: Casino

Description: Fresh ore non-agglomerated w/None

Cell Diameter: 15.55 cm S.G.: 2.63 Grav.M.C.: 0.3% Agglomeration. Level: L0

NUMERICAL RESULTS

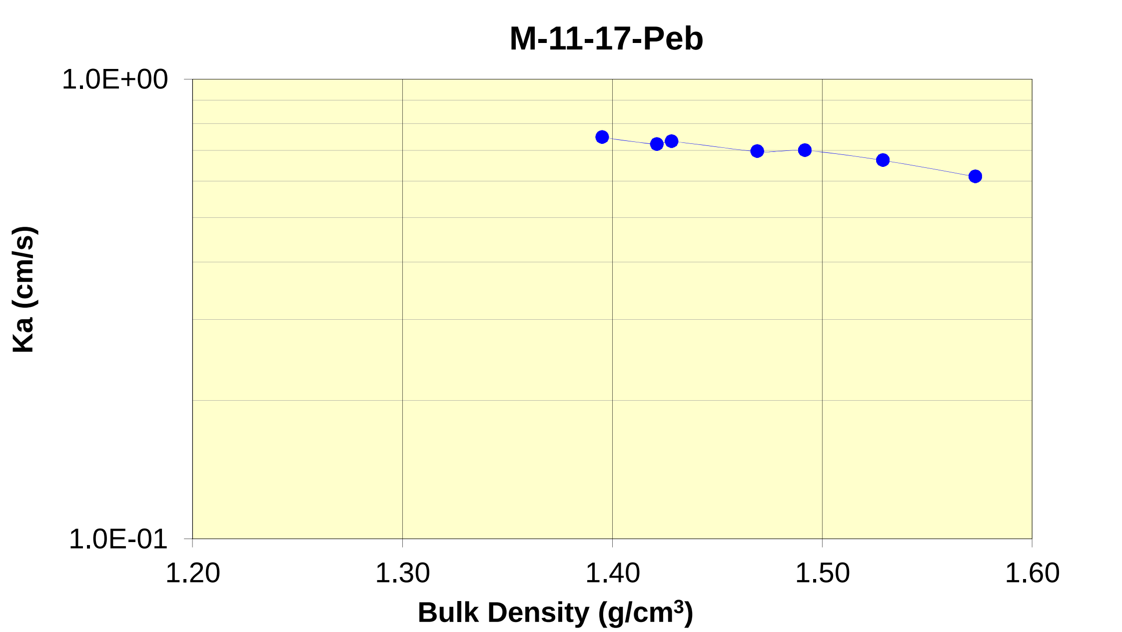
Est Heap Height (m)	Dry Bulk Density (g/cm3)	Ka (cm/s)	Kw (cm/s)
0.3	1.40	7.5E-01	2.8E-01
4.7	1.42	7.2E-01	2.7E-01
9.1	1.43	7.3E-01	2.7E-01
21.3	1.47	7.0E-01	2.6E-01
33.4	1.49	7.0E-01	2.6E-01
53.8	1.53	6.7E-01	2.5E-01
82.5	1.57	6.1E-01	2.3E-01

Final Ks available? 2.3E-01 cm/s

Ks/Ka = 0.38

Two Flow Meters in Parallel? Yes

GRAPHICAL RESULTS



CONSTANT HEAD - HYDRAULIC CONDUCTIVITY TEST

HydroGeoSense
Because you need to know!

Client:	WGC	**Date:**	6/26/2014	**Time:**	16:48
Sample ID:	M-11-17-Peb			**Operator(s):**	ACS
Wet Ore Mass (g):	6,032.0	**Initial Grav. Moist. Content:**	0.3 %	**T:**	27.7 C
Bottom of ore (cm):	31.4 (from collar to top of grid)			**Initial Head Space (cm):**	11.3
Cell Diameter (in):	6.0	**Cell Area (cm^2):**	189.81	**Final Head Space (cm):**	11.2
Reservoir Area (cm^2):	42.85	**Bubble Inlet Elev (cm):**	54.0	**Discharge Elevation(cm):**	45

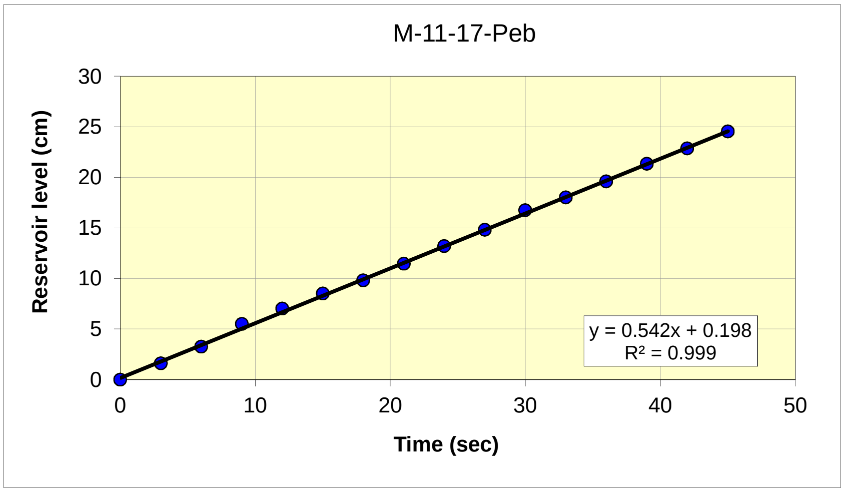
Test - Data

dt (s):	3
Time	Reservoir Level (cm)
0	0.00
3	1.60
6	3.25
9	5.50
12	7.03
15	8.50
18	9.80
21	11.45
24	13.20
27	14.82
30	16.75
33	18.00
36	19.60
39	21.35
42	22.86
45	24.55

Ks Data Analysis

First Row: 20 Last Row: 35.00 Q (cm^3/s): 23.22

Sample Height: 20.2 cm dh (cm): 9.0



ρ_b = 1.57 g/cm^3

K_s = 2.7E-01 cm/s at T = 27.7 C

Standard Temperature = 20.0 C

	Viscosity (mPa S)	Density (g/cm^3)
at T °C	0.838	9.956E-01
at Standard Temperature (°C)	1.002	9.974E-01

$K_{s\ Standard\ T}$ = 2.3E-01

10-Min Drain Down Analysis

Preliminary Volumetric porosity partitioning estimates				
Total	**Macro**	**Fraction**	**Micro**	**Fraction**
0.40	0.35	0.86	0.06	0.14
Preliminary Gravimetric porosity partitioning estimates				
	0.35	0.86	0.06	0.14

HYDRODYNAMIC LABORATORY REPORT

HydroGeoSense
Because you need to know!

STACKING TEST - Density and Permeability Profiles

SAMPLE DESCRIPTION

Client/Project: Casino
Date Tested: 6/26/2014

Sample ID: M-11-17-Pow
Mine/Project Site: WCG

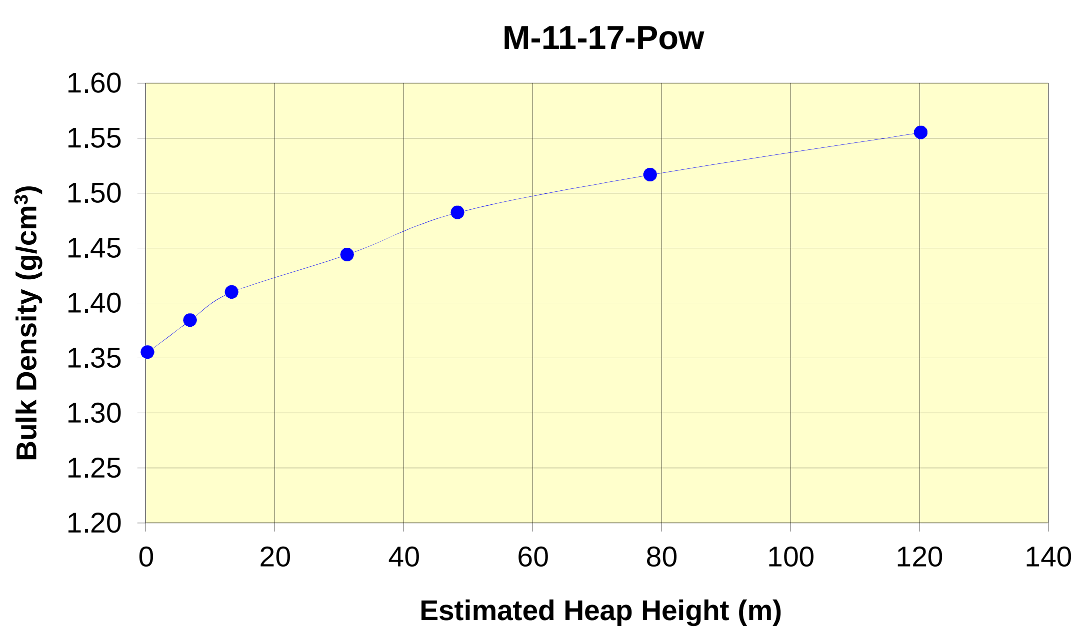
Description: Fresh ore non-agglomerated w/None

Cell Diameter: 15.48 cm
S.G.: 2.63
Grav.M.C.: 0.3%
Agglomeration Level: L0

NUMERICAL RESULTS

Est Heap Height (m)	Dry Bulk Density (g/cm^3)	Permeability (cm^2)	Porosity ( )
0.3	1.36	3.7E-05	0.49
6.9	1.38	3.6E-05	0.47
13.3	1.41	3.1E-05	0.46
31.2	1.44	3.2E-05	0.45
48.4	1.48	2.9E-05	0.44
78.2	1.52	2.6E-05	0.42
120.3	1.56	2.2E-05	0.41

GRAPHICAL RESULTS



HYDRODYNAMIC LABORATORY REPORT

HydroGeoSense
Because you need to know!

STACKING TEST - Hydraulic Conductivity versus dry bulk density

SAMPLE DESCRIPTION

Client/Project: Casino
Date Tested: 6/26/2014
Sample ID: M-11-17-Pow
Mine/Project Site: WCG
Description: Fresh ore non-agglomerated w/None
Cell Diameter: 15.48 cm
S.G.: 2.63
Grav.M.C.: 0.3%
Agglomeration. Level: L0

NUMERICAL RESULTS

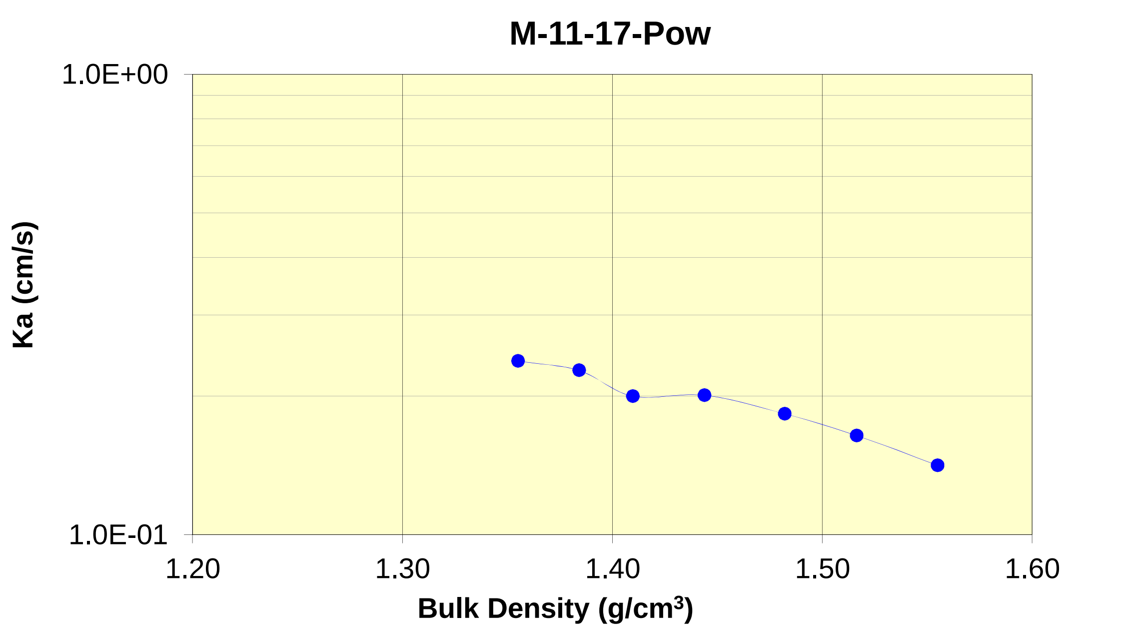
Est Heap Height (m)	Dry Bulk Density (g/cm3)	Ka (cm/s)	Kw (cm/s)
0.3	1.36	2.4E-01	1.3E-01
6.9	1.38	2.3E-01	1.2E-01
13.3	1.41	2.0E-01	1.1E-01
31.2	1.44	2.0E-01	1.1E-01
48.4	1.48	1.8E-01	1.0E-01
78.2	1.52	1.6E-01	9.0E-02
120.3	1.56	1.4E-01	7.7E-02

Final Ks available? 7.7E-02 cm/s

Ks/Ka = 0.55

Two Flow Meters in Parallel? Yes

GRAPHICAL RESULTS



CONSTANT HEAD - HYDRAULIC CONDUCTIVITY TEST

HydroGeoSense
Because you need to know!

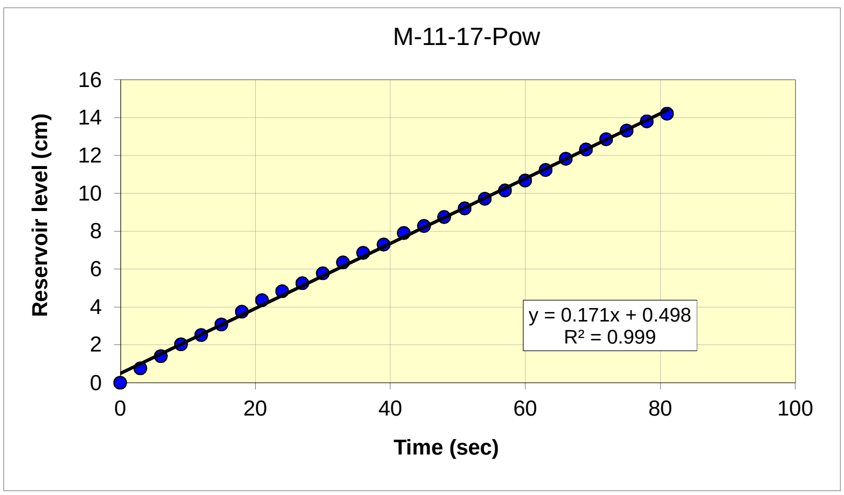
Client:	Casino		**Date:**	6/26/2014	**Time:**	10:26
Sample ID:	M-11-17-Pow				**Operator(s):**	RGS
Wet Ore Mass (g):	5,998.0	**Initial Grav. Moist. Content:**	0.3	%	**T:**	25.8 C
Bottom of ore (cm):	31.7	(from collar to top of grid)			**Initial Head Space (cm):**	11.3
Cell Diameter (in):	6.0	**Cell Area (cm^2):**	188.10		**Final Head Space (cm):**	11.3
Reservoir Area (cm^2):	42.85	**Bubble Inlet Elev (cm):**	54.0		**Discharge Elevation(cm):**	45

Test - Data

dt (s):	3
Time	Reservoir Level (cm)
0	0.00
3	0.75
6	1.40
9	2.02
12	2.52
15	3.07
18	3.75
21	4.35
24	4.82
27	5.25
30	5.77
33	6.35
36	6.85
39	7.30
42	7.90
45	8.27
48	8.75
51	9.20
54	9.70
57	10.15
60	10.67
63	11.23
66	11.81
69	12.30
72	12.85
75	13.30
78	13.80
81	14.20

Ks Data Analysis

First Row:	20	Last Row:	47.00	Q (cm^3/s):	7.35
Sample Height:	20.4 cm			dh (cm):	9.0



ρ_b = 1.56 g/cm^3

K_s = 8.9E-02 cm/s at T = 25.8 C

Standard Temperature = 20.0 C

	Viscosity (mPa S)	Density (g/cm^3)
at T °C	0.874	9.961E-01
at Standard Temperature (°C)	1.002	9.974E-01

$K_{s\ Standard\ T}$ = 7.7E-02

10-Min Drain Down Analysis

Preliminary Volumetric porosity partitioning estimates				
Total	**Macro**	**Fraction**	**Micro**	**Fraction**
0.41	0.33	0.80	0.08	0.20
Preliminary Gravimetric porosity partitioning estimates				
	0.33	0.80	0.08	0.20

HYDRODYNAMIC LABORATORY REPORT

HydroGeoSense
Because you need to know!

STACKING TEST - Density and Permeability Profiles

SAMPLE DESCRIPTION

Client/Project: Casino | Date Tested: 6/27/2014

Sample ID: M-11-17 | Mine/Project Site: WCG

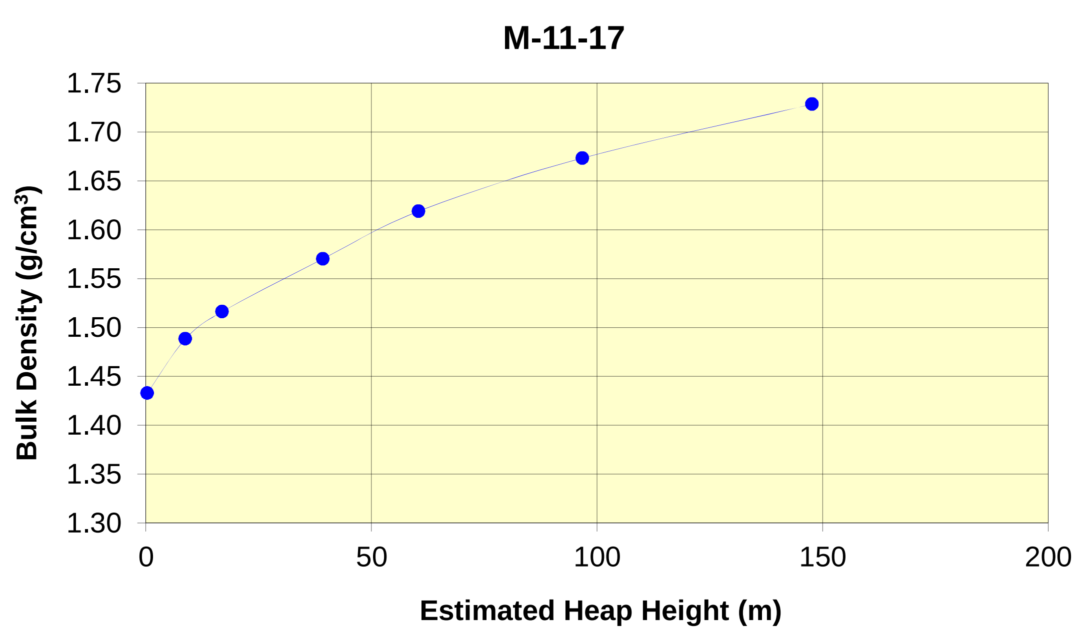
Description: Fresh ore Agglomerated w/H20 w/Lime at pH 11.0

Cell Diameter: 20.30 cm | S.G.: 2.63 | Grav.M.C.: 2.4% | Agglomeration Level: L2

NUMERICAL RESULTS

Est Heap Height (m)	Dry Bulk Density (g/cm^3)	Permeability (cm^2)	Porosity ( )
0.3	1.43	4.1E-04	0.46
8.8	1.49	3.1E-04	0.43
16.9	1.52	2.4E-04	0.42
39.2	1.57	1.5E-04	0.40
60.5	1.62	1.2E-04	0.38
96.7	1.67	8.8E-05	0.36
147.7	1.73	6.6E-05	0.34

GRAPHICAL RESULTS



HYDRODYNAMIC LABORATORY REPORT

HydroGeoSense
Because you need to know!

STACKING TEST - Hydraulic Conductivity versus dry bulk density

SAMPLE DESCRIPTION

Client/Project: Casino

Date Tested: 6/27/2014

Sample ID: M-11-17

Mine/Project Site: WCG

Description: Fresh ore Agglomerated w/H20 w/Lime at pH 11.0

Cell Diameter: 20.30 cm   S.G.: 2.63   Grav.M.C.: 2.4%   Agglomeration. Level: L2

NUMERICAL RESULTS

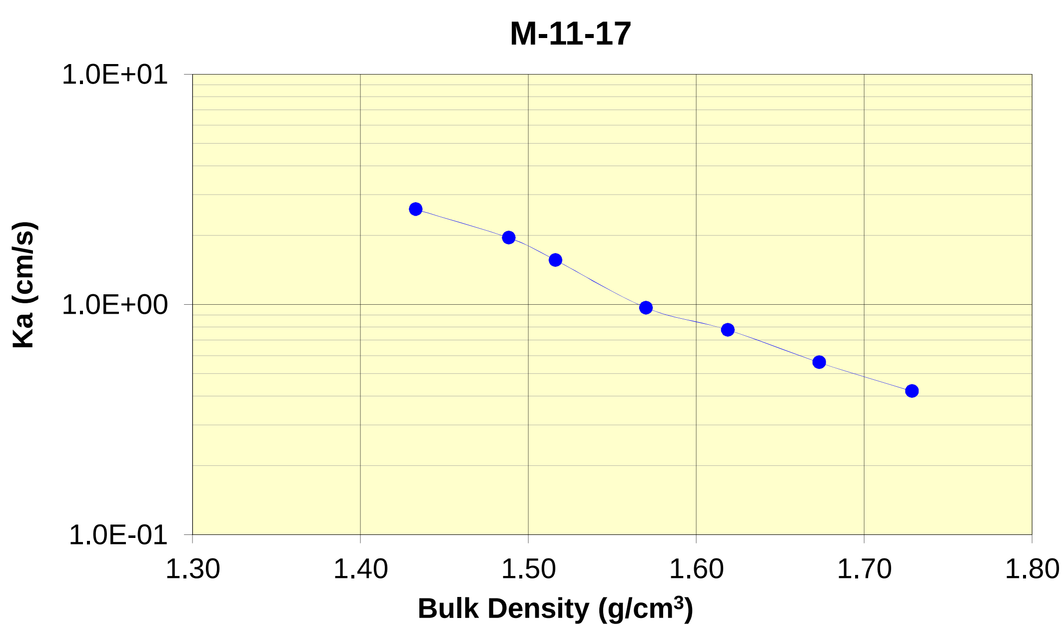
Est Heap Height (m)	Dry Bulk Density (g/cm3)	Ka (cm/s)	Kw (cm/s)
0.3	1.43	2.6E+00	1.2E+00
8.8	1.49	1.9E+00	9.4E-01
16.9	1.52	1.6E+00	7.5E-01
39.2	1.57	9.7E-01	4.7E-01
60.5	1.62	7.8E-01	3.7E-01
96.7	1.67	5.6E-01	2.7E-01
147.7	1.73	4.2E-01	2.0E-01

Final Ks available? 2.0E-01 cm/s

Ks/Ka = 0.48

Two Flow Meters in Parallel? Yes

GRAPHICAL RESULTS



CONSTANT HEAD - HYDRAULIC CONDUCTIVITY TEST

HydroGeoSense
Because you need to know!

Client: Casino **Date:** 6/27/2014 **Time:** 14:23

Sample ID: M-11-17 **Operator(s):** RGS

Wet Ore Mass (g): 10,925.0 **Initial Grav. Moist. Content:** 2.4 % **T:** 27.7 C

Bottom of ore (cm): 28.0 (from collar to top of grid) **Initial Head Space (cm):** 8.9

Cell Diameter (in): 8.0 **Cell Area (cm^2):** 323.79 **Final Head Space (cm):** 8.7

Reservoir Area (cm^2): 42.85 **Bubble Inlet Elev (cm):** 54.0 **Discharge Elevation(cm):** 45

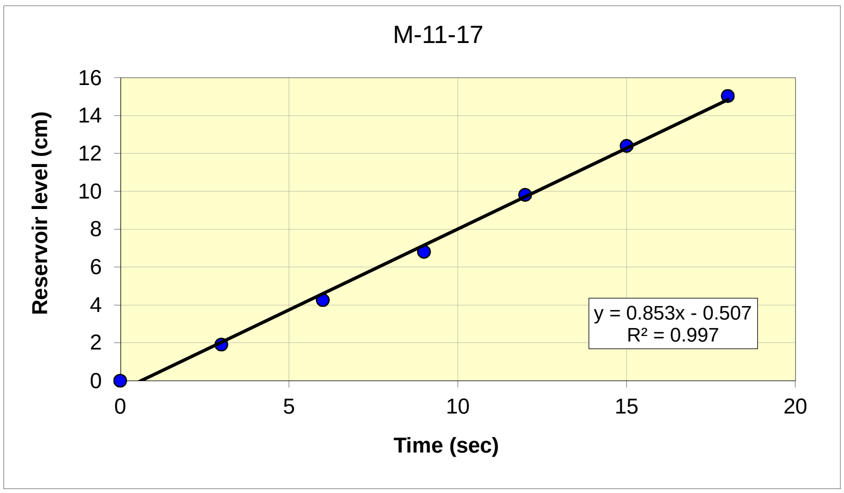
Test - Data

dt (s):	3
Time	Reservoir Level (cm)
0	0.00
3	1.90
6	4.25
9	6.80
12	9.80
15	12.40
18	15.03

Ks Data Analysis

First Row: 20 Last Row: 26.00 Q (cm^3/s): 36.54

Sample Height: 19.2 cm dh (cm): 9.0



ρ_b = 1.72 g/cm^3

K_s = 2.4E-01 cm/s at T = 27.7 C

Standard Temperature = 20.0 C

	Viscosity (mPa S)	Density (g/cm^3)
at T °C	0.838	9.956E-01
at Standard Temperature (°C)	1.002	9.974E-01

$K_{s\ Standard\ T}$ = 2.0E-01

10-Min Drain Down Analysis

Preliminary Volumetric porosity partitioning estimates				
Total	**Macro**	**Fraction**	**Micro**	**Fraction**
0.35	0.26	0.74	0.09	0.26
Preliminary Gravimetric porosity partitioning estimates				
	0.26	0.74	0.09	0.26

HYDRODYNAMIC LABORATORY REPORT

HydroGeoSense
Because you need to know!

STACKING TEST - Density and Permeability Profiles

SAMPLE DESCRIPTION

Client/Project: WCG | Date Tested: 7/3/2014

Sample ID: M-Blend | Mine/Project Site: Casino

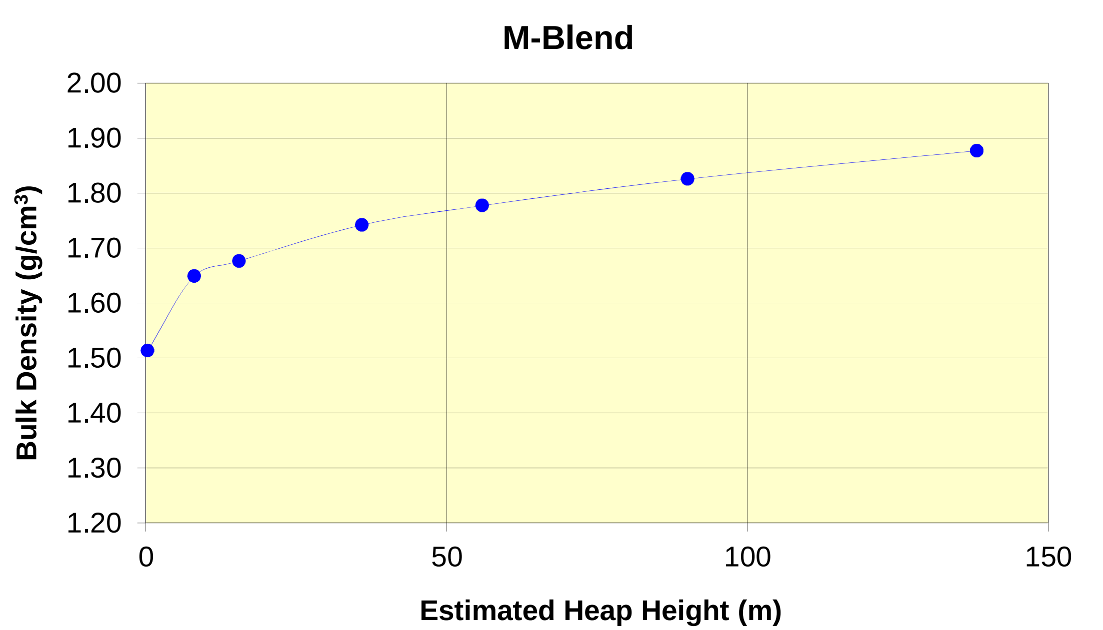
Description: Fresh non-agglomerated w/N/A

Cell Diameter: 20.35 cm | S.G.: 2.65 | Grav.M.C.: 0.3% | Agglomeration Level: L0

NUMERICAL RESULTS

Est Heap Height (m)	Dry Bulk Density (g/cm^3)	Permeability (cm^2)	Porosity ( )
0.3	1.51	1.8E-05	0.43
8.0	1.65	1.7E-05	0.38
15.5	1.68	1.7E-05	0.37
35.9	1.74	1.1E-05	0.34
55.9	1.78	9.6E-06	0.33
90.0	1.83	7.2E-06	0.31
138.1	1.88	5.7E-06	0.29

GRAPHICAL RESULTS



HYDRODYNAMIC LABORATORY REPORT

HydroGeoSense
Because you need to know!

STACKING TEST - Hydraulic Conductivity versus dry bulk density

SAMPLE DESCRIPTION

Client/Project: WCG

Date Tested: 7/3/2014

Sample ID: M-Blend

Mine/Project Site: Casino

Description: Fresh non-agglomerated w/N/A

Cell Diameter: 20.35 cm   S.G.: 2.65   Grav.M.C.: 0.3%   Agglomeration. Level: L0

NUMERICAL RESULTS

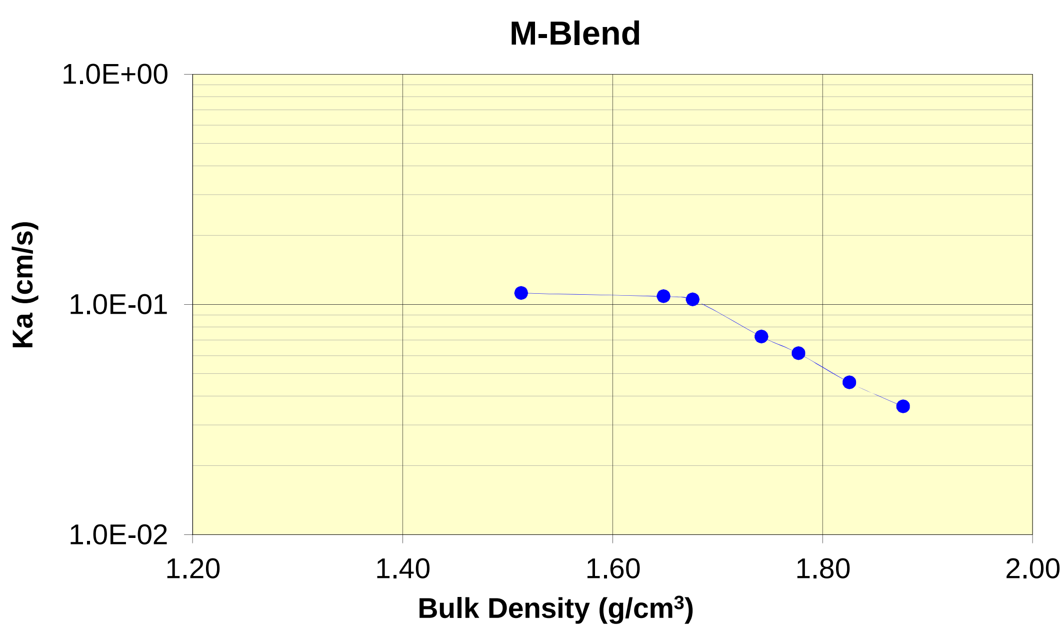
Est Heap Height (m)	Dry Bulk Density (g/cm3)	Ka (cm/s)	Kw (cm/s)
0.3	1.51	1.1E-01	4.3E-01
8.0	1.65	1.1E-01	4.1E-01
15.5	1.68	1.1E-01	4.0E-01
35.9	1.74	7.2E-02	2.8E-01
55.9	1.78	6.1E-02	2.3E-01
90.0	1.83	4.6E-02	1.8E-01
138.1	1.88	3.6E-02	1.4E-01

Final Ks available? 1.4E-01 cm/s

Ks/Ka = 3.83

Two Flow Meters in Parallel? Yes

GRAPHICAL RESULTS



CONSTANT HEAD - HYDRAULIC CONDUCTIVITY TEST

HydroGeoSense
Because you need to know!

Client: WCG **Date:** 7/3/2014 **Time:** 15:06

Sample ID: M-Blend **Operator(s):** Agg

Wet Ore Mass (g): 10,372.0 **Initial Grav. Moist. Content:** 0.3 % **T:** 30.4 C

Bottom of ore (cm): 28.0 (from collar to top of grid) **Initial Head Space (cm):** 11.1

Cell Diameter (in): 8.0 **Cell Area (cm^2):** 325.39 **Final Head Space (cm):** 10.8

Reservoir Area (cm^2): 42.85 **Bubble Inlet Elev (cm):** 54.0 **Discharge Elevation(cm):** 45

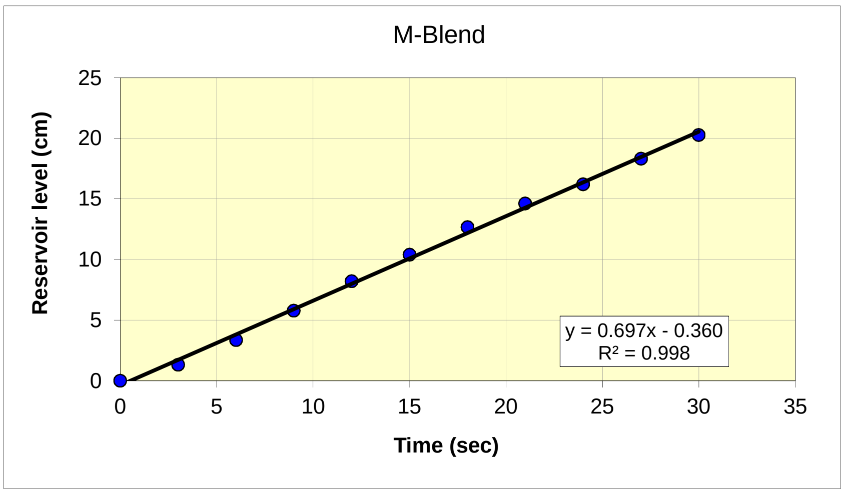
Test - Data

dt (s):	3
Time	Reservoir Level (cm)
0	0.00
3	1.30
6	3.35
9	5.78
12	8.20
15	10.38
18	12.65
21	14.60
24	16.20
27	18.30
30	20.27

Ks Data Analysis

First Row: 20 Last Row: 30.00 Q (cm^3/s): 29.86

Sample Height: 17.1 cm dh (cm): 9.0



ρ_b = 1.86 g/cm³

K_s = 1.7E-01 cm/s at T = 30.4 C

Standard Temperature = 20.0 C

	Viscosity (mPa S)	Density (g/cm³)
at T °C	0.790	9.948E-01
at Standard Temperature (°C)	1.002	9.974E-01

$K_{s\ Standard\ T}$ = 1.4E-01

10-Min Drain Down Analysis

Preliminary Volumetric porosity partitioning estimates				
Total	Macro	Fraction	Micro	Fraction
0.30	0.14	0.49	0.15	0.51
Preliminary Gravimetric porosity partitioning estimates				
	0.14	0.48	0.15	0.52

APENDICE B

HYDRODYNAMIC COLUMN TESTS
LABORATORY REPORTS

HYDRODYNAMIC LABORATORY REPORT

HydroGeoSense
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HYDRODYNAMIC COLUMN TEST - Hydraulic Conductivity Curve & Saturation Characteristic Curve

SAMPLE DESCRIPTION

Client/Project: WCG | Date Tested: July 11, 2014

Sample ID: Met 02-05 | Mine/Project Site: Casino

Description: Not Agglomerated w/ 2.93 kg/t lime

Moisture Content of Agglomeration: 0.42% | Raffinate Description: Synthetic, pH ~11

Test Parameters

Init. Bulk Density: 1.77 | Ore S.G.: 2.66 | Solution S.G.: 1.00 | Level of Agglomeration: L0

NUMERICAL RESULTS

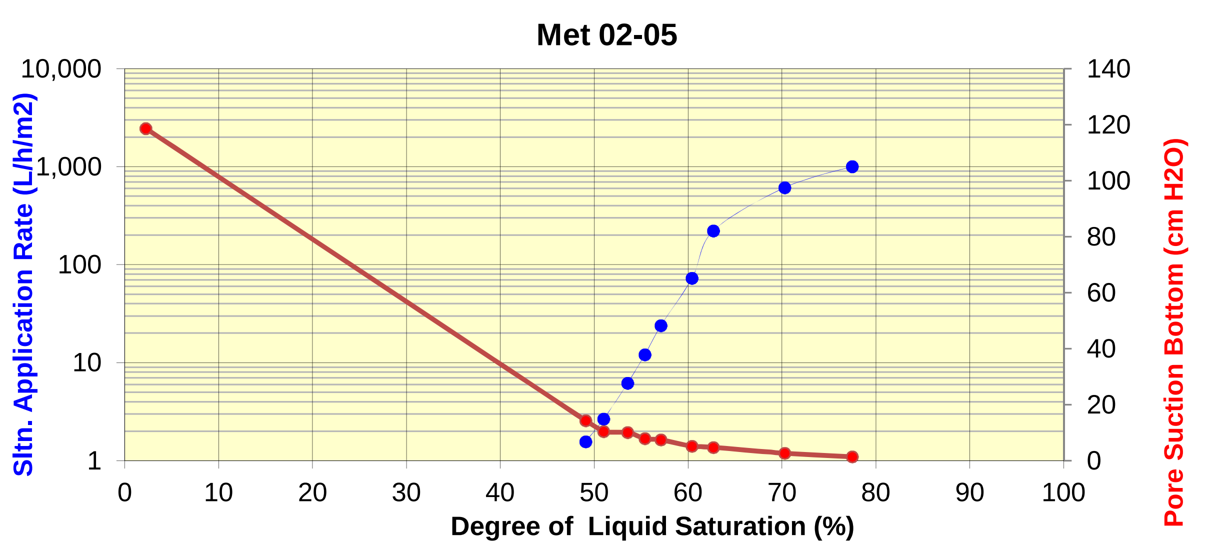
193

Sltn. Application Rate (L/h/m^2)	Grav. Moist. Cont. Dry Basis (%w_s)	Pore Suction Top (cm H_2O)	Pore Suction Bottom (cm H_2O)	Degree of Liquid Saturation (%)
0.0	0.4	118.7	227.7	2.2
1.6	9.2	14.3	6.7	49.1
2.7	9.6	10.4	3.7	51.0
6.2	10.1	10.1	2.1	53.6
12.1	10.4	7.9	1.4	55.4
23.9	10.7	7.4	1.2	57.1
72.8	11.3	5.2	1.6	60.4
221.8	11.7	4.8	1.7	62.7
612.7	13.1	2.7	0.9	70.3
1005.2	14.4	1.4	1.4	77.5

Porosity Estimates

	Total	Drained	Macro	Micro Drainable	Residual	Micro-Total
	0.331	0.197	0.137	0.059	0.134	0.193
Porosity Fraction:		0.594	0.415	0.179	0.406	0.585

GRAPHICAL RESULTS



HYDRODYNAMIC LABORATORY REPORT

HydroGeoSense
Because you need to know!

HYDRODYNAMIC COLUMN TEST - Conductivity Curves

SAMPLE DESCRIPTION

Client/Project: WCG

Date Tested: July 11, 2014

Sample ID: Met 02-05

Mine/Project Site: Casino

Description: Not Agglomerated w/ 2.93 kg/t lime

Moisture Content of Agglomeration: 0.42%

Raffinate Description: Synthetic, pH ~11

Test Parameters

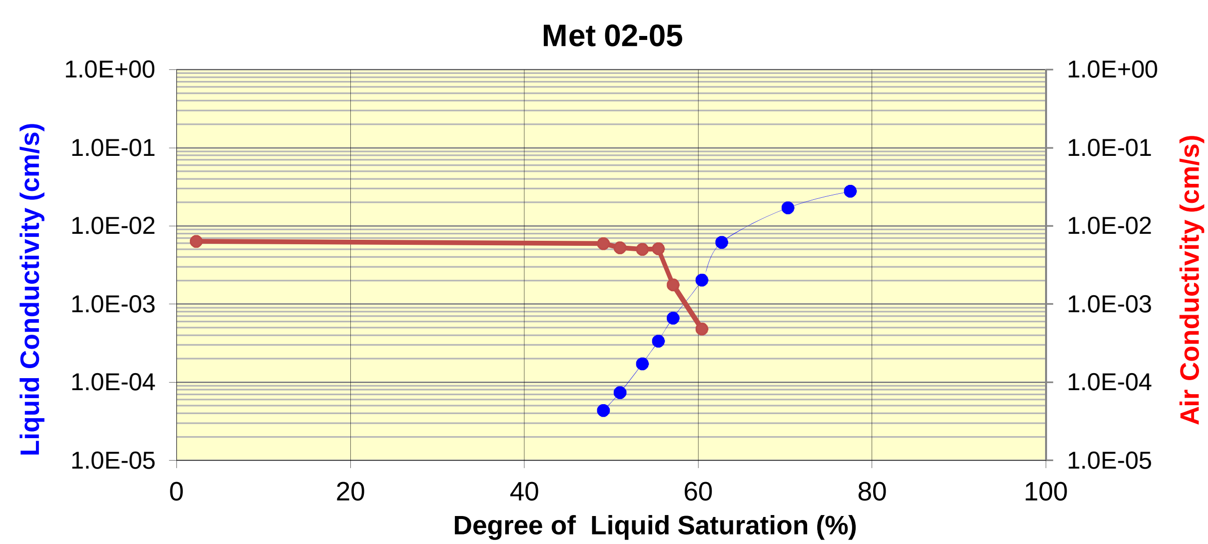
Init. Bulk Density: 1.77 Ore S.G.: 2.66 Solution S.G.: 1.00 Level of Agglomeration: L0

NUMERICAL RESULTS

193

Sltn. Application Rate ($L/h/m^2$)	Degree of Liquid Saturation (%)	Pore Suction (cm H_2O)	Conductivity Liquid (cm/s)	Conductivity Air (cm/s)
	2.2	118.7		6.3E-03
1.6	49.1	14.3	4.3E-05	5.9E-03
2.7	51.0	10.4	7.4E-05	5.3E-03
6.2	53.6	10.1	1.7E-04	5.0E-03
12.1	55.4	7.9	3.3E-04	5.1E-03
23.9	57.1	7.4	6.6E-04	1.8E-03
72.8	60.4	5.2	2.0E-03	4.8E-04
221.8	62.7	4.8	6.2E-03	
612.7	70.3	2.7	1.7E-02	
1005.2	77.5	1.4	2.8E-02	

GRAPHICAL RESULTS



HYDRODYNAMIC LABORATORY REPORT

HydroGeoSense
Because you need to know!

HYDRODYNAMIC COLUMN TEST - Hydraulic Conductivity Curve & Saturation Characteristic Curve

SAMPLE DESCRIPTION

Client/Project: WCG

Date Tested: July 11, 2014

Sample ID: Met 11-17

Mine/Project Site: Casino

Description: Not Agglomerated w/2.93 kg/t Lime

Moisture Content of Agglomeration: 0.30%

Raffinate Description: Synthetic, pH ~11

Test Parameters

Init. Bulk Density: 1.54 Ore S.G.: 2.63 Solution S.G.: 1.00 Level of Agglomeration: L0

NUMERICAL RESULTS

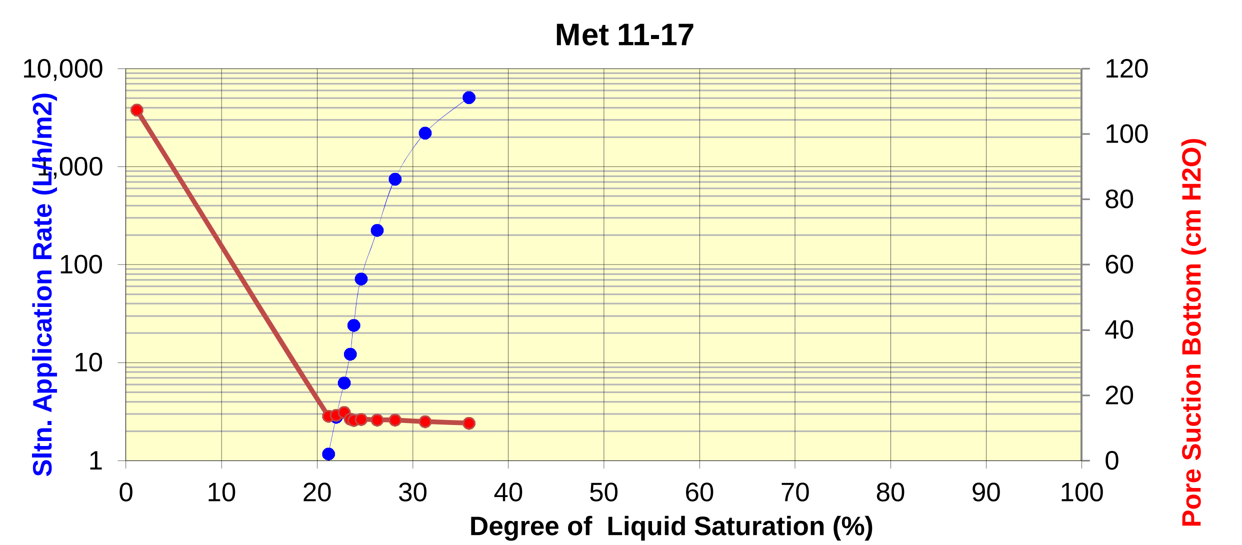
193

Sltn. Application Rate (L/h/m^2)	Grav. Moist. Cont. Dry Basis (%w_s)	Pore Suction Top (cm H_2O)	Pore Suction Bottom (cm H_2O)	Degree of Liquid Saturation (%)
0.0	0.3	107.4	265.0	1.1
1.2	5.7	13.6	5.1	21.2
2.8	6.0	13.9	4.5	22.0
6.2	6.2	14.8	3.4	22.8
12.2	6.3	12.7	2.8	23.5
24.2	6.4	12.3	2.1	23.8
71.8	6.6	12.7	2.2	24.6
224.8	7.0	12.5	1.2	26.3
748.6	7.5	12.4	0.9	28.1
2213.4	8.3	12.0	0.9	31.3
5097.2	9.5	11.5	1.6	35.9

Porosity Estimates

	Total	Drained	Macro	Micro Drainable	Residual	Micro-Total
	0.409	0.347	0.302	0.045	0.063	0.107
Porosity Fraction:		0.847	0.738	0.109	0.153	0.262

GRAPHICAL RESULTS



HYDRODYNAMIC LABORATORY REPORT

HydroGeoSense
Because you need to know!

HYDRODYNAMIC COLUMN TEST - Conductivity Curves

SAMPLE DESCRIPTION

Client/Project: WCG

Date Tested: July 11, 2014

Sample ID: Met 11-17

Mine/Project Site: Casino

Description: Not Agglomerated w/2.93 kg/t Lime

Moisture Content of Agglomeration: 0.30%

Raffinate Description: Synthetic, pH ~11

Test Parameters

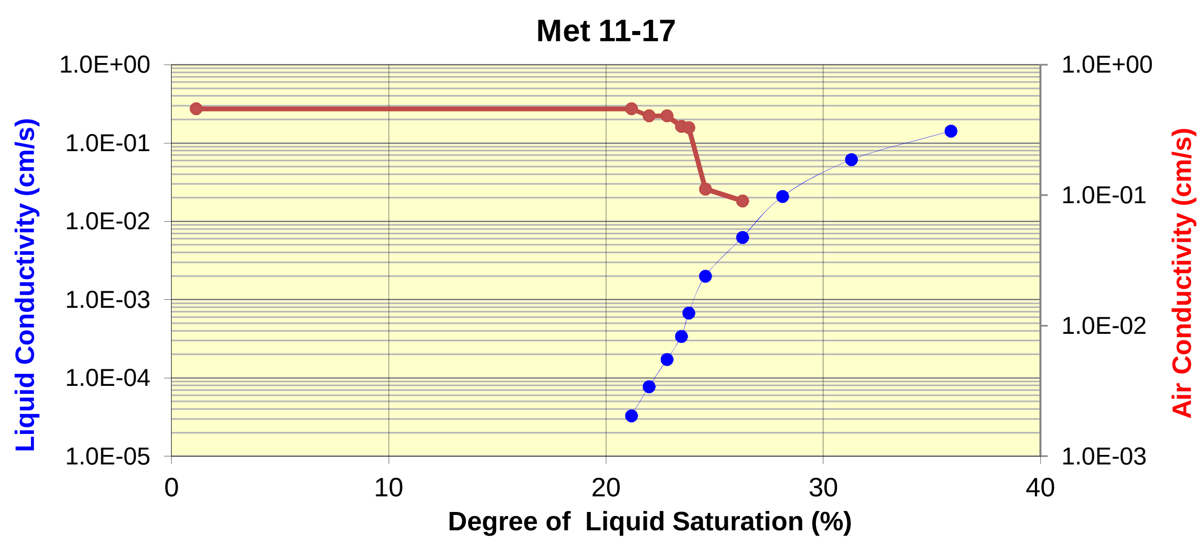
Init. Bulk Density: 1.54 Ore S.G.: 2.63 Solution S.G.: 1.00 Level of Agglomeration: L0

NUMERICAL RESULTS

193

Sltn. Application Rate ($L/h/m^2$)	Degree of Liquid Saturation (%)	Pore Suction (cm H_2O)	Conductivity Liquid (cm/s)	Conductivity Air (cm/s)
	1.1	107.4		4.6E-01
1.2	21.2	13.6	3.3E-05	4.6E-01
2.8	22.0	13.9	7.7E-05	4.1E-01
6.2	22.8	14.8	1.7E-04	4.1E-01
12.2	23.5	12.7	3.4E-04	3.4E-01
24.2	23.8	12.3	6.7E-04	3.3E-01
71.8	24.6	12.7	2.0E-03	1.1E-01
224.8	26.3	12.5	6.2E-03	9.1E-02
748.6	28.1	12.4	2.1E-02	
2213.4	31.3	12.0	6.1E-02	
5097.2	35.9	11.5	1.4E-01	

GRAPHICAL RESULTS



APPENDIX B.4G: Review and Updates to the Conceptual Wetland Water Treatment Design

VOLUME B.I: PROJECT INTRODUCTION & OVERVIEW

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Saskatoon, SK S7N4N1
306 978 3111
contangostrategies.com

Forward looking. Lateral thinking.

Technical Memo

To: Mary Mioska, Casino Mining Corp

From: Monique Haakensen, Contango Strategies Ltd

Date: December 2015

Project: Casino

Subject: Review and Updates to the Conceptual Wetland Water Treatment Design for the Casino Project

Document #: 005_1215_02B

1. Purpose

Contango Strategies Ltd (Contango) is providing this technical memorandum which reviews the conceptual wetland design provided in the document "Technical Memo: Wetland Water Treatment for the Casino Project (Clear Coast, 2013)", and describes subsequent analysis undertaken to refine the conceptual sizing for the constructed wetland treatment systems (CWTS, also referred to as treatment wetlands). This is part of a phased approach being taken for the development of closure water treatment options for the Casino Project (Appendix A). Future work is outlined to develop and implement the CWTS such that they will perform in a robust, predictable, and sustainable manner and will consistently achieve downstream water quality objectives. Additionally, an overview of the mine closure plan, with contingencies available to the Proponent to mitigate sources of contaminated water, or to improve water quality, are also discussed.

2. CWTS Design Selection

Benefits of CWTSs can include a decrease of total suspended solids (TSS), treatment of total and dissolved metals, and neutralization of acidic waters. CWTSs can be designed for seasonal or year-round water treatment, requiring varying degrees of maintenance ranging from passive care to semi-active management. CWTS can also be built into a treatment train with other passive, semi-passive, or active technologies to achieve objectives and/or lower overall operational water treatment costs. These options must take into account the water chemistry and flows, but also the overall site objectives and goals for water treatment and therefore, the CWTS.

The ITRC (Interstate Technology and Regulatory Council) design tree for mining impacted waters was used to aid in the selection of a CWTS as a preferred treatment technology for the Casino Mine (ITRC, 2003). There are numerous layouts and configurations that can be implemented for treatment wetlands, with varied hydrology, performance parameters, and operation and maintenance requirements.

For the modelling and sizing exercise described and discussed in this technical memorandum, the most passive design possible was considered for the Casino Mine. This design was chosen as the goal of final mine site closure is to ensure long-term physical and geochemical stability and to minimize reliance on long-term active treatment. To meet the requirements for water treatment with minimal intervention, the selected passive treatment wetland design is one where there is no operational management necessary, and only minimal periodic maintenance is required, which could be performed by manpower (i.e., without machinery). Based on these guiding objectives, the selected configuration at the Casino Mine is a horizontal surface flow treatment wetland (Figure 1). It is acknowledged that there are, other designs (e.g., subsurface flow, vertical flow) that could potentially achieve treatment in a smaller footprint, but these would be associated with greater operations and maintenance requirements. As such, these have been reserved as possible contingency measures and are presented in Appendix B.

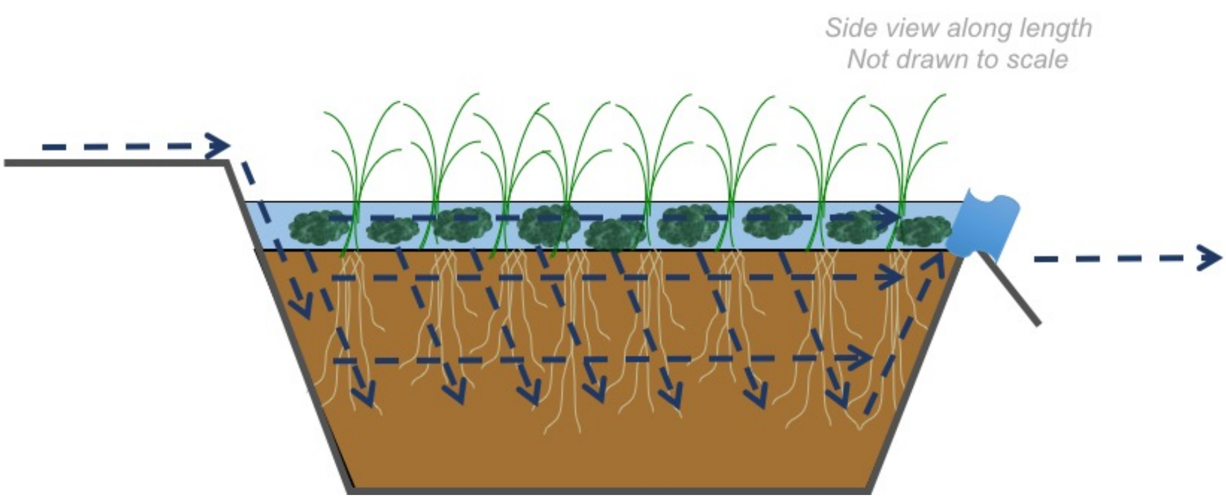

Figure 1. Conceptual diagram of horizontal surface flow wetland

Dotted arrows show flow path through wetland and into substrate and root zone. Vegetation in this example includes both emergent macrophytes (e.g., *Carex aquatilis*, aquatic sedge), and bryophytes (aquatic mosses), which have been found at the Casino site.

3. Methodology for Conceptual Sizing and Water Quality Prediction

3.1. Project Design

The Casino Project is a proposed Open Pit copper-gold-molybdenum mine in Yukon Territory. The Project includes an open pit mine, heap leach facility for gold ore extraction, process mill for copper and molybdenum concentrates, and tailings and waste rock management facility. Following the cessation of milling and mining activities, the tailings and waste rock will be stored subaqueously in the tailings management facility (TMF) which eventually will discharge from the south end to the receiving environment. Also, the open pit will fill with groundwater and precipitation, and will also overflow into the north end of the TMF. Water quality models predict that water from the TMF pond and the open pit may be elevated in metals (e.g., copper), metalloids (e.g., selenium), and sulphate, compared to the receiving environment, and as such, require treatment prior to discharge. The contaminants are predicted to be present at relatively low concentrations (i.e., in terms of excess over CCME and also treatability potential in a CWTS) and circum-neutral pH, but at relatively high flows in consideration of the receiving stream (i.e., >100 L/s). These conditions favour the use of passive treatment technologies such as CWTSs. Initial design of the CWTS was provided in a Technical Memo: Wetland Water Treatment for the Casino Project (Clear Coast, 2013).

To evaluate the robustness of the initial CWTS design, and provide planning for future testwork, Contango has conducted an assessment of the sizing and water quality under the following Project considerations, which have been varied from the original assessment provided in the 2013 technical memo (Clear Coast, 2013) as outlined in Table 1.

Data used for conceptual sizing was derived from the Water Quality Model used in the Casino Project Proposal for Executive Committee Review pursuant to the Yukon Environmental and Socio-Economic Assessment Act Appendix A.7B (Casino Mining Corp, 2014) and included the following water quality assumptions:

- North TMF Wetland: Data included both the median (P50) model output from 52 realizations of the model, and results from a single realization (R1) which presents greater variability.
- TMF Pond entering the South TMF Wetland: Includes water quality predictions for the R1 scenario outflow from a 12 hectares North TMF Wetland, provided by Contango Strategies. The TMF pond is also modelled for flows as a median (P50) model output from 52 realizations, and as a single realization (R1) which presents greater variability.

Table 1 - Comparison of Original Design and Updated Assessment Criteria

Original Design (Clear Coast, 2013)	Updated Assessment Criteria
Regulated flow from the Open Pit to the North TMF wetland	Unregulated/uncontrolled flows at all points
Bioreactor treatment of draindown from the heap leach facility	Heap leach facility (HLF) has no treatment during draindown while reporting to Open Pit
Treatment wetlands at North and South TMF	No change
TMF pond water quality included W43 adit discharge, inaccurately contributing excess cadmium to TMF pond in the post-closure period	TMF pond water quality has updated background runoff concentrations (i.e., from Brynelson Creek)
Controlled discharge of the South TMF wetland through the spillway, in relation to discharge from the water management pond	South TMF wetland outflow modelled assuming no flow control
Assumed no freezing of Open Pit, TMF, or treatment wetland water in winter	No change

3.2. Site Investigation

Following years of site-specific data analysis and information gathering using baseline studies and water quality modelling, a CWTS site feasibility assessment was conducted by Contango at the Casino site on August 11-13, 2015 to fill in remaining information gaps. The objectives were to determine feasibility of CWTS implementation, identify potential borrow sites for plants and hydrosoil substrate, evaluate natural remediation processes occurring on site, and collect plants for future pilot-scale CWTS testing.

The results from the site assessment are reported in Document #005_1215_01B (Contango, 2015) and briefly summarized here:

- The predicted closure water quality for the Casino Mine is amenable to water treatment by CWTSs.
- Wetland treatment capacity could be improved beyond what is naturally observed at the site by using soils with better hydrology and microbial habitat properties.
- Four types of wetland plants were identified as potential candidates for CWTS, including *Carex aquatilis* (aquatic sedge), *Carex utriculata* (beaked sedge), *Calamagrostis canadensis* (bluejoint reedgrass), and aquatic bryophytes (mosses).
- Natural and passive beneficial processes were identified at the Casino site. These include microbially catalyzed sulphide production associated with soils, plant roots, and mosses, which can remove metals from water as sulphide minerals. Additionally, uranium-, selenium-, and molybdenum-reducing

microorganisms were found to be abundant in numerous samples from the site. Beneficial microbes were found to be capable of living in more than 14.7 mg/L dissolved copper.

- Mosses were found to host a broad range of beneficial microorganisms and have high sorption/uptake, and are recommended for co-planting in the CWTS along with emergent macrophytes (i.e., *Carex*).
- Results from pilot-scale CWTSs will be required to further refine recommended sizing and outflow predictions.
- The beneficial microorganisms and plants were natural to the Casino site, and therefore capable of withstanding the climatic and chemical fluctuations experienced in the watersheds of the area.

3.3. Assumptions

The following assumptions were incorporated into the CWTS modelling:

- The water is near neutral pH and net alkaline.

- The water balance model assumed no freezing in winter, which in Northern environments is an exceptionally conservative estimate given the location and climate of the Casino Mine. Therefore, the models may predict higher concentrations of constituents of concern in the downstream receiving environment than is likely to occur under freezing conditions.

- Sizing of CWTSs are typically driven by parameters that are elevated compared to water quality objectives, and also by accessory compounds that are either required for, or interfere with, treatment. For the Casino CWTSs, aluminum, cadmium, copper, fluoride, selenium, sulphate, uranium, and zinc were elevated in the model predictions. Other than fluoride, these constituents can be targeted for treatment through a CWTS. Sulphate is addressed in Section 5. Based on predicted concentrations and rates of removal, aluminum and zinc are not expected to be factors for sizing and are easily treated by a CWTS, and hence cadmium, copper, selenium, and uranium were used in the CWTS model to develop conceptual sizing. Copper was selected because it is a key constituent of concern at the Casino Mine, while cadmium, selenium, and uranium were selected as they tend to either have low rate coefficients, or low targeted levels, both of which result in a larger wetland size requirement for treatment. Because the removal of most elements in a treatment wetland abides by a first order rate kinetic, lower target concentrations require exponentially larger sizing.

- Rate kinetics were used for water of approximately +4 to +10°C, which is similar to water temperatures recorded at the site during the CWTS feasibility assessment.

- The treatment wetland is conceptually designed to incorporate features that make it less prone to temperature fluctuations. These include beneficial cold-loving (psychrophilic) bacteria that have been found to associate with the roots of wetland plants at the Casino site, and also the incorporation of aquatic bryophytes (mosses) into the planted area such that there will be an annual balance between sorption (cold months) and remineralization and sedimentation of the sorbed elements via microbial sulphate reduction in warmer months.

- Because naturally psychrophilic (cold loving), copper-tolerant, and sulphide-producing bacteria have been confirmed to exist at the Casino site (Contango, 2015), lower temperatures are not expected to result in a decreased performance rate. Moreover, owing to the stoichiometry of the predicted water chemistry, sulphides are expected to be produced in orders of magnitude excesses through warmer temperature months, such that sulphide production is not rate limiting during colder months.

3.4. Removal Rate Coefficients and Calculations

An important factor for wetland design is the rate of treatment, also known as the treatment rate coefficient (*k*). The treatment rate coefficient is based on the treatability of a specific compound and the hydraulic retention time of the system, both of which are site-specific based on water chemistry, wetland designs, and characteristics of the system. A treatment rate coefficient (*k*) was applied for Cd, Cu, Se, and U, in order to develop a conceptual size for the Casino Project CWTSs and determine which elements and load sources were key for treatment (Table 2).

Based on experience from other treatment wetlands in the Yukon, the treatment rate coefficient *(*k) applied for Se follows a zero-order reaction kinetic, while the rate coefficients for Cu, U, and Cd follows first-order kinetics. The treatment rate coefficients for Cu and Se were derived from pilot-scale systems vegetated with *Carex aquatilis* that were tested for another site in the Yukon for treatment of these elements. Meanwhile, the coefficients for Cd and U were from pilot-scale testing that has been conducted for a mine in the Northwest Territories. The water chemistry in both cases is similar to that predicted for the Casino mine, as they are also low in iron, which depresses treatment rates.

In Equations 1-4, *Cf* is final concentration, *Ci* is initial concentration, V is volume of water in the system, and Q is flow rate. Using the removal rate coefficients (*k*) in Table 2 and Equations 1-4, parameters can be rearranged to solve for those of interest, such as the volume needed, that in turn determines the area of wetland required which is dependent upon the design. In order to determine the area required, a conceptual water depth of 80 cm was used, which is calculated from the assumptions of a horizontal surface flow wetland with 30 cm of free water at the surface and 1.5 meters of substrate with an expected 33% pore space filled with the water.

The treatment rate coefficients applied here are intended to be a conservative estimate for conceptual sizing purposes, and will need to be refined through pilot-scale (off site), and demonstration-scale (on site) testing, as removal rate coefficients are highly site-specific and must be developed in a site-specific manner, for each element of interest. While they may sometimes be applied in a conceptual manner to other situations/sites (as was done here), caution should be taken in applying a removal rate coefficient developed for one design and water chemistry to a very different chemistry or design basis. It is also often the case that *k* must be calculated and applied for different ranges of certain constituents, which can be further refined with pilot-scale and demonstration-scale testing.

Table 2 – Elements considered in treatment wetland models, with respective CCME guidelines and treatment rate coefficient (*k*) values

Element	CCME guideline (mg/L) [1]	*k* [2]
Cd	0.00037	0.008
Cu	0.004	0.0488
Se	0.001	0.0001
U	0.015	0.008

[1] CCME guidelines are based on predicted hardness of 357 mg/L for the North TMF wetland and 493 mg/L hardness for the South TMF Wetland, and long-term concentration guidelines for the protection of aquatic life

[2] All treatment rate coefficients are for first-order reaction kinetics except for selenium which is a zero-order reaction rate kinetic.

$$k = \frac{-\ln\left(\frac{Cf}{Ci}\right)}{V}\, x\, Q$$

Equation 1. Equation for calculation of first-order removal rate coefficient.

$$V = \frac{-\ln\left(\frac{Cf}{Ci}\right)}{k} \, x \, Q$$

Equation 2. Equation for calculation of first-order removal rate coefficient, rearranged to solve for volume of water in the system.

$$k = \frac{(Ci - Cf)}{V} \, x \, Q$$

Equation 3. Equation for calculation of zero-order removal rate coefficient.

$$V = \frac{(Ci - Cf)}{k} \, x \, Q$$

Equation 4. Equation for calculation of zero-order removal rate coefficient, rearranged to solve for volume of water in the system.

3.5. Sensitivity Analysis

While flow regulation was included in the original Project Design, the post-closure objectives include minimizing on-site activities, which may include maintenance of those flow regulation systems. Therefore, the treatment wetlands were evaluated to determine the impact of no flow regulation. The original wetland sizes proposed (Clear Coast, 2013) were assessed to determine if they would be capable of treating the water with variable (i.e., natural instead of controlled) flows.

Sensitivity analysis was conducted by testing the P50 and R1 water quality and flows in a model for each of the four elements on a month to month basis. The wetland sizes originally proposed resulted in an improvement of water quality; however, especially in periods of high flow, the decrease in concentrations of constituents of concern is less than would be desired. As such, a second round of sensitivity analysis was conducted for both the North and South TMF treatment wetlands to determine what size would be able to meet a specified outflow concentration without flow regulation.

The original sizing and outflow predictions for each treatment wetland at Casino proposed outflow concentrations meeting CCME guidelines (Clear Coast, 2013). As such, Contango compared outflow concentrations of the treatment wetlands to CCME guidelines for reference purposes. However, the treatment wetlands are not necessarily required to meet CCME at the outflow. Rather, an appropriate outflow concentration will need to be determined once site-specific water quality guidelines are developed for the receiving environment downstream of the treatment wetlands outflow (e.g., the W4 or W5 monitoring points). Once the downstream water quality objectives are set, outflow objectives can be set for the South TMF. At that time, the treatment wetlands sizing, placement, and design can be revisited to ensure appropriate outflow concentrations are being achieved according to seasonal receiving capacity of Dip Creek and/or Casino Creek, to meet compliance at the monitoring point. Although a treatment wetland can be designed to ensure a maximum outflow concentration is not exceeded, the actual outflow concentrations will vary according to inflow volumes and chemistries. Therefore, an additional sensitivity analysis on the receiving environment should be performed to assess assimilative capacity and identify critical times where the lowest outflow concentrations are needed from the treatment wetlands.

3.6. Treatment Wetland Sizing

First, the North TMF treatment wetland was assessed, to determine plausible outflow concentrations reporting to the TMF with different wetland sizes and no flow control of the water from the open pit. Once the North TMF was sized, then the TMF water quality was re-calculated with this new inflow water quality from the North TMF wetland flowing naturally to the TMF.

Subsequently, the same exercise was conducted for the South TMF wetland, to first assess the size that would be needed to meet CCME concentrations at outflow without flow regulation, and secondly to determine a realistic conceptual size that could be constructed.

The results of this modeling are provided below.

4. Results

Conceptual sizing based on the calculations and sensitivity analysis is provided in Table 2 and Table 3. The sizes in Table 2 are the treatment area needed in hectares, and does not include berms and access points, for which 10-25% should be added to the treatment size. The wetland size for the North TMF (12 ha) was selected to decrease metal loads to the TMF in order to lessen the reliance on the South TMF treatment wetland (Table 4). The South TMF wetland size of 12 hectares was selected such that the outflow concentrations would be at or below CCME guidelines in all average and median cases (Table 5). The sensitivity analysis found that the treatment is more greatly affected by moderate concentrations at high flow volumes, than by elevated concentrations with low flow volumes. Uranium drives the wetland sizing for the South TMF wetland (Table 3), and this will be examined further to identify loading sources to the TMF for further mitigation and treatment.

Table 2. Conceptual sizes (in hectares) for North TMF treatment wetland with no flow regulation to meet CCME guidelines in the discharge (as per Table 1).

Size	Cadmium		Copper		Selenium		Uranium	
	P50	R1	P50	R1	P50	R1	P50	R1
Maximum	33	60	17	32	7	11	19	33
Average	7.0	8.5	3.6	4.5	1.3	1.5	4.0	4.8
Median	2.6	2.7	1.3	1.4	0.6	0.5	1.5	1.5
Conceptual Size Selected	12							

Table 3. Conceptual sizes (in hectares) for South TMF treatment wetland with no flow regulation to meet CCME guidelines in the discharge (as per Table 1).

Size	Cadmium		Copper		Selenium		Uranium	
	P50	R1	P50	R1	P50	R1	P50	R1
Maximum	6	19	13	47	7	25	25	95
Average	0.7	1.0	4.1	6.2	1.5	2.4	7.8	11.7
Median	0.4	0.3	3.0	3.0	1.0	1.1	5.6	5.6
Conceptual Size Selected	12							

Table 4. Conceptual outflow concentrations for 12 hectare North TMF treatment wetland with no flow regulation.

Size: 12 ha	Cadmium		Copper		Selenium		Uranium	
	P50	R1	P50	R1	P50	R1	P50	R1
Maximum	0.001526	0.00207	0.03317	0.30443	≤0.001	≤0.001	0.0237	0.0321
Average	≤0.00037	≤0.00037	≤0.004	0.00506	≤0.001	≤0.001	≤0.015	≤0.015
Median	≤0.00037	≤0.00037	≤0.004	≤0.004	≤0.001	≤0.001	≤0.015	≤0.015

Table 5. Conceptual Outflow concentrations for 12 hectare South TMF treatment wetland with no flow regulation.

Size: 12 ha	Cadmium		Copper		Selenium		Uranium	
	P50	R1	P50	R1	P50	R1	P50	R1
Maximum	≤0.00037	0.000418	0.00533	0.04905	≤0.001	0.00376	0.02703	0.03973
Average	≤0.00037	≤0.00037	≤0.004	≤0.004	≤0.001	≤0.001	≤0.015	≤0.015
Median	≤0.00037	≤0.00037	≤0.004	≤0.004	≤0.001	≤0.001	≤0.015	≤0.015

5. Sulphate

Sulphate was not included in the modelling for CWTS sizing. In general terms, sulphide (reduced form of sulphate) is necessary for metals treatment, but in turn, metals (cations) are required to remove sulphide from solution. Based on stoichiometry, the ratio of sulphide mineral forming metals and metalloids in the water (e.g., Fe, Cu, Cd, etc) to sulphide suggests that there is a molar ratio of several orders of magnitude excess sulphate compared to cationic metals. The predicted closure water chemistry at the Casino Mine therefore suggests that removal of metals and metalloids from the water should be consistently accomplished with little impacts of seasonal variation; however, it also implies that only very minimal sulphate treatment will be achieved passively for these waters (e.g., decreases of <10mg/L in most cases).

That is to say, the reason that sulphate concentrations are not expected to decrease greatly in the treatment wetlands is because there are low concentrations of metals to be treated in general. While this is not ideal for sulphate treatment, this does mean that there are sufficient concentrations of sulphate in the water to safeguard against fluctuations of influent metal concentrations.
It should be thoroughly evaluated what the downstream water quality objectives will be for sulphate, as well as whether or not sulphate treatment will be required in order to meet those objectives.

If deemed necessary, sulphate treatment can be achieved by semi-passive methods which are being evaluated as contingency options. For example, the system could remain operationally passive with only an increase of periodic maintenance requirements by incorporating iron bearing rock into treatment wetland substrates or conveyance channels to balance cationic requirements for sulphate removal. These would periodically require replenishment. If necessary, semi-passive approaches that require a greater degree of management could be considered, including bioreactors, or metering liquid organic carbon sources into the treatment wetlands to provide additional electron sources equivalent to the magnitude of sulphate reduction that is required.

6. Contingencies

Treatment performance of the wetlands will be further refined through site-specific pilot-scale and demonstration-scale testing and optimization (Appendix A). In addition, alternatives and contingencies continue to be explored as alternative or additional options to further improve water quality, and minimize potential risk during closure of the Casino Mine. This will be an ongoing exercise throughout planning and the active mine life. This is expected to be achieved not only through the direct improvement of the treatment wetland performance (through pilot- and demonstration-scale testing and optimization), but also through integration of other potential treatment areas and mechanisms. A list of contingencies to be considered is provided in Appendix B, which is a living document intended to remain evergreen.

One such contingency is the implementation of CWTSs at additional sources of high metal water at the mine site, most notably the area downstream of the TMF embankment, where seepage under the embankment is collected. With the treatment wetland in place at the South TMF, the seepage discharge has the highest loading of constituents of concern to Casino Creek. This is currently mitigated through a seepage collection and discharge system (i.e., the Water Management Pond (WMP) that collects seepage in the winter, and discharges it in spring and summer. To provide additional protection of the receiving environment, it may be prudent to install a secondary treatment wetland in the area of seepage discharge, to further reduce the load being discharged to Casino Creek and to minimize flow control. Therefore, the seepage collection area is under consideration for an additional treatment wetland, should it prove to be feasible for construction and water management. Alternatively, other semi-passive water treatment technologies (e.g., bioreactors) may be considered in the WMP area.

Whichever contingencies are explored, this must be done in the context of both the site water management plan, and predicted effects on the downstream receiving environment. Before further modelling is performed to optimize the conceptual treatment wetland design and layouts, a receiving water quality objective (e.g., W4 or W5) should be set for constituents of concern. Looking again at Equations 1-4, they can be rearranged to solve for a desired *Cf* (outflow concentration). Therefore, if a targeted concentration objective is set, the treatment wetlands (or alternative contingency technologies if necessary) can then be designed to achieve that downstream water quality objective.

Examples of contingencies being considered include:

- Incorporate treatment wetland at the WMP area. Design the South TMF treatment wetland and WMP treatment wetland to jointly meet downstream water quality objectives.
- In pit treatment during/through early closure, prior to release from pit.
- Addition of HLF wetland to decrease loads or interfering compounds (nitrate) to the South TMF wetland.
- Enhancing wetland treatment by dosing of electrons (e.g., ethanol, methanol, straw, wood chips).
- Incorporation of materials with iron in conveyance channels and wetland construction materials to promote sulphate treatment.
- Strategic co-management of water sources.
- Incorporation of spillways/conveyance channels to promote glaciation in winter months.

7. Recommendations and Next Phases of Work

The conceptual sizes recommended at this time are 12 hectares of treatment wetland at both the North TMF and South TMF. This sizing is conceptual, and the size, location, and design will continue to be refined and optimized through a phased program throughout the Project design and during construction and operations, as representative water quality becomes available. This phased program is further outlined in Appendix A.

The next steps for recommended work are:

1) Once downstream water quality objectives are set, outflow objectives can be set for the South TMF and the treatment wetland sizes can be evaluated to achieve appropriate outflow concentrations according to seasonal receiving capacity of Dip Creek and/or Casino Creek, depending on the monitoring point.
2) Assess whether additional treatment wetlands may be required to meet downstream water quality objectives (e.g., at WMP).
3) Refine predictions and sizing through off-site pilot-scale testing and optimization.
4) On-site demonstration-scale confirmation and optimization.
5) Full-scale implementation.

8. Closure

We trust the information herein satisfies your present requirements. Should you have any questions, please contact the persons listed below. We appreciate the opportunity to provide the services detailed in this report, and look forward to discussing any comments you may have.

Regards,

Contango Strategies Ltd.

Monique Haakensen, PhD, RPBio, PBiol, EP

Vanessa Pittet, PhD, EPt

9. References

Casino Mining Corporation (January 2014) Casino Project Proposal for Executive Committee Review pursuant to the Yukon Environmental and Socio-Economic Assessment Act (Project #2014-0002). Appendix A.7B Water Quality Predictions Report – Source Environmental Associates, February 2015.

Clear Coast Consulting Ltd. (December 2013) Casino Project – Wetland Treatment System Design. Prepared for Casino Mining Corporation.

Contango Strategies (December 2015) CWTS Site Assessment Report for Casino Mine. Draft Report. Document #005_1215_01B

ITRC (December 2003) Technical and Regulatory Guidance Document for Constructed Treatment Wetlands. The Interstate Technology & Regulatory Council Wetlands Team.

Appendix A – Phased CWTS Development

1. Introduction to phased CWTS development

The following is a general outline of the steps required to develop an effective CWTS with predictable and robust performance. The phases for CWTS development incorporate information gathered from a site assessment and several scales of testing which may include bench/laboratory-scale, pilot-scale (controlled environment and/or outdoor cold-climate at Contango's dedicated CWTS facilities), and demonstration-scale (smaller scale than full-size, on-site). The purposes of each testing scale are outlined in Table A1. Phase 1 has recently been completed and is reported in Contango Document #005_1215_01B. A description of Phase 2 and Phase 3 is provided in the following sections.

Phase 1: Information Gathering and Site Assessment (revisited as needed throughout all phases)

1. Characterization of water for treatment
2. Evaluation of water reuse options (or discharge and mixing points)
3. Site assessment to:
    a) Determine feasibility of CWTS implementation
    b) Identify targeted constituents and performance goals
    c) Identify borrow sites for plants and hydrosoil substrate
    d) Evaluate natural remediation processes occurring on site
    e) Collect plants for pilot-scale CWTS testing
4. Conceptual design of pilot-scale CWTS based on information gathered (one or more designs may be tested in Phase 2)

Phase 2: Off-site Pilot-scale Testing and Optimization

1. Assembly of pilot-scale CWTS at Contango (indoors and/or outdoors)
2. Performance monitoring and stress testing using simulated influent

Phase 3: On-site demonstration-scale design and monitoring

1. Design of on-site demonstration scale CWTS
2. Construction of demonstration scale CWTS at site
3. Performance monitoring

Phase 4: Full-scale implementation

4. Design of full-scale CWTS
5. Construction bids, permit and initiation
6. Construction and post-construction monitoring
7. Planting and/or maturation
8. Acclimation and initial monitoring
9. Ongoing operation and periodic monitoring of CWTS

Table A1: Stages of CWTS testing and optimization

Aspects and Parameters	CWTS Scale			
	Phase 2		Phase 3	Phase 4
	Bench/ Lab	Pilot (off site)	Demo (on site)	Full
Test various chemistries	+	+		
Test different sediment makeups	+	+		
Test different plant efficacies/properties	+	+		
Environmental parameter control[1]	+	+		
Develop flow rates and water depths (and resultant hydraulic retention time)		+		
Develop rate coefficients and kinetics		+		
Acquire proof-of-concept		+		
Intensive monitoring	+	+	+[2]	
Determine parameters for proper sizing		+	+	
Measure removal extent		+	+	+
Evaluate cold weather performance		+	+	+
Compare demo/full- and pilot-scale data			+	+
Confirm removal rates/extents			+	+

[1]if performed in facility with controlled environment.
[2]intensive monitoring on-site may or may not be possible depending on circumstances.

1.1. Phase 2 CWTS Development: Pilot-scale Testing and Optimization

Successful CWTS design incorporates site-specificity, appropriate piloting and optimization, and a detailed understanding of microbial processes. When a design has been established for a CWTS, it needs to be tested to verify successful operation. To start this process, a series of bench- and/or pilot-scale experiments are initiated to confirm specific treatment mechanisms, and since these are conducted at a smaller scale, making corrections and adjustments to the design, uncovering unforeseen complications, and other unexpected problems can be remedied very quickly and cost-effectively. This facilitates the scaling-up process and potential troubleshooting when demonstration- or full-scale CWTSs are implemented.

Depending on the site-specific considerations and characteristics of the water (Phase 1), the recommended number of pilot-phase (Phase 2) iterations may be one or multiple. It must be recognized that a single site with more than one type of water requiring treatment may accordingly require multiple passive treatment systems, each with their own design, testing, and implementation plans. In certain cases, Phase 2 can be split into Phases 2A and 2B, where the first pilot-scale CWTS is tested in indoor greenhouse facilities, followed by Phase 2B which is constructed outdoors to test a cold climate environment.

Pilot-scale systems are typically built using large tubs or tanks to represent individual wetland treatment cells, which enables removal rate coefficients to be developed across a range of concentrations as treatment occurs and subsequently, the rate coefficients can be used for appropriate sizing of the full-scale system. A simulated version of the water requiring treatment is used in the pilot-scale study, where the entire water chemistry is reflected in order to be representative of actual treatability (i.e., not just be comprised of the key elements of concern for treatment). This also provides the opportunity to test a range of water chemistries that mimic different scenarios (e.g., worst-case, predicted long-term water quality, etc) and/or water sources. Flow rate fluctuations can also be imposed and system upsets triggered purposefully (e.g., drought or flooding) to test the effects on treatment.

For the Casino site, in addition to developing rate coefficients for effective sizing of full-scale systems, other design aspects for the CWTS need to be tested at a pilot-scale, such as optimal plant selection, and organic amendments for the substrates. Plant-specific attributes are also evaluated, such as suitability for transplanting, effects on water flow (i.e., short circuiting of water), uptake of constituents of potential concern, natural plant density achieved, effects of plant species on soil redox, tolerance to variations in water depth, and biomass production (organic carbon production for following year). A period of three or more months is often necessary for pilot-scale testing not only for plant acclimation, but also to observe actual treatment within a system beyond that which is attributable to sorption. The loading of constituents of concern into the sediment is also determined at the end of pilot-scale testing.

1.2. Phase 3 CWTS Development: On-Site Demonstration-scale Design and Monitoring

Following pilot-scale testing, an on-site demonstration-scale wetland is recommended. The purpose of the on-site demonstration-scale wetland is to confirm the functionality on site, and make adjustments to rate coefficient calculations required for full-scale sizing. In many cases, the on-site demonstration system can become a part of the full-scale system. For example, it may be the first of two or three parallel systems that will comprise the full-scale design. Other times, the on-site demonstration is a stand-alone system that is decommissioned prior to the construction of the full-scale system.

Appendix B – Addressing risks and uncertainties through Contingencies

1. Risks and uncertainties associated with passive treatment for Casino Project

There are many cases where passive treatment has been successfully applied. Some of these cases were recently reviewed by the Yukon College (2014). Fortunately for learning purposes, there are also cases where passive treatment has not been successful. These serve as an opportunity to identify risks and uncertainties with such systems, and retrospectively develop mitigation strategies to address these on future applications. Generally speaking, unsuccessful passive treatment designs are typically lacking site-specificity, appropriate piloting and optimization, and a detailed understanding of microbial processes (Haakensen et al, 2015a; Table 1). Based on review of the proposed plan for passive treatment at the Casino Project as outlined in Brodie 2013, Contango has identified risks and uncertainties associated with the proposed passive treatment for the Casino Project (Table 2). Each of these risks or uncertainties can be addressed through a process-driven phased approach for CWTS design, as outlined in Appendix A.

Table 1 - Features of successful CWTS designs
*Modified from Haakensen et al, J. Environmental Solutions for Oil, Gas, Mining, vol. 1: 59-81, 2015a.

Design Aspect	Risks	Steps Towards Success
Site-specific	Design is based only on calculations from other sites or text book	Design incorporates consideration of data and experience from other sites with site-specific data
	Site-assessment has not been performed	Natural attenuation/treatment at site has been evaluated and characterized (e.g., testing through areas receiving effluent or seepage)
		Information regarding site-specific design aspects has been gathered (e.g., constructability, snowfall, freshet, growing season, storm events)
	Water characterization is focused only on parameters needing treatment, and does not consider total water chemistry that will affect treatability	Detailed water characterization has been performed in the context of passive treatment
		Potential treatment pathways have been identified in context of entire water chemistry (not just constituent of concern)
Appropriate process-driven piloting and optimization	Implemented based on calculations only	Calculations form a conceptual basis, but are revisited through phases of piloting and optimization
	Pilot CWTS implemented directly on site	Phased approach taken to piloting, allowing for optimization of design prior to implementation
		Often would involve bench and/or pilot-scale testing in a controlled facility, pilot/demonstration on site, then full-scale implementation
	Short duration (<3months)	Sufficient length to test actual treatment beyond initial sorption capacity of system
		Timeline allows for plant acclimation and system maturation
Detailed understanding of microbial processes	Plant uptake is considered main treatment mechanism	Plant uptake should be minimized in most cases, actual uptake quantified, and subsequent cycling evaluated to prevent re-release through decomposition
	'Common culprits' listed, but no microbiological testing performed	Most-probable number growth-based testing for processes of interest (e.g., reduction of iron, molybdate, nitrate, selenate, selenite, sulphate; oxidation of ammonia, iron; decomposition of organic compounds)
		Baseline testing of microbial communities to identify diversity and robustness of natural community capable of performing treatment reactions
		Key plants at site have been characterized for associations with beneficial microbes for needed processes

Table 2 - Risks and uncertainties with proposed passive water treatment wetlands for Casino Project (order in table does not hold relevance)

	Risk/Uncertainty	Addressed during Phase	Addressed By	Conceptual Contingency Measures
1	Outflow concentration objectives and ability to meet these at ranges of flows, concentrations, and temperatures	(1) Information Gathering (2) Pilot-scale testing (off-site), (3) demonstration-scale testing (on-site)	- Analysis of literature for outflow concentrations of similar passive treatment systems. - Reassessing wetlands sizing with refined water quality models, using kinetic-based removal rate coefficients. - Consideration of wetland locations and sizes in context of load contribution. - Evaluate wetland objectives in context of goal for outflow concentration *vs* load reduction (i.e., meeting a wetland outflow objective *vs* meeting a downstream receiving environment objective), with consideration for evaporation and evapotranspiration rates in wetlands sizing and effects on concentration. - Pilot-scale design and optimization program to develop site-specific removal rate coefficients and thermodynamic minimums for relevant water chemistry predictions. - Demonstration-scale optimization and testing program on site to confirm and refine above designs, analyses, and calculations.	- The revised recommendations for conceptual treatment wetland sizes should be larger than expected to be needed, providing additional footprint for construction if additional treatment area needed. - Control of flow from open pit with solar powered valve. - Treatment of HLF draindown by bioreactor. - In-pit treatment. - Added treatment wetland for HLF seepage to TMF. - Construction of demonstration-scale treatment wetland at WMP early in operations. - Enhancing wetland treatment by dosing of electron donors (e.g., ethanol, methanol, straw, wood chips). - Incorporation of materials with iron in conveyance channels and wetland construction materials to promote desired cation-anion balance.
2	Range of element concentrations that local wetland plant species are able to thrive in	1, 2	- Site-assessment comparing water and soil elemental concentrations to locations where plants of interest are naturally growing - Testing at pilot-scale.	- Strategic co-management of water sources. - Application of bioreactors or in pit treatment for partial pre-treatment.
3	Plant selection for wetlands, ensuring other plants do not invade treatment wetland and alter operation	1, 3	- Site assessment to identify most abundant and early colonizing plants at site. - On-site demonstration-scale wetland built early in operations and monitored for non-desired plant species.	- Monitoring and maintenance schedule includes survey for and removal of non-desirable plant species.

Risk/Uncertainty		Addressed during Phase	Addressed By	Conceptual Contingency Measures
4	Understanding of natural microbial potential associated with environments at Casino Project	1, 2, 3	- The site assessment will identify environments that encourage beneficial microbial communities (e.g., plant species, water flow and depth). - These will be compared with pilot and demonstration scale wetlands to determine if the designs were successful in promoting robust microbial treatment capacity.	- Multiple wetland designs may be tested to achieve operating parameters necessary to optimize robustness and performance.
5	Stability of sequestered constituents in wetland sediments	2, 3	- Pilot-scale testing will outline the fate and distribution of elements (mass balance); sequential ICP will determine the stability of elements in the sediment. - Confirmation with on-site demonstration-scale wetlands.	- Multiple wetland designs may be tested to achieve operating parameters necessary to optimize mineral forms for stability.
6	Return of treatment performance after freeze-thaw and functionality during freeze-up and freshet.	1, 2, 3	- Literature search of comparable systems and relevant testing. - Freeze-thaw testing with pilot-scale system plants and sediments (Haakensen et al., 2013). - On-site demonstration-scale systems will test the operational efficacy of treatment through freezing and thawing. - Final sizes of full-scale wetlands will be based on findings from Phase 1-3 to achieve necessary treatment in all months/conditions.	- The revised recommendations for conceptual treatment wetland sizes should be larger than expected to be needed, providing additional footprint for construction if additional treatment area needed. - Incorporation of spillways/conveyance channels to promote glaciation in winter months.
7	North TMF wetland becoming operational after open pit has filled (anticipated ~95 yrs after mining has ceased)	1, 3	- Assess if in-pit treatment is feasible during closure, with North TMF as a contingency should open pit water not stratify or respond to in-pit treatment. - Evaluate loading and treatment potential of other water sources contributing to TMF. - Evaluate stability of demonstration-scale wetland during mine-life. - Evaluate performance of South TMF wetland to determine whether it is likely to have the additional treatment capacity available to treat TMF water with open pit water incorporated at year 95 or if North TMF wetland remains potentially needed. - Consider pros/cons of constructing North TMF in	- Bioreactor to treat HLF draindown water prior to release to open pit in order to decrease loading. - Addition of HLF wetland to decrease loads to South TMF wetland. - In-pit treatment during/through early closure, prior to release from pit. - Addition of WMP wetland to improve downstream water quality, decreasing reliance on North and South TMF wetlands.

Risk/Uncertainty		Addressed during Phase	Addressed By	Conceptual Contingency Measures
			early closure vs prior to open pit overflow.	
8	Valve operation for Open Pit	1	- Sizing of North TMF based on unregulated release of water from Open Pit (i.e., for scenario with no valve)	- North TMF wetland will be sized to achieve treatment needed for maximum uncontrolled flows, based on concentrations needed for downstream receiving environment and treatability in South TMF wetland. - Receiving capacity of the TMF and contingency treatment by South TMF wetland. - Addition of HLF wetland to decrease demands on South TMF wetland.
9	Performance of proposed bioreactor for HLF draindown discharging to open pit	1, 2	- Investigate possibility of repurposing HLF as an in situ bioreactor. - Testing through phased research program such as that for wetlands at a pilot-scale.	- Bioreactor itself is a contingency measure. - In-pit treatment of water in open pit.
10	Effects of water from HLF toe seepage after draindown on treatability of TMF water (e.g., nitrate)	1, 2, 3	- Investigate treatment wetland options for HLF toe seepage and surface runoff to treat nitrate in early closure and reduce loads of other elements to TMF after draindown.	- This item is itself a contingency.
11	Compatibility of proposed treatment methods	Ongoing	- Address through integrative planning, ensuring that any active treatment or new developments for treatment take into consideration effects on downstream treatment plans	- Consider the passive treatment of the whole site as a treatment train. Assess any changes or implementation of contingency methods in context of effects on downstream treatment.

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Yukon College (2014) Passive treatment of mine impacted water in cold climates: A review. Yukon Research Centre, Yukon College, Whitehorse, Yukon.

APPENDIX B.6A: Tables and Figures from Appendix 6E

VOLUME B.II: BIOPHYSICAL VALUED COMPONENTS

Knight Piésold CONSULTING

TABLE 1

CASINO MINING CORPORATION
CASINO PROJECT

PROPOSED ACCESS ROADS
PHYSIOGRAPHY, MAJOR STREAM CROSSINGS, AND FLUVIAL TERRAIN UNITS

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Road	Physiographic Section	Road Chainage and Length (km)			No. of Major Stream Crossings				Road Length on Floodplain (km)	No. of Tributary Fan Crossings
		Start	End	Length	Main Channel	Side Channels	Tributaries	Total		
Carmacks By-pass Route	Nordenskiold River Crossing	-	-	-	1	0	0	1	-	-
Freegold Road Upgrade	Seymour Creek Crossing	-	-	-	1	0	0	1	-	-
Freegold Road Extension	Seymour Creek Valley	0	6	6	0	0	1	1	1	1
	Big Creek Valley (Main)	6	35	29	3	0	1	4	5	10
	Big Creek Valley (Tributary)	35	43	8	0	0	0	0	-	1
	Hayes Creek Valley (Tributary)	43	56	13	0	0	1	1	< 1	3
	Hayes Creek Valley (Main)	56	85	29	7	2	1	10	6	4
	Selwyn River Valley	85	86	1	1	0	0	1	< 1	-
	Upland Terrain	86	133	47	0	0	0	0	-	-
Airstrip Access Road	Dip Creek Valley	0	5	5	1	0	0	1	<1	6
	Casino Creek Valley	5	15	10	0	0	0	0	-	2
Totals				**148**	**14**	**2**	**4**	**20**	**12**	**27**

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NOTES:

1. ROAD ALIGNMENT AND CHAINAGE BASED ON JUNE 6, 2011 FILE FROM ASSOCIATED ENGINEERING.
2. MAJOR STREAM CROSSINGS IDENTIFIED BY AECOM DDEM.

0	12 JUN'13	ISSUED WITH REPORT VA101-325/14-9	CJN	DJG	KJB
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D

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CONSULTING

TABLE 2

CASINO MINING CORPORATION
CASINO PROJECT

PROPOSED ACCESS ROADS
FLUVIAL GEOMORPHOLOGY HAZARDS

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Road	Physiographic Section	Report Section	Site Description	Potential Fluvial Geomorphology Hazards		
				Lateral Erosion	Channel Avulsion	Aggradation, Degradation
Carmacks By-pass Route	Nordenskiold River	4.1	Nordernskiold River Crossing	●	-	●
Freegold Road Upgrade	Seymour Creek Valley	4.2	Seymour Creek Crossing	●	●	●
Freegold Road Extension	Seymour Creek Valley	4.3.1	Bow Creek Crossing, 0+280	●	●	●
		4.3.2	Seymour Creek Impingement Site, 2+800	●	-	●
		4.3.3	Seymour Creek Impingement Site, 4+600	●	-	●
	Big Creek Valley (Main)	4.4.1	Big Creek Placer Mined Tributary Crossings, 9+400, 10+600, and 11+400	●	●	●
		4.4.2	Big Creek Impingement Site, 10+200 to 10+800	●	-	-
		4.4.3	Big Creek Impingement Site, 11+600	●	-	-
		4.4.4	Big Creek Side Channel Infill Site, 12+200 to 12+600	-	●	●
		4.4.5	Big Creek Crossings, 13+120 and 13+660	●	●	●
		4.4.6	Big Creek Crossing, 18+370	-	-	-
		4.4.7	Big Creek Tributary Alluvial Fan Crossing, 23+320	●	●	●
		4.4.7	Other Tributary Fan Crossings in the Big Creek Valley	●	●	●
		4.4.8	Big Creek Crossings, 26+770 and 26+840	●	●	●
	Big Creek Valley (Tributary)	4.5	Sub-tributary Fan Crossing, 41+400	●	●	●
	Hayes Creek Valley (Tributary)	4.6	Hayes Creek Tributary Crossing, 51+190	●	-	-
	Hayes Creek Valley (Main)	4.7.1	Hayes Creek Crossing, 56+820	●	●	●
		4.7.2	Fourmile and Butterfield Creek Crossings, 61+900 and 63+900	●	●	●
		4.7.3	Hayes Creek Impingement Site, 62+200 to 64+200	●	-	●
		4.7.4	Hayes Creek Crossing, 64+710	-	-	-
		4.7.5	Hayes Creek Side Channel Crossings, 66+200 and 66+340	●	●	●
		4.7.6	Hayes Creek Crossing, 67+600	-	-	-
		4.7.7	Hayes Creek Crossing, 68+470	●	●	●
		4.7.7	Hayes Creek Crossings, 69+510	●	●	●
		4.7.8	Hayes Creek Crossings, 79+090	●	-	-
		4.7.8	Hayes Creek Crossings, 79+490	●	-	-
	Selwyn River Valley	4.8	Selwyn River Crossing, 85+280	●	-	-
	Upland Terrain	4.9	--	-	-	-
Airstrip Access Road	Dip Creek Valley	4.10.1	Dip Creek Tributary Alluvial Fans, 0+000 to 4+400	●	●	●
		4.10.2	Dip Creek Crossing, 4+700	●	-	-
	Casino Creek Valley	4.11	Two Tributary Alluvial Fan Crossings	●	●	●

M:\1\01\00325\12\A\Data\Task 340 - Terrain Hazards\Fluvial Hazard Assessment - Roads\For Report 14-9\[Casino Roads FG Hazards - Tables.xlsx]Table 2

NOTES:

1. ROAD ALIGNMENT AND CHAINAGE BASED ON JUNE 6, 2011 FILE FROM ASSOCIATED ENGINEERING.
2. MAJOR STREAM CROSSINGS IDENTIFIED BY AECOM DDEM.

REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D
0	12 JUN'13	ISSUED WITH REPORT VA101-325/14-9	CJN	DJG	KJB

TERRAIN UNIT MAP LEGEND

aCk - R: texture (a); surficial material (C); surface expression (k); geomorphological process (R)

TEXTURE

a blocks (>256 mm; angular)
b boulders (>256 mm; round)
c clay (<0.002 mm)
d angular and rounded particles; >2 mm
e fibric organics
g gravel (rounded particles, >2mm)
h humic organics
k cobbles (64-256 mm, rounded)
m mud (silt and /or clay)
p pebbles (2-64 mm, rounded)
r rubble (2-256 mm, angular)
s sand (0.63-2 mm)
u mesic organics
x 2 to 256 mm, angular
z silt (0.002-0.63 mm)

SURFICIAL MATERIALS

A anthropogenic material
C colluvium
D weathered bedrock
E aolian sediments
F fluvial sediments
FG glaciofluvial sediments
I ice
L lacustrine sediments
LG glacial lake sediments
M till
Ml ablation till
O organic materials
R bedrock
U undifferentiated materials
V volcanic sediments

Superscripts: ^A = active, ^I = inactive

SURFACE EXPRESSION

a moderate slope(s) (27-49%)
b blanket
c cone
cl cliff
d depression
e plateau (no upslope catchment)
f fan
fp fill platform
g gully slope
h hummocky topography
j gentle slope(s) (6-26%)
k moderately steep slope(s) (50-70%)
l lobe
m rolling topography
p plain (0-5%)
r ridge topography
s steep slope(s) (>70%)
t terraced
u undulating topography
v veneer
w mantle of variable thickness
x thin veneer
y1 topographically confined hill slope
y2 topographically confined plain
z1 hill top (rounded)
z2 hill top (sharp)

GEOMORPHOLOGICAL PROCESSES

A snow avalanches
B braided channel
E glacial meltwater channels
F slow mass movement
G glacial processes
H kettled
I irregularly sinuous channel
J anstomosing channel
L abundant seepage
M meandering channel
N nivation
O decomposition of plant remains
R rapid mass movement
S solifluction
U sheet erosion
V gully erosion
W weathering
X permafrost processes
Z general periglacial processes

GEOMORPHOLOGICAL PROCESSES: SUBCLASSES AND SUBTYPES

F" slow mass movement, initiation zone
Fc soil creep
Fe slow earthflow(s)
Fg rock creep
Fk tension cracks
Fr slow rockslide(s)
Fs slow debris slide(s)
R" rapid mass movement, initiation zone
Ra rock avalanche
Rb rockfall(s)
Rd debris flow(s)
Rr rapid rockslide(s)
Rs rapid debris slide(s)
Rt debris torrent(s)

TERRAIN SYMBOLS

. components on either side of the symbol are of approximately equal proportion
/ the component in front of the symbol is more extensive than the one that follows
// the component in front of the symbol is considerably more extensive than the one that follows
_ the component in front of the symbol overlays the one that follows

NOTES:

1. BASE MAP: (C) ESRI ARCGIS ONLINE MAPPING.
2. COORDINATE GRID IS IN METRES. COORDINATE SYSTEM: NAD 1983 UTM ZONE 7N.
3. THIS FIGURE IS PRODUCED AT A NOMINAL SCALE OF 1:2,000,000 FOR 11x17 (TABLOID) PAPER. ACTUAL SCALE MAY DIFFER ACCORDING TO CHANGES IN PRINTER SETTINGS OR PRINTED PAPER SIZE.

SCALE 20 10 0 20 40 60 80 100 km

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
0	31MAY'13	ISSUED WITH REPORT	JEH	AMD	CJN	KJB

CASINO MINING CORPORATION

CASINO PROJECT

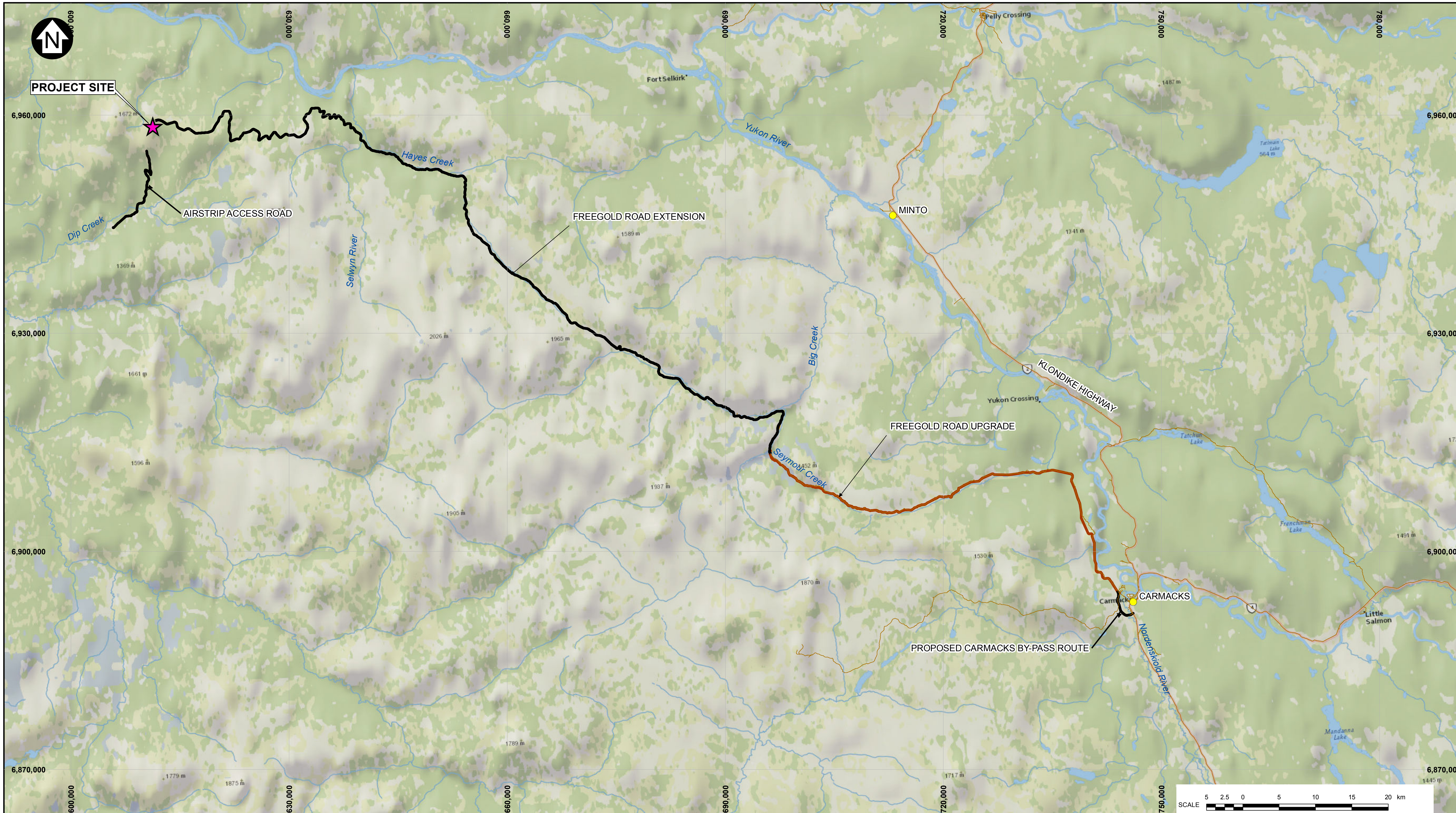
PROJECT LOCATION MAP AND TERRAIN MAP LEGEND

Knight Piésold CONSULTING

P/A NO. VA101-325/14 | REF NO. 9

FIGURE 1 | REV 0

SAVED: M:\1\01\00325\14\A\GIS\Figs\Report9_AccessRoadsFluvialHazards\Figure 1_TerrainHazardLegend.mxd; May 30, 2013 12:12 PM; adinca



LEGEND

- ★ PROJECT LOCATION
- CITY / TOWN
- EXISTING ROAD
- PROPOSED ROAD
- ROAD UPGRADE

NOTES:

1. BASE MAP: ESRI ARCGIS ONLINE NATIONAL GEOGRAPHIC MAPPING.
2. COORDINATE GRID IS IN METRES. COORDINATE SYSTEM: NAD 1983 UTM ZONE 7N.
3. THIS FIGURE IS PRODUCED AT A NOMINAL SCALE OF 1:500,000 FOR 11x17 (TABLOID) PAPER. ACTUAL SCALE MAY DIFFER ACCORDING TO CHANGES IN PRINTER SETTINGS OR PRINTED PAPER SIZE.
4. FREEGOLD ROAD EXTENSION AND AIR STRIP ACCESS ROAD ALIGNMENTS BASED ON JUNE 6, 2011 FILE FROM ASSOCIATED ENGINEERING.
5. UPGRADED ROAD ALIGNMENT BASED ON JANUARY 3, 2013 FILE FROM FREEGOLD.

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
0	31MAY'13	ISSUED WITH REPORT	JEH	AMD	CJN	KJB

CASINO MINING CORPORATION

CASINO PROJECT

ACCESS ROAD SITE MAP

Knight Piésold CONSULTING

P/A NO.	REF NO.
VA101-325/14	9

FIGURE 2 REV 0

SAVED: M:\1\01\00325\14\A\GIS\Figs\Report9_AccessRoadsFluvialHazards\Figure2_AccessRoadSiteMap.mxd; Sep 06, 2013 3:28 PM; kkrauszova

APPENDIX B.7A: Surface WQ Statistics

VOLUME B.II: BIOPHYSICAL VALUED COMPONENTS

Parameters	CCME Guideline[1]	Unit	W12												W8											
			n	min	max	mean	median	sd	10th	25th	75th	90th	95th	<DL	n	min	max	mean	median	sd	10th	25th	75th	90th	95th	<DL
pH	6.5 - 9.0	pH Units	16	3.06	4.25	3.51	3.43	0.36	3.13	3.22	3.83	3.95	4.06	0	13	6.90	7.80	7.48	7.60	0.31	7.02	7.35	7.70	7.75	7.78	0
Conductivity	-	uS/cm	16	209	1610	875	930	379	395	635	1110	1275	1415	0	13	72	373	244	265	95	104	210	324	348	359	0
Total Hardness CaCO3	-	mg/L	16	56	521	286	258	144	120	189	405	472	507	0	13	30	156	106	107	41	49	91	139	155	155	0
Dissolved Hardness CaCO3	-	mg/L	16	57	589	300	300	148	125	188	400	466	515	0	13	31	164	108	116	42	50	86	144	156	160	0
Total Dissolved Solids	-	mg/L	16	120	1120	590	610	273	280	405	768	910	1030	0	13	54	238	166	160	53	100	150	210	226	233	0
Total Suspended Solids	-	mg/L	15	2.0	77.6	18.7	11.0	21.2	3.8	6.0	18.5	46.0	61.1	0	13	2.0	30.9	8.3	5.0	7.8	3.0	3.0	9.0	13.8	20.8	0
Turbidity		NTU	16	2.5	59.6	19.4	15.4	15.5	4.0	9.9	26.7	38.3	45.5	0	13	1.0	13.4	5.3	3.4	3.7	1.9	3.1	8.2	9.8	11.4	0
Ammonia as N	0.499[a]	mg/L	16	0.007	0.180	0.061	0.050	0.049	0.019	0.030	0.082	0.125	0.165	0	13	0.005	0.048	0.017	0.014	0.012	0.005	0.008	0.025	0.028	0.036	2
Alkalinity (Total as CaCO3)	-	mg/L	16	0.25	0.25	0.25	0.25	0.00	0.25	0.25	0.25	0.25	0.25	16	13	4.80	59.00	34.37	38.00	19.45	8.31	12.20	46.00	57.36	59.00	0
Acidity to pH 4.5 (as CaCO3)	-	mg/L	13	2.43	130.00	50.73	38.50	37.46	16.02	24.10	73.80	99.00	115.00	0	9	0.25	0.25	0.25	0.25	0.00	0.25	0.25	0.25	0.25	0.25	9
Acidity to pH 8.3 (as CaCO3)	-	mg/L	13	22.20	229.00	106.85	107.00	57.16	55.14	69.10	131.00	178.60	205.60	0	9	0.25	4.60	2.01	2.10	1.40	0.25	1.51	2.20	3.72	4.16	2
Bromide	-	mg/L	12	0.01	0.20	0.17	0.20	0.07	0.04	0.20	0.20	0.20	0.20	12	10	0.01	0.20	0.16	0.20	0.08	0.01	0.20	0.20	0.20	0.20	10
Chloride	120	mg/L	16	0.25	1.10	0.53	0.55	0.29	0.25	0.25	0.70	0.90	1.03	7	13	0.25	2.00	0.56	0.25	0.53	0.25	0.25	0.70	1.13	1.52	8
Fluoride	0.12	mg/L	12	0.066	0.410	0.241	0.220	0.104	0.151	0.160	0.330	0.357	0.383	0	10	0.049	0.140	0.098	0.100	0.026	0.068	0.090	0.110	0.122	0.131	0
Sulphate	-	mg/L	16	79.20	820.00	370.76	380.00	203.61	141.50	215.00	505.00	585.00	670.00	0	13	18.90	126.00	75.45	73.00	31.52	31.20	62.00	96.00	108.00	116.40	0
Total Nitrogen	-	mg/L	16	0.14	0.59	0.29	0.25	0.14	0.16	0.19	0.38	0.50	0.58	0	13	0.11	0.60	0.26	0.24	0.12	0.15	0.21	0.25	0.35	0.45	0
Nitrate (as N)	13	mg/L	16	0.014	0.105	0.048	0.031	0.031	0.021	0.027	0.066	0.097	0.101	0	13	0.011	0.165	0.088	0.090	0.049	0.029	0.055	0.119	0.151	0.161	0
Nitrate plus Nitrite	-	mg/L	16	0.014	0.105	0.050	0.035	0.030	0.026	0.030	0.069	0.099	0.101	0	12	0.015	0.165	0.087	0.082	0.050	0.030	0.049	0.121	0.155	0.161	0
Nitrite (as N)	0.06	mg/L	16	0.001	0.010	0.004	0.003	0.003	0.001	0.002	0.004	0.008	0.010	6	13	0.001	0.120	0.011	0.001	0.033	0.001	0.001	0.004	0.009	0.054	9
Total Kjeldahl Nitrogen	-	mg/L	16	0.05	0.56	0.24	0.19	0.16	0.10	0.13	0.30	0.47	0.54	0	12	0.05	0.57	0.19	0.13	0.15	0.08	0.09	0.21	0.33	0.44	0
Orthophosphate as P	-	mg/L	16	0.0005	0.0150	0.0027	0.0020	0.0035	0.0008	0.0010	0.0026	0.0040	0.0068	3	13	0.0005	0.0070	0.0017	0.0010	0.0017	0.0006	0.0010	0.0020	0.0024	0.0043	3
Cyanide, Total	0.005	mg/L																								
Cyanide, Weak Acid Diss	-	mg/L	16	0.00025	0.00380	0.00050	0.00025	0.00089	0.00025	0.00025	0.00025	0.00048	0.00148	14	13	0.00025	0.00110	0.00043	0.00025	0.00030	0.00025	0.00025	0.00060	0.00086	0.00098	9
Dissolved Organic Carbon	-	mg/L	9	1.70	7.00	3.08	2.20	1.98	1.75	1.90	2.70	6.20	6.60	0	6	1.40	7.50	3.39	2.85	2.26	1.52	1.81	3.93	5.80	6.65	0
Total Organic Carbon	-	mg/L	13	1.50	14.20	5.56	3.00	4.76	2.01	2.50	9.90	12.54	13.24	0	10	0.25	18.20	5.69	3.30	6.28	1.38	1.76	5.20	16.40	17.30	1
Total Aluminum	0.1[b]	mg/L	16	2.26	18.50	8.49	6.85	5.03	2.51	5.29	11.60	15.55	17.08	0	13	0.36	0.99	0.57	0.53	0.18	0.37	0.49	0.62	0.82	0.90	0
Total Antimony	-	mg/L	16	0.00005	0.00035	0.00016	0.00016	0.00007	0.00010	0.00012	0.00018	0.00021	0.00027	1	13	0.00006	0.00014	0.00009	0.00009	0.00002	0.00007	0.00007	0.00010	0.00011	0.00012	0
Total Arsenic	0.005	mg/L	16	0.00010	0.00235	0.00069	0.00042	0.00063	0.00028	0.00031	0.00084	0.00149	0.00207	0	13	0.00023	0.00090	0.00037	0.00030	0.00019	0.00025	0.00028	0.00038	0.00054	0.00069	0
Total Barium	-	mg/L	16	0.01	0.04	0.02	0.03	0.01	0.01	0.01	0.03	0.03	0.04	0	13	0.04	0.07	0.05	0.05	0.01	0.04	0.05	0.06	0.07	0.07	0
Total Beryllium	-	mg/L	16	0.000025	0.000880	0.000426	0.000425	0.000247	0.000123	0.000268	0.000593	0.000745	0.000813	1	13	0.000020	0.000050	0.000036	0.000040	0.000010	0.000022	0.000030	0.000040	0.000048	0.000050	0
Total Bismuth	-	mg/L	16	0.0000025	0.0000820	0.0000157	0.0000105	0.0000211	0.0000025	0.0000025	0.0000153	0.0000335	0.0000565	9	13	0.0000025	0.0000307	0.0000057	0.0000025	0.0000078	0.0000025	0.0000025	0.0000050	0.0000086	0.0000177	9
Total Boron	1.5	mg/L	16	0.03	0.15	0.05	0.03	0.05	0.03	0.03	0.03	0.15	0.15	16	13	0.03	0.03	0.03	0.03	0.00	0.03	0.03	0.03	0.03	0.03	13
Total Cadmium	0.000032[c]	mg/L	16	0.000050	0.004600	0.002206	0.002015	0.001290	0.000660	0.001393	0.003155	0.003810	0.004135	0	13	0.000152	0.000382	0.000242	0.000252	0.000068	0.000159	0.000186	0.000286	0.000307	0.000337	0
Total Calcium	-	mg/L	16	16.50	151.00	86.19	83.60	41.81	35.20	56.03	121.00	139.00	148.00	0	13	9.08	46.40	31.51	31.30	12.00	14.62	27.10	41.40	45.98	46.28	0
Total Chromium	0.001	mg/L	16	0.00025	0.00080	0.00057	0.00060	0.00017	0.00035	0.00048	0.00070	0.00077	0.00080	1	13	0.00005	0.00051	0.00017	0.00010	0.00015	0.00005	0.00005	0.00020	0.00038	0.00044	5
Total Cobalt	-	mg/L	16	0.000630	0.079700	0.033348	0.029800	0.021088	0.007920	0.020400	0.047200	0.055150	0.064400	0	13	0.001130	0.005020	0.002349	0.002310	0.001015	0.001230	0.001950	0.002430	0.003202	0.004000	0
Total Copper	0.0023[d]	mg/L	16	0.0162	1.4300	0.7243	0.7100	0.4134	0.1990	0.4710	1.0475	1.2200	1.3325	0	13	0.0317	0.0922	0.0573	0.0581	0.0155	0.0387	0.0506	0.0615	0.0729	0.0819	0
Total Iron	0.3	mg/L	16	0.355	39.100	20.078	17.700	11.764	6.550	12.775	31.450	34.800	36.850	0	13	0.076	1.650	0.873	0.873	0.508	0.152	0.654	1.160	1.538	1.590	0
Total Lead	0.003[e]	mg/L	16	0.000050	0.002730	0.001449	0.001500	0.000599	0.000991	0.001135	0.001685	0.002080	0.002280	0	13	0.000176	0.001370	0.000501	0.000293	0.000437	0.000184	0.000225	0.000547	0.001188	0.001262	0
Total Lithium	-	mg/L	16	0.00093	0.00800	0.00473	0.00530	0.00209	0.00200	0.00305	0.00628	0.00675	0.00725	0	13	0.00025	0.00140	0.00092	0.00100	0.00035	0.00032	0.00090	0.00110	0.00118	0.00128	2
Total Magnesium	-	mg/L	16	0.34	37.20	17.29	15.70	10.32	4.33	11.45	25.00	29.20	32.18	0	13	1.87	10.30	6.65	7.03	2.61	3.02	5.47	8.73	9.63	9.92	0
Total Manganese	-	mg/L	16	0.0154	1.9700	0.9133	0.8660	0.5262	0.2840	0.5840	1.2625	1.4950	1.6700	0	13	0.0539	0.1570	0.0780	0.0679	0.0278	0.0559	0.0608	0.0817	0.1016	0.1258	0
Total Mercury	0.000026	mg/L	14	0.0000050	0.0000250	0.0000107	0.0000050	0.0000087	0.0000050	0.0000050	0.0000175	0.0000250	0.0000250	12	10	0.0000050	0.0000050	0.0000050	0.0000050	0.0000000	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	10
Total Molybdenum	0.073	mg/L	16	0.00003	0.00034	0.00018	0.00016	0.00009	0.00009	0.00014	0.00024	0.00032	0.00033	4	13	0.00014	0.00078	0.00027	0.00023	0.00016	0.00016	0.00019	0.00027	0.00030	0.00050	0
Total Nickel	0.0033[f]	mg/L	16	0.00020	0.01230	0.00557	0.00516	0.00304	0.00220	0.00379	0.00748	0.00868	0.00998	0	13	0.00071	0.00126	0.00093	0.00092	0.00018	0.00073	0.00080	0.00101	0.00118	0.00122	0
Total Phosphorus	-	mg/L	14	0.0040	0.1110	0.0214	0.0095	0.0314	0.0050	0.0063	0.0170	0.0578	0.0870	2	10	0.0010	0.0310	0.0107	0.0045	0.0117	0.0010	0.0015	0.0170	0.0295	0.0302	3
Total Potassium	-	mg/L	16	1.05	2.50	1.74	1.83	0.49	1.13	1.26	2.18	2.29	2.35	0	13	0.73	1.16	0.89	0.88	0.13	0.74	0.84	0.97	1.05	1.11	0
Total Selenium	0.001	mg/L	16	0.00008	0.00040	0.00021	0.00021	0.00008	0.00012	0.00015	0.00027	0.00029	0.00033	1	13	0.00002	0.00009	0.00005	0.00006	0.00002	0.00002	0.00004	0.00006	0.00007	0.00008	2
Total Silicon	-	mg/L	16	2.78	13.00	7.71	8.35	2.90	3.40	5.60	9.38	10.30	11.13	0	13	2.84	6.90	5.45	5.80	1.34	3.22	5.00	6.50	6.50	6.66	0
Total Silver	0.0001	mg/L	16	0.000008	0.000096	0.000025	0.000019	0.000021	0.000014	0.000015	0.000026	0.000039	0.000058	3	13	0.000003	0.000063	0.000009	0.000003	0.000017	0.000003	0.000003	0.000003	0.000019	0.000038	10
Total Sodium	-	mg/L	16	1.24	1430.00	94.59	5.43	356.12	2.42	3.65	7.87	9.70	365.30	0	13	1.01	4.88	3.33	3.53	1.18	1.59	3.10	3.94	4.64	4.76	0
Total Strontium	-	mg/L	16	0.051	0.457	0.252	0.266	0.118	0.101	0.172	0.327	0.392	0.426	0	13	0.059	0.361	0.220	0.217	0.091	0.098	0.180	0.288	0.335	0.351	0
Total Sulphur	-	mg/L	16	27.00	280.00	143.50	145.00	69.28	61.50	90.25	192.75	210.00	229.75	0	13	5.00	45.00	27.23	28.00	12.34	10.40	21.00	36.00	42.20	43.80	1
Total Thallium	0.0008	mg/L	16	0.0000226	0.0001200	0.0000644	0.0000665	0.0000264	0.0000315	0.0000448	0.0000813	0.0000910	0.0001005	0	13	0.0000040	0.0000100	0.0000071	0.0000070	0.0000020	0.0000042	0.0000060	0.0000080	0.0000096	0.0000099	0
Total Tin	-	mg/L	16	0.000005	0.000500	0.000048	0.000005	0.000124	0.000005	0.000005	0.000025	0.000085	0.000200	15	13	0.000005	0.000100	0.000027	0.000005	0.000039	0.000005	0.000005	0.000030	0.000096	0.000100	11
Total Titanium	-	mg/L	16	0.00025	0.01050	0.00277	0.00150	0.00339	0.00025	0.00044	0.00335	0.00830	0.00990	7	13	0.00025	0.01260	0.00223	0.00025	0.00365	0.00025	0.00025	0.00250	0.00562	0.00852	8
Total Uranium	0.015	mg/L	16	0.00033	0.02280	0.01034	0.00964	0.00596	0.00337	0.00685	0.01443	0.01695	0.01898	0	13	0.00098	0.00429	0.00224	0.00193	0.00100	0.00122	0.00164	0.00280	0.00359	0.00395	0
Total Vanadium	-	mg/L	16	0.00010	0.00160	0.00048	0.00045	0.00043	0.00010	0.00010	0.00060	0.00099	0.00135	8	13	0.00010	0.00094	0.00022	0.00010	0.00024	0.00010	0.00010	0.00030	0.00038	0.00062	9
Total Zinc	0.03	mg/L	16	0.00340	0.37700	0.16538	0.14950	0.10034	0.04935	0.10400	0.22500	0.28450	0.32600	0	13	0.01240	0.03160	0.01880	0.01830	0.00530	0.01288	0.01480	0.02170	0.02238	0.02608	0
Total Zirconium	-	mg/L	16	0.00005	0.00050	0.00021	0.00023	0.00014	0.00005	0.00005	0.00030	0.00035	0.00043	8	13	0.00005	0.00042	0.00013	0.00005	0.00012	0.00005	0.00005	0.00020	0.00028	0.00035	7
Dissolved Aluminum	0.1	mg/L	16	1.78	18.80	9.00	8.60	4.91	3.71	5.66	11.53	15.65	17.75	0	13	0.03	0.43	0.11	0.06	0.12	0.03	0.05	0.09	0.26	0.34	0
Dissolved Antimony	-	mg/L	16	0.00004	0.00020	0.00012	0.00014	0.00006	0.00005	0.00008	0.00016	0.00019	0.00019	2	13	0.00005	0.00011	0.00008	0.00008	0.00002	0.00006	0.00007	0.00009	0.00010	0.00010	0
Dissolved Arsenic	-	mg/L	16	0.00023	0.00060	0.00035	0.00031	0.00010	0.00026	0.00029	0.00038	0.00050	0.00053	0	13	0.00007	0.00035	0.00021	0.00018	0.00008	0.00011	0.00017	0.00025	0.00030	0.00032	0
Dissolved Barium	-	mg/L	16	0.007900	0.043600	0.020491	0.022600	0.010879	0.009050	0.010163	0.028575	0.030350	0.033925	0	13	0.030500	0.067800	0.051415	0.049800	0.011700	0.035580	0.045100	0.061500	0.065280	0.066660	0
Dissolved Beryllium	-	mg/L	16	0.000086	0.000880	0.000445	0.000510	0.000214	0.000200	0.000280	0.000553	0.000670	0.000775	0	13	0.000005	0.000030	0.000012	0.000010	0.000008	0.000005	0.000005	0.000020	0.000022	0.000025	6
Dissolved Bismuth	-	mg/L	16	0.0000025	0.0000150	0.0000057	0.0000025	0.0000051	0.0000025	0.0000025	0.0000085	0.0000150	0.0000150	14	13	0.0000025	0.0000025	0.0000025	0.0000025	0.0000000	0.0000025	0.0000025	0.0000025	0.0000025	0.0000025	13
Dissolved Boron	-	mg/L	16	0.025	0.150	0.048	0.025	0.050	0.025	0.025	0.025	0.150	0.150	16	13	0.025	0.025	0.025	0.025	0.000	0.025	0.025	0.025	0.025	0.025	13
Dissolved Cadmium	-	mg/L	16	0.000050	0.004620	0.002316	0.002415	0.001138	0.001073	0.001455	0.002938	0.003660	0.004133	0	13	0.000117	0.000316	0.000200	0.000190	0.000058	0.000135	0.000156	0.000241	0.000269	0.000291	0
Dissolved Calcium	-	mg/L	16	16.50	175.00	88.84	88.50	43.58	36.55	55.88	118.25	135.50	151.00	0	13	9.38	49.50	32.22	34.00	12.48	14.90	25.10	43.00	46.22	47.88	0
Dissolved Chromium	-	mg/L	16	0.00025	0.00080	0.00048	0.00050	0.00017	0.00025	0.00038	0.00060	0.00070	0.00073	2	13	0.00005	0.00030	0.00010	0.00005	0.00008	0.00005	0.00005	0.00010	0.00020	0.00024	7
Dissolved Cobalt	-	mg/L	16	0.000630	0.076100	0.035913	0.035850	0.018756	0.014475	0.023150	0.049500	0.054300	0.062300	0	13	0.000914	0.004760	0.002251	0.002270	0.001020	0.000964	0.002000	0.002430	0.003168	0.003878	0

Parameters	CCME Guideline[1]	Unit	W12 n	W12 min	W12 max	W12 mean	W12 median	W12 sd	W12 10th	W12 25th	W12 75th	W12 90th	W12 95th	W12 <DL
Dissolved Copper	-	mg/L	16	0.0162	1.3400	0.7801	0.8220	0.3634	0.3435	0.4858	1.0233	1.2350	1.2800	0
Dissolved Iron	-	mg/L	16	0.355	35.100	18.138	15.550	11.628	2.920	10.800	27.150	33.200	34.650	0
Dissolved Lead	-	mg/L	16	0.000050	0.001900	0.001200	0.001185	0.000424	0.000618	0.001001	0.001503	0.001700	0.001788	0
Dissolved Lithium	-	mg/L	16	0.00093	0.00800	0.00458	0.00520	0.00201	0.00200	0.00295	0.00593	0.00640	0.00680	0
Dissolved Magnesium	-	mg/L	16	0.34	37.20	19.13	19.15	9.64	8.10	11.93	25.53	31.15	33.45	0
Dissolved Manganese	-	mg/L	16	0.0154	1.8800	0.9813	1.0010	0.4609	0.4585	0.6645	1.2700	1.5250	1.6400	0
Dissolved Mercury	-	mg/L	13	0.0000050	0.0000250	0.0000081	0.0000050	0.0000075	0.0000050	0.0000050	0.0000050	0.0000210	0.0000250	13
Dissolved Molybdenum	-	mg/L	16	0.00003	0.00031	0.00014	0.00013	0.00010	0.00003	0.00007	0.00021	0.00028	0.00030	6
Dissolved Nickel	-	mg/L	16	0.00020	0.01160	0.00605	0.00591	0.00263	0.00321	0.00423	0.00782	0.00903	0.00980	0
Dissolved Phosphorus	-	mg/L	13	0.0040	0.0160	0.0065	0.0050	0.0040	0.0032	0.0050	0.0070	0.0116	0.0137	3
Dissolved Potassium	-	mg/L	16	1.05	2.60	1.73	1.80	0.48	1.16	1.26	2.11	2.24	2.38	0
Dissolved Selenium	-	mg/L	16	0.00008	0.00050	0.00023	0.00022	0.00010	0.00012	0.00017	0.00029	0.00030	0.00035	0
Dissolved Silicon	-	mg/L	16	2.78	14.10	8.13	8.90	3.06	3.60	6.55	10.03	10.50	11.48	0
Dissolved Silver	-	mg/L	16	0.000008	0.000030	0.000016	0.000016	0.000007	0.000007	0.000013	0.000021	0.000022	0.000024	3
Dissolved Sodium	-	mg/L	16	1.24	10.30	5.79	6.15	2.70	2.53	3.68	7.53	9.22	9.85	0
Dissolved Strontium	-	mg/L	16	0.051	0.444	0.249	0.257	0.113	0.106	0.173	0.315	0.383	0.417	0
Dissolved Sulphur	-	mg/L	16	27.00	278.00	142.88	145.50	70.40	59.50	90.00	199.75	214.00	233.00	0
Dissolved Thallium	-	mg/L	16	0.0000226	0.0001000	0.0000651	0.0000700	0.0000270	0.0000280	0.0000448	0.0000905	0.0000935	0.0000963	0
Dissolved Tin	-	mg/L	16	0.000005	0.000500	0.000055	0.000005	0.000124	0.000005	0.000005	0.000036	0.000110	0.000215	13
Dissolved Titanium	-	mg/L	16	0.00025	0.00250	0.00099	0.00105	0.00074	0.00025	0.00025	0.00150	0.00190	0.00235	9
Dissolved Uranium	-	mg/L	16	0.00033	0.02090	0.01084	0.01145	0.00534	0.00455	0.00672	0.01468	0.01655	0.01843	0
Dissolved Vanadium	-	mg/L	16	0.00010	0.00060	0.00024	0.00010	0.00019	0.00010	0.00010	0.00043	0.00050	0.00053	12
Dissolved Zinc	-	mg/L	16	0.00340	0.32800	0.17843	0.18000	0.08630	0.08855	0.11150	0.22375	0.30150	0.31225	0
Dissolved Zirconium	-	mg/L	16	0.00005	0.00030	0.00017	0.00020	0.00010	0.00005	0.00005	0.00025	0.00030	0.00030	8

Parameters	W8 n	W8 min	W8 max	W8 mean	W8 median	W8 sd	W8 10th	W8 25th	W8 75th	W8 90th	W8 95th	W8 <DL
Dissolved Copper	13	0.0097	0.0493	0.0272	0.0278	0.0100	0.0144	0.0253	0.0313	0.0341	0.0404	0
Dissolved Iron	13	0.001	0.423	0.219	0.203	0.150	0.018	0.118	0.334	0.416	0.421	0
Dissolved Lead	13	0.000003	0.000712	0.000136	0.000092	0.000180	0.000053	0.000070	0.000105	0.000196	0.000414	1
Dissolved Lithium	13	0.00025	0.00150	0.00091	0.00100	0.00032	0.00052	0.00080	0.00110	0.00118	0.00132	1
Dissolved Magnesium	13	1.74	10.10	6.77	7.47	2.66	3.07	5.54	8.84	9.73	9.89	0
Dissolved Manganese	13	0.0374	0.1510	0.0738	0.0683	0.0295	0.0453	0.0617	0.0817	0.1002	0.1222	0
Dissolved Mercury	9	0.0000050	0.0000050	0.0000050	0.0000050	0.0000000	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	9
Dissolved Molybdenum	13	0.00014	0.00028	0.00022	0.00021	0.00004	0.00018	0.00019	0.00026	0.00027	0.00027	0
Dissolved Nickel	13	0.00072	0.00110	0.00088	0.00081	0.00013	0.00075	0.00079	0.00095	0.00105	0.00108	0
Dissolved Phosphorus	9	0.0010	0.0115	0.0046	0.0020	0.0047	0.0010	0.0010	0.0100	0.0111	0.0113	4
Dissolved Potassium	13	0.66	1.20	0.89	0.88	0.14	0.74	0.78	1.00	1.03	1.10	0
Dissolved Selenium	13	0.00002	0.00009	0.00006	0.00006	0.00002	0.00002	0.00005	0.00007	0.00008	0.00008	2
Dissolved Silicon	13	2.69	7.30	5.55	5.90	1.49	3.16	5.40	6.40	7.10	7.24	0
Dissolved Silver	13	0.000003	0.000018	0.000004	0.000003	0.000005	0.000003	0.000003	0.000003	0.000009	0.000013	11
Dissolved Sodium	13	0.99	4.89	3.40	3.72	1.21	1.66	3.07	4.03	4.74	4.82	0
Dissolved Strontium	13	0.056	0.350	0.219	0.210	0.091	0.098	0.177	0.294	0.331	0.342	0
Dissolved Sulphur	13	5.00	44.00	27.38	30.00	12.31	10.60	19.00	34.00	41.80	42.80	1
Dissolved Thallium	13	0.0000030	0.0000090	0.0000061	0.0000060	0.0000018	0.0000041	0.0000050	0.0000070	0.0000080	0.0000084	0
Dissolved Tin	13	0.000005	0.000100	0.000025	0.000005	0.000039	0.000005	0.000005	0.000005	0.000096	0.000100	12
Dissolved Titanium	13	0.00025	0.00140	0.00057	0.00025	0.00044	0.00025	0.00025	0.00090	0.00122	0.00133	8
Dissolved Uranium	13	0.00064	0.00220	0.00150	0.00135	0.00054	0.00102	0.00108	0.00210	0.00218	0.00219	0
Dissolved Vanadium	13	0.00010	0.00035	0.00013	0.00010	0.00007	0.00010	0.00010	0.00010	0.00018	0.00026	11
Dissolved Zinc	13	0.00630	0.02180	0.01349	0.01300	0.00448	0.00824	0.01050	0.01730	0.01802	0.01964	0
Dissolved Zirconium	13	0.00005	0.00030	0.00010	0.00005	0.00008	0.00005	0.00005	0.00010	0.00021	0.00025	8

Notes:

1) Canadian water quality guidelines for the protection of aquatic life, Council of Ministers of the Environment, 2007

a) Ammonia (NH_3) guideline based on ph=8 and temp=20

b) Aluminum (AL-T)= 0.005 mg/L at pH < 6.5: 0.1 mg/L at pH ≥ 6.5

c) Cadmium (Cd) mg/L: 10^(0.86*(log(hardness))-3.2)/1000

d) Copper (Cu) mg/L: (e^0.8545[ln(hardness)]-1.465)*0.2/1000; minimum is 0.002mg/L regardless of water hardness

e) Lead (Pb) mg/L: (e^1.273[ln(hardness)]-4.705)/1000; minimum is 0.001mg/L regardless of water hardness

f) Nickel (Ni) mg/L: (e^0.76[(ln(hardness)]+1.06)/1000; minimum is 0.025mg/L regardless of water hardness

n	Count
min	Minimum Value
max	Maxmimum Value
sd	Stadard Deviation
10th	10th percentile value
25th	25th percentile value
75th	75th percentile value
90th	90th percentile value
95th	95th percentile value
<DL	# of non-detectable values

Parameters	CCME Guideline[1]	Unit	W43 n	min	max	mean	median	sd	10th	25th	75th	90th	95th	<DL
pH	6.5 - 9.0	pH Units	11	7.20	7.70	7.47	7.50	0.15	7.30	7.38	7.55	7.64	7.67	0
Conductivity	-	uS/cm	11	208	300	240	224	31	220	220	260	279	290	0
Total Hardness CaCO3	-	mg/L	12	80	141	105	99	18	89	93	118	127	133	0
Dissolved Hardness CaCO3	-	mg/L	9	90	146	109	100	20	92	95	125	132	139	0
Total Dissolved Solids	-	mg/L	11	110	210	151	150	29	120	128	170	170	190	0
Total Suspended Solids	-	mg/L	9	0.5	4.0	1.1	0.5	1.2	0.5	0.5	0.5	2.4	3.2	7
Turbidity		NTU	11	0.2	3.7	0.8	0.5	1.0	0.2	0.4	0.9	0.9	2.3	0
Ammonia as N	0.499[a]	mg/L	9	0.003	0.016	0.008	0.005	0.005	0.005	0.005	0.015	0.015	0.016	6
Alkalinity (Total as CaCO3)	-	mg/L	11	59.00	94.00	75.35	69.00	12.38	66.50	67.00	86.50	93.00	93.50	0
Acidity to pH 4.5 (as CaCO3)	-	mg/L	9	0.25	0.25	0.25	0.25	0.00	0.25	0.25	0.25	0.25	0.25	8
Acidity to pH 8.3 (as CaCO3)	-	mg/L	9	4.60	15.20	9.24	8.28	3.86	5.26	6.80	13.20	14.00	14.60	0
Bromide	-	mg/L	6	0.01	0.20	0.14	0.20	0.10	0.01	0.05	0.20	0.20	0.20	5
Chloride	120	mg/L	11	0.25	5.00	0.79	0.25	1.41	0.25	0.25	0.60	0.80	2.90	6
Fluoride	0.12	mg/L	6	0.080	0.100	0.089	0.090	0.008	0.080	0.082	0.092	0.096	0.098	0
Sulphate	-	mg/L	10	34.00	54.00	42.30	41.50	6.24	35.80	38.25	45.50	49.50	51.75	0
Total Nitrogen	-	mg/L	11	0.13	0.58	0.30	0.25	0.15	0.17	0.19	0.42	0.48	0.53	0
Nitrate (as N)	13	mg/L	11	0.128	0.479	0.255	0.183	0.139	0.138	0.153	0.370	0.454	0.467	0
Nitrate plus Nitrite	-	mg/L	11	0.130	0.479	0.255	0.183	0.139	0.138	0.153	0.371	0.454	0.467	0
Nitrite (as N)	0.06	mg/L	11	0.001	0.002	0.001	0.001	0.000	0.001	0.001	0.001	0.002	0.002	8
Total Kjeldahl Nitrogen	-	mg/L	11	0.01	0.10	0.05	0.04	0.03	0.01	0.03	0.07	0.07	0.09	2
Orthophosphate as P	-	mg/L	11	0.0005	0.0060	0.0025	0.0020	0.0017	0.0010	0.0018	0.0025	0.0053	0.0057	1
Cyanide, Total	0.005	mg/L												
Cyanide, Weak Acid Diss	-	mg/L	9	0.00025	0.00100	0.00033	0.00025	0.00025	0.00025	0.00025	0.00025	0.00040	0.00070	8
Dissolved Organic Carbon	-	mg/L	2	1.00	2.00	1.50	1.50	0.71	1.10	1.25	1.75	1.90	1.95	0
Total Organic Carbon	-	mg/L	5	0.90	2.00	1.34	1.40	0.43	0.94	1.00	1.40	1.76	1.88	0
Total Aluminum	0.1[b]	mg/L	12	0.00	0.03	0.01	0.01	0.01	0.00	0.00	0.02	0.03	0.03	#VALUE!
Total Antimony	-	mg/L	12	0.00201	0.00342	0.00278	0.00281	0.00039	0.00238	0.00258	0.00301	0.00321	0.00332	0
Total Arsenic	0.005	mg/L	12	0.00043	0.00152	0.00067	0.00063	0.00030	0.00043	0.00047	0.00073	0.00079	0.00112	0
Total Barium	-	mg/L	12	0.04	0.07	0.05	0.05	0.01	0.05	0.05	0.06	0.07	0.07	0
Total Beryllium	-	mg/L	12	0.000005	0.000005	0.000005	0.000005	0.000000	0.000005	0.000005	0.000005	0.000005	0.000005	11
Total Bismuth	-	mg/L	12	0.0000025	0.0000100	0.0000031	0.0000025	0.0000022	0.0000025	0.0000025	0.0000025	0.0000025	0.0000059	10
Total Boron	1.5	mg/L	12	0.03	0.03	0.03	0.03	0.00	0.03	0.03	0.03	0.03	0.03	11
Total Cadmium	0.000032[c]	mg/L	12	0.039600	0.068000	0.047275	0.045700	0.007892	0.040390	0.042400	0.049050	0.054690	0.061015	0
Total Calcium	-	mg/L	12	21.40	38.90	28.88	27.35	5.29	24.07	25.83	32.98	35.27	36.92	0
Total Chromium	0.001	mg/L	12	0.00005	0.00005	0.00005	0.00005	0.00000	0.00005	0.00005	0.00005	0.00005	0.00005	11
Total Cobalt	-	mg/L	12	0.000164	0.000524	0.000261	0.000222	0.000105	0.000180	0.000187	0.000315	0.000361	0.000437	0
Total Copper	0.0023[d]	mg/L	12	0.0463	0.0909	0.0663	0.0692	0.0137	0.0474	0.0559	0.0751	0.0778	0.0838	0
Total Iron	0.3	mg/L	12	0.021	0.112	0.048	0.041	0.027	0.025	0.026	0.065	0.072	0.090	0
Total Lead	0.003[e]	mg/L	12	0.004270	0.018300	0.011005	0.010955	0.005282	0.004448	0.006403	0.015250	0.018070	0.018190	0
Total Lithium	-	mg/L	12	0.00160	0.00300	0.00225	0.00215	0.00043	0.00182	0.00200	0.00250	0.00280	0.00289	0
Total Magnesium	-	mg/L	12	6.38	10.70	7.93	7.54	1.29	6.91	7.00	8.74	9.39	9.99	0
Total Manganese	-	mg/L	12	0.2470	1.0700	0.4211	0.3540	0.2265	0.2498	0.3043	0.4850	0.5258	0.7708	0
Total Mercury	0.000026	mg/L	11	0.0000050	0.0000050	0.0000050	0.0000050	0.0000000	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	10
Total Molybdenum	0.073	mg/L	12	0.00003	0.00003	0.00003	0.00003	0.00000	0.00003	0.00003	0.00003	0.00003	0.00003	11
Total Nickel	0.0033[f]	mg/L	12	0.00040	0.00062	0.00049	0.00049	0.00007	0.00043	0.00043	0.00054	0.00057	0.00059	0
Total Phosphorus	-	mg/L	11	0.0010	0.0050	0.0026	0.0030	0.0013	0.0010	0.0015	0.0033	0.0039	0.0045	3
Total Potassium	-	mg/L	12	1.10	1.62	1.36	1.37	0.13	1.21	1.33	1.40	1.43	1.52	0
Total Selenium	0.001	mg/L	12	0.00002	0.00002	0.00002	0.00002	0.00000	0.00002	0.00002	0.00002	0.00002	0.00002	11
Total Silicon	-	mg/L	12	4.60	6.20	5.56	5.75	0.46	5.01	5.34	5.83	5.90	6.04	0
Total Silver	0.0001	mg/L	12	0.000045	0.000215	0.000114	0.000111	0.000054	0.000048	0.000080	0.000134	0.000192	0.000205	0
Total Sodium	-	mg/L	12	2.74	3.75	3.27	3.25	0.31	2.94	3.09	3.53	3.59	3.67	0
Total Strontium	-	mg/L	12	0.195	0.342	0.258	0.247	0.046	0.217	0.220	0.288	0.317	0.329	0
Total Sulphur	-	mg/L	12	11.00	21.00	14.92	14.50	2.71	11.30	14.00	16.25	17.00	18.80	0
Total Thallium	0.0008	mg/L	12	0.0000230	0.0000293	0.0000258	0.0000255	0.0000020	0.0000240	0.0000240	0.0000270	0.0000288	0.0000291	0
Total Tin	-	mg/L	12	0.000005	0.000120	0.000030	0.000005	0.000046	0.000005	0.000005	0.000029	0.000100	0.000109	10
Total Titanium	-	mg/L	12	0.00025	0.00060	0.00028	0.00025	0.00010	0.00025	0.00025	0.00025	0.00025	0.00041	10
Total Uranium	0.015	mg/L	12	0.00077	0.00238	0.00143	0.00126	0.00056	0.00089	0.00107	0.00167	0.00230	0.00234	0
Total Vanadium	-	mg/L	12	0.00010	0.00030	0.00012	0.00010	0.00006	0.00010	0.00010	0.00010	0.00010	0.00019	10
Total Zinc	0.03	mg/L	12	2.22000	3.62000	2.62500	2.57000	0.37797	2.35000	2.37250	2.61750	3.01800	3.31200	0
Total Zirconium	-	mg/L	12	0.00005	0.00005	0.00005	0.00005	0.00000	0.00005	0.00005	0.00005	0.00005	0.00005	11
Dissolved Aluminum	0.1	mg/L	9	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0
Dissolved Antimony	-	mg/L	9	0.00180	0.00335	0.00267	0.00257	0.00048	0.00226	0.00243	0.00286	0.00331	0.00333	0
Dissolved Arsenic	-	mg/L	9	0.00028	0.00047	0.00034	0.00030	0.00007	0.00029	0.00029	0.00034	0.00046	0.00047	0
Dissolved Barium	-	mg/L	9	0.045100	0.063100	0.054222	0.055000	0.007274	0.045500	0.048000	0.060700	0.062220	0.062660	0
Dissolved Beryllium	-	mg/L	9	0.000005	0.000005	0.000005	0.000005	0.000000	0.000005	0.000005	0.000005	0.000005	0.000005	9
Dissolved Bismuth	-	mg/L	9	0.0000025	0.0000025	0.0000025	0.0000025	0.0000000	0.0000025	0.0000025	0.0000025	0.0000025	0.0000025	9
Dissolved Boron	-	mg/L	9	0.025	0.025	0.025	0.025	0.000	0.025	0.025	0.025	0.025	0.025	9
Dissolved Cadmium	-	mg/L	9	0.041100	0.070500	0.047844	0.043800	0.009437	0.041340	0.041500	0.049800	0.055300	0.062900	0
Dissolved Calcium	-	mg/L	9	24.70	40.40	30.24	27.30	5.52	25.26	26.70	35.00	36.72	38.56	0
Dissolved Chromium	-	mg/L	9	0.00005	0.00030	0.00008	0.00005	0.00008	0.00005	0.00005	0.00005	0.00010	0.00020	8
Dissolved Cobalt	-	mg/L	9	0.000157	0.000488	0.000269	0.000245	0.000106	0.000169	0.000172	0.000316	0.000363	0.000426	0

Parameters	CCME Guideline[1]	Unit	W13 n	min	max	mean	median	sd	10th	25th	75th	90th	95th	<DL
pH	6.5 - 9.0	pH Units	12	7.46	8.20	7.89	8.00	0.25	7.51	7.71	8.10	8.12	8.16	0
Conductivity	-	uS/cm	12	76	444	253	259	104	119	201	306	362	401	0
Total Hardness CaCO3	-	mg/L	12	41	214	123	125	49	63	94	153	169	190	0
Dissolved Hardness CaCO3	-	mg/L	12	38	223	122	125	51	63	91	151	168	193	0
Total Dissolved Solids	-	mg/L	12	70	260	154	145	57	96	110	180	226	242	0
Total Suspended Solids	-	mg/L	12	0.5	91.5	15.0	5.8	25.3	0.5	2.4	17.5	21.7	53.3	3
Turbidity		NTU	12	0.1	13.3	2.1	0.5	4.0	0.3	0.3	1.3	6.2	9.7	0
Ammonia as N	0.499[a]	mg/L	12	0.003	0.047	0.017	0.009	0.016	0.005	0.005	0.026	0.044	0.046	3
Alkalinity (Total as CaCO3)	-	mg/L	12	4.40	141.00	86.85	92.00	42.77	29.92	71.50	120.00	129.00	134.95	0
Acidity to pH 4.5 (as CaCO3)	-	mg/L	7	0.25	0.25	0.25	0.25	0.00	0.25	0.25	0.25	0.25	0.25	7
Acidity to pH 8.3 (as CaCO3)	-	mg/L	7	0.25	5.70	2.43	1.90	2.25	0.25	0.93	3.65	5.52	5.61	2
Bromide	-	mg/L	9	0.01	0.20	0.16	0.20	0.09	0.01	0.20	0.20	0.20	0.20	9
Chloride	120	mg/L	12	0.25	1.10	0.56	0.43	0.35	0.25	0.25	0.80	1.07	1.10	6
Fluoride	0.12	mg/L	9	0.034	0.110	0.065	0.060	0.022	0.047	0.050	0.070	0.087	0.098	0
Sulphate	-	mg/L	12	0.25	110.00	33.50	28.00	30.04	2.34	18.75	37.25	63.38	85.36	1
Total Nitrogen	-	mg/L	12	0.30	0.74	0.45	0.42	0.12	0.33	0.39	0.51	0.59	0.66	0
Nitrate (as N)	13	mg/L	12	0.082	0.419	0.272	0.291	0.103	0.100	0.243	0.338	0.361	0.387	0
Nitrate plus Nitrite	-	mg/L	12	0.084	0.419	0.272	0.291	0.102	0.103	0.243	0.338	0.361	0.387	0
Nitrite (as N)	0.06	mg/L	12	0.001	0.003	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.003	10
Total Kjeldahl Nitrogen	-	mg/L	12	0.03	0.66	0.18	0.14	0.17	0.05	0.09	0.24	0.29	0.46	0
Orthophosphate as P	-	mg/L	12	0.0005	0.0040	0.0015	0.0012	0.0010	0.0005	0.0009	0.0020	0.0025	0.0032	4
Cyanide, Total	0.005	mg/L												
Cyanide, Weak Acid Diss	-	mg/L	12	0.00025	0.00130	0.00045	0.00025	0.00038	0.00025	0.00025	0.00036	0.00110	0.00121	9
Dissolved Organic Carbon	-	mg/L	5	1.31	11.50	4.28	2.70	4.12	1.71	2.30	3.60	8.34	9.92	0
Total Organic Carbon	-	mg/L	9	0.25	10.80	3.34	2.80	3.02	1.01	1.90	3.60	5.28	8.04	1
Total Aluminum	0.1[b]	mg/L	12	0.01	0.72	0.16	0.07	0.21	0.01	0.04	0.18	0.35	0.52	0
Total Antimony	-	mg/L	12	0.00010	0.00033	0.00023	0.00023	0.00006	0.00019	0.00021	0.00027	0.00029	0.00031	0
Total Arsenic	0.005	mg/L	12	0.00047	0.00190	0.00132	0.00136	0.00043	0.00091	0.00109	0.00158	0.00188	0.00189	0
Total Barium	-	mg/L	12	0.05	0.11	0.09	0.09	0.02	0.07	0.08	0.09	0.10	0.11	0
Total Beryllium	-	mg/L	12	0.000005	0.000047	0.000012	0.000005	0.000013	0.000005	0.000005	0.000020	0.000020	0.000032	8
Total Bismuth	-	mg/L	12	0.0000025	0.0000140	0.0000050	0.0000025	0.0000043	0.0000025	0.0000025	0.0000063	0.0000125	0.0000135	8
Total Boron	1.5	mg/L	12	0.03	0.03	0.03	0.03	0.00	0.03	0.03	0.03	0.03	0.03	12
Total Cadmium	0.000032[c]	mg/L	12	0.000026	0.000519	0.000124	0.000087	0.000134	0.000041	0.000046	0.000145	0.000174	0.000330	0
Total Calcium	-	mg/L	12	11.40	56.60	33.05	33.60	12.47	17.19	26.33	40.85	43.43	49.45	0
Total Chromium	0.001	mg/L	12	0.00005	0.00190	0.00042	0.00015	0.00061	0.00005	0.00005	0.00040	0.00135	0.00165	4
Total Cobalt	-	mg/L	12	0.000018	0.000645	0.000161	0.000074	0.000195	0.000018	0.000028	0.000221	0.000380	0.000504	0
Total Copper	0.0023[d]	mg/L	12	0.0005	0.0092	0.0024	0.0011	0.0028	0.0005	0.0007	0.0028	0.0064	0.0079	0
Total Iron	0.3	mg/L	12	0.021	0.906	0.206	0.071	0.272	0.022	0.035	0.246	0.533	0.714	0
Total Lead	0.003[e]	mg/L	12	0.000025	0.073000	0.010740	0.003560	0.020573	0.000262	0.000732	0.007295	0.019910	0.044125	0
Total Lithium	-	mg/L	12	0.00070	0.00270	0.00153	0.00150	0.00064	0.00074	0.00108	0.00193	0.00236	0.00254	0
Total Magnesium	-	mg/L	12	3.07	17.60	9.80	9.67	4.35	4.74	6.96	12.10	15.55	16.61	0
Total Manganese	-	mg/L	12	0.0045	0.1730	0.0517	0.0401	0.0518	0.0080	0.0124	0.0616	0.1234	0.1494	0
Total Mercury	0.000026	mg/L	10	0.0000050	0.0000050	0.0000050	0.0000050	0.0000000	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	10
Total Molybdenum	0.073	mg/L	12	0.00034	0.00088	0.00058	0.00053	0.00019	0.00035	0.00043	0.00072	0.00082	0.00085	0
Total Nickel	0.0033[f]	mg/L	12	0.00016	0.00146	0.00056	0.00036	0.00042	0.00020	0.00028	0.00087	0.00105	0.00124	0
Total Phosphorus	-	mg/L	10	0.0020	0.0647	0.0132	0.0070	0.0189	0.0020	0.0033	0.0138	0.0218	0.0432	0
Total Potassium	-	mg/L	12	0.89	1.41	1.09	1.08	0.14	0.95	0.98	1.17	1.22	1.31	0
Total Selenium	0.001	mg/L	12	0.00002	0.00028	0.00006	0.00005	0.00007	0.00002	0.00002	0.00005	0.00010	0.00019	4
Total Silicon	-	mg/L	12	3.02	6.00	5.06	5.35	1.01	3.26	4.93	5.80	5.89	5.95	0
Total Silver	0.0001	mg/L	12	0.000003	0.000152	0.000027	0.000016	0.000042	0.000003	0.000003	0.000025	0.000044	0.000093	5
Total Sodium	-	mg/L	12	1.17	5.59	3.71	3.85	1.32	1.95	3.06	4.66	5.14	5.36	0
Total Strontium	-	mg/L	12	0.072	0.380	0.214	0.222	0.087	0.109	0.166	0.249	0.317	0.348	0
Total Sulphur	-	mg/L	12	4.00	39.00	11.83	9.00	10.21	5.00	5.00	12.75	22.20	30.20	4
Total Thallium	0.0008	mg/L	12	0.0000010	0.0000249	0.0000064	0.0000030	0.0000076	0.0000011	0.0000020	0.0000075	0.0000150	0.0000195	2
Total Tin	-	mg/L	12	0.000005	0.000300	0.000038	0.000005	0.000087	0.000005	0.000005	0.000005	0.000091	0.000190	11
Total Titanium	-	mg/L	12	0.00025	0.02890	0.00723	0.00195	0.01034	0.00025	0.00044	0.00958	0.02540	0.02780	3
Total Uranium	0.015	mg/L	12	0.00369	0.02440	0.01217	0.01195	0.00685	0.00435	0.00651	0.01598	0.02106	0.02275	0
Total Vanadium	-	mg/L	12	0.00010	0.00231	0.00058	0.00035	0.00068	0.00010	0.00010	0.00078	0.00136	0.00181	5
Total Zinc	0.03	mg/L	12	0.00140	0.03290	0.00770	0.00610	0.00864	0.00205	0.00250	0.00765	0.01182	0.02135	0
Total Zirconium	-	mg/L	12	0.00005	0.00030	0.00011	0.00005	0.00010	0.00005	0.00005	0.00013	0.00028	0.00029	8
Dissolved Aluminum	0.1	mg/L	12	0.00	0.14	0.03	0.02	0.05	0.00	0.01	0.03	0.12	0.14	0
Dissolved Antimony	-	mg/L	12	0.00009	0.00026	0.00020	0.00021	0.00005	0.00016	0.00017	0.00023	0.00025	0.00025	0
Dissolved Arsenic	-	mg/L	12	0.00045	0.00178	0.00112	0.00111	0.00044	0.00059	0.00080	0.00140	0.00175	0.00177	0
Dissolved Barium	-	mg/L	12	0.039800	0.107000	0.078408	0.084350	0.018685	0.049880	0.072650	0.088525	0.089530	0.097430	0
Dissolved Beryllium	-	mg/L	12	0.000005	0.000020	0.000007	0.000005	0.000004	0.000005	0.000005	0.000005	0.000010	0.000015	10
Dissolved Bismuth	-	mg/L	12	0.0000025	0.0000025	0.0000025	0.0000025	0.0000000	0.0000025	0.0000025	0.0000025	0.0000025	0.0000025	12
Dissolved Boron	-	mg/L	12	0.025	0.025	0.025	0.025	0.000	0.025	0.025	0.025	0.025	0.025	12
Dissolved Cadmium	-	mg/L	12	0.000023	0.000120	0.000062	0.000049	0.000037	0.000026	0.000032	0.000094	0.000119	0.000120	0
Dissolved Calcium	-	mg/L	12	10.60	58.60	32.81	33.30	12.94	17.30	25.40	40.85	42.59	49.86	0
Dissolved Chromium	-	mg/L	12	0.00005	0.00030	0.00010	0.00005	0.00009	0.00005	0.00005	0.00013	0.00020	0.00025	8
Dissolved Cobalt	-	mg/L	12	0.000010	0.000253	0.000041	0.000018	0.000068	0.000010	0.000012	0.000036	0.000051	0.000143	0

Parameters	CCME Guideline[1]	Unit	W43											
			n	min	max	mean	median	sd	10th	25th	75th	90th	95th	<DL
Dissolved Copper	-	mg/L	9	0.0447	0.0709	0.0579	0.0555	0.0107	0.0452	0.0510	0.0700	0.0704	0.0707	0
Dissolved Iron	-	mg/L	9	0.007	0.034	0.015	0.011	0.008	0.009	0.010	0.020	0.023	0.028	0
Dissolved Lead	-	mg/L	9	0.002050	0.012600	0.006084	0.006260	0.003967	0.002186	0.002220	0.006800	0.011960	0.012280	0
Dissolved Lithium	-	mg/L	9	0.00180	0.00320	0.00233	0.00210	0.00045	0.00196	0.00200	0.00270	0.00280	0.00300	0
Dissolved Magnesium	-	mg/L	9	6.81	11.00	8.14	7.80	1.44	6.91	7.00	9.14	9.70	10.35	0
Dissolved Manganese	-	mg/L	9	0.2490	1.0800	0.4526	0.3680	0.2614	0.2514	0.2530	0.5370	0.6504	0.8652	0
Dissolved Mercury	-	mg/L	7	0.0000050	0.0000050	0.0000050	0.0000050	0.0000000	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	7
Dissolved Molybdenum	-	mg/L	9	0.00003	0.00035	0.00007	0.00003	0.00011	0.00003	0.00003	0.00003	0.00014	0.00025	7
Dissolved Nickel	-	mg/L	9	0.00045	0.00064	0.00054	0.00051	0.00007	0.00047	0.00048	0.00060	0.00062	0.00063	0
Dissolved Phosphorus	-	mg/L	7	0.0010	0.0020	0.0013	0.0010	0.0005	0.0010	0.0010	0.0015	0.0020	0.0020	5
Dissolved Potassium	-	mg/L	9	1.18	1.68	1.41	1.39	0.13	1.30	1.36	1.45	1.53	1.60	0
Dissolved Selenium	-	mg/L	9	0.00002	0.00002	0.00002	0.00002	0.00000	0.00002	0.00002	0.00002	0.00002	0.00002	9
Dissolved Silicon	-	mg/L	9	5.20	6.00	5.57	5.60	0.30	5.20	5.30	5.80	5.92	5.96	0
Dissolved Silver	-	mg/L	9	0.000008	0.000090	0.000027	0.000023	0.000024	0.000009	0.000022	0.000023	0.000039	0.000064	0
Dissolved Sodium	-	mg/L	9	2.89	3.95	3.29	3.26	0.35	2.95	2.99	3.48	3.65	3.80	0
Dissolved Strontium	-	mg/L	9	0.224	0.362	0.269	0.255	0.050	0.226	0.226	0.313	0.326	0.344	0
Dissolved Sulphur	-	mg/L	9	13.00	22.00	15.89	16.00	2.76	13.00	14.00	17.00	18.00	20.00	0
Dissolved Thallium	-	mg/L	9	0.0000210	0.0000270	0.0000243	0.0000250	0.0000019	0.0000218	0.0000240	0.0000250	0.0000262	0.0000266	0
Dissolved Tin	-	mg/L	9	0.000005	0.000080	0.000013	0.000005	0.000025	0.000005	0.000005	0.000005	0.000020	0.000050	8
Dissolved Titanium	-	mg/L	9	0.00025	0.00100	0.00033	0.00025	0.00025	0.00025	0.00025	0.00025	0.00040	0.00070	8
Dissolved Uranium	-	mg/L	9	0.00081	0.00233	0.00154	0.00127	0.00057	0.00109	0.00125	0.00217	0.00230	0.00231	0
Dissolved Vanadium	-	mg/L	9	0.00010	0.00010	0.00010	0.00010	0.00000	0.00010	0.00010	0.00010	0.00010	0.00010	9
Dissolved Zinc	-	mg/L	9	2.26000	3.73000	2.61778	2.47000	0.46016	2.27600	2.28000	2.65000	3.01800	3.37400	0
Dissolved Zirconium	-	mg/L	9	0.00005	0.00005	0.00005	0.00005	0.00000	0.00005	0.00005	0.00005	0.00005	0.00005	9

Parameters	W13											
	n	min	max	mean	median	sd	10th	25th	75th	90th	95th	<DL
Dissolved Copper	12	0.0003	0.0069	0.0015	0.0008	0.0018	0.0004	0.0005	0.0016	0.0026	0.0045	0
Dissolved Iron	12	0.001	0.108	0.028	0.012	0.034	0.004	0.008	0.027	0.080	0.095	0
Dissolved Lead	12	0.000007	0.002730	0.000580	0.000122	0.000878	0.000034	0.000088	0.000599	0.001623	0.002131	0
Dissolved Lithium	12	0.00025	0.00270	0.00140	0.00135	0.00071	0.00071	0.00088	0.00185	0.00227	0.00248	1
Dissolved Magnesium	12	2.80	18.60	9.86	9.89	4.47	4.79	6.83	11.83	14.90	16.68	0
Dissolved Manganese	12	0.0015	0.0939	0.0214	0.0117	0.0279	0.0026	0.0069	0.0195	0.0576	0.0761	0
Dissolved Mercury	9	0.0000050	0.0000050	0.0000050	0.0000050	0.0000000	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	9
Dissolved Molybdenum	12	0.00018	0.00099	0.00060	0.00056	0.00022	0.00036	0.00051	0.00073	0.00084	0.00091	0
Dissolved Nickel	12	0.00015	0.00097	0.00040	0.00031	0.00025	0.00016	0.00021	0.00050	0.00073	0.00085	0
Dissolved Phosphorus	9	0.0010	0.0110	0.0038	0.0030	0.0039	0.0010	0.0010	0.0030	0.0102	0.0106	4
Dissolved Potassium	12	0.80	1.38	1.09	1.15	0.15	0.94	1.00	1.17	1.20	1.28	0
Dissolved Selenium	12	0.00002	0.00031	0.00007	0.00005	0.00008	0.00002	0.00002	0.00005	0.00011	0.00021	5
Dissolved Silicon	12	2.49	6.50	4.96	5.20	1.15	3.26	4.78	5.50	6.07	6.28	0
Dissolved Silver	12	0.000003	0.000020	0.000005	0.000003	0.000005	0.000003	0.000003	0.000003	0.000011	0.000015	9
Dissolved Sodium	12	1.16	5.39	3.77	3.99	1.35	1.96	3.01	4.67	5.25	5.31	0
Dissolved Strontium	12	0.065	0.366	0.210	0.217	0.085	0.109	0.163	0.248	0.310	0.337	0
Dissolved Sulphur	12	4.00	42.00	12.58	10.00	10.82	5.00	5.00	13.75	22.30	31.55	3
Dissolved Thallium	12	0.0000010	0.0000030	0.0000014	0.0000010	0.0000008	0.0000010	0.0000010	0.0000013	0.0000029	0.0000030	9
Dissolved Tin	12	0.000005	0.000100	0.000022	0.000005	0.000037	0.000005	0.000005	0.000009	0.000092	0.000100	11
Dissolved Titanium	12	0.00025	0.00144	0.00049	0.00025	0.00046	0.00025	0.00025	0.00039	0.00134	0.00142	9
Dissolved Uranium	12	0.00243	0.02390	0.01188	0.01182	0.00690	0.00422	0.00650	0.01590	0.02040	0.02214	0
Dissolved Vanadium	12	0.00010	0.00035	0.00015	0.00010	0.00009	0.00010	0.00010	0.00013	0.00029	0.00032	9
Dissolved Zinc	12	0.00110	0.00840	0.00379	0.00280	0.00247	0.00145	0.00198	0.00634	0.00658	0.00741	0
Dissolved Zirconium	12	0.00005	0.00020	0.00008	0.00005	0.00005	0.00005	0.00005	0.00010	0.00015	0.00017	8

Notes:

1) Canadian water quality guidelines for the protection of aquatic life,

a) Ammonia (NH_3) guideline based on ph=8 and temp=20

b) Aluminum (AL-T)= 0.005 mg/L at pH < 6.5: 0.1 mg/L at pH ≥ 6.5

c) Cadmium (Cd) mg/L: 10^(0.86*(log(hardness))-3.2)/1000

d) Copper (Cu) mg/L: (e^0.8545[ln(hardness)]-1.465)*0.2/1000; minim

e) Lead (Pb) mg/L: (e^1.273[ln(hardness)]-4.705)/1000; minimum is 0.

f) Nickel (Ni) mg/L: (e^0.76[(ln(hardness)]+1.06)/1000; minimum is 0.0

Parameters	CCME Guideline[1]	Unit	W11												W18											
			n	min	max	mean	median	sd	10th	25th	75th	90th	95th	<DL	n	min	max	mean	median	sd	10th	25th	75th	90th	95th	<DL
pH	6.5 - 9.0	pH Units	25	7.20	8.12	7.85	7.90	0.24	7.55	7.80	8.00	8.10	8.10	0	23	7.20	8.20	7.80	7.83	0.22	7.53	7.78	7.91	8.00	8.00	0
Conductivity	-	uS/cm	25	85	492	271	280	104	130	210	317	399	442	0	23	53	267	172	164	67	86	122	233	257	263	0
Total Hardness CaCO3	-	mg/L	25	45	248	134	138	51	63	107	160	199	204	0	23	25	124	80	75	30	45	58	111	116	120	0
Dissolved Hardness CaCO3	-	mg/L	25	45	251	131	141	50	64	98	154	187	204	0	23	26	125	81	87	30	44	59	106	123	124	0
Total Dissolved Solids	-	mg/L	25	78	350	181	200	60	104	150	210	220	266	0	23	54	170	110	110	38	58	86	140	166	170	0
Total Suspended Solids	-	mg/L	25	0.5	53.0	9.0	2.0	14.8	0.5	0.5	8.0	35.3	39.8	7	23	0.5	46.0	6.2	1.0	11.6	0.5	0.5	3.5	20.4	28.2	10
Turbidity		NTU	25	0.1	22.5	3.0	1.6	4.7	0.5	0.9	2.3	5.4	10.9	0	23	0.1	4.6	0.8	0.3	1.1	0.1	0.2	1.0	1.6	3.4	0
Ammonia as N	0.499[a]	mg/L	25	0.003	0.260	0.028	0.005	0.052	0.003	0.005	0.035	0.054	0.068	13	23	0.003	0.190	0.028	0.010	0.041	0.003	0.005	0.035	0.064	0.079	8
Alkalinity (Total as CaCO3)	-	mg/L	25	4.90	127.00	67.70	80.00	39.50	9.24	27.60	94.00	120.00	120.00	0	23	4.90	92.00	54.64	60.00	29.06	12.54	31.50	83.00	84.00	91.11	0
Acidity to pH 4.5 (as CaCO3)	-	mg/L	15	0.25	0.25	0.25	0.25	0.00	0.25	0.25	0.25	0.25	0.25	15	15	0.25	0.25	0.25	0.25	0.00	0.25	0.25	0.25	0.25	0.25	15
Acidity to pH 8.3 (as CaCO3)	-	mg/L	15	0.25	4.80	1.69	1.60	1.38	0.25	0.63	2.00	3.66	4.17	4	15	0.25	4.30	1.54	1.40	1.17	0.25	0.63	2.30	2.80	3.25	4
Bromide	-	mg/L	21	0.01	0.20	0.17	0.20	0.07	0.05	0.20	0.20	0.20	0.20	21	21	0.01	0.20	0.17	0.20	0.07	0.05	0.20	0.20	0.20	0.20	21
Chloride	120	mg/L	25	0.25	4.60	0.66	0.25	0.90	0.25	0.25	0.70	1.16	1.36	15	23	0.25	2.50	0.62	0.25	0.58	0.25	0.25	0.70	1.24	1.84	12
Fluoride	0.12	mg/L	21	0.055	0.100	0.083	0.080	0.013	0.070	0.080	0.090	0.100	0.100	0	21	0.028	0.060	0.044	0.040	0.009	0.040	0.040	0.050	0.060	0.060	0
Sulphate	-	mg/L	25	9.30	120.00	59.66	62.00	24.98	28.60	44.00	71.00	85.00	103.40	0	23	0.25	49.00	24.30	23.00	13.75	4.72	17.00	32.00	43.92	47.70	2
Total Nitrogen	-	mg/L	25	0.17	0.61	0.37	0.37	0.11	0.24	0.32	0.43	0.53	0.56	0	23	0.18	0.62	0.39	0.41	0.12	0.22	0.34	0.46	0.53	0.59	0
Nitrate (as N)	13	mg/L	25	0.031	0.451	0.180	0.189	0.099	0.060	0.107	0.245	0.275	0.287	0	23	0.037	0.333	0.188	0.171	0.091	0.073	0.125	0.270	0.304	0.319	0
Nitrate plus Nitrite	-	mg/L	24	0.034	0.454	0.181	0.194	0.101	0.061	0.100	0.249	0.276	0.288	0	23	0.037	0.333	0.189	0.171	0.091	0.077	0.125	0.270	0.304	0.319	0
Nitrite (as N)	0.06	mg/L	25	0.001	0.140	0.007	0.001	0.028	0.001	0.001	0.003	0.003	0.009	16	23	0.001	0.010	0.002	0.001	0.002	0.001	0.001	0.002	0.003	0.004	19
Total Kjeldahl Nitrogen	-	mg/L	24	0.01	0.51	0.20	0.16	0.14	0.06	0.13	0.25	0.45	0.46	1	23	0.01	0.52	0.20	0.17	0.14	0.04	0.11	0.28	0.36	0.50	2
Orthophosphate as P	-	mg/L	25	0.0005	0.0420	0.0036	0.0010	0.0086	0.0005	0.0005	0.0020	0.0042	0.0138	8	23	0.0005	0.0420	0.0032	0.0010	0.0085	0.0005	0.0010	0.0020	0.0030	0.0030	6
Cyanide, Total	0.005	mg/L																								
Cyanide, Weak Acid Diss	-	mg/L	25	0.00025	0.00110	0.00039	0.00025	0.00025	0.00025	0.00025	0.00050	0.00076	0.00088	18	23	0.00025	0.00120	0.00045	0.00025	0.00029	0.00025	0.00025	0.00060	0.00088	0.00090	14
Dissolved Organic Carbon	-	mg/L	8	1.44	13.60	5.61	4.00	4.28	2.11	2.93	6.93	11.50	12.55	0	9	1.84	14.90	6.69	6.20	4.51	1.89	3.60	10.20	11.62	13.26	0
Total Organic Carbon	-	mg/L	21	0.25	19.90	6.21	4.80	5.08	1.90	2.90	6.90	14.30	16.00	1	21	0.25	21.80	7.55	5.30	5.98	2.17	3.70	10.20	17.10	19.20	1
Total Aluminum	0.1[b]	mg/L	25	0.01	0.63	0.21	0.15	0.17	0.05	0.08	0.25	0.47	0.57	0	23	0.01	0.71	0.13	0.07	0.17	0.01	0.02	0.15	0.32	0.47	0
Total Antimony	-	mg/L	25	0.00011	0.00039	0.00016	0.00015	0.00006	0.00012	0.00012	0.00015	0.00018	0.00023	0	23	0.00007	0.00018	0.00014	0.00014	0.00003	0.00011	0.00013	0.00016	0.00017	0.00017	0
Total Arsenic	0.005	mg/L	25	0.00037	0.00152	0.00076	0.00065	0.00026	0.00055	0.00059	0.00087	0.00111	0.00123	0	23	0.00030	0.00110	0.00046	0.00040	0.00018	0.00032	0.00034	0.00056	0.00065	0.00067	0
Total Barium	-	mg/L	25	0.04	0.11	0.07	0.06	0.02	0.05	0.06	0.07	0.08	0.09	0	23	0.03	0.06	0.05	0.05	0.01	0.04	0.04	0.05	0.06	0.06	0
Total Beryllium	-	mg/L	25	0.000005	0.000050	0.000016	0.000010	0.000015	0.000005	0.000005	0.000020	0.000040	0.000048	10	23	0.000005	0.000030	0.000010	0.000005	0.000008	0.000005	0.000005	0.000010	0.000020	0.000029	15
Total Bismuth	-	mg/L	25	0.0000025	0.0000310	0.0000052	0.0000025	0.0000076	0.0000025	0.0000025	0.0000025	0.0000088	0.0000247	21	23	0.0000025	0.0000140	0.0000030	0.0000025	0.0000024	0.0000025	0.0000025	0.0000025	0.0000025	0.0000025	22
Total Boron	1.5	mg/L	25	0.03	0.03	0.03	0.03	0.00	0.03	0.03	0.03	0.03	0.03	25	23	0.03	0.03	0.03	0.03	0.00	0.03	0.03	0.03	0.03	0.03	23
Total Cadmium	0.000032[c]	mg/L	25	0.000015	0.000278	0.000091	0.000083	0.000051	0.000043	0.000067	0.000108	0.000137	0.000157	0	23	0.000003	0.000071	0.000023	0.000013	0.000020	0.000006	0.000009	0.000035	0.000057	0.000064	2
Total Calcium	-	mg/L	25	12.50	62.50	35.91	36.90	12.98	17.28	28.80	43.60	51.54	54.02	0	23	6.71	34.00	21.56	20.10	7.80	12.16	16.20	29.50	30.56	31.68	0
Total Chromium	0.001	mg/L	25	0.00005	0.00100	0.00023	0.00010	0.00026	0.00005	0.00005	0.00030	0.00051	0.00082	9	23	0.00005	0.00070	0.00020	0.00010	0.00019	0.00005	0.00005	0.00025	0.00049	0.00059	8
Total Cobalt	-	mg/L	25	0.000032	0.000973	0.000380	0.000313	0.000292	0.000047	0.000136	0.000528	0.000823	0.000940	0	23	0.000009	0.000421	0.000097	0.000057	0.000115	0.000014	0.000023	0.000086	0.000293	0.000333	0
Total Copper	0.0023[d]	mg/L	25	0.0014	0.0328	0.0156	0.0159	0.0088	0.0046	0.0078	0.0215	0.0264	0.0276	0	23	0.0004	0.0080	0.0021	0.0013	0.0024	0.0005	0.0007	0.0020	0.0066	0.0079	0
Total Iron	0.3	mg/L	25	0.007	1.040	0.325	0.303	0.259	0.049	0.096	0.447	0.700	0.750	0	23	0.004	0.617	0.135	0.055	0.188	0.008	0.018	0.137	0.469	0.563	0
Total Lead	0.003[e]	mg/L	25	0.000041	0.074800	0.004250	0.000671	0.014834	0.000132	0.000258	0.001770	0.002898	0.008586	0	23	0.000003	0.000711	0.000178	0.000067	0.000231	0.000003	0.000017	0.000254	0.000554	0.000694	4
Total Lithium	-	mg/L	25	0.00025	0.00260	0.00129	0.00130	0.00049	0.00072	0.00110	0.00150	0.00162	0.00218	1	23	0.00025	0.00200	0.00079	0.00070	0.00038	0.00050	0.00060	0.00085	0.00120	0.00129	2
Total Magnesium	-	mg/L	25	3.28	22.30	10.76	11.40	4.60	4.76	8.10	12.50	16.16	18.12	0	23	1.95	9.96	6.35	6.02	2.54	3.50	4.28	8.79	9.78	9.81	0
Total Manganese	-	mg/L	25	0.0001	0.1340	0.0449	0.0327	0.0314	0.0181	0.0290	0.0539	0.0785	0.1134	0	23	0.0015	0.0330	0.0099	0.0037	0.0104	0.0023	0.0027	0.0150	0.0270	0.0280	0
Total Mercury	0.000026	mg/L	22	0.0000050	0.0000100	0.0000057	0.0000050	0.0000018	0.0000050	0.0000050	0.0000050	0.0000095	0.0000100	19	19	0.0000050	0.0000100	0.0000053	0.0000050	0.0000011	0.0000050	0.0000050	0.0000050	0.0000050	0.0000055	18
Total Molybdenum	0.073	mg/L	25	0.00025	0.00108	0.00066	0.00071	0.00024	0.00034	0.00051	0.00084	0.00095	0.00100	0	23	0.00045	0.00239	0.00125	0.00114	0.00052	0.00070	0.00090	0.00157	0.00199	0.00220	0
Total Nickel	0.0033[f]	mg/L	25	0.00024	0.00167	0.00062	0.00053	0.00038	0.00028	0.00036	0.00069	0.00115	0.00141	0	23	0.00011	0.00109	0.00041	0.00030	0.00029	0.00013	0.00019	0.00048	0.00084	0.00101	0
Total Phosphorus	-	mg/L	22	0.0010	0.0310	0.0094	0.0050	0.0098	0.0010	0.0023	0.0125	0.0275	0.0289	5	19	0.0010	0.0320	0.0079	0.0030	0.0088	0.0010	0.0015	0.0135	0.0173	0.0236	5
Total Potassium	-	mg/L	25	0.50	2.38	1.03	0.96	0.35	0.77	0.85	1.13	1.33	1.40	0	23	0.64	1.50	1.08	1.04	0.26	0.78	0.89	1.29	1.48	1.50	0
Total Selenium	0.001	mg/L	25	0.00002	0.00028	0.00012	0.00012	0.00005	0.00007	0.00009	0.00014	0.00018	0.00021	1	23	0.00002	0.00009	0.00004	0.00004	0.00002	0.00002	0.00002	0.00006	0.00008	0.00009	10
Total Silicon	-	mg/L	25	2.83	6.50	5.03	5.20	0.96	3.92	4.30	5.80	6.06	6.18	0	23	2.30	5.90	4.95	5.30	0.88	3.80	4.50	5.60	5.80	5.89	0
Total Silver	0.0001	mg/L	25	0.000003	0.000091	0.000010	0.000003	0.000019	0.000003	0.000003	0.000008	0.000014	0.000039	16	23	0.000003	0.000010	0.000003	0.000003	0.000002	0.000003	0.000003	0.000003	0.000006	0.000007	19
Total Sodium	-	mg/L	25	1.33	5.68	3.63	3.76	1.18	1.87	3.02	4.38	5.05	5.45	0	23	1.07	6.42	3.37	3.30	1.21	2.05	2.64	4.11	4.86	5.01	0
Total Strontium	-	mg/L	25	0.073	0.381	0.226	0.237	0.081	0.111	0.186	0.264	0.336	0.363	0	23	0.041	0.231	0.121	0.116	0.050	0.064	0.083	0.152	0.189	0.194	0
Total Sulphur	-	mg/L	25	5.00	48.00	21.80	22.00	9.82	10.40	16.00	25.00	32.00	37.60	1	23	3.00	17.00	8.78	8.00	4.40	5.00	5.00	12.50	14.80	16.80	8
Total Thallium	0.0008	mg/L	25	0.0000010	0.0000220	0.0000045	0.0000030	0.0000043	0.0000010	0.0000030	0.0000040	0.0000082	0.0000098	4	23	0.0000010	0.0000100	0.0000035	0.0000030	0.0000025	0.0000010	0.0000015	0.0000040	0.0000078	0.0000080	6
Total Tin	-	mg/L	25	0.000005	0.000100	0.000013	0.000005	0.000026	0.000005	0.000005	0.000005	0.000005	0.000081	25	23	0.000005	0.000500	0.000040	0.000005	0.000116	0.000005	0.000005	0.000005	0.000025	0.000255	20
Total Titanium	-	mg/L	25	0.00025	0.02050	0.00390	0.00090	0.00567	0.00025	0.00025	0.00560	0.01258	0.01530	8	23	0.00025	0.02040	0.00362	0.00060	0.00581	0.00025	0.00025	0.00335	0.01348	0.01563	10
Total Uranium	0.015	mg/L	25	0.00209	0.03280	0.01068	0.00978	0.00720	0.00332	0.00536	0.01300	0.01978	0.02346	0	23	0.00121	0.00830	0.00418	0.00371	0.00240	0.00152	0.00238	0.00590	0.00802	0.00824	0
Total Vanadium	-	mg/L	25	0.00010	0.00260	0.00048	0.00020	0.00063	0.00010	0.00010	0.00060	0.00132	0.00156	12	23	0.00010	0.00210	0.00057	0.00030	0.00059	0.00010	0.00020	0.00060	0.00160	0.00188	5
Total Zinc	0.03	mg/L	25	0.00070	0.02110	0.00625	0.00540	0.00414	0.00204	0.00400	0.00700	0.01064	0.01204	0	23	0.00020	0.00770	0.00214	0.00160	0.00212	0.00022	0.00050	0.00305	0.00424	0.00682	0
Total Zirconium	-	mg/L	25	0.00005	0.00070	0.00016	0.00010	0.00014	0.00005	0.00005	0.00020	0.00030	0.00030	9	23	0.00005	0.00060	0.00016	0.00010	0.00014	0.00005	0.00005	0.00020	0.00030	0.00039	8
Dissolved Aluminum	0.1	mg/L	25	0.01	0.27	0.07	0.03	0.08	0.01	0.02	0.06	0.21	0.24	0	23	0.00	0.35	0.07	0.04	0.09	0.01	0.02	0.10	0.17	0.24	0
Dissolved Antimony	-	mg/L	25	0.00009	0.00023	0.00014	0.00014	0.00003	0.00011	0.00012	0.00015	0.00017	0.00019	0	23	0.00006	0.00021	0.00014	0.00014	0.00003	0.00010	0.00012	0.00016	0.00018	0.00018	0
Dissolved Arsenic	-	mg/L	25	0.00035	0.00091	0.00057	0.00053	0.00014	0.00042	0.00049	0.00067	0.00074	0.00077	0	23	0.00027	0.00069	0.00039	0.00037	0.00010	0.00032	0.00034	0.00039	0.00050	0.00058	0
Dissolved Barium	-	mg/L	25	0.032900	0.106000	0.061108	0.061900	0.016951	0.040100	0.050800	0.069100	0.079460	0.089380	0	23	0.025200	0.061900	0.044352	0.041400	0.011162	0.029960	0.036250	0.054000	0.058980	0.059360	0
Dissolved Beryllium	-	mg/L	25	0.000005	0.000030	0.000010	0.000005	0.000009	0.000005	0.000005	0.000010	0.000026	0.000030	18	23	0.000005	0.000020	0.000007	0.000005	0.000004	0.000005	0.000005	0.000008	0.000010	0.000013	17
Dissolved Bismuth	-	mg/L	25	0.0000025	0.0000150	0.0000033	0.0000025	0.0000028	0.0000025	0.0000025	0.0000025	0.0000025	0.0000077	23	23	0.0000025	0.0000025	0.0000025	0.0000025	0.0000000	0.0000025	0.0000025	0.0000025	0.0000025	0.0000025	23
Dissolved Boron	-	mg/L	25	0.025	0.025	0.025	0.025	0.000	0.025	0.025	0.025	0.025	0.025	25	23	0.025	0.025	0.025	0.025	0.000	0.025	0.025	0.025	0.025	0.025	23
Dissolved Cadmium	-	mg/L	25	0.000012	0.000130	0.000066	0.000067	0.000028	0.000027	0.000052	0.000081	0.000092	0.000120	0	23	0.000003	0.000063	0.000017	0.000011	0.000018	0.000003	0.000007	0.000020	0.000044	0.000061	4
Dissolved Calcium	-	mg/L	25	12.50	63.50	35.49	37.60	12.70	17.58	27.80	43.30	49.44	54.36	0	23	7.21	34.00	21.67	19.70	8.16	11.90	15.55	28.80	32.56	32.88	0
Dissolved Chromium	-	mg/L	25	0.00005	0.00030	0.00011	0.00010	0.00008	0.00005	0.00005	0.00010	0.00021	0.00028	10	23	0.00005	0.00050	0.00016	0.00010	0.00012	0.00005	0.00005	0.00020	0.00028	0.00039	7
Dissolved Cobalt	-	mg/L	25	0.000025	0.000572	0.000251	0.000248	0.000163	0.000039	0.000101	0.000389	0.000475	0.000487	0	23	0.000010	0.000131	0.000043	0.000032	0.000031	0.000013	0.000021	0.000062	0.000079	0.000085	0

Parameters	CCME Guideline[1]	Unit	W11												W18											
			n	min	max	mean	median	sd	10th	25th	75th	90th	95th	<DL	n	min	max	mean	median	sd	10th	25th	75th	90th	95th	<DL
Dissolved Copper	-	mg/L	25	0.0014	0.0292	0.0112	0.0083	0.0077	0.0036	0.0059	0.0164	0.0227	0.0262	0	23	0.0004	0.0078	0.0018	0.0010	0.0021	0.0005	0.0007	0.0018	0.0048	0.0071	0
Dissolved Iron	-	mg/L	25	0.002	0.376	0.102	0.061	0.099	0.006	0.036	0.145	0.236	0.253	0	23	0.002	0.192	0.048	0.035	0.052	0.005	0.013	0.065	0.118	0.160	0
Dissolved Lead	-	mg/L	25	0.000009	0.009890	0.000561	0.000115	0.001952	0.000021	0.000031	0.000267	0.000519	0.000681	0	23	0.000003	0.000388	0.000069	0.000019	0.000107	0.000007	0.000013	0.000037	0.000202	0.000295	1
Dissolved Lithium	-	mg/L	25	0.00025	0.00240	0.00121	0.00130	0.00051	0.00064	0.00090	0.00140	0.00166	0.00218	2	23	0.00025	0.00220	0.00067	0.00060	0.00047	0.00025	0.00025	0.00075	0.00120	0.00138	8
Dissolved Magnesium	-	mg/L	25	3.23	22.50	10.51	10.90	4.44	4.83	8.09	12.50	15.50	17.46	0	23	1.89	10.20	6.25	5.92	2.51	3.39	4.26	7.91	9.78	10.07	0
Dissolved Manganese	-	mg/L	25	0.0001	0.1110	0.0332	0.0260	0.0236	0.0153	0.0221	0.0355	0.0618	0.0748	0	23	0.0011	0.0266	0.0058	0.0027	0.0076	0.0017	0.0021	0.0046	0.0199	0.0240	0
Dissolved Mercury	-	mg/L	21	0.0000050	0.0000200	0.0000062	0.0000050	0.0000035	0.0000050	0.0000050	0.0000050	0.0000100	0.0000100	18	18	0.0000050	0.0000100	0.0000053	0.0000050	0.0000012	0.0000050	0.0000050	0.0000050	0.0000050	0.0000057	17
Dissolved Molybdenum	-	mg/L	25	0.00025	0.00105	0.00066	0.00063	0.00022	0.00034	0.00048	0.00084	0.00094	0.00098	0	23	0.00045	0.00239	0.00124	0.00115	0.00053	0.00071	0.00088	0.00157	0.00190	0.00230	0
Dissolved Nickel	-	mg/L	25	0.00019	0.00112	0.00051	0.00047	0.00023	0.00027	0.00033	0.00059	0.00082	0.00091	0	23	0.00010	0.00076	0.00034	0.00028	0.00020	0.00013	0.00018	0.00047	0.00066	0.00071	0
Dissolved Phosphorus	-	mg/L	21	0.0010	0.0100	0.0034	0.0010	0.0032	0.0010	0.0010	0.0050	0.0080	0.0098	11	18	0.0010	0.0250	0.0042	0.0015	0.0059	0.0010	0.0010	0.0055	0.0084	0.0117	9
Dissolved Potassium	-	mg/L	25	0.45	2.43	1.02	0.94	0.36	0.76	0.84	1.08	1.35	1.45	0	23	0.63	1.53	1.06	1.08	0.26	0.75	0.88	1.24	1.45	1.50	0
Dissolved Selenium	-	mg/L	25	0.00007	0.00028	0.00012	0.00012	0.00005	0.00007	0.00009	0.00014	0.00018	0.00019	0	23	0.00002	0.00012	0.00004	0.00002	0.00003	0.00002	0.00002	0.00005	0.00008	0.00010	12
Dissolved Silicon	-	mg/L	25	2.74	6.40	4.95	5.20	0.91	3.74	4.50	5.60	5.76	5.96	0	23	2.34	6.10	4.88	5.00	0.91	3.70	4.70	5.45	5.80	6.07	0
Dissolved Silver	-	mg/L	25	0.000003	0.000013	0.000005	0.000003	0.000004	0.000003	0.000003	0.000006	0.000011	0.000011	18	23	0.000003	0.000007	0.000003	0.000003	0.000001	0.000003	0.000003	0.000003	0.000005	0.000007	20
Dissolved Sodium	-	mg/L	25	1.37	5.73	3.56	3.67	1.13	1.88	2.91	4.17	4.93	5.31	0	23	1.10	6.46	3.32	3.21	1.17	2.01	2.55	3.94	4.36	4.89	0
Dissolved Strontium	-	mg/L	25	0.072	0.377	0.223	0.238	0.079	0.111	0.172	0.268	0.324	0.359	0	23	0.041	0.250	0.121	0.118	0.053	0.061	0.082	0.148	0.192	0.198	0
Dissolved Sulphur	-	mg/L	25	5.00	49.00	21.60	21.00	9.88	10.00	16.00	26.00	31.40	38.60	1	23	3.00	17.00	8.57	7.00	4.23	5.00	5.00	12.00	14.60	15.90	8
Dissolved Thallium	-	mg/L	25	0.0000010	0.0000050	0.0000029	0.0000030	0.0000013	0.0000010	0.0000020	0.0000040	0.0000043	0.0000049	5	23	0.0000010	0.0000050	0.0000023	0.0000029	0.0000011	0.0000010	0.0000010	0.0000030	0.0000030	0.0000039	7
Dissolved Tin	-	mg/L	25	0.000005	0.000100	0.000013	0.000005	0.000026	0.000005	0.000005	0.000005	0.000005	0.000081	25	23	0.000005	0.000100	0.000014	0.000005	0.000027	0.000005	0.000005	0.000005	0.000010	0.000091	21
Dissolved Titanium	-	mg/L	25	0.00025	0.00210	0.00058	0.00025	0.00060	0.00025	0.00025	0.00070	0.00164	0.00202	17	23	0.00025	0.00260	0.00061	0.00025	0.00064	0.00025	0.00025	0.00090	0.00153	0.00178	16
Dissolved Uranium	-	mg/L	25	0.00144	0.03220	0.01037	0.00969	0.00709	0.00317	0.00460	0.01290	0.01836	0.02304	0	23	0.00102	0.00867	0.00414	0.00350	0.00253	0.00134	0.00224	0.00583	0.00831	0.00861	0
Dissolved Vanadium	-	mg/L	25	0.00010	0.00060	0.00018	0.00010	0.00014	0.00010	0.00010	0.00020	0.00031	0.00046	17	23	0.00010	0.00100	0.00033	0.00030	0.00021	0.00010	0.00020	0.00045	0.00054	0.00060	4
Dissolved Zinc	-	mg/L	25	0.00060	0.00980	0.00405	0.00430	0.00199	0.00130	0.00310	0.00500	0.00584	0.00654	0	23	0.00020	0.00520	0.00122	0.00060	0.00127	0.00032	0.00050	0.00136	0.00318	0.00348	0
Dissolved Zirconium	-	mg/L	25	0.00005	0.00050	0.00012	0.00010	0.00010	0.00005	0.00005	0.00019	0.00020	0.00028	11	23	0.00005	0.00050	0.00017	0.00020	0.00012	0.00005	0.00005	0.00020	0.00030	0.00039	8

Notes:

1) Canadian water quality guidelines for the protection of aquatic life,

a) Ammonia (NH3) guideline based on ph=8 and temp=20

b) Aluminum (AL-T)= 0.005 mg/L at pH < 6.5: 0.1 mg/L at pH ≥ 6.5

c) Cadmium (Cd) mg/L: 10^(0.86*(log(hardness))-3.2)/1000

d) Copper (Cu) mg/L: (e^0.8545[ln(hardness)]-1.465)*0.2/1000; minim

e) Lead (Pb) mg/L: (e^1.273[ln(hardness)]-4.705)/1000; minimum is 0.

f) Nickel (Ni) mg/L: (e^0.76[(ln(hardness)]+1.06)/1000; minimum is 0.0

Parameters	CCME Guideline[1]	Unit	W4												W22											
			n	min	max	mean	median	sd	10th	25th	75th	90th	95th	<DL	n	min	max	mean	median	sd	10th	25th	75th	90th	95th	<DL
pH	6.5 - 9.0	pH Units	24	7.30	8.20	7.84	7.90	0.24	7.41	7.83	8.00	8.00	8.05	0	6	7.26	8.00	7.65	7.68	0.34	7.29	7.35	7.94	7.97	7.99	0
Conductivity	-	uS/cm	24	71	387	234	236	82	118	186	292	324	353	0	6	69	289	161	149	99	70	73	234	264	276	0
Total Hardness CaCO3	-	mg/L	24	37	176	111	111	39	59	87	135	164	169	0	6	27	132	67	56	43	28	31	94	117	125	0
Dissolved Hardness CaCO3	-	mg/L	23	33	176	111	111	39	57	87	137	159	169	0	6	30	128	67	55	41	30	33	95	116	122	0
Total Dissolved Solids	-	mg/L	24	72	232	154	150	44	92	130	190	210	219	0	6	54	164	94	76	43	59	66	118	147	156	0
Total Suspended Solids	-	mg/L	24	0.5	130.0	13.9	2.0	32.8	0.5	0.5	7.5	21.4	93.4	7	6	0.5	10.0	3.5	0.5	4.7	0.5	0.5	6.9	9.5	9.8	4
Turbidity		NTU	24	0.2	51.0	3.5	0.8	10.4	0.2	0.3	1.4	3.0	11.3	0	6	0.1	2.2	0.9	0.6	0.9	0.2	0.2	1.5	1.9	2.1	0
Ammonia as N	0.499[a]	mg/L	24	0.003	0.250	0.033	0.010	0.053	0.003	0.005	0.036	0.069	0.096	10	6	0.010	0.046	0.020	0.017	0.013	0.011	0.012	0.021	0.034	0.040	0
Alkalinity (Total as CaCO3)	-	mg/L	24	4.40	125.00	66.04	78.50	37.67	9.43	31.00	93.50	107.00	118.50	0	6	14.00	137.00	61.23	50.20	49.40	15.00	20.85	91.25	118.50	127.75	0
Acidity to pH 4.5 (as CaCO3)	-	mg/L	14	0.25	0.25	0.25	0.25	0.00	0.25	0.25	0.25	0.25	0.25	14	6	0.25	0.25	0.25	0.25	0.00	0.25	0.25	0.25	0.25	0.25	6
Acidity to pH 8.3 (as CaCO3)	-	mg/L	14	0.25	4.50	1.54	1.26	1.29	0.25	0.31	2.35	2.94	3.53	4	6	0.25	7.50	2.24	1.60	2.72	0.25	0.46	2.21	4.88	6.19	2
Bromide	-	mg/L	20	0.01	0.20	0.17	0.20	0.07	0.05	0.20	0.20	0.20	0.20	20	6	0.01	0.20	0.14	0.20	0.10	0.01	0.05	0.20	0.20	0.20	6
Chloride	120	mg/L	24	0.25	6.40	0.83	0.25	1.27	0.25	0.25	1.03	1.37	1.66	13	6	0.25	0.80	0.43	0.25	0.28	0.25	0.25	0.66	0.80	0.80	4
Fluoride	0.12	mg/L	20	0.040	0.100	0.068	0.070	0.013	0.059	0.060	0.070	0.081	0.091	0	6	0.038	0.062	0.045	0.040	0.009	0.039	0.040	0.048	0.056	0.059	0
Sulphate	-	mg/L	24	7.16	70.50	39.02	41.00	16.68	14.50	29.75	45.75	60.10	65.25	0	6	8.10	15.00	11.59	11.63	2.88	8.65	9.37	13.85	14.50	14.75	0
Total Nitrogen	-	mg/L	24	0.10	0.74	0.34	0.34	0.14	0.18	0.26	0.39	0.50	0.54	0	6	0.22	0.54	0.38	0.38	0.10	0.29	0.36	0.41	0.48	0.51	0
Nitrate (as N)	13	mg/L	24	0.022	0.264	0.145	0.158	0.080	0.041	0.073	0.208	0.240	0.249	0	6	0.090	0.296	0.172	0.149	0.090	0.091	0.095	0.240	0.275	0.286	0
Nitrate plus Nitrite	-	mg/L	23	0.022	0.264	0.145	0.155	0.081	0.042	0.066	0.209	0.240	0.249	0	6	0.090	0.296	0.173	0.152	0.090	0.091	0.095	0.240	0.275	0.286	0
Nitrite (as N)	0.06	mg/L	24	0.001	0.160	0.008	0.001	0.032	0.001	0.001	0.002	0.003	0.004	17	6	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.002	4
Total Kjeldahl Nitrogen	-	mg/L	22	0.01	0.69	0.21	0.17	0.16	0.06	0.11	0.22	0.46	0.48	1	6	0.02	0.44	0.21	0.21	0.15	0.05	0.10	0.28	0.36	0.40	0
Orthophosphate as P	-	mg/L	24	0.0005	0.0480	0.0036	0.0010	0.0097	0.0005	0.0009	0.0020	0.0030	0.0089	7	6	0.0005	0.0030	0.0016	0.0015	0.0009	0.0008	0.0010	0.0020	0.0025	0.0028	1
Cyanide, Total	0.005	mg/L																								
Cyanide, Weak Acid Diss	-	mg/L	24	0.00025	0.00170	0.00049	0.00025	0.00036	0.00025	0.00025	0.00066	0.00087	0.00099	14	6	0.00025	0.00070	0.00048	0.00048	0.00025	0.00025	0.00025	0.00070	0.00070	0.00070	3
Dissolved Organic Carbon	-	mg/L	8	2.10	13.40	6.01	5.20	3.78	2.18	3.55	7.85	9.83	11.62	0	6	2.04	7.90	5.66	6.80	2.50	2.52	3.83	7.38	7.65	7.78	0
Total Organic Carbon	-	mg/L	20	0.25	19.80	6.79	5.10	5.04	2.24	3.73	8.78	12.21	17.81	1	6	2.00	8.30	5.03	5.00	2.59	2.25	2.90	7.03	7.85	8.08	1
Total Aluminum	0.1[b]	mg/L	24	0.01	0.95	0.16	0.08	0.24	0.02	0.04	0.14	0.34	0.75	0	6	0.01	0.20	0.09	0.10	0.07	0.01	0.03	0.11	0.15	0.18	0
Total Antimony	-	mg/L	24	0.00010	0.00046	0.00015	0.00013	0.00007	0.00011	0.00013	0.00014	0.00015	0.00016	0	6	0.00005	0.00008	0.00006	0.00006	0.00001	0.00006	0.00006	0.00006	0.00007	0.00008	0
Total Arsenic	0.005	mg/L	24	0.00029	0.00243	0.00059	0.00043	0.00047	0.00034	0.00038	0.00054	0.00083	0.00143	0	6	0.00024	0.00054	0.00032	0.00028	0.00011	0.00025	0.00026	0.00031	0.00043	0.00048	0
Total Barium	-	mg/L	24	0.04	0.10	0.06	0.06	0.02	0.05	0.05	0.07	0.08	0.09	0	6	0.01	0.10	0.05	0.05	0.04	0.01	0.02	0.07	0.09	0.10	0
Total Beryllium	-	mg/L	24	0.000005	0.000073	0.000013	0.000005	0.000019	0.000005	0.000005	0.000010	0.000027	0.000064	16	6	0.000005	0.000017	0.000008	0.000005	0.000005	0.000005	0.000005	0.000009	0.000014	0.000015	4
Total Bismuth	-	mg/L	24	0.0000025	0.0000177	0.0000044	0.0000025	0.0000048	0.0000025	0.0000025	0.0000025	0.0000120	0.0000167	20	6	0.0000025	0.0000025	0.0000025	0.0000025	0.0000000	0.0000025	0.0000025	0.0000025	0.0000025	0.0000025	6
Total Boron	1.5	mg/L	24	0.03	0.03	0.03	0.03	0.00	0.03	0.03	0.03	0.03	0.03	24	6	0.03	0.03	0.03	0.03	0.00	0.03	0.03	0.03	0.03	0.03	6
Total Cadmium	0.000032[c]	mg/L	24	0.000012	0.000271	0.000048	0.000027	0.000067	0.000014	0.000017	0.000037	0.000065	0.000219	0	6	0.000003	0.000026	0.000015	0.000016	0.000008	0.000007	0.000012	0.000021	0.000024	0.000025	1
Total Calcium	-	mg/L	24	10.10	47.20	29.55	29.40	10.02	15.92	23.38	36.33	42.27	43.92	0	6	8.22	34.50	18.04	15.10	10.87	8.26	9.02	25.00	30.75	32.63	0
Total Chromium	0.001	mg/L	24	0.00005	0.00126	0.00023	0.00010	0.00027	0.00005	0.00005	0.00030	0.00047	0.00059	9	6	0.00005	0.00029	0.00017	0.00020	0.00010	0.00005	0.00009	0.00020	0.00025	0.00027	2
Total Cobalt	-	mg/L	24	0.000017	0.001700	0.000227	0.000079	0.000403	0.000025	0.000043	0.000186	0.000427	0.001124	0	6	0.000041	0.000149	0.000084	0.000069	0.000045	0.000044	0.000051	0.000114	0.000139	0.000144	0
Total Copper	0.0023[d]	mg/L	24	0.0015	0.0278	0.0079	0.0059	0.0070	0.0019	0.0036	0.0090	0.0149	0.0251	0	6	0.0003	0.0017	0.0011	0.0011	0.0006	0.0004	0.0006	0.0015	0.0016	0.0016	0
Total Iron	0.3	mg/L	24	0.011	1.930	0.258	0.126	0.422	0.020	0.073	0.230	0.470	0.992	0	6	0.054	0.371	0.143	0.086	0.125	0.055	0.061	0.177	0.288	0.330	0
Total Lead	0.003[e]	mg/L	24	0.000028	0.119000	0.005678	0.000189	0.024233	0.000042	0.000091	0.000509	0.001137	0.009270	0	6	0.000012	0.000438	0.000143	0.000126	0.000154	0.000020	0.000051	0.000131	0.000285	0.000361	0
Total Lithium	-	mg/L	24	0.00060	0.00160	0.00109	0.00100	0.00026	0.00082	0.00090	0.00125	0.00147	0.00150	0	6	0.00107	0.00470	0.00273	0.00280	0.00132	0.00134	0.00180	0.00335	0.00405	0.00438	0
Total Magnesium	-	mg/L	24	2.85	15.10	9.13	9.03	3.37	4.76	6.52	11.35	13.89	14.19	0	6	1.62	11.30	5.30	4.38	3.93	1.67	2.04	7.73	9.85	10.57	0
Total Manganese	-	mg/L	24	0.0038	0.2150	0.0275	0.0115	0.0474	0.0053	0.0082	0.0249	0.0334	0.1172	0	6	0.0011	0.0771	0.0351	0.0392	0.0298	0.0011	0.0099	0.0503	0.0651	0.0711	0
Total Mercury	0.000026	mg/L	21	0.0000050	0.0000100	0.0000055	0.0000050	0.0000015	0.0000050	0.0000050	0.0000050	0.0000050	0.0000100	19	5	0.0000050	0.0000050	0.0000050	0.0000050	0.0000000	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	5
Total Molybdenum	0.073	mg/L	24	0.00037	0.00138	0.00103	0.00113	0.00030	0.00059	0.00088	0.00122	0.00135	0.00137	0	6	0.00023	0.00052	0.00037	0.00037	0.00010	0.00028	0.00034	0.00042	0.00048	0.00050	0
Total Nickel	0.0033[f]	mg/L	24	0.00016	0.00171	0.00047	0.00037	0.00039	0.00019	0.00022	0.00048	0.00088	0.00138	0	6	0.00021	0.00057	0.00031	0.00027	0.00013	0.00022	0.00025	0.00032	0.00045	0.00051	0
Total Phosphorus	-	mg/L	21	0.0010	0.0910	0.0136	0.0060	0.0234	0.0020	0.0030	0.0090	0.0250	0.0720	2	5	0.0030	0.0208	0.0078	0.0040	0.0076	0.0030	0.0030	0.0080	0.0157	0.0182	0
Total Potassium	-	mg/L	24	0.59	1.54	1.04	1.01	0.23	0.81	0.90	1.19	1.30	1.48	0	6	0.34	1.16	0.69	0.69	0.31	0.35	0.44	0.83	1.02	1.09	0
Total Selenium	0.001	mg/L	24	0.00002	0.00015	0.00007	0.00007	0.00002	0.00005	0.00006	0.00008	0.00009	0.00011	1	6	0.00002	0.00004	0.00002	0.00002	0.00001	0.00002	0.00002	0.00002	0.00003	0.00004	5
Total Silicon	-	mg/L	24	3.07	6.10	4.97	5.10	0.82	4.03	4.50	5.60	5.80	5.80	0	6	3.09	5.80	4.88	5.00	0.98	3.90	4.75	5.55	5.75	5.78	0
Total Silver	0.0001	mg/L	24	0.000003	0.000090	0.000009	0.000003	0.000021	0.000003	0.000003	0.000003	0.000008	0.000050	21	6	0.000003	0.000007	0.000003	0.000003	0.000002	0.000003	0.000003	0.000003	0.000005	0.000006	5
Total Sodium	-	mg/L	24	1.22	6.02	4.00	4.08	1.33	2.16	3.16	4.88	5.84	5.96	0	6	1.56	5.07	2.82	2.35	1.40	1.65	1.78	3.59	4.46	4.77	0
Total Strontium	-	mg/L	24	0.065	0.309	0.184	0.179	0.065	0.096	0.145	0.234	0.266	0.287	0	6	0.051	0.339	0.154	0.121	0.115	0.052	0.061	0.218	0.289	0.314	0
Total Sulphur	-	mg/L	24	5.00	26.00	14.33	14.50	5.98	5.30	10.75	18.00	22.40	23.00	2	6	5.00	5.00	5.00	5.00	0.00	5.00	5.00	5.00	5.00	5.00	6
Total Thallium	0.0008	mg/L	24	0.0000010	0.0000300	0.0000040	0.0000020	0.0000066	0.0000010	0.0000010	0.0000040	0.0000054	0.0000161	11	6	0.0000010	0.0000038	0.0000025	0.0000025	0.0000010	0.0000015	0.0000020	0.0000030	0.0000034	0.0000036	1
Total Tin	-	mg/L	24	0.000005	0.000100	0.000013	0.000005	0.000027	0.000005	0.000005	0.000005	0.000005	0.000086	24	6	0.000005	0.000300	0.000078	0.000028	0.000115	0.000005	0.000005	0.000088	0.000200	0.000250	4
Total Titanium	-	mg/L	24	0.00025	0.03130	0.00394	0.00145	0.00702	0.00025	0.00025	0.00333	0.00870	0.01636	7	6	0.00025	0.00692	0.00204	0.00085	0.00261	0.00025	0.00039	0.00255	0.00501	0.00597	2
Total Uranium	0.015	mg/L	24	0.00222	0.01850	0.00746	0.00663	0.00428	0.00294	0.00420	0.01000	0.01324	0.01526	0	6	0.00162	0.01440	0.00534	0.00297	0.00513	0.00163	0.00178	0.00726	0.01142	0.01291	0
Total Vanadium	-	mg/L	24	0.00010	0.00389	0.00067	0.00040	0.00097	0.00010	0.00010	0.00060	0.00118	0.00309	8	6	0.00010	0.00078	0.00033	0.00020	0.00026	0.00015	0.00020	0.00043	0.00064	0.00071	1
Total Zinc	0.03	mg/L	24	0.00050	0.02380	0.00379	0.00180	0.00553	0.00090	0.00110	0.00283	0.00823	0.01574	0	6	0.00030	0.00360	0.00126	0.00093	0.00119	0.00045	0.00068	0.00114	0.00240	0.00300	0
Total Zirconium	-	mg/L	24	0.00005	0.00070	0.00018	0.00015	0.00016	0.00005	0.00005	0.00020	0.00040	0.00043	9	6	0.00005	0.00021	0.00010	0.00010	0.00006	0.00005	0.00006	0.00010	0.00016	0.00018	2
Dissolved Aluminum	0.1	mg/L	24	0.01	0.25	0.06	0.03	0.07	0.01	0.02	0.07	0.16	0.19	0	6	0.00	0.11	0.06	0.07	0.06	0.01	0.01	0.11	0.11	0.11	0
Dissolved Antimony	-	mg/L	24	0.00007	0.00022	0.00013	0.00013	0.00003	0.00010	0.00012	0.00014	0.00016	0.00016	0	6	0.00005	0.00007	0.00006	0.00006	0.00001	0.00006	0.00006	0.00006	0.00007	0.00007	0
Dissolved Arsenic	-	mg/L	24	0.00030	0.00075	0.00041	0.00039	0.00010	0.00032	0.00035	0.00046	0.00050	0.00052	0	6	0.00020	0.00034	0.00026	0.00025	0.00006	0.00022	0.00023	0.00031	0.00033	0.00034	0
Dissolved Barium	-	mg/L	24	0.027000	0.098700	0.057133	0.054150	0.017435	0.034750	0.046525	0.070500	0.079010	0.083020	0	6	0.010100	0.104000	0.050767	0.049000	0.038220	0.010200	0.017575	0.076300	0.093100	0.098550	0
Dissolved Beryllium	-	mg/L	24	0.000005	0.000020	0.000007	0.000005	0.000004	0.000005	0.000005	0.000010	0.000011	0.000019	17	6	0.000005	0.000013	0.000008	0.000008	0.000003	0.000005	0.000005	0.000010	0.000012	0.000012	3
Dissolved Bismuth	-	mg/L	24	0.0000025	0.0000050	0.0000026	0.0000025	0.0000005	0.0000025	0.0000025	0.0000025	0.0000025	0.0000025	23	6	0.0000025	0.0000025	0.0000025	0.0000025	0.0000000	0.0000025	0.0000025	0.0000025	0.0000025	0.0000025	6
Dissolved Boron	-	mg/L	24	0.025	0.025	0.025	0.025	0.000	0.025	0.025	0.025	0.025	0.025	24	6	0.025	0.025	0.025	0.025	0.000	0.025	0.025	0.025	0.025	0.025	6
Dissolved Cadmium	-	mg/L	24	0.000006	0.000047	0.000023	0.000021	0.000010	0.000014	0.000015	0.000029	0.000040	0.000043	0	6	0.000003	0.000023	0.000012	0.000012	0.000008	0.000004	0.000006	0.000018	0.000021	0.000022	1
Dissolved Calcium	-	mg/L	24	8.91	46.60	29.06	28.45	9.94	16.14	22.68	35.90	42.05	42.89	0	6	9.05	32.80	17.80	14.65	10.00	9.15	9.61	24.45	29.60	31.20	0
Dissolved Chromium	-	mg/L	24	0.00005	0.00030	0.00012	0.00008	0.00009	0.00005	0.00005	0.00020	0.00027	0.00030	12	6	0.00005	0.00020	0.00013	0.00014	0.00007	0.00005	0.00006	0.00020	0.00020	0.00020	2
Dissolved Cobalt	-	mg/L	24	0.000014	0.000174	0.000071	0.000062	0.000048	0.000019	0.000031	0.000109	0.000140	0.000148	0	6	0.000035	0.000061	0.000047	0.000044	0.000011	0.000037	0.000040	0.000056	0.000060	0.000061	0

Parameters	CCME Guideline[1]	Unit	W4											
			n	min	max	mean	median	sd	10th	25th	75th	90th	95th	<DL
Dissolved Copper	-	mg/L	24	0.0014	0.0147	0.0056	0.0041	0.0040	0.0017	0.0029	0.0070	0.0120	0.0143	0
Dissolved Iron	-	mg/L	24	0.003	0.201	0.066	0.043	0.060	0.008	0.024	0.096	0.169	0.181	0
Dissolved Lead	-	mg/L	24	0.000006	0.014700	0.000687	0.000036	0.002987	0.000008	0.000018	0.000129	0.000163	0.000445	0
Dissolved Lithium	-	mg/L	24	0.00025	0.00150	0.00102	0.00100	0.00032	0.00063	0.00080	0.00120	0.00147	0.00150	1
Dissolved Magnesium	-	mg/L	24	2.54	15.30	9.08	8.52	3.33	4.65	6.74	11.35	13.22	14.34	0
Dissolved Manganese	-	mg/L	24	0.0034	0.0233	0.0093	0.0076	0.0054	0.0049	0.0057	0.0104	0.0159	0.0220	0
Dissolved Mercury	-	mg/L	20	0.0000050	0.0000100	0.0000053	0.0000050	0.0000011	0.0000050	0.0000050	0.0000050	0.0000050	0.0000053	19
Dissolved Molybdenum	-	mg/L	24	0.00033	0.00141	0.00106	0.00110	0.00029	0.00064	0.00092	0.00128	0.00134	0.00139	0
Dissolved Nickel	-	mg/L	24	0.00015	0.00089	0.00037	0.00032	0.00021	0.00017	0.00020	0.00045	0.00071	0.00078	0
Dissolved Phosphorus	-	mg/L	20	0.0010	0.0120	0.0040	0.0030	0.0034	0.0010	0.0010	0.0055	0.0091	0.0104	6
Dissolved Potassium	-	mg/L	24	0.59	1.57	1.03	1.02	0.23	0.80	0.89	1.17	1.27	1.49	0
Dissolved Selenium	-	mg/L	24	0.00002	0.00015	0.00007	0.00007	0.00003	0.00004	0.00005	0.00008	0.00009	0.00011	1
Dissolved Silicon	-	mg/L	24	2.24	6.40	4.90	5.10	0.97	3.86	4.45	5.55	5.80	5.80	0
Dissolved Silver	-	mg/L	24	0.000003	0.000028	0.000004	0.000003	0.000005	0.000003	0.000003	0.000003	0.000004	0.000007	21
Dissolved Sodium	-	mg/L	24	1.19	6.16	3.99	3.82	1.29	2.23	3.23	4.87	5.65	6.00	0
Dissolved Strontium	-	mg/L	24	0.057	0.299	0.183	0.179	0.064	0.094	0.142	0.234	0.261	0.274	0
Dissolved Sulphur	-	mg/L	24	5.00	27.00	14.46	13.50	5.83	6.90	11.00	17.50	21.70	24.55	1
Dissolved Thallium	-	mg/L	24	0.0000010	0.0000050	0.0000019	0.0000010	0.0000011	0.0000010	0.0000010	0.0000030	0.0000030	0.0000033	13
Dissolved Tin	-	mg/L	24	0.000005	0.000100	0.000014	0.000005	0.000027	0.000005	0.000005	0.000005	0.000023	0.000089	23
Dissolved Titanium	-	mg/L	24	0.00025	0.00230	0.00060	0.00025	0.00062	0.00025	0.00025	0.00070	0.00150	0.00201	16
Dissolved Uranium	-	mg/L	24	0.00150	0.01820	0.00734	0.00639	0.00440	0.00225	0.00404	0.00991	0.01292	0.01502	0
Dissolved Vanadium	-	mg/L	24	0.00010	0.00080	0.00027	0.00025	0.00018	0.00010	0.00010	0.00040	0.00040	0.00056	9
Dissolved Zinc	-	mg/L	24	0.00050	0.00690	0.00212	0.00155	0.00173	0.00080	0.00098	0.00246	0.00487	0.00588	0
Dissolved Zirconium	-	mg/L	24	0.00005	0.00050	0.00014	0.00010	0.00011	0.00005	0.00005	0.00020	0.00027	0.00030	9

Parameters	W22											
	n	min	max	mean	median	sd	10th	25th	75th	90th	95th	<DL
Dissolved Copper	6	0.0002	0.0017	0.0010	0.0009	0.0006	0.0003	0.0005	0.0015	0.0017	0.0017	0
Dissolved Iron	6	0.013	0.122	0.060	0.058	0.035	0.032	0.052	0.058	0.090	0.106	0
Dissolved Lead	6	0.000003	0.000124	0.000048	0.000018	0.000058	0.000005	0.000009	0.000096	0.000123	0.000123	1
Dissolved Lithium	6	0.00108	0.00470	0.00278	0.00305	0.00139	0.00119	0.00165	0.00348	0.00410	0.00440	0
Dissolved Magnesium	6	1.84	11.20	5.45	4.40	3.94	1.84	2.16	8.19	10.12	10.66	0
Dissolved Manganese	6	0.0009	0.0704	0.0245	0.0105	0.0299	0.0010	0.0030	0.0434	0.0622	0.0663	0
Dissolved Mercury	2	0.0000050	0.0000050	0.0000050	0.0000050	0.0000000	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	2
Dissolved Molybdenum	6	0.00033	0.00049	0.00041	0.00041	0.00007	0.00034	0.00037	0.00047	0.00049	0.00049	0
Dissolved Nickel	6	0.00019	0.00047	0.00028	0.00027	0.00010	0.00021	0.00023	0.00029	0.00038	0.00043	0
Dissolved Phosphorus	2	0.0020	0.0090	0.0055	0.0055	0.0049	0.0027	0.0038	0.0073	0.0083	0.0087	0
Dissolved Potassium	6	0.38	1.11	0.70	0.69	0.30	0.38	0.45	0.90	1.04	1.08	0
Dissolved Selenium	6	0.00002	0.00004	0.00002	0.00002	0.00001	0.00002	0.00002	0.00002	0.00003	0.00004	5
Dissolved Silicon	6	2.98	5.70	4.90	5.10	0.98	3.99	5.03	5.40	5.60	5.65	0
Dissolved Silver	6	0.000003	0.000003	0.000003	0.000003	0.000000	0.000003	0.000003	0.000003	0.000003	0.000003	6
Dissolved Sodium	6	1.57	5.01	2.90	2.42	1.35	1.78	2.00	3.71	4.51	4.76	0
Dissolved Strontium	6	0.055	0.330	0.155	0.121	0.112	0.055	0.063	0.223	0.288	0.309	0
Dissolved Sulphur	6	5.00	5.00	5.00	5.00	0.00	5.00	5.00	5.00	5.00	5.00	6
Dissolved Thallium	6	0.0000010	0.0000030	0.0000017	0.0000010	0.0000010	0.0000010	0.0000010	0.0000025	0.0000030	0.0000030	4
Dissolved Tin	6	0.000005	0.000100	0.000037	0.000005	0.000049	0.000005	0.000005	0.000076	0.000100	0.000100	6
Dissolved Titanium	6	0.00025	0.00122	0.00053	0.00043	0.00038	0.00025	0.00025	0.00060	0.00091	0.00107	3
Dissolved Uranium	6	0.00170	0.01460	0.00546	0.00299	0.00521	0.00175	0.00184	0.00751	0.01164	0.01312	0
Dissolved Vanadium	6	0.00010	0.00060	0.00032	0.00030	0.00018	0.00015	0.00023	0.00040	0.00052	0.00056	1
Dissolved Zinc	6	0.00040	0.00120	0.00080	0.00075	0.00035	0.00046	0.00054	0.00113	0.00120	0.00120	0
Dissolved Zirconium	6	0.00005	0.00020	0.00011	0.00010	0.00006	0.00005	0.00006	0.00015	0.00018	0.00019	2

Notes:

1) Canadian water quality guidelines for the protection of aquatic life,

a) Ammonia (NH3) guideline based on ph=8 and temp=20

b) Aluminum (AL-T)= 0.005 mg/L at pH < 6.5: 0.1 mg/L at pH ≥ 6.5

c) Cadmium (Cd) mg/L: 10^(0.86*(log(hardness))-3.2)/1000

d) Copper (Cu) mg/L: (e^0.8545[ln(hardness)]-1.465)*0.2/1000; minim

e) Lead (Pb) mg/L: (e^1.273[ln(hardness)]-4.705)/1000; minimum is 0.

f) Nickel (Ni) mg/L: (e^0.76[(ln(hardness)]+1.06)/1000; minimum is 0.0

Parameters	CCME Guideline[1]	Unit	R2												W9											
			n	min	max	mean	median	sd	10th	25th	75th	90th	95th	<DL	n	min	max	mean	median	sd	10th	25th	75th	90th	95th	<DL
pH	6.5 - 9.0	pH Units	19	7.37	7.90	7.68	7.70	0.17	7.39	7.61	7.82	7.90	7.90	0	29	7.20	8.30	7.78	7.80	0.21	7.49	7.70	7.90	7.94	8.00	0
Conductivity	-	uS/cm	19	51	263	153	160	56	90	110	188	211	226	0	29	65	277	179	172	63	108	130	243	263	264	0
Total Hardness CaCO3	-	mg/L	19	26	118	73	74	25	42	58	92	95	99	0	29	33	128	86	81	29	51	63	113	123	126	0
Dissolved Hardness CaCO3	-	mg/L	19	26	125	72	74	26	43	52	91	97	100	0	28	31	130	85	81	29	51	64	110	126	127	0
Total Dissolved Solids	-	mg/L	19	62	150	101	100	26	72	79	120	132	139	0	29	56	180	112	110	30	82	92	130	150	163	0
Total Suspended Solids	-	mg/L	19	0.5	31.1	4.7	1.0	9.3	0.5	0.5	2.0	13.1	29.8	10	29	0.5	160.0	16.7	3.0	34.2	0.5	0.5	14.0	59.9	71.2	10
Turbidity		NTU	19	0.1	3.3	0.6	0.2	1.0	0.1	0.1	0.6	1.7	3.1	1	29	0.2	29.0	2.5	0.6	5.6	0.2	0.3	1.4	6.5	8.3	0
Ammonia as N	0.499[a]	mg/L	19	0.003	0.070	0.015	0.005	0.017	0.003	0.005	0.018	0.029	0.046	10	29	0.003	0.083	0.016	0.005	0.021	0.003	0.005	0.020	0.039	0.063	15
Alkalinity (Total as CaCO3)	-	mg/L	19	2.90	88.00	46.84	58.00	30.16	6.58	17.80	72.00	80.00	88.00	0	29	3.30	117.00	59.40	60.00	36.54	6.60	25.70	89.00	102.00	111.80	0
Acidity to pH 4.5 (as CaCO3)	-	mg/L	14	0.25	0.25	0.25	0.25	0.00	0.25	0.25	0.25	0.25	0.25	14	18	0.25	0.25	0.25	0.25	0.00	0.25	0.25	0.25	0.25	0.25	18
Acidity to pH 8.3 (as CaCO3)	-	mg/L	14	0.25	7.30	2.39	1.67	1.85	0.99	1.43	2.80	4.40	5.42	1	18	0.25	11.10	2.54	1.55	2.74	0.25	0.55	3.55	5.35	6.51	4
Bromide	-	mg/L	19	0.01	0.20	0.17	0.20	0.07	0.01	0.20	0.20	0.20	0.20	19	25	0.01	0.20	0.16	0.20	0.08	0.01	0.20	0.20	0.20	0.20	25
Chloride	120	mg/L	19	0.25	1.20	0.41	0.25	0.29	0.25	0.25	0.50	0.70	1.11	13	29	0.25	1.60	0.61	0.60	0.41	0.25	0.25	0.90	1.14	1.36	13
Fluoride	0.12	mg/L	19	0.037	0.080	0.052	0.050	0.010	0.039	0.050	0.054	0.060	0.062	0	25	0.041	0.060	0.053	0.050	0.005	0.050	0.050	0.060	0.060	0.060	0
Sulphate	-	mg/L	19	0.25	43.00	16.43	14.00	9.95	7.09	11.00	22.00	25.60	29.50	2	29	0.25	33.00	14.90	15.00	7.81	3.60	11.00	19.00	24.04	27.08	2
Total Nitrogen	-	mg/L	19	0.20	0.61	0.41	0.38	0.10	0.33	0.35	0.47	0.57	0.59	0	29	0.11	0.61	0.34	0.34	0.11	0.17	0.28	0.42	0.46	0.47	0
Nitrate (as N)	13	mg/L	19	0.009	0.403	0.206	0.199	0.135	0.028	0.092	0.323	0.384	0.388	0	29	0.016	0.317	0.142	0.134	0.091	0.025	0.068	0.207	0.252	0.303	0
Nitrate plus Nitrite	-	mg/L	19	0.011	0.409	0.207	0.199	0.135	0.028	0.093	0.323	0.388	0.391	0	28	0.016	0.317	0.144	0.148	0.092	0.026	0.064	0.211	0.260	0.303	0
Nitrite (as N)	0.06	mg/L	19	0.001	0.005	0.002	0.001	0.001	0.001	0.001	0.002	0.003	0.005	13	29	0.001	0.180	0.008	0.001	0.033	0.001	0.001	0.003	0.003	0.004	20
Total Kjeldahl Nitrogen	-	mg/L	19	0.02	0.59	0.21	0.17	0.16	0.06	0.11	0.25	0.36	0.58	0	27	0.01	0.58	0.19	0.16	0.13	0.07	0.12	0.25	0.35	0.42	1
Orthophosphate as P	-	mg/L	19	0.0005	0.0310	0.0029	0.0010	0.0068	0.0005	0.0010	0.0020	0.0021	0.0053	4	29	0.0005	0.0070	0.0019	0.0020	0.0014	0.0009	0.0010	0.0020	0.0030	0.0042	4
Cyanide, Total	0.005	mg/L												0	2	0.00025	0.00089	0.00057	0.00057	0.00045	0.00031	0.00041	0.00073	0.00083	0.00086	1
Cyanide, Weak Acid Diss	-	mg/L	19	0.00025	0.00110	0.00043	0.00025	0.00029	0.00025	0.00025	0.00063	0.00083	0.00101	13	29	0.00025	0.00110	0.00046	0.00025	0.00029	0.00025	0.00025	0.00070	0.00083	0.00098	18
Dissolved Organic Carbon	-	mg/L	9	2.24	17.80	8.49	5.70	5.77	2.37	4.40	11.90	16.12	16.96	0	10	2.62	14.10	6.16	5.15	3.46	2.78	3.86	7.57	9.33	11.72	0
Total Organic Carbon	-	mg/L	19	0.25	19.50	7.52	6.10	5.55	2.49	3.80	10.10	16.08	18.87	1	25	0.25	17.30	6.46	5.20	3.91	3.30	3.84	7.90	11.12	14.48	1
Total Aluminum	0.1[b]	mg/L	19	0.01	0.37	0.08	0.03	0.12	0.01	0.01	0.08	0.32	0.37	0	29	0.01	0.78	0.14	0.03	0.20	0.01	0.01	0.16	0.47	0.54	0
Total Antimony	-	mg/L	19	0.00002	0.00006	0.00003	0.00003	0.00001	0.00002	0.00003	0.00004	0.00004	0.00005	0	29	0.00005	0.00012	0.00008	0.00008	0.00001	0.00006	0.00007	0.00008	0.00009	0.00009	0
Total Arsenic	0.005	mg/L	19	0.00010	0.00051	0.00023	0.00021	0.00011	0.00014	0.00016	0.00026	0.00038	0.00048	0	29	0.00019	0.00141	0.00041	0.00031	0.00027	0.00020	0.00028	0.00045	0.00076	0.00089	0
Total Barium	-	mg/L	19	0.04	0.07	0.05	0.05	0.01	0.04	0.04	0.06	0.06	0.07	0	29	0.04	0.09	0.06	0.05	0.01	0.04	0.05	0.07	0.08	0.08	0
Total Beryllium	-	mg/L	19	0.000005	0.000034	0.000010	0.000005	0.000009	0.000005	0.000005	0.000010	0.000022	0.000032	13	29	0.000005	0.000070	0.000015	0.000005	0.000017	0.000005	0.000005	0.000020	0.000038	0.000052	17
Total Bismuth	-	mg/L	19	0.0000025	0.0000155	0.0000035	0.0000025	0.0000032	0.0000025	0.0000025	0.0000025	0.0000035	0.0000085	17	29	0.0000025	0.0000120	0.0000040	0.0000025	0.0000028	0.0000025	0.0000025	0.0000050	0.0000086	0.0000102	21
Total Boron	1.5	mg/L	19	0.03	0.03	0.03	0.03	0.00	0.03	0.03	0.03	0.03	0.03	19	29	0.03	0.03	0.03	0.03	0.00	0.03	0.03	0.03	0.03	0.03	29
Total Cadmium	0.000032[c]	mg/L	19	0.000003	0.000044	0.000009	0.000005	0.000012	0.000003	0.000003	0.000009	0.000020	0.000038	8	29	0.000003	0.000057	0.000015	0.000011	0.000016	0.000003	0.000006	0.000017	0.000036	0.000056	7
Total Calcium	-	mg/L	19	6.24	26.20	17.45	18.00	5.60	9.67	14.35	21.90	22.60	23.32	0	29	8.38	32.80	21.91	21.20	7.34	13.20	16.50	28.80	31.10	31.96	0
Total Chromium	0.001	mg/L	19	0.00005	0.00060	0.00020	0.00010	0.00018	0.00005	0.00005	0.00030	0.00053	0.00056	6	29	0.00005	0.00100	0.00025	0.00010	0.00026	0.00005	0.00005	0.00036	0.00066	0.00070	10
Total Cobalt	-	mg/L	19	0.000013	0.000348	0.000074	0.000036	0.000099	0.000019	0.000021	0.000060	0.000205	0.000322	0	29	0.000016	0.000825	0.000152	0.000071	0.000191	0.000038	0.000043	0.000158	0.000482	0.000520	0
Total Copper	0.0023[d]	mg/L	19	0.0005	0.0027	0.0012	0.0009	0.0007	0.0005	0.0007	0.0015	0.0023	0.0026	0	29	0.0005	0.0053	0.0014	0.0009	0.0010	0.0006	0.0007	0.0016	0.0023	0.0031	0
Total Iron	0.3	mg/L	19	0.006	0.625	0.120	0.044	0.195	0.007	0.010	0.110	0.402	0.625	0	29	0.008	1.440	0.259	0.084	0.353	0.035	0.050	0.259	0.898	0.924	0
Total Lead	0.003[e]	mg/L	19	0.000003	0.000291	0.000061	0.000018	0.000084	0.000007	0.000009	0.000086	0.000161	0.000238	1	29	0.000012	0.002130	0.000265	0.000084	0.000465	0.000017	0.000023	0.000240	0.000635	0.001076	0
Total Lithium	-	mg/L	19	0.00060	0.00130	0.00097	0.00100	0.00021	0.00070	0.00080	0.00110	0.00122	0.00130	0	29	0.00145	0.00310	0.00233	0.00230	0.00045	0.00188	0.00200	0.00280	0.00291	0.00304	0
Total Magnesium	-	mg/L	19	2.43	12.70	7.09	7.35	2.63	3.91	5.30	8.78	9.63	10.45	0	29	2.83	12.60	7.53	7.22	2.64	4.42	5.44	9.97	10.86	11.16	0
Total Manganese	-	mg/L	19	0.0032	0.0390	0.0087	0.0050	0.0105	0.0035	0.0039	0.0067	0.0159	0.0373	0	29	0.0025	0.1070	0.0307	0.0232	0.0235	0.0127	0.0148	0.0353	0.0668	0.0746	0
Total Mercury	0.000026	mg/L	16	0.0000050	0.0000100	0.0000053	0.0000050	0.0000013	0.0000050	0.0000050	0.0000050	0.0000050	0.0000063	15	26	0.0000050	0.0000050	0.0000050	0.0000050	0.0000000	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	26
Total Molybdenum	0.073	mg/L	19	0.00027	0.00098	0.00072	0.00072	0.00020	0.00053	0.00064	0.00089	0.00093	0.00095	0	29	0.00028	0.00081	0.00059	0.00059	0.00013	0.00041	0.00052	0.00071	0.00072	0.00074	0
Total Nickel	0.0033[f]	mg/L	19	0.00020	0.00118	0.00046	0.00036	0.00029	0.00024	0.00027	0.00054	0.00092	0.00109	0	29	0.00022	0.00210	0.00054	0.00034	0.00043	0.00024	0.00027	0.00060	0.00100	0.00136	0
Total Phosphorus	-	mg/L	16	0.0010	0.0463	0.0090	0.0040	0.0136	0.0020	0.0030	0.0060	0.0255	0.0416	1	26	0.0020	0.1260	0.0179	0.0055	0.0284	0.0027	0.0040	0.0163	0.0511	0.0678	0
Total Potassium	-	mg/L	19	0.41	0.85	0.63	0.63	0.11	0.50	0.55	0.71	0.75	0.79	0	29	0.51	1.30	0.77	0.71	0.20	0.54	0.63	0.89	0.98	1.14	0
Total Selenium	0.001	mg/L	19	0.00002	0.00010	0.00006	0.00006	0.00002	0.00004	0.00005	0.00007	0.00009	0.00009	2	29	0.00002	0.00007	0.00004	0.00004	0.00002	0.00002	0.00002	0.00005	0.00006	0.00006	13
Total Silicon	-	mg/L	19	2.15	5.00	4.33	4.60	0.87	3.08	4.40	4.90	5.00	5.00	0	29	2.58	5.89	4.78	5.10	0.81	3.60	4.50	5.30	5.50	5.56	0
Total Silver	0.0001	mg/L	19	0.000003	0.000009	0.000003	0.000003	0.000002	0.000003	0.000003	0.000003	0.000003	0.000007	17	29	0.000003	0.000010	0.000003	0.000003	0.000002	0.000003	0.000003	0.000003	0.000007	0.000008	25
Total Sodium	-	mg/L	19	0.89	4.04	2.76	2.89	0.92	1.70	2.13	3.40	3.67	3.98	0	29	1.31	5.86	3.78	3.74	1.24	2.39	2.83	4.93	5.16	5.54	0
Total Strontium	-	mg/L	19	0.052	0.229	0.145	0.151	0.049	0.090	0.112	0.176	0.196	0.223	0	29	0.069	0.290	0.179	0.170	0.061	0.109	0.131	0.244	0.249	0.259	0
Total Sulphur	-	mg/L	19	5.00	16.00	6.47	5.00	2.82	5.00	5.00	7.50	9.20	10.60	12	29	1.50	11.00	5.45	5.00	1.95	4.00	5.00	6.00	8.00	8.18	15
Total Thallium	0.0008	mg/L	19	0.0000010	0.0000058	0.0000017	0.0000010	0.0000015	0.0000010	0.0000010	0.0000015	0.0000042	0.0000052	14	29	0.0000010	0.0000080	0.0000025	0.0000010	0.0000023	0.0000010	0.0000010	0.0000030	0.0000068	0.0000076	17
Total Tin	-	mg/L	19	0.000005	0.000100	0.000020	0.000005	0.000036	0.000005	0.000005	0.000005	0.000100	0.000100	19	29	0.000005	0.000100	0.000018	0.000005	0.000033	0.000005	0.000005	0.000005	0.000100	0.000100	29
Total Titanium	-	mg/L	19	0.00025	0.01250	0.00229	0.00060	0.00406	0.00025	0.00025	0.00105	0.01040	0.01133	9	29	0.00025	0.02710	0.00524	0.00150	0.00760	0.00025	0.00025	0.00630	0.01880	0.02080	11
Total Uranium	0.015	mg/L	19	0.00111	0.00569	0.00234	0.00227	0.00124	0.00117	0.00149	0.00266	0.00408	0.00475	0	29	0.00232	0.01140	0.00590	0.00529	0.00268	0.00286	0.00340	0.00811	0.00910	0.01008	0
Total Vanadium	-	mg/L	19	0.00010	0.00140	0.00036	0.00010	0.00042	0.00010	0.00010	0.00040	0.00114	0.00132	10	29	0.00010	0.00500	0.00077	0.00030	0.00104	0.00010	0.00010	0.00090	0.00204	0.00236	8
Total Zinc	0.03	mg/L	19	0.00020	0.00307	0.00080	0.00050	0.00078	0.00025	0.00040	0.00065	0.00185	0.00250	0	29	0.00030	0.00600	0.00135	0.00070	0.00146	0.00040	0.00050	0.00140	0.00339	0.00434	0
Total Zirconium	-	mg/L	19	0.00005	0.00040	0.00018	0.00010	0.00013	0.00005	0.00008	0.00030	0.00037	0.00038	5	29	0.00005	0.00080	0.00022	0.00020	0.00017	0.00005	0.00010	0.00030	0.00040	0.00046	5
Dissolved Aluminum	0.1	mg/L	19	0.01	0.17	0.05	0.02	0.05	0.01	0.01	0.07	0.10	0.16	0	29	0.01	0.18	0.04	0.02	0.04	0.01	0.01	0.06	0.10	0.12	0
Dissolved Antimony	-	mg/L	19	0.00001	0.00005	0.00003	0.00003	0.00001	0.00002	0.00003	0.00004	0.00004	0.00005	1	29	0.00005	0.00012	0.00007	0.00007	0.00001	0.00006	0.00006	0.00008	0.00008	0.00010	1
Dissolved Arsenic	-	mg/L	19	0.00014	0.00031	0.00021	0.00020	0.00005	0.00015	0.00017	0.00024	0.00026	0.00029	0	29	0.00019	0.00055	0.00030	0.00031	0.00008	0.00020	0.00025	0.00033	0.00040	0.00040	0
Dissolved Barium	-	mg/L	19	0.025800	0.068700	0.048111	0.046900	0.013282	0.033040	0.038200	0.059650	0.065220	0.068520	0	29	0.027900	0.090100	0.055414	0.050000	0.018498	0.036920	0.041100	0.071400	0.081960	0.085200	0
Dissolved Beryllium	-	mg/L	19	0.000005	0.000020	0.000008	0.000005	0.000005	0.000005	0.000005	0.000008	0.000018	0.000020	14	29	0.000005	0.000030	0.000010	0.000005	0.000007	0.000005	0.000005	0.000010	0.000020	0.000023	20
Dissolved Bismuth	-	mg/L	19	0.0000025	0.0000025	0.0000025	0.0000025	0.0000000	0.0000025	0.0000025	0.0000025	0.0000025	0.0000025	19	29	0.0000025	0.0000150	0.0000029	0.0000025	0.0000023	0.0000025	0.0000025	0.0000025	0.0000025	0.0000025	29
Dissolved Boron	-	mg/L	19	0.025	0.025	0.025	0.025	0.000	0.025	0.025	0.025	0.025	0.025	19	29	0.025	0.150	0.029	0.025	0.023	0.025	0.025	0.025	0.025	0.025	29
Dissolved Cadmium	-	mg/L	19	0.000003	0.000035	0.000007	0.000003	0.000009	0.000003	0.000003	0.000008	0.000017	0.000025	11	29	0.000003	0.000016	0.000007	0.000006	0.000004	0.000003	0.000003	0.000008	0.000014	0.000015	12
Dissolved Calcium	-	mg/L	19	6.24	29.00	17.26	17.40	6.08	10.38	12.20	21.70	23.30	24.23	0	29	7.81	34.10	21.64	20.20	7.45	13.06	16.30	27.30	31.30	32.96	0
Dissolved Chromium	-	mg/L	19	0.00005	0.00050	0.00017	0.00010	0.00012	0.00005	0.00008	0.00024	0.00030	0.00033	5	29	0.00005	0.00030	0.00014	0.00010	0.00009	0.00005	0.00005	0.00020	0.00026	0.00030	11
Dissolved Cobalt	-	mg/L	19	0.000019	0.000129	0.000042	0.000031	0.000032	0.000020	0.000023	0.000044	0.000072	0.000126	0	29	0.000017	0.000110	0.000055	0.000049	0.000023	0.000034	0.000037	0.000062	0.000093	0.000102	0

Parameters	CCME Guideline[1]	Unit	R2												W9											
			n	min	max	mean	median	sd	10th	25th	75th	90th	95th	<DL	n	min	max	mean	median	sd	10th	25th	75th	90th	95th	<DL
Dissolved Copper	-	mg/L	19	0.0004	0.0019	0.0011	0.0009	0.0005	0.0005	0.0007	0.0014	0.0017	0.0019	0	29	0.0005	0.0019	0.0010	0.0009	0.0004	0.0006	0.0007	0.0014	0.0017	0.0018	0
Dissolved Iron	-	mg/L	19	0.004	0.216	0.052	0.034	0.063	0.006	0.010	0.070	0.112	0.213	0	29	0.006	0.220	0.079	0.060	0.061	0.026	0.035	0.100	0.192	0.201	0
Dissolved Lead	-	mg/L	19	0.000003	0.000133	0.000026	0.000017	0.000035	0.000003	0.000004	0.000023	0.000060	0.000105	5	29	0.000003	0.000172	0.000040	0.000019	0.000045	0.000003	0.000011	0.000062	0.000094	0.000138	4
Dissolved Lithium	-	mg/L	19	0.00054	0.00120	0.00091	0.00100	0.00021	0.00060	0.00075	0.00105	0.00110	0.00111	0	29	0.00120	0.00310	0.00223	0.00210	0.00050	0.00178	0.00190	0.00260	0.00300	0.00302	0
Dissolved Magnesium	-	mg/L	19	2.42	12.70	7.05	7.49	2.55	4.03	5.42	8.76	9.43	10.03	0	29	2.75	12.80	7.43	6.81	2.63	4.48	5.61	9.91	11.00	11.06	0
Dissolved Manganese	-	mg/L	19	0.0025	0.0107	0.0050	0.0046	0.0022	0.0032	0.0036	0.0055	0.0069	0.0104	0	29	0.0015	0.0486	0.0181	0.0128	0.0127	0.0078	0.0092	0.0238	0.0357	0.0445	0
Dissolved Mercury	-	mg/L	16	0.0000050	0.0000050	0.0000050	0.0000050	0.0000000	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	16	25	0.0000050	0.0000250	0.0000058	0.0000050	0.0000040	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	25
Dissolved Molybdenum	-	mg/L	19	0.00027	0.00101	0.00072	0.00069	0.00020	0.00050	0.00064	0.00088	0.00095	0.00096	0	29	0.00029	0.00084	0.00062	0.00061	0.00013	0.00048	0.00055	0.00070	0.00079	0.00081	0
Dissolved Nickel	-	mg/L	19	0.00020	0.00090	0.00044	0.00041	0.00020	0.00024	0.00029	0.00054	0.00065	0.00089	0	29	0.00022	0.00073	0.00041	0.00037	0.00017	0.00024	0.00028	0.00045	0.00069	0.00070	0
Dissolved Phosphorus	-	mg/L	16	0.0010	0.0099	0.0036	0.0030	0.0028	0.0010	0.0010	0.0043	0.0073	0.0097	5	25	0.0010	0.0120	0.0043	0.0040	0.0027	0.0014	0.0029	0.0050	0.0074	0.0094	4
Dissolved Potassium	-	mg/L	19	0.44	0.84	0.63	0.62	0.11	0.51	0.53	0.72	0.74	0.76	0	29	0.50	1.27	0.76	0.71	0.21	0.55	0.61	0.89	1.01	1.14	0
Dissolved Selenium	-	mg/L	19	0.00002	0.00012	0.00006	0.00006	0.00002	0.00005	0.00005	0.00006	0.00008	0.00012	1	29	0.00002	0.00010	0.00004	0.00004	0.00002	0.00002	0.00002	0.00005	0.00006	0.00006	14
Dissolved Silicon	-	mg/L	19	1.98	5.70	4.27	4.50	0.99	2.96	4.05	4.85	5.22	5.34	0	29	2.22	6.20	4.63	4.80	0.88	3.72	4.50	5.10	5.49	5.88	0
Dissolved Silver	-	mg/L	19	0.000003	0.000003	0.000003	0.000003	0.000000	0.000003	0.000003	0.000003	0.000003	0.000003	19	29	0.000003	0.000015	0.000003	0.000003	0.000002	0.000003	0.000003	0.000003	0.000003	0.000003	29
Dissolved Sodium	-	mg/L	19	0.94	3.95	2.79	2.98	0.87	1.74	2.26	3.34	3.82	3.84	0	29	1.34	5.88	3.74	3.49	1.20	2.38	2.93	4.78	5.13	5.45	0
Dissolved Strontium	-	mg/L	19	0.051	0.233	0.145	0.149	0.051	0.087	0.106	0.179	0.198	0.222	0	29	0.066	0.288	0.178	0.172	0.063	0.106	0.131	0.237	0.261	0.267	0
Dissolved Sulphur	-	mg/L	19	5.00	14.00	6.21	5.00	2.37	5.00	5.00	6.50	8.40	10.40	12	29	1.50	1530.00	57.76	5.00	283.16	4.00	5.00	6.00	7.60	8.00	15
Dissolved Thallium	-	mg/L	19	0.0000010	0.0000010	0.0000010	0.0000010	0.0000000	0.0000010	0.0000010	0.0000010	0.0000010	0.0000010	19	29	0.0000010	0.0000050	0.0000013	0.0000010	0.0000009	0.0000010	0.0000010	0.0000010	0.0000021	0.0000029	26
Dissolved Tin	-	mg/L	19	0.000005	0.000100	0.000021	0.000005	0.000035	0.000005	0.000005	0.000005	0.000100	0.000100	18	29	0.000005	0.000100	0.000019	0.000005	0.000033	0.000005	0.000005	0.000005	0.000100	0.000100	29
Dissolved Titanium	-	mg/L	19	0.00025	0.00164	0.00051	0.00025	0.00046	0.00025	0.00025	0.00060	0.00112	0.00160	13	29	0.00025	0.00230	0.00061	0.00025	0.00058	0.00025	0.00025	0.00110	0.00142	0.00164	20
Dissolved Uranium	-	mg/L	19	0.00104	0.00601	0.00232	0.00219	0.00134	0.00106	0.00129	0.00267	0.00412	0.00488	0	29	0.00161	0.01190	0.00575	0.00543	0.00285	0.00228	0.00308	0.00816	0.00886	0.00998	0
Dissolved Vanadium	-	mg/L	19	0.00010	0.00063	0.00026	0.00030	0.00019	0.00010	0.00010	0.00030	0.00060	0.00061	9	29	0.00010	0.00080	0.00032	0.00030	0.00020	0.00010	0.00020	0.00040	0.00053	0.00068	8
Dissolved Zinc	-	mg/L	19	0.00010	0.00296	0.00061	0.00050	0.00062	0.00020	0.00030	0.00060	0.00086	0.00129	0	29	0.00010	0.00590	0.00102	0.00050	0.00148	0.00020	0.00030	0.00083	0.00252	0.00476	0
Dissolved Zirconium	-	mg/L	19	0.00005	0.00030	0.00015	0.00010	0.00008	0.00005	0.00010	0.00020	0.00025	0.00030	3	29	0.00005	0.00040	0.00017	0.00020	0.00009	0.00005	0.00010	0.00022	0.00030	0.00030	5

Notes:

1) Canadian water quality guidelines for the protection of aquatic life,

a) Ammonia (NH3) guideline based on ph=8 and temp=20

b) Aluminum (AL-T)= 0.005 mg/L at pH < 6.5: 0.1 mg/L at pH ≥ 6.5

c) Cadmium (Cd) mg/L: 10^(0.86*(log(hardness))-3.2)/1000

d) Copper (Cu) mg/L: (e^0.8545[ln(hardness)]-1.465)*0.2/1000; minim

e) Lead (Pb) mg/L: (e^1.273[ln(hardness)]-4.705)/1000; minimum is 0.

f) Nickel (Ni) mg/L: (e^0.76[(ln(hardness)]+1.06)/1000; minimum is 0.0

W5

Parameters	CCME Guideline[1]	Unit	n	min	max	mean	median	sd	10th	25th	75th	90th	95th	<DL
pH	6.5 - 9.0	pH Units	23	7.30	8.20	7.80	7.85	0.22	7.50	7.69	7.93	8.00	8.00	0
Conductivity	-	uS/cm	23	68	305	187	190	69	112	142	242	278	285	0
Total Hardness CaCO3	-	mg/L	23	33	140	90	88	32	57	68	113	135	136	0
Dissolved Hardness CaCO3	-	mg/L	21	33	135	90	91	31	57	66	115	129	134	0
Total Dissolved Solids	-	mg/L	23	68	180	120	110	29	79	105	140	150	159	0
Total Suspended Solids	-	mg/L	23	0.5	96.0	14.9	4.0	25.2	0.5	0.5	15.5	51.4	67.9	9
Turbidity		NTU	23	0.2	7.8	1.7	1.1	2.1	0.2	0.3	1.6	4.0	6.5	0
Ammonia as N	0.499[a]	mg/L	23	0.003	0.260	0.029	0.005	0.056	0.003	0.003	0.025	0.057	0.105	12
Alkalinity (Total as CaCO3)	-	mg/L	23	3.90	115.00	65.71	67.00	30.87	24.64	48.00	91.00	99.40	109.00	0
Acidity to pH 4.5 (as CaCO3)	-	mg/L	12	0.25	0.25	0.25	0.25	0.00	0.25	0.25	0.25	0.25	0.25	12
Acidity to pH 8.3 (as CaCO3)	-	mg/L	12	0.25	4.90	2.14	2.05	1.63	0.25	0.51	3.18	4.21	4.57	3
Bromide	-	mg/L	19	0.01	0.20	0.17	0.20	0.07	0.04	0.20	0.20	0.20	0.20	19
Chloride	120	mg/L	23	0.25	2.50	0.67	0.60	0.52	0.25	0.25	0.90	1.08	1.19	10
Fluoride	0.12	mg/L	19	0.040	0.070	0.059	0.060	0.007	0.050	0.060	0.060	0.070	0.070	0
Sulphate	-	mg/L	23	0.25	45.00	21.92	23.00	11.02	8.88	15.50	28.50	33.80	37.15	2
Total Nitrogen	-	mg/L	23	0.12	0.56	0.33	0.36	0.12	0.14	0.29	0.39	0.44	0.54	0
Nitrate (as N)	13	mg/L	23	0.006	0.300	0.141	0.143	0.084	0.030	0.071	0.191	0.241	0.286	0
Nitrate plus Nitrite	-	mg/L	21	0.006	0.300	0.144	0.145	0.087	0.028	0.066	0.192	0.245	0.291	0
Nitrite (as N)	0.06	mg/L	23	0.001	0.220	0.019	0.001	0.060	0.001	0.001	0.002	0.004	0.180	16
Total Kjeldahl Nitrogen	-	mg/L	20	0.02	0.51	0.21	0.18	0.14	0.06	0.12	0.27	0.43	0.48	0
Orthophosphate as P	-	mg/L	23	0.0005	0.0030	0.0017	0.0020	0.0008	0.0005	0.0010	0.0020	0.0025	0.0030	6
Cyanide, Total	0.005	mg/L												
Cyanide, Weak Acid Diss	-	mg/L	23	0.00025	0.00130	0.00047	0.00025	0.00030	0.00025	0.00025	0.00070	0.00086	0.00090	13
Dissolved Organic Carbon	-	mg/L	8	2.50	14.10	6.38	5.65	3.81	2.73	3.93	7.60	10.39	12.25	0
Total Organic Carbon	-	mg/L	19	0.25	16.40	6.01	5.10	4.51	2.21	3.42	6.60	13.28	16.04	2
Total Aluminum	0.1[b]	mg/L	23	0.01	0.57	0.15	0.04	0.17	0.01	0.03	0.18	0.45	0.49	0
Total Antimony	-	mg/L	23	0.00007	0.00014	0.00010	0.00010	0.00002	0.00008	0.00008	0.00011	0.00011	0.00012	0
Total Arsenic	0.005	mg/L	23	0.00026	0.00106	0.00045	0.00036	0.00021	0.00027	0.00033	0.00053	0.00075	0.00086	0
Total Barium	-	mg/L	23	0.04	0.09	0.06	0.05	0.01	0.05	0.05	0.07	0.08	0.08	0
Total Beryllium	-	mg/L	23	0.000005	0.000050	0.000015	0.000005	0.000014	0.000005	0.000005	0.000020	0.000038	0.000045	12
Total Bismuth	-	mg/L	23	0.0000025	0.0000123	0.0000038	0.0000025	0.0000026	0.0000025	0.0000025	0.0000038	0.0000076	0.0000080	17
Total Boron	1.5	mg/L	23	0.03	0.03	0.03	0.03	0.00	0.03	0.03	0.03	0.03	0.03	23
Total Cadmium	0.000032[c]	mg/L	23	0.000003	0.000101	0.000024	0.000016	0.000022	0.000006	0.000012	0.000028	0.000050	0.000060	2
Total Calcium	-	mg/L	23	8.44	36.10	23.45	22.90	8.20	15.00	17.95	28.70	35.04	35.76	0
Total Chromium	0.001	mg/L	23	0.00005	0.00079	0.00025	0.00020	0.00024	0.00005	0.00005	0.00040	0.00058	0.00069	9
Total Cobalt	-	mg/L	23	0.000029	0.000645	0.000164	0.000093	0.000167	0.000044	0.000048	0.000209	0.000407	0.000487	0
Total Copper	0.0023[d]	mg/L	23	0.0008	0.0093	0.0032	0.0023	0.0024	0.0011	0.0015	0.0040	0.0063	0.0090	0
Total Iron	0.3	mg/L	23	0.039	0.973	0.251	0.099	0.271	0.048	0.059	0.320	0.693	0.778	0
Total Lead	0.003[e]	mg/L	23	0.000018	0.004120	0.000567	0.000124	0.001010	0.000032	0.000055	0.000536	0.001362	0.002780	0
Total Lithium	-	mg/L	23	0.00130	0.00250	0.00185	0.00180	0.00031	0.00150	0.00160	0.00200	0.00210	0.00237	0
Total Magnesium	-	mg/L	23	2.77	12.90	7.65	7.51	2.83	4.65	5.48	9.70	11.16	12.01	0
Total Manganese	-	mg/L	23	0.0104	0.0785	0.0280	0.0242	0.0185	0.0124	0.0147	0.0313	0.0445	0.0729	0
Total Mercury	0.000026	mg/L	20	0.0000050	0.0000100	0.0000053	0.0000050	0.0000011	0.0000050	0.0000050	0.0000050	0.0000050	0.0000053	19
Total Molybdenum	0.073	mg/L	23	0.00040	0.00099	0.00075	0.00080	0.00016	0.00051	0.00063	0.00088	0.00091	0.00092	0
Total Nickel	0.0033[f]	mg/L	23	0.00020	0.00122	0.00050	0.00033	0.00032	0.00023	0.00025	0.00064	0.00105	0.00117	0
Total Phosphorus	-	mg/L	20	0.0010	0.0530	0.0144	0.0080	0.0173	0.0019	0.0030	0.0165	0.0493	0.0521	2
Total Potassium	-	mg/L	23	0.57	1.37	0.83	0.76	0.22	0.61	0.69	0.98	1.07	1.29	0
Total Selenium	0.001	mg/L	23	0.00002	0.00009	0.00005	0.00005	0.00002	0.00002	0.00005	0.00006	0.00007	0.00007	3
Total Silicon	-	mg/L	23	2.63	5.90	4.83	5.20	0.84	3.78	4.40	5.30	5.50	5.77	0
Total Silver	0.0001	mg/L	23	0.000003	0.000023	0.000005	0.000003	0.000005	0.000003	0.000003	0.000004	0.000009	0.000012	17
Total Sodium	-	mg/L	23	1.25	5.85	3.68	3.66	1.23	2.34	2.81	4.56	5.15	5.48	0
Total Strontium	-	mg/L	23	0.068	0.281	0.170	0.165	0.060	0.105	0.126	0.217	0.246	0.254	0
Total Sulphur	-	mg/L	23	1.50	15.00	7.98	6.00	3.93	4.20	5.00	11.00	13.00	13.90	8
Total Thallium	0.0008	mg/L	23	0.0000010	0.0000104	0.0000031	0.0000020	0.0000027	0.0000010	0.0000010	0.0000040	0.0000070	0.0000079	10
Total Tin	-	mg/L	23	0.000005	0.000200	0.000020	0.000005	0.000045	0.000005	0.000005	0.000005	0.000049	0.000096	21
Total Titanium	-	mg/L	23	0.00025	0.02190	0.00503	0.00230	0.00657	0.00025	0.00025	0.00635	0.01376	0.01902	8
Total Uranium	0.015	mg/L	23	0.00234	0.01320	0.00593	0.00554	0.00320	0.00275	0.00304	0.00871	0.00998	0.01072	0
Total Vanadium	-	mg/L	23	0.00010	0.00216	0.00069	0.00040	0.00065	0.00010	0.00020	0.00090	0.00170	0.00206	5
Total Zinc	0.03	mg/L	23	0.00030	0.00734	0.00198	0.00120	0.00184	0.00044	0.00075	0.00225	0.00428	0.00556	0
Total Zirconium	-	mg/L	23	0.00005	0.00050	0.00020	0.00020	0.00014	0.00005	0.00008	0.00030	0.00040	0.00040	6
Dissolved Aluminum	0.1	mg/L	23	0.01	0.36	0.06	0.02	0.08	0.01	0.01	0.06	0.14	0.19	0
Dissolved Antimony	-	mg/L	23	0.00006	0.00012	0.00009	0.00009	0.00002	0.00007	0.00008	0.00010	0.00011	0.00012	0
Dissolved Arsenic	-	mg/L	23	0.00022	0.00052	0.00033	0.00033	0.00006	0.00025	0.00030	0.00036	0.00038	0.00042	0
Dissolved Barium	-	mg/L	23	0.028500	0.089100	0.053465	0.048900	0.016103	0.038960	0.041550	0.065500	0.072780	0.080660	0
Dissolved Beryllium	-	mg/L	23	0.000005	0.000030	0.000009	0.000005	0.000006	0.000005	0.000005	0.000010	0.000013	0.000019	13
Dissolved Bismuth	-	mg/L	23	0.0000025	0.0000080	0.0000027	0.0000025	0.0000011	0.0000025	0.0000025	0.0000025	0.0000025	0.0000025	22
Dissolved Boron	-	mg/L	23	0.025	0.025	0.025	0.025	0.000	0.025	0.025	0.025	0.025	0.025	23
Dissolved Cadmium	-	mg/L	23	0.000003	0.000042	0.000013	0.000011	0.000009	0.000006	0.000009	0.000016	0.000020	0.000033	2
Dissolved Calcium	-	mg/L	23	8.82	35.00	22.87	21.80	7.68	14.76	17.60	28.50	33.12	33.38	0
Dissolved Chromium	-	mg/L	23	0.00005	0.00030	0.00015	0.00010	0.00010	0.00005	0.00005	0.00022	0.00030	0.00030	10
Dissolved Cobalt	-	mg/L	23	0.000037	0.000362	0.000071	0.000052	0.000067	0.000038	0.000041	0.000076	0.000089	0.000111	0

W16

Parameters	CCME Guideline[1]	Unit	n	min	max	mean	median	sd	10th	25th	75th	90th	95th	<DL
pH	6.5 - 9.0	pH Units	24	7.36	8.30	7.81	7.90	0.21	7.48	7.78	7.91	7.96	8.00	0
Conductivity	-	uS/cm	24	108	327	207	203	62	140	150	256	289	293	0
Total Hardness CaCO3	-	mg/L	24	57	154	98	97	29	68	70	125	134	139	0
Dissolved Hardness CaCO3	-	mg/L	23	54	151	98	98	28	68	71	123	135	136	0
Total Dissolved Solids	-	mg/L	24	92	190	138	140	27	110	120	160	170	179	0
Total Suspended Solids	-	mg/L	24	0.5	74.0	10.9	3.5	16.7	0.5	2.0	14.3	25.8	35.5	4
Turbidity		NTU	24	0.3	12.6	2.6	0.9	3.5	0.4	0.6	2.5	6.5	11.3	0
Ammonia as N	0.499[a]	mg/L	24	0.003	0.260	0.027	0.010	0.052	0.003	0.005	0.031	0.041	0.052	9
Alkalinity (Total as CaCO3)	-	mg/L	24	4.80	110.00	64.98	63.50	33.70	11.29	46.50	93.00	106.10	110.00	0
Acidity to pH 4.5 (as CaCO3)	-	mg/L	16	0.25	0.25	0.25	0.25	0.00	0.25	0.25	0.25	0.25	0.25	16
Acidity to pH 8.3 (as CaCO3)	-	mg/L	16	0.25	6.00	1.50	0.48	1.81	0.25	0.25	2.33	4.05	5.10	8
Bromide	-	mg/L	21	0.05	0.20	0.19	0.20	0.03	0.20	0.20	0.20	0.20	0.20	21
Chloride	120	mg/L	24	0.25	5.00	0.70	0.38	0.97	0.25	0.25	0.83	1.07	1.19	12
Fluoride	0.12	mg/L	21	0.050	0.080	0.060	0.060	0.008	0.050	0.050	0.060	0.070	0.070	0
Sulphate	-	mg/L	24	15.00	62.00	29.25	28.00	11.61	18.00	23.25	30.00	46.90	52.85	0
Total Nitrogen	-	mg/L	24	0.10	4.10	0.48	0.34	0.78	0.15	0.28	0.42	0.50	0.54	0
Nitrate (as N)	13	mg/L	24	0.001	0.274	0.112	0.105	0.081	0.020	0.055	0.148	0.226	0.266	1
Nitrate plus Nitrite	-	mg/L	23	0.001	0.274	0.114	0.111	0.082	0.019	0.055	0.156	0.229	0.268	1
Nitrite (as N)	0.06	mg/L	24	0.001	0.300	0.014	0.001	0.061	0.001	0.001	0.002	0.003	0.004	15
Total Kjeldahl Nitrogen	-	mg/L	22	0.01	4.00	0.39	0.20	0.82	0.09	0.15	0.34	0.40	0.48	1
Orthophosphate as P	-	mg/L	24	0.0005	0.0110	0.0021	0.0020	0.0021	0.0005	0.0010	0.0020	0.0029	0.0039	5
Cyanide, Total	0.005	mg/L												
Cyanide, Weak Acid Diss	-	mg/L	24	0.00025	0.00120	0.00059	0.00055	0.00034	0.00025	0.00025	0.00093	0.00107	0.00110	10
Dissolved Organic Carbon	-	mg/L	10	3.50	15.50	7.17	5.85	3.80	3.59	5.18	8.15	12.08	13.79	0
Total Organic Carbon	-	mg/L	20	0.25	15.50	7.23	6.15	3.85	3.60	4.93	9.43	12.28	13.13	1
Total Aluminum	0.1[b]	mg/L	24	0.01	0.47	0.14	0.08	0.14	0.02	0.03	0.22	0.34	0.40	0
Total Antimony	-	mg/L	24	0.00006	0.00016	0.00009	0.00009	0.00002	0.00007	0.00008	0.00010	0.00010	0.00011	0
Total Arsenic	0.005	mg/L	24	0.00031	0.00123	0.00058	0.00053	0.00021	0.00039	0.00046	0.00063	0.00083	0.00096	0
Total Barium	-	mg/L	24	0.04	0.08	0.06	0.06	0.01	0.04	0.05	0.07	0.08	0.08	0
Total Beryllium	-	mg/L	24	0.000005	0.000040	0.000013	0.000008	0.000011	0.000005	0.000005	0.000020	0.000030	0.000030	12
Total Bismuth	-	mg/L	24	0.0000025	0.0000100	0.0000034	0.0000025	0.0000020	0.0000025	0.0000025	0.0000025	0.0000060	0.0000077	19
Total Boron	1.5	mg/L	24	0.03	0.03	0.03	0.03	0.00	0.03	0.03	0.03	0.03	0.03	24
Total Cadmium	0.000032[c]	mg/L	24	0.000003	0.000073	0.000021	0.000017	0.000017	0.000008	0.000012	0.000021	0.000047	0.000048	2
Total Calcium	-	mg/L	24	14.20	36.40	24.42	24.35	6.90	16.66	17.60	29.40	33.60	35.73	0
Total Chromium	0.001	mg/L	24	0.00005	0.00070	0.00030	0.00020	0.00023	0.00005	0.00010	0.00050	0.00067	0.00070	4
Total Cobalt	-	mg/L	24	0.000063	0.000575	0.000188	0.000134	0.000136	0.000073	0.000088	0.000238	0.000371	0.000438	0
Total Copper	0.0023[d]	mg/L	24	0.0008	0.0089	0.0026	0.0022	0.0018	0.0009	0.0014	0.0035	0.0045	0.0052	0
Total Iron	0.3	mg/L	24	0.078	1.090	0.342	0.251	0.256	0.112	0.180	0.419	0.669	0.798	0
Total Lead	0.003[e]	mg/L	24	0.000015	0.003010	0.000346	0.000128	0.000626	0.000036	0.000056	0.000345	0.000770	0.001019	0
Total Lithium	-	mg/L	24	0.00110	0.00190	0.00139	0.00140	0.00017	0.00120	0.00130	0.00143	0.00160	0.00160	0
Total Magnesium	-	mg/L	24	5.15	15.40	9.02	8.73	2.85	6.01	6.52	11.00	12.94	13.39	0
Total Manganese	-	mg/L	24	0.0204	0.1330	0.0424	0.0382	0.0230	0.0230	0.0290	0.0524	0.0567	0.0588	0
Total Mercury	0.000026	mg/L	18	0.0000050	0.0000050	0.0000050	0.0000050	0.0000000	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	18
Total Molybdenum	0.073	mg/L	24	0.00049	0.00104	0.00079	0.00084	0.00016	0.00056	0.00066	0.00089	0.00099	0.00103	0
Total Nickel	0.0033[f]	mg/L	24	0.00031	0.00151	0.00072	0.00061	0.00038	0.00034	0.00041	0.00098	0.00130	0.00135	0
Total Phosphorus	-	mg/L	18	0.0030	0.0520	0.0137	0.0095	0.0121	0.0030	0.0055	0.0203	0.0243	0.0291	0
Total Potassium	-	mg/L	24	0.60	1.52	0.93	0.87	0.24	0.64	0.76	1.09	1.24	1.30	0
Total Selenium	0.001	mg/L	24	0.00002	0.00009	0.00006	0.00006	0.00002	0.00003	0.00005	0.00007	0.00008	0.00009	3
Total Silicon	-	mg/L	24	3.50	5.70	4.66	4.65	0.66	3.63	4.20	5.20	5.47	5.59	0
Total Silver	0.0001	mg/L	24	0.000003	0.000010	0.000003	0.000003	0.000002	0.000003	0.000003	0.000003	0.000006	0.000008	21
Total Sodium	-	mg/L	24	2.30	6.72	4.03	3.96	1.17	2.74	3.01	4.79	5.59	5.62	0
Total Strontium	-	mg/L	24	0.091	0.245	0.167	0.165	0.048	0.112	0.120	0.206	0.234	0.239	0
Total Sulphur	-	mg/L	24	5.00	20.00	10.04	10.50	4.80	5.00	5.75	13.00	16.80	19.70	6
Total Thallium	0.0008	mg/L	24	0.0000010	0.0000090	0.0000025	0.0000010	0.0000021	0.0000010	0.0000010	0.0000033	0.0000054	0.0000060	13
Total Tin	-	mg/L	24	0.000005	0.000005	0.000005	0.000005	0.000000	0.000005	0.000005	0.000005	0.000005	0.000005	24
Total Titanium	-	mg/L	24	0.00025	0.01830	0.00481	0.00280	0.00538	0.00025	0.00060	0.00758	0.01114	0.01605	5
Total Uranium	0.015	mg/L	24	0.00178	0.00971	0.00491	0.00473	0.00233	0.00234	0.00250	0.00725	0.00763	0.00769	0
Total Vanadium	-	mg/L	24	0.00010	0.00250	0.00086	0.00070	0.00073	0.00010	0.00020	0.00123	0.00194	0.00217	5
Total Zinc	0.03	mg/L	24	0.00040	0.00580	0.00182	0.00150	0.00132	0.00056	0.00088	0.00228	0.00339	0.00428	0
Total Zirconium	-	mg/L	24	0.00005	0.00050	0.00026	0.00020	0.00016	0.00010	0.00010	0.00040	0.00050	0.00050	1
Dissolved Aluminum	0.1	mg/L	24	0.01	0.12	0.04	0.03	0.04	0.01	0.01	0.06	0.10	0.11	0
Dissolved Antimony	-	mg/L	24	0.00005	0.00013	0.00009	0.00009	0.00002	0.00006	0.00008	0.00009	0.00010	0.00010	0
Dissolved Arsenic	-	mg/L	24	0.00029	0.00053	0.00043	0.00045	0.00007	0.00034	0.00038	0.00048	0.00050	0.00051	0
Dissolved Barium	-	mg/L	24	0.031300	0.082200	0.054750	0.053100	0.014758	0.039380	0.041875	0.064300	0.075080	0.080855	0
Dissolved Beryllium	-	mg/L	24	0.000005	0.000030	0.000008	0.000005	0.000006	0.000005	0.000005	0.000010	0.000010	0.000019	17
Dissolved Bismuth	-	mg/L	24	0.0000025	0.0000050	0.0000026	0.0000025	0.0000005	0.0000025	0.0000025	0.0000025	0.0000025	0.0000025	23
Dissolved Boron	-	mg/L	24	0.025	0.025	0.025	0.025	0.000	0.025	0.025	0.025	0.025	0.025	24
Dissolved Cadmium	-	mg/L	24	0.000003	0.000022	0.000010	0.000010	0.000005	0.000003	0.000007	0.000015	0.000017	0.000018	4
Dissolved Calcium	-	mg/L	24	13.40	36.00	24.13	23.95	6.82	16.83	18.15	29.53	33.90	34.46	0
Dissolved Chromium	-	mg/L	24	0.00005	0.00040	0.00017	0.00010	0.00013	0.00005	0.00005	0.00030	0.00037	0.00040	8
Dissolved Cobalt	-	mg/L	24	0.000043	0.000133	0.000085	0.000087	0.000023	0.000057	0.000071	0.000102	0.000108	0.000123	0

W5

Parameters	CCME Guideline[1]	Unit	n	min	max	mean	median	sd	10th	25th	75th	90th	95th	<DL
Dissolved Copper	-	mg/L	23	0.0007	0.0080	0.0025	0.0019	0.0017	0.0011	0.0015	0.0031	0.0046	0.0052	0
Dissolved Iron	-	mg/L	23	0.013	0.581	0.093	0.042	0.118	0.033	0.038	0.101	0.183	0.202	0
Dissolved Lead	-	mg/L	23	0.000003	0.000760	0.000078	0.000039	0.000158	0.000003	0.000011	0.000058	0.000144	0.000213	3
Dissolved Lithium	-	mg/L	23	0.00092	0.00250	0.00177	0.00180	0.00037	0.00150	0.00150	0.00200	0.00210	0.00237	0
Dissolved Magnesium	-	mg/L	23	2.77	12.80	7.57	7.09	2.75	4.93	5.50	9.67	11.20	11.38	0
Dissolved Manganese	-	mg/L	23	0.0014	0.0410	0.0157	0.0113	0.0100	0.0066	0.0093	0.0226	0.0290	0.0317	0
Dissolved Mercury	-	mg/L	19	0.0000050	0.0000050	0.0000050	0.0000050	0.0000000	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	19
Dissolved Molybdenum	-	mg/L	23	0.00033	0.00099	0.00076	0.00081	0.00017	0.00051	0.00069	0.00088	0.00093	0.00094	0
Dissolved Nickel	-	mg/L	23	0.00020	0.00087	0.00040	0.00033	0.00019	0.00024	0.00026	0.00047	0.00067	0.00082	0
Dissolved Phosphorus	-	mg/L	19	0.0010	0.0170	0.0046	0.0030	0.0044	0.0010	0.0020	0.0050	0.0115	0.0134	4
Dissolved Potassium	-	mg/L	23	0.55	1.34	0.83	0.77	0.21	0.63	0.69	0.96	1.02	1.29	0
Dissolved Selenium	-	mg/L	23	0.00002	0.00007	0.00005	0.00005	0.00001	0.00004	0.00004	0.00006	0.00006	0.00006	2
Dissolved Silicon	-	mg/L	23	2.34	5.70	4.70	4.90	0.86	3.70	4.45	5.25	5.46	5.59	0
Dissolved Silver	-	mg/L	23	0.000003	0.000009	0.000003	0.000003	0.000002	0.000003	0.000003	0.000003	0.000005	0.000008	20
Dissolved Sodium	-	mg/L	23	1.34	5.90	3.64	3.50	1.19	2.41	2.80	4.64	5.08	5.19	0
Dissolved Strontium	-	mg/L	23	0.065	0.270	0.169	0.169	0.059	0.104	0.126	0.221	0.242	0.252	0
Dissolved Sulphur	-	mg/L	23	1.50	15.00	7.67	5.00	3.70	5.00	5.00	11.00	12.80	13.00	8
Dissolved Thallium	-	mg/L	23	0.0000010	0.0000070	0.0000017	0.0000010	0.0000014	0.0000010	0.0000010	0.0000020	0.0000025	0.0000039	14
Dissolved Tin	-	mg/L	23	0.000005	0.000100	0.000020	0.000005	0.000034	0.000005	0.000005	0.000005	0.000092	0.000100	20
Dissolved Titanium	-	mg/L	23	0.00025	0.02480	0.00167	0.00025	0.00508	0.00025	0.00025	0.00090	0.00201	0.00219	15
Dissolved Uranium	-	mg/L	23	0.00163	0.01300	0.00581	0.00539	0.00326	0.00228	0.00287	0.00867	0.00981	0.01053	0
Dissolved Vanadium	-	mg/L	23	0.00010	0.00140	0.00035	0.00030	0.00030	0.00010	0.00015	0.00045	0.00060	0.00078	6
Dissolved Zinc	-	mg/L	23	0.00040	0.00530	0.00144	0.00070	0.00155	0.00042	0.00060	0.00130	0.00429	0.00515	0
Dissolved Zirconium	-	mg/L	23	0.00005	0.00040	0.00017	0.00020	0.00010	0.00005	0.00010	0.00020	0.00030	0.00030	4

W16

Parameters	n	min	max	mean	median	sd	10th	25th	75th	90th	95th	<DL
Dissolved Copper	24	0.0008	0.0062	0.0021	0.0019	0.0012	0.0010	0.0011	0.0027	0.0033	0.0034	0
Dissolved Iron	24	0.063	0.240	0.140	0.130	0.053	0.082	0.101	0.182	0.209	0.235	0
Dissolved Lead	24	0.000006	0.000399	0.000047	0.000027	0.000078	0.000010	0.000013	0.000047	0.000066	0.000080	0
Dissolved Lithium	24	0.00090	0.00200	0.00135	0.00130	0.00020	0.00120	0.00128	0.00140	0.00157	0.00160	0
Dissolved Magnesium	24	5.03	14.90	9.05	8.73	2.75	6.14	6.73	10.48	13.11	13.67	0
Dissolved Manganese	24	0.0008	0.0529	0.0291	0.0257	0.0154	0.0135	0.0163	0.0420	0.0513	0.0526	0
Dissolved Mercury	16	0.0000050	0.0000050	0.0000050	0.0000050	0.0000000	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	16
Dissolved Molybdenum	24	0.00056	0.00104	0.00081	0.00082	0.00014	0.00065	0.00069	0.00092	0.00098	0.00102	0
Dissolved Nickel	24	0.00030	0.00116	0.00055	0.00047	0.00023	0.00033	0.00036	0.00069	0.00082	0.00092	0
Dissolved Phosphorus	16	0.0020	0.0070	0.0046	0.0050	0.0018	0.0020	0.0038	0.0055	0.0070	0.0070	0
Dissolved Potassium	24	0.57	1.49	0.92	0.89	0.24	0.67	0.74	1.06	1.26	1.34	0
Dissolved Selenium	24	0.00002	0.00009	0.00006	0.00006	0.00002	0.00002	0.00005	0.00007	0.00008	0.00008	5
Dissolved Silicon	24	3.30	5.60	4.63	4.80	0.63	3.83	4.23	5.05	5.37	5.49	0
Dissolved Silver	24	0.000003	0.000003	0.000003	0.000003	0.000000	0.000003	0.000003	0.000003	0.000003	0.000003	24
Dissolved Sodium	24	2.32	6.44	4.03	3.97	1.09	2.84	2.96	4.86	5.33	5.57	0
Dissolved Strontium	24	0.089	0.248	0.167	0.165	0.048	0.113	0.123	0.209	0.235	0.236	0
Dissolved Sulphur	24	5.00	20.00	9.71	9.00	4.74	5.00	5.00	12.00	17.20	19.00	7
Dissolved Thallium	24	0.0000010	0.0000020	0.0000012	0.0000010	0.0000004	0.0000010	0.0000010	0.0000010	0.0000020	0.0000020	20
Dissolved Tin	24	0.000005	0.000005	0.000005	0.000005	0.000000	0.000005	0.000005	0.000005	0.000005	0.000005	24
Dissolved Titanium	24	0.00025	0.00170	0.00066	0.00038	0.00050	0.00025	0.00025	0.00110	0.00137	0.00157	12
Dissolved Uranium	24	0.00162	0.00998	0.00482	0.00470	0.00241	0.00210	0.00259	0.00700	0.00764	0.00770	0
Dissolved Vanadium	24	0.00010	0.00120	0.00042	0.00040	0.00027	0.00010	0.00020	0.00053	0.00070	0.00079	5
Dissolved Zinc	24	0.00020	0.00640	0.00105	0.00050	0.00136	0.00040	0.00040	0.00110	0.00120	0.00349	0
Dissolved Zirconium	24	0.00005	0.00040	0.00021	0.00020	0.00013	0.00005	0.00010	0.00030	0.00040	0.00040	5

Notes:

1) Canadian water quality guidelines for the protection of aquatic life,

a) Ammonia (NH3) guideline based on ph=8 and temp=20

b) Aluminum (AL-T)= 0.005 mg/L at pH < 6.5: 0.1 mg/L at pH ≥ 6.5

c) Cadmium (Cd) mg/L: 10^(0.86*(log(hardness))-3.2)/1000

d) Copper (Cu) mg/L: (e^0.8545[ln(hardness)]-1.465)*0.2/1000; minim

e) Lead (Pb) mg/L: (e^1.273[ln(hardness)]-4.705)/1000; minimum is 0.

f) Nickel (Ni) mg/L: (e^0.76[(ln(hardness)]+1.06)/1000; minimum is 0.0

Parameters	CCME Guideline[1]	Unit	W19											
			n	min	max	mean	median	sd	10th	25th	75th	90th	95th	<DL
pH	6.5 - 9.0	pH Units	5	7.48	7.91	7.72	7.79	0.18	7.52	7.59	7.85	7.89	7.90	0
Conductivity	-	uS/cm	5	101	248	171	174	66	104	108	224	238	243	0
Total Hardness CaCO3	-	mg/L	5	53	105	80	80	25	54	55	105	105	105	0
Dissolved Hardness CaCO3	-	mg/L	5	50	105	78	78	27	51	52	103	104	105	0
Total Dissolved Solids	-	mg/L	5	84	158	122	130	30	90	100	140	151	154	0
Total Suspended Solids	-	mg/L	5	1.1	123.0	41.2	12.0	53.4	1.5	2.0	68.0	101.0	112.0	0
Turbidity		NTU	5	1.1	16.5	8.7	5.4	6.8	2.7	5.1	15.2	16.0	16.2	0
Ammonia as N	0.499[a]	mg/L	5	0.014	0.059	0.031	0.027	0.018	0.016	0.018	0.037	0.050	0.055	0
Alkalinity (Total as CaCO3)	-	mg/L	5	34.00	92.70	65.04	67.00	25.27	38.60	45.50	86.00	90.02	91.36	0
Acidity to pH 4.5 (as CaCO3)	-	mg/L	5	0.25	0.25	0.25	0.25	0.00	0.25	0.25	0.25	0.25	0.25	5
Acidity to pH 8.3 (as CaCO3)	-	mg/L	5	0.25	12.10	3.19	1.60	5.03	0.25	0.25	1.75	7.96	10.03	2
Bromide	-	mg/L	5	0.01	0.20	0.12	0.20	0.11	0.01	0.01	0.20	0.20	0.20	5
Chloride	120	mg/L	5	0.25	0.90	0.51	0.25	0.36	0.25	0.25	0.90	0.90	0.90	3
Fluoride	0.12	mg/L	5	0.059	0.070	0.063	0.060	0.005	0.059	0.060	0.064	0.068	0.069	0
Sulphate	-	mg/L	5	12.00	31.00	20.10	20.00	8.16	12.20	12.50	25.00	28.60	29.80	0
Total Nitrogen	-	mg/L	5	0.19	0.74	0.41	0.31	0.22	0.23	0.30	0.50	0.64	0.69	0
Nitrate (as N)	13	mg/L	5	0.036	0.104	0.071	0.081	0.029	0.039	0.044	0.088	0.098	0.101	0
Nitrate plus Nitrite	-	mg/L	5	0.039	0.106	0.072	0.081	0.029	0.042	0.046	0.088	0.099	0.102	0
Nitrite (as N)	0.06	mg/L	5	0.001	0.003	0.002	0.002	0.001	0.001	0.001	0.002	0.003	0.003	2
Total Kjeldahl Nitrogen	-	mg/L	5	0.08	0.69	0.34	0.23	0.24	0.14	0.22	0.46	0.60	0.65	0
Orthophosphate as P	-	mg/L	5	0.0019	0.0110	0.0050	0.0050	0.0037	0.0019	0.0020	0.0050	0.0086	0.0098	0
Cyanide, Total	0.005	mg/L												
Cyanide, Weak Acid Diss	-	mg/L	5	0.00025	0.00110	0.00049	0.00025	0.00037	0.00025	0.00025	0.00061	0.00090	0.00100	3
Dissolved Organic Carbon	-	mg/L	5	5.44	17.80	10.89	10.20	5.21	5.90	6.60	14.40	16.44	17.12	0
Total Organic Carbon	-	mg/L	5	5.58	17.80	11.42	11.10	5.41	6.03	6.70	15.90	17.04	17.42	0
Total Aluminum	0.1[b]	mg/L	5	0.01	0.78	0.34	0.23	0.35	0.03	0.05	0.64	0.73	0.75	0
Total Antimony	-	mg/L	5	0.00005	0.00009	0.00008	0.00008	0.00002	0.00006	0.00008	0.00009	0.00009	0.00009	0
Total Arsenic	0.005	mg/L	5	0.00090	0.00230	0.00133	0.00112	0.00058	0.00091	0.00093	0.00140	0.00194	0.00212	0
Total Barium	-	mg/L	5	0.05	0.09	0.06	0.06	0.02	0.05	0.05	0.07	0.08	0.08	0
Total Beryllium	-	mg/L	5	0.000005	0.000052	0.000027	0.000020	0.000022	0.000007	0.000010	0.000050	0.000051	0.000052	1
Total Bismuth	-	mg/L	5	0.0000025	0.0000103	0.0000056	0.0000025	0.0000042	0.0000025	0.0000025	0.0000100	0.0000102	0.0000102	3
Total Boron	1.5	mg/L	5	0.03	0.03	0.03	0.03	0.00	0.03	0.03	0.03	0.03	0.03	5
Total Cadmium	0.000032[c]	mg/L	5	0.000013	0.000091	0.000036	0.000018	0.000033	0.000014	0.000015	0.000043	0.000072	0.000081	0
Total Calcium	-	mg/L	5	13.10	25.90	19.90	20.70	5.99	13.62	14.40	25.40	25.70	25.80	0
Total Chromium	0.001	mg/L	5	0.00010	0.00120	0.00065	0.00060	0.00052	0.00014	0.00020	0.00117	0.00119	0.00119	0
Total Cobalt	-	mg/L	5	0.000207	0.001000	0.000514	0.000411	0.000327	0.000233	0.000271	0.000682	0.000873	0.000936	0
Total Copper	0.0023[d]	mg/L	5	0.0008	0.0083	0.0038	0.0031	0.0030	0.0011	0.0016	0.0052	0.0070	0.0077	0
Total Iron	0.3	mg/L	5	0.748	2.680	1.377	1.210	0.794	0.751	0.755	1.490	2.204	2.442	0
Total Lead	0.003[e]	mg/L	5	0.000015	0.002220	0.000741	0.000375	0.000918	0.000039	0.000074	0.001020	0.001740	0.001980	0
Total Lithium	-	mg/L	5	0.00060	0.00130	0.00107	0.00110	0.00028	0.00080	0.00110	0.00126	0.00128	0.00129	0
Total Magnesium	-	mg/L	5	4.71	10.10	7.29	7.01	2.57	4.78	4.88	9.73	9.95	10.03	0
Total Manganese	-	mg/L	5	0.0474	0.2750	0.1428	0.0965	0.0976	0.0601	0.0792	0.2160	0.2514	0.2632	0
Total Mercury	0.000026	mg/L	4	0.0000050	0.0000050	0.0000050	0.0000050	0.0000000	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	4
Total Molybdenum	0.073	mg/L	5	0.00048	0.00101	0.00069	0.00065	0.00021	0.00051	0.00055	0.00075	0.00091	0.00096	0
Total Nickel	0.0033[f]	mg/L	5	0.00060	0.00207	0.00124	0.00105	0.00068	0.00062	0.00065	0.00184	0.00198	0.00202	0
Total Phosphorus	-	mg/L	4	0.0120	0.0817	0.0409	0.0350	0.0324	0.0138	0.0165	0.0594	0.0728	0.0772	0
Total Potassium	-	mg/L	5	0.65	1.22	0.91	0.82	0.23	0.71	0.81	1.07	1.16	1.19	0
Total Selenium	0.001	mg/L	5	0.00002	0.00010	0.00006	0.00006	0.00003	0.00003	0.00005	0.00008	0.00009	0.00010	1
Total Silicon	-	mg/L	5	3.80	5.40	4.68	4.80	0.64	4.00	4.30	5.10	5.28	5.34	0
Total Silver	0.0001	mg/L	5	0.000003	0.000023	0.000009	0.000007	0.000008	0.000003	0.000003	0.000009	0.000017	0.000020	2
Total Sodium	-	mg/L	5	2.19	5.19	3.71	3.76	1.44	2.25	2.33	5.09	5.15	5.17	0
Total Strontium	-	mg/L	5	0.082	0.190	0.136	0.135	0.049	0.086	0.093	0.181	0.186	0.188	0
Total Sulphur	-	mg/L	5	5.00	12.00	7.60	5.00	3.58	5.00	5.00	11.00	11.60	11.80	3
Total Thallium	0.0008	mg/L	5	0.0000010	0.0000090	0.0000045	0.0000030	0.0000039	0.0000010	0.0000010	0.0000083	0.0000087	0.0000089	2
Total Tin	-	mg/L	5	0.000005	0.000100	0.000043	0.000005	0.000052	0.000005	0.000005	0.000100	0.000100	0.000100	5
Total Titanium	-	mg/L	5	0.00025	0.02800	0.01325	0.01080	0.01277	0.00103	0.00220	0.02500	0.02680	0.02740	1
Total Uranium	0.015	mg/L	5	0.00161	0.00580	0.00315	0.00265	0.00162	0.00187	0.00227	0.00343	0.00485	0.00533	0
Total Vanadium	-	mg/L	5	0.00060	0.00437	0.00221	0.00160	0.00160	0.00080	0.00110	0.00340	0.00398	0.00418	0
Total Zinc	0.03	mg/L	5	0.00050	0.00640	0.00300	0.00290	0.00260	0.00050	0.00050	0.00470	0.00572	0.00606	0
Total Zirconium	-	mg/L	5	0.00020	0.00060	0.00042	0.00040	0.00018	0.00024	0.00030	0.00059	0.00060	0.00060	0
Dissolved Aluminum	0.1	mg/L	5	0.01	0.12	0.05	0.04	0.05	0.01	0.02	0.08	0.11	0.11	0
Dissolved Antimony	-	mg/L	5	0.00005	0.00008	0.00007	0.00008	0.00001	0.00006	0.00007	0.00008	0.00008	0.00008	0
Dissolved Arsenic	-	mg/L	5	0.00052	0.00082	0.00066	0.00063	0.00013	0.00054	0.00056	0.00075	0.00079	0.00081	0
Dissolved Barium	-	mg/L	5	0.031400	0.087700	0.052260	0.041700	0.023163	0.033760	0.037300	0.063200	0.077900	0.082800	0
Dissolved Beryllium	-	mg/L	5	0.000005	0.000020	0.000010	0.000010	0.000006	0.000005	0.000005	0.000011	0.000016	0.000018	2
Dissolved Bismuth	-	mg/L	5	0.0000025	0.0000025	0.0000025	0.0000025	0.0000000	0.0000025	0.0000025	0.0000025	0.0000025	0.0000025	5
Dissolved Boron	-	mg/L	5	0.025	0.025	0.025	0.025	0.000	0.025	0.025	0.025	0.025	0.025	5
Dissolved Cadmium	-	mg/L	5	0.000007	0.000015	0.000012	0.000013	0.000003	0.000008	0.000010	0.000014	0.000015	0.000015	0
Dissolved Calcium	-	mg/L	5	12.90	25.80	19.42	20.00	6.33	12.94	13.00	25.40	25.64	25.72	0
Dissolved Chromium	-	mg/L	5	0.00020	0.00040	0.00027	0.00025	0.00008	0.00020	0.00020	0.00030	0.00036	0.00038	0
Dissolved Cobalt	-	mg/L	5	0.000044	0.000414	0.000171	0.000123	0.000142	0.000072	0.000113	0.000160	0.000312	0.000363	0

Parameters	CCME Guideline[1]	Unit	W19											
			n	min	max	mean	median	sd	10th	25th	75th	90th	95th	<DL
Dissolved Copper	-	mg/L	5	0.0006	0.0039	0.0023	0.0022	0.0013	0.0009	0.0014	0.0034	0.0037	0.0038	0
Dissolved Iron	-	mg/L	5	0.241	0.585	0.416	0.345	0.158	0.276	0.328	0.582	0.584	0.584	0
Dissolved Lead	-	mg/L	5	0.000012	0.000126	0.000059	0.000057	0.000046	0.000016	0.000021	0.000081	0.000108	0.000117	0
Dissolved Lithium	-	mg/L	5	0.00060	0.00120	0.00087	0.00080	0.00023	0.00067	0.00077	0.00100	0.00112	0.00116	0
Dissolved Magnesium	-	mg/L	5	4.34	9.75	7.06	6.86	2.60	4.48	4.69	9.67	9.72	9.73	0
Dissolved Manganese	-	mg/L	5	0.0024	0.2650	0.0798	0.0295	0.1078	0.0092	0.0193	0.0829	0.1922	0.2286	0
Dissolved Mercury	-	mg/L	2	0.0000050	0.0000050	0.0000050	0.0000050	0.0000000	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	2
Dissolved Molybdenum	-	mg/L	5	0.00062	0.00104	0.00085	0.00095	0.00020	0.00063	0.00064	0.00099	0.00102	0.00103	0
Dissolved Nickel	-	mg/L	5	0.00056	0.00120	0.00081	0.00074	0.00024	0.00062	0.00070	0.00085	0.00106	0.00113	0
Dissolved Phosphorus	-	mg/L	2	0.0060	0.0121	0.0091	0.0091	0.0043	0.0066	0.0075	0.0106	0.0115	0.0118	0
Dissolved Potassium	-	mg/L	5	0.60	1.16	0.87	0.77	0.23	0.66	0.75	1.05	1.12	1.14	0
Dissolved Selenium	-	mg/L	5	0.00002	0.00009	0.00005	0.00005	0.00003	0.00002	0.00002	0.00008	0.00009	0.00009	2
Dissolved Silicon	-	mg/L	5	2.93	4.90	4.27	4.90	0.91	3.24	3.70	4.90	4.90	4.90	0
Dissolved Silver	-	mg/L	5	0.000003	0.000003	0.000003	0.000003	0.000000	0.000003	0.000003	0.000003	0.000003	0.000003	5
Dissolved Sodium	-	mg/L	5	2.14	5.14	3.67	3.67	1.40	2.25	2.41	4.98	5.08	5.11	0
Dissolved Strontium	-	mg/L	5	0.081	0.185	0.133	0.132	0.051	0.082	0.084	0.185	0.185	0.185	0
Dissolved Sulphur	-	mg/L	5	5.00	11.00	6.20	5.00	2.68	5.00	5.00	5.00	8.60	9.80	4
Dissolved Thallium	-	mg/L	5	0.0000010	0.0000010	0.0000010	0.0000010	0.0000000	0.0000010	0.0000010	0.0000010	0.0000010	0.0000010	5
Dissolved Tin	-	mg/L	5	0.000005	0.000100	0.000043	0.000005	0.000052	0.000005	0.000005	0.000100	0.000100	0.000100	5
Dissolved Titanium	-	mg/L	5	0.00025	0.00200	0.00111	0.00137	0.00082	0.00025	0.00025	0.00170	0.00188	0.00194	2
Dissolved Uranium	-	mg/L	5	0.00114	0.00580	0.00281	0.00226	0.00189	0.00125	0.00142	0.00344	0.00486	0.00533	0
Dissolved Vanadium	-	mg/L	5	0.00050	0.00110	0.00080	0.00080	0.00022	0.00058	0.00071	0.00090	0.00102	0.00106	0
Dissolved Zinc	-	mg/L	5	0.00030	0.00080	0.00064	0.00070	0.00021	0.00042	0.00060	0.00079	0.00080	0.00080	0
Dissolved Zirconium	-	mg/L	5	0.00020	0.00040	0.00029	0.00025	0.00010	0.00020	0.00020	0.00040	0.00040	0.00040	0

Notes:

1) Canadian water quality guidelines for the protection of aquatic life,

a) Ammonia (NH3) guideline based on ph=8 and temp=20

b) Aluminum (AL-T)= 0.005 mg/L at pH < 6.5: 0.1 mg/L at pH ≥ 6.5

c) Cadmium (Cd) mg/L: 10^(0.86*(log(hardness))-3.2)/1000

d) Copper (Cu) mg/L: (e^0.8545[ln(hardness)]-1.465)*0.2/1000; minim

e) Lead (Pb) mg/L: (e^1.273[ln(hardness)]-4.705)/1000; minimum is 0.

f) Nickel (Ni) mg/L: (e^0.76[(ln(hardness)]+1.06)/1000; minimum is 0.0

APPENDIX B.18A: Heritage Resource Management Plan

Heritage Resources Management Plan
for the
Casino Project

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for the
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Ecofor Consulting Ltd. (Ecofor) prepared this plan on behalf of Casino Mining Corporation.

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Ecofor is solely responsible for any errors evident in this plan.

MANAGEMENT SUMMARY

Ecofor Consulting Ltd., (Ecofor) is pleased to provide Casino Mining Corporation (CMC) with this Heritage Resources Management Plan (HRMP) to ensure the ongoing protection and management of heritage resources within their existing developments and planned work at the Casino Project. This plan presents action items and communication protocols to assist with the orderly and successful management of known heritage sites and chance finds. This document replaces the previous Interim Heritage Resources Management Plan (Mooney 2013a) and has been reviewed by the Tr'ondëk Hwëch'in and the Heritage Resources Unit of the Yukon Department of Tourism and Culture and was issued for review by the Selkirk First Nation and Little Salmon Carmacks First Nation.

For the purposes of this plan, "Heritage Sites" are those which contain historical and archaeological structures or artifacts, and does not necessarily incorporate heritage resources as defined by the Tr'ondëk Hwëch'in (Tr'ondëk Hwëch'in, 2011), as harvestable resources; migration routes, waterways, salt licks, calving area, and trapline; medicines; raw materials; place names; camps, trails and caches or traditional knowledge. However, it *does* include burial sites, sacred sites and archaeological and historic sites. These non-included "heritage resources" are incorporated into the impact assessment conducted by CMC under the Yukon Environmental and Socio-Economic Assessment Act (submitted January 2014).

The suggested action items include completion of any remaining heritage resource assessment work necessary within the proposed impact area of the Casino Mine Property, prior to construction activities. This includes the mine site proper (mine, mill, tailings storage facility, airstrip, storage areas and other ancillary facilities), the road to the Yukon River, the road to the proposed airstrip and the proposed upgrades to the Freegold Road (including all borrow pits and any associated components). Additionally, previously identified heritage sites must be revisited and reflagged prior to construction. Any proposed ground disturbance targets will require a heritage resource assessment prior to moving forward with any work. Each identified site is to be reflagged with 1 inch wide yellow flagging tape marked in black with "**No Work Zone**". Signage will be added to each site with clear wording stating "**No Disturbance Zone**". This will ensure that crews doing ground disturbing construction are able to clearly identify protected heritage resources in the area. A poster has been created and is posted at the exploration camp at the Casino Project reminding staff and consultants of the protected status of heritage resources; that known sites are marked (showing the type of flagging and signage used); and what to do in case of chance finds. This poster will be updated prior to construction and placed in all construction camps for reference. The currently identified heritage resources will have a site-by-site management review. Avoidance of all sites is suggested, however if that is not possible data recovery is recommended, depending on decisions by the Heritage Resources Unit and the affected First Nation. Lastly, it is important to identify any newly recorded sites; these sites could be discovered through chance finds or future heritage resource assessments.

During site disturbance and/or construction activities, a communications protocol will be implemented between equipment operators and the site manager to review areas of planned impacts compared to known heritage resources prior to heavy equipment use. All workers at the Casino Project will be educated on the protected status of heritage resources and instructed on what to do during each step in the management plan as part of the site orientation. Subsequently identified sites will be flagged and signed in the same manner noted above. CMC will continue to inform the Heritage Resources Unit and

relevant First Nations of heritage resources, sites identified and any impacts to heritage resources. If any sites are the subject of mitigation measures they will remain identified in the field as noted above and impacts will be avoided until directed by the Heritage Resources Unit that the mitigation measures have been completed.

In 2014 Ecofor completed a Heritage Resources Summary Report (Mooney and Dale 2014) for the entire proposed Casino Project (including the mine site, all associated roads, and ancillary developments). This report outlined the remaining areas to be assessed and heritage resources to be managed. The cumulative report is used as the basis for the action items listed throughout this HRMP.

TABLE OF CONTENTS

1.0 INTRODUCTION

This Heritage Resources Management Plan (HRMP) is designed for immediate use at the Casino Project. This includes the proposed mine site area (mine, mill, tailings storage facility, airstrip, storage areas and other associated facilities), the road to the Yukon River, the road to the proposed airstrip, the proposed extension of the Freegold Road and any other ancillary developments. The action items and communication protocols presented here are intended to be used moving forward for the entire project unless replaced by a future Heritage Resources Management Plan.

The proposed Casino Project, all proposed roads, road extensions and associated ancillary developments have been the subject of heritage resources impact assessments in 1994 (Handly et al 1994), 1988 (Gotthardt 1988), 2009 (Soucey et al 2010a), 2010 (Soucey et al 2010b), 2011 (Mooney 2011), 2012 (Mooney 2013b), 2013 (Mooney 2013c, DeGuzman et al 2014) and a data recovery excavation in 2013 (Mooney 2014). Many heritage resources have been identified and recorded across the proposed project area. The results of these efforts have been submitted to the CMC, the Heritage Resources Unit, and corresponding First Nations. As sites were found in the field they were assessed for significance and the potential impacts by proposed developments and management recommendations were presented on a site-by-site basis. Identified sites were flagged at the time of discovery; however flagging tape is not permanent and as time passes it could be destroyed weather, disturbed by wildlife or even removed by humans. Hence, further work is required at the Casino Project prior to the commencement of construction activities.

1.1 Scope of Plan

The objectives of this plan are to protect and manage heritage resources during ongoing and future exploration and/or development activities. The protection and management steps include direction to:

- Complete remaining Heritage Resource Assessments;
- Conduct a heritage resource review on any new ground disturbance impacts;
- Revisit and reflag any known sites prior to construction;
- Update and review heritage resources management poster;
- Review site by site management recommendations; and to
- Provide communication protocols to manage future ground disturbances and chance finds to avoid impacts to heritage resources.

These objectives will be met through a combination of field work and continued communication between CMC, the Heritage Resources Unit, the Selkirk First Nation, the Little Salmon/ Carmacks First Nation and the Tr’ondëk Hwëch’in.

1.2 Plan Format

Section 2 reviews relevant legislation and definitions while Section 3 presents the action items and communication protocols. Section 4 lists the references cited. Appendix I presents the Yukon Heritage Resources Policy for Heritage Resources Management on Yukon Lands. Appendix II presents the Guidelines Respecting the Discovery of Human Remains and First Nation Burial Sites in the Yukon. Appendix III contains the detailed table of remaining areas to be assessed, the archaeology sites to be managed, the historic structures and resources to be managed, and some previously noted First Nation use sites along the proposed Freegold Road upgrade. While Appendix IV contains project mapping with all current heritage resources identified.

1.3 Plan Updates

This plan will be reviewed in regards to any changes in the proposed project footprint and components and any related changes in applicable legislation. This review will be conducted through continued communication between CMC, the Heritage Resources Unit, the Selkirk First Nation, the Little Salmon/ Carmacks First Nation and the Tr’ondëk Hwëch’in.

2.0 RELEVANT LEGISLATION

Heritage resources in the Yukon are protected and managed under provisions of the Yukon First Nations Umbrella Final Agreement (UFA), Chapter 13 and the enabling legislation: the Yukon *Historic Resources Act*, and the Inuvialuit Final Agreement. An operational policy that communicates the Yukon Government's position on ownership and management of heritage resources has been prepared by Yukon Heritage Resources, and is provided in Appendix I.

Besides the *Historic Resources Act*, the HRMP was prepared with the following additional legislation in mind so that heritage resources may be protected and managed including chance finds:

- The Placer Mining Regulation (O.I.C. 2003/59) – under the *Placer Mining Act* specifically Schedule 1 Operating Conditions, Section E regarding historic objects and burial grounds;
- The Quartz Mining Regulation (YOIC 2003/64) – under the *Quartz Mining Act* specifically Schedule 1 Operating Conditions, Section E regarding historic objects and burial grounds;
- The Land Use Regulation - under the *Territorial Lands (Yukon) Act* specifically Section 9 (Prohibitions);
  Archaeological Sites Regulation (O.I.C. 2003/73) – under the *Historic Resources Act*;
- Chapter 13 (Heritage) of the Selkirk First Nation Final Agreement;
- Chapter 13 (Heritage) of the Little Salmon/ Carmacks Final Agreement; and,
- Chapter 13 (Heritage) of the Tr'ondëk Hwëch'in Final Agreement.

Additionally, this plan has been written with consideration of the best management practices outlined in the following documents:

- Tr'ondëk Hwëch'in Best Practices for Heritage Resources. Tr'ondëk Hwëch'in, March 2011.
- Yukon Mineral Exploration Best Management Practices for Heritage Resources. Yukon Tourism and Culture, April 2010.
- Handbook for the Identification of Heritage Sites and Features. Yukon Tourism and Culture, 2007.

2.1 Heritage Resources Protection and Long Term Curation of Materials Collected

Heritage resources (with the exception of heritage sites identified in First Nation Final Agreements, and ethnographic objects) on non-settlement Yukon lands are considered the property of all Yukoners and are held in trust for all Yukoners, and are managed by the Yukon Government.

Heritage resources on First Nation Settlement lands are owned and managed by the First Nation. In this case the Casino Project area (including the road to the Yukon River and the road to the proposed airstrip) does not cross over any First Nation Settlement lands. However there are sections of the proposed extension of the Freegold Road that are currently located within or near Selkirk First Nation and Little Salmon/ Carmacks First Nation Settlement lands.

Under the *Historic Resources Act* and the Archaeological Sites Regulation heritage contactors and researchers prepare permit applications which are received for review by the Yukon Government and the First Nation in whose traditional terriorty the project is proposed. If the permit is approved the contractor or researcher conducts the fieldwork and prepares required written reports as well as artifacts and materials collected in the field for long-term record keeping and artifact curation. This includes preparing artifact catalogs, labeling artifacts, packaging and preparing artifacts to meet specific long term curation goals as needed, as well as additional project documentation such as photos, GPS tracks and waypoints. In order to ensure proper completion of permit requirements, heritage contractors submit interim and final reports as well as collected materials to the Yukon Heritage Resources for review. After the permit reporting and artifact curation preparation requirements are met, the Heritage Resources Unit submits materials to appropriate First Nations as requested for further management or continued to hold the materials at the direction of the First Nations.

2.2 Resource Definitions

The UFA does provide definitions of heritage resources but it does not distinguish all the types of resources. Part 6 of the *Historic Resources Act* does provide other definitions. Presented below are specific definitions from the UFA, the *Histroic Resources Act*, as well as general definitions used in the common practice of heritage resource impact assessments.

Umbrella Final Agreement Definitions:

"*Heritage Resources*" includes Moveable Heritage Resources, Heritage Sites and Documentary Heritage Resources.

"*Heritage Site*" means an area of land which contains Moveable Heritage Resources, or which is of value for aesthetic or cultural reasons.

"*Documentary Heritage Resources*" means Public Records or Non-Public Records, regardless of physical form or characteristics, memoranda, books, plans, maps, drawings, diagrams, pictoral or graphic works, photographs, films, microforms, sound recordings, videotapes, machine-readable records, and any copy thereof.

***Histroic Resources Act* Definitions:**

"*Archaeological object*" means an object that

a) Is the product of human art, workmanship, or use, and it includes plant and animal remains that have been modified by or deposited in consequence of human activities,
b) Is of value for its archaeological significance, and
c) Is or has been discovered on or beneath land in the Yukon or is or has been submerged or partially submerged beneath the surface of any watercourse or permanent body of water in the Yukon.

"*Ethnographic objects*" means an item of material culture relating to the history and traditional culture of an ethnic group.

"*Historic object*"

a) An archaeological object that has been abandoned,
b) A paleontological object that has been abandoned,

c) An abandoned object that is designated under section (2) as a historic object.

"Human remains" means non-fossilized remains of human bodies that have historic significance and are found outside a recognized cemetery or burial site.

"*Paleontological object*" does not include human remains but does refer to the remains or a fossil or other object that indicates the existence of extinct or prehistoric plants or animals and that

a) Is of value for its historic paleontological significance, and
b) Is or has been discovered on or beneath land in the Yukon, or is or has been submerged or partially submerged beneath the surface of any watercourse or permanent body of water in the Yukon.

Heritage Resource Management Common Definitions:

Historic Sites contain heritage resources that are greater than 45 years in age and possess significant heritage value. By convention, historic sites date to the period for which written records are available; in this case, the historic period commences with the arrival of the Hudson's Bay Company in the early-mid 19th century. Historic sites may include cabins, caches, camps, brush camps, and any other man-made structures, features or objects that date between about 1970 and 1830.

Archaeological or Prehistoric Sites generally represent use before European contact and are found on or under the ground surface, and may consist of the remains of ancient camps, including hearths, animal bone and stone tools and debris. In this usage, an Archaeological Site equates to a Prehistoric Site (a site that dates to the period before written history). Note, however, that in heritage resource management usage, archaeological resources are viewed as resources that are in subsurface context (buried) and may also include historic period objects and features.

Proto-historic Sites can be viewed as prehistoric sites from a time period which includes the effects of foreign historic cultures but lacks the first hand written descriptions of that area. For example, in the Yukon the proto-historic period ends with the appearance of first hand written descriptions in the mid-1800s. However the proto-historic time period extends back through time when foreign materials such as "drift-iron" from ship wrecks on the west coast, or foreign trade items were carried into the Yukon. Examples of foreign historic materials which predate the mid-1800s found in prehistoric contexts usually represent this proto-historic period.

Palaeontological Resources include the fossilized, mummified, or skeletal remains of previous life forms. These resources may be found in sedimentary rock formations, or eroding streams and creeks and contain a great deal of information concerning past environments. The most common of these resources include the skeletal remains of ice age mammals which are often associated with dark humic deposits. These remains may date from approximately ten of thousands to many hundreds of thousands of years before present.

3.0 HERITAGE RESOURCES MANAGEMENT PLAN TASKS

The HRMP action items and communication protocols presented below incorporate communications between CMC, the Heritage Resources Unit, and the First Nations. Site flagging and communication protocols are intended to be carried forward through continued exploration, geotechnical drilling, and throughout construction development of the Casino Project.

3.1 Action Items

Action Item 1: Complete Remaining Heritage Resource Assessment

Heritage resources assessment that remains to be completed for the Casino project was identified in the heritage summary report conducted by Ecofor in 2014 (Mooney and Dale 2014). Areas requiring further assessment consist of seventeen (17) proposed borrow pits and approximately 7.45 km of right of way (ROW) between the Klondike Highway and km 33+000, as well as access roads to borrow pits, and any future additions of borrow pits or other ancillary components, or road re-alignments. Appendix III includes a detailed table of all remaining areas to be assessed.

Throughout the project area there are numerous proposed borrow pits. Some proposed borrow pits are directly adjacent to the proposed ROW and do not require a separate access road to move borrow materials to the construction ROW. Other proposed borrow pits are not adjacent to the ROW, and will require access roads between the borrow pit and the ROW. No access roads for borrow pits have been specifically assessed (only in a few cases have approximate location of access roads been assessed). Each of the proposed borrow pits, that require an access road, will have to have their respective access road assessed.

Ecofor recommends that these locations be assessed once detailed design of the access road is completed, prior to construction activities.

Action Item 2: Heritage Resources Impact Assessment of Any New Proposed Ground Disturbing Activities

As the Casino Project design progresses, further revisions or ancillary components may be included. It is recommended that any areas of potential ground disturbance not previously assessed be reviewed and assessed in the field by a team of archaeologists prior to the commencement of construction activities. If any of the proposed locations are evaluated in the field to contain heritage resources, heritage staff will record, flag, and sign the resources as noted below in action item 3.

Action Item 3: Revisit and Reflag all Heritage Resource Sites Prior to Construction

There have been a number of archaeological assessments conducted within the proposed Casino Project area, including roads and ancillary developments. During the course of these assessments a number of historic and prehistoric sites have been discovered, recorded and identified in the field. Identification consists of affixing a 1 inch wide yellow flagging tape with black printing that states "**No Work Zone**" to a tree, shrub or rock at the centre of the site which includes written on it the field identification number, the date and a contact number (sites discovered by Altamira used white and blue flagging tape). Then a buffer area of 30 m around the known historic or prehistoric site was flagged with the same flagging tape. In addition, previous sites uncovered within the proposed mine site area, the road to the barge and the road to the airstrip were additionally marked with “No Disturbance Zone” signage. Site flagging and signage should not be removed or disturbed.

Revisiting these sites in order to reflag them is necessary prior to construction as flagging tape is not permanent and as time passes it could be destroyed by weather, disturbed by wildlife or removed by humans. Appendix III includes a full list of all sites that require revisiting and reflagging and their relation to the currently proposed project area.

Action Item 4: Update Heritage Resource Warning & Information Poster

Ecofor and CMC prepared a heritage resource warning and information poster in 2013. It was placed in a prominent location at the Casino Camp and displays the following:

- a reminder of the protected status of heritage resources;
- how the sites are marked in the field;
- general location of heritage sites in the Casino area;
- what to do prior to ground disturbance activities; and,
- what to do in case of a chance finds discovery.

Ecofor will review the information on this poster with CMC staff and the site managers. Site managers will review this poster and the Heritage Resource Management Plan with all current and future staff/visitors to Casino. The poster will be reviewed and updated prior to construction and placed in a public location in the main camp and any subsidiary camp locations that could be used during development. The information in the Heritage Resource Management Plan will be communicated to all workers at the Casino Project in the site orientation.

Action Item 5: Site by Site Management Efforts

Impacts to recorded historic and prehistoric resources will be avoided were possible, or mitigation efforts will be completed prior to construction impacts. Mitigation efforts may include: construction monitoring to ensure sites agreed to be avoided are not impacted; systematic data recovery excavations of sites agreed to be impacted; and construction monitoring of areas of concern. Site by site recommendations were presented in full detail within the Casino Heritage Summary Report conducted by Ecofor in 2014 (Mooney and Dale 2014). There are currently 97 heritage resource sites and 10 previously noted First Nation use sites to be managed within the currently proposed Casino Project area. Appendix III contains the detailed table of the archaeology sites to be managed, the historic structures and resources to be managed, and some previously noted First Nation use sites along the proposed Freegold Road upgrade. Appendix IV contains project mapping with all current heritage resources identified.

Action Item 6: Identification of Any Newly Recorded Heritage Sites

All heritage sites subsequently discovered and recorded at the Casino Project (including the mine site, all roads, borrow pits, airstrip, barge landing and any ancillary developments) will be identified and assessed prior to possible construction impacts as per action item 2. All heritage sites recorded in relation to the Casino Project will be subjected to this HRMP or any subsequent plans.

3.2 Communication Protocols

Communication Protocol 1: Ground Disturbing Activities

Prior to any new ground disturbance activities the site manager will review the location of the planned disturbance against previously recorded heritage site locations. If any sites have been recorded in or near the planned ground disturbance location the site manager will review the location of the heritage sites with the equipment operators in the field, on foot, and will provide directions to avoid impacts to the identified sites with a 30 m buffer area, in consultation with project engineers to ensure the avoidance route meets the specifications required for the relevant construction activity.

Communication Protocol 2: Chance Finds Procedures

It is possible that heritage resources as noted above may be accidentally discovered during further exploration efforts, baseline environmental efforts, and ground disturbing activities. These resources may range in size from small flakes and chips of lithic debitage remaining from stone tool manufacturing, up to large historic structures such as cabins. Other possible heritage resources include culturally modified trees, fire cracked rock, historic adits, cache pits, house pits, paleontological remains, isolated prehistoric tools of wood, bone or antler, and isolated historic debris (cans, bottles, etc.).

In the event of accidental discovery of heritage resources, all work in the immediate area will cease. The resources will be left in place, recorded (see below), and the area of the find will be protected from further impacts with a minimum 30m buffer. The site manager will be notified of the type, amount, and location of the find. Information collected and passed on regarding the chance find will include:

- GPS location of the find;
- Date and time when the find was identified;
- Approximate size of find and type of materials present;
- Description of setting and access to the location of the find; and
- Digital photographs of the find(s) and general area of the find.

The site manager will then contact the Heritage Resources Unit to discuss further management options and notify the appropriate First Nation contacts. If the area can be protected and immediate salvage operations are not required then a resource specific or site specific mitigation plan may be developed to recover data and information under direction of the Heritage Resources Unit and the appropriate First Nation(s).

If the remains include paleontological remains then the Yukon Paleontologist will also be contacted.

If human remains are identified during operations, all work in the area will immediately cease and further impacts to the area will be prevented, and the R.C.M.P will be notified. If the R.C.M.P. and Coroner determine that the remains are from a historic burial, the First Nation(s) and Yukon Heritage Resources Unit will be notified, as per the Guidelines Respecting the Discovery of Human Remains and First Nation Burial Sites in the Yukon (Appendix II).

As part of the ongoing and continuing efforts to increase awareness of the possible heritage resources that may be found in the area, and those that have been recorded, CMC will leave multiple copies of the booklet entitled *Handbook for the Identification of Heritage Sites and Features* (Gotthardt and Thomas 2005) at the Casino Camp to be shared with management, workers and visitors.

Heritage Resources Contact Information

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Communication Protocol 3: Planned Impact to Known Sites

Where planned project development may impact a heritage site, approval to proceed must be obtained in advance from Heritage Resources Unit and affected First Nations. If these sites are planned to be impacted then approval for impact must be granted by the Heritage Resources Unit. Typically, impacted sites will be require a data recovery mitigation plan and fieldwork efforts. In the case of prehistoric archaeological sites, detailed 1 x 1 m block excavation of a significant sample of square meters of the site is often used to collect and record information from the site prior to site impact. In the case of historic resources more detailed photographic, ethnographic, informant, and archival research may also be used to document a resource before it is impacted.

Each heritage resource at the Casino Project will be flagged for avoidance as noted above. If any sites have received systematic data recovery excavations and/or other mitigation efforts these efforts and results must be reviewed by the Heritage Resources Unit and affected First Nations prior to final approval for the site to be impacted. Until such approval, each site area will remained flagged to avoid additional impacts. Only after approval for impact has been granted may the site be impacted. Sites located on non-settlement lands are managed by the Yukon Government, while sites located on settlement lands are managed by First Nations. The Casino Project area does not include any First Nation settlement lands, however; the proposed extension of the Freegold Road does currently pass through settlement lands.

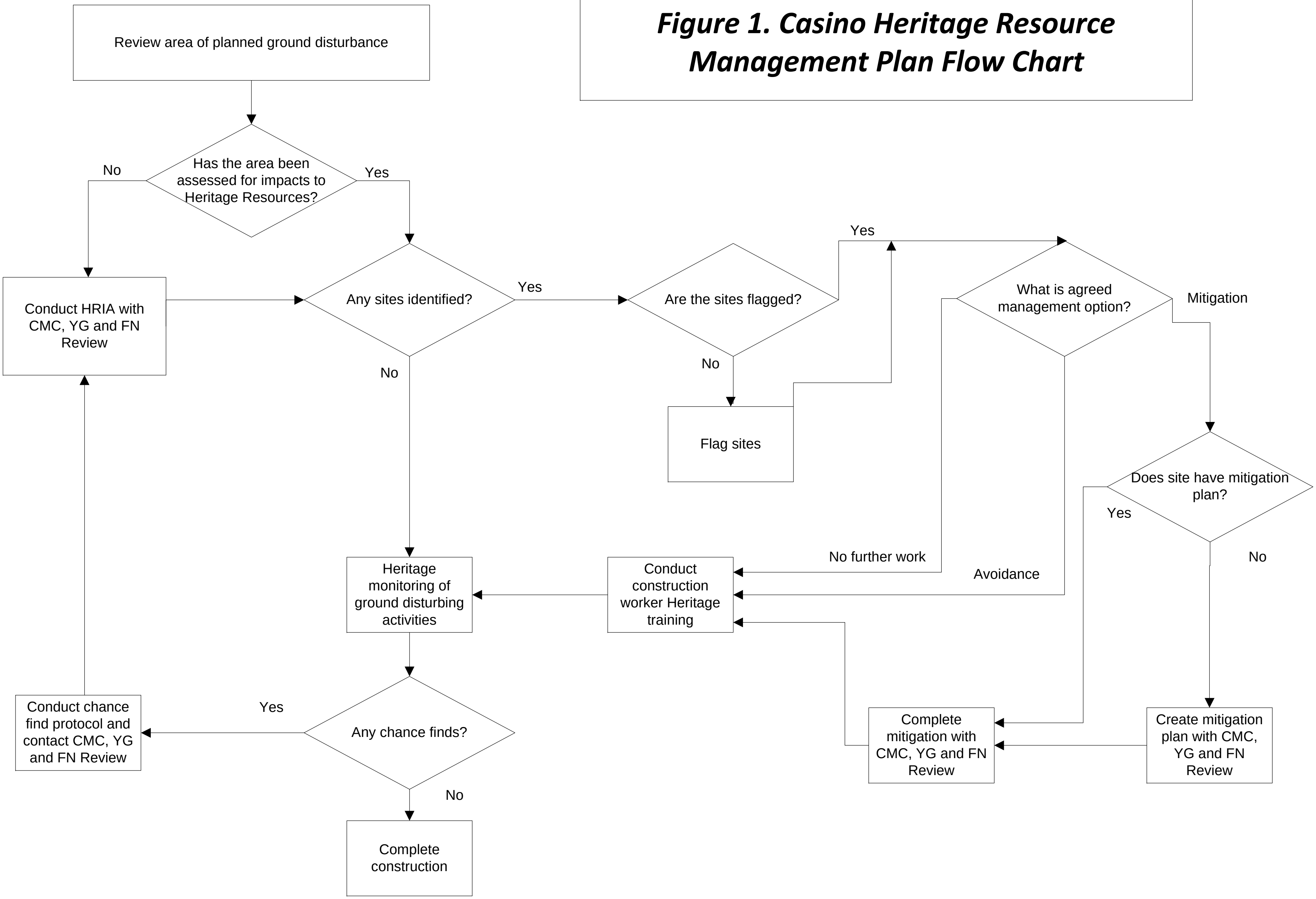
Some site management recommendations may include construction monitoring after mitigation efforts have been approved.

Communication Protocol 4: Continued Communication with First Nations and the Heritage Resources Unit

It is important that communications regarding newly recorded heritage sites and resources, or impacts to heritage sites or resources be passed along in a timely manner to the Heritage Resources Unit and affected First Nations. All results from the heritage assessments and mitigation efforts must be shared in a timely manner with the Heritage Resources Unit and the affected First Nations.

Figure 1 below, is a generalized flow chart for the Casino Heritage Resource Management Plan which is based on the six action items and four communication protocols.

Figure 1. Casino Heritage Resource Management Plan Flow Chart



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APPENDIX I: HERITAGE RESOURCE MANAGEMENT ON YUKON LANDS

Operational Policy for Heritage Resources Management on Yukon Lands

This document has been developed to communicate the Yukon Government's position on ownership and management of heritage resources in the context of the development assessment and review process in the Yukon. The Operational Policy for Heritage Resources Management is based in the provisions of the Yukon First Nations Umbrella Final Agreement (UFA), Chapter 13 and the enabling legislation: the Yukon *Historic Resources Act,* and the Inuvialuit Final Agreement. In the implementation of the legislation, Yukon Government is acting to protect and manage heritage resources on behalf of all Yukoners.

Ownership and Management Authority – Moveable Heritage Resources
Yukon Government is identified as the responsible authority for heritage resource management on non-settlement (Yukon) lands based on the specific provisions concerning ownership of moveable heritage resources in the UFA, Chapter 13 (13.3.3):

- Government owns all moveable and documentary heritage resources that are not "ethnographic resources directly related to culture and history of Yukon First Nation people".

Significant management direction is provided by the UFA in the use of the term '**moveable**' in connection with heritage resources. Anticipating the requirement to manage heritage resources in future land developments and activities, the option to move heritage resources with the objective of protection is fundamental in the UFA Chapter 13.

Ownership and Management - Heritage Sites
UFA 13.8.1 Ownership and management of Heritage Sites in a Yukon First Nation's Traditional Territory shall be addressed in that Yukon First Nation Final Agreement. Examples of heritage sites that have been identified in First Nation Final Agreements: Fort Selkirk, Forty Mile, Rampart House, Lansing Post, Tagish Post, Canyon City, Lapierre House, Tr'ochëk.

With the exception of heritage sites set out in FNFA as per 13.8.1, heritage sites and non-moveable heritage resources (structures/built heritage) are governed by Laws of General Application (*Historic Resources Act*). Ownership vests in Yukon Government.

Designation of Heritage Sites under the *Historic Resources Act* ensures sites are protected from activity or development impacts. Sites or areas of historical significance in theYukon, beyond those listed in FNFA, may also be nominated for designation under the HRA. The nominations are reviewed by the Yukon Heritage Resources Board, who then recommends to the Minister that a site be designated as a Yukon Historic Site.

Heritage Resources – Definitions
The UFA Chapter 13 does not provide definitions of heritage resources, but makes the distinction among types of heritage resources as follows (13.3.6.): ethnographic objects directly related to the culture and history of Yukon Indian People, palaeontological objects, and archaeological objects. Definitions for these terms are provided in *Historic Resources Act* (Part 6 Historic Objects and Human Remains – Definitions). Generally, palaeontological objects are the fossil remains of ancient plants and animals; archaeological objects are abandoned objects that are older than 45 years. For operational purposes, "**moveable ethnographic objects directly related to the culture and history of Yukon Indian People**" (UFA 13.3.2) are objects that were

known to have been owned or used by First Nations individuals or families within living memory[1]. 'Direct' indicates the line of ownership for the object is unbroken or can be reconstructed. As per UFA 13.3.5 – if an object cannot readily be determined to be ethnographic, it is held in custody by Yukon Government until its nature has been determined.

Protection of Heritage Resources
Accidental discovery of heritage resources (UFA 13.8.7) – heritage resources discovered during construction or excavation are protected under Laws of General Application (*Historic Resources Act, Mining Land Use Regulations; Land Use Regulations*). The *Historic Resources Act* (64) prohibits destruction or alteration of a heritage resource except in accordance with a historic resources permit.

Report of Findings

Historic Resources Act Part 6 Report of Findings:

71(1) Every person who finds an object that is or that likely is a historic object, or remains that are or that likely are human remains, shall immediately report the find to the Minister.

(2) If the object is found on settlement land the finder shall also report the find to the Yukon first Nation which governs the settlement land.

Quartz and Placer Mining Land Use Regulations – E Historic objects and burial grounds

> **9 .** Any sites containing archaeological objects, palaeontological objects or human remains or burial sites discovered in the course of carrying out an operation must be immediately marked and protected from further disturbance and, as soon as practicable, the discovery reported to the Chief (of Mining Land Use).

In respect of UFA 13.4.8, 13.7.1, Yukon Government provides to First Nations archaeological, palaeontological and historic site inventories and research reports on heritage resources found in their traditional territories.

First Nation Burial Sites
Procedures to manage and protect First Nation burial sites have been established by the Yukon Government and Yukon First Nations: "Guidelines Respecting the Discovery of Human Remains and First Nation Burial Sites in the Yukon". http://www.tc.gov.yk.ca/pdf/respecting_guidelines.pdf . General provisions include:

- Restrict access to preserve dignity of the site
- Newly discovered sites/accidental discovery
  - RCMP/Chief Coroner to be informed
  - If determined to be a First Nation burial, First Nation to be informed
  - general rule no further disturbance

Heritage Resource Assessment and Permits
Standard archaeological impact assessment and mitigation procedures are followed to guide heritage resources assessment in the Yukon. The Government of British Columbia Archaeological Impact Assessment Guidelines are the recommended guideline for Yukon and are comparable to standards used in other Canadian jurisdictions: http://www.tsa.gov.bc.ca/archaeology/docs/impact_assessment_guidelines/in dex.htm

Heritage assessments ideally are undertaken in cooperation with affected First Nations. Archaeological consultants are required to communicate with affected First Nations prior to undertaking field research. A First Nation may choose not to provide oral history or traditional knowledge input to the consultant, however. In such cases, the First Nations may keep confidential information on traditional use areas, subsistence resources and

[1] Ethnographic objects of themselves may not be informative of ownership. Many historic objects (for example, guns, axes, knives) were used equally by all Yukoners and attribution of ownership (for example to Nacho Nyak Dun vs. Selkirk First Nation vs. a non-First Nation trapper) cannot be made without direct knowledge of who made or used the object or in whose former camp the object was found. Therefore knowledge or memory of historic use is critical in determining if the objects are ethnographic.

cultural values and work independently with the Yukon Environmental and Socio-Economic Review board to ensure concerns with these values are addressed for a particular project.

Under the *Yukon Environmental and Socio-Economic Assessment Act*, heritage resource assessment is generally required for all activities that will impact or will potentially impact heritage resources. All heritage resource assessments are required to be carried out under permit:

Historic Resources Act

> **62** No person shall search or excavate for historic objects or human remains except in accordance with a historic resources permit. *S.Y. 1991, c.8, s.61.*

Archaeological Sites Regulation

> **3.** No person shall survey and document the characteristics of an archaeological site without a Class 1 or Class 2 permit.
>
> **4.** No person shall excavate, alter, or otherwise disturb an archaeological site, or remove an archaeological object from an archaeological site, without a Class 2 permit.

APPENDIX II: HUMAN REMAINS GUIDELINES

Guidelines Respecting the Discovery of Human Remains and First Nation Burial Sites in the Yukon

With approvals as of August 1999

This document was prepared pursuant to provisions of
Yukon First Nation Final Agreements
and the Yukon Transboundary Agreement with the Gwich'in Tribal Council

Yukon
Tourism
Heritage Branch

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Introduction and Background

The treatment of every burial site requires respect. Legislation of various types protects burial sites and cemeteries from being disturbed. Government agencies and First Nations keep and consult records of known sites so that land use plans or proposals can avoid such sites.

There are many historic and First Nation graves in the Yukon however which are no longer marked and which may be disturbed accidentally through land use or development. Other sites may be disturbed by natural forces, such as erosion, leading to the exposure of human remains.

As more people travel in backcountry areas, for work or pleasure, it is expected that the number of such discoveries may increase. It is important therefore to have guidelines for reporting, investigating and managing such sites in a coordinated and effective manner, to give them proper respect.

Yukon First Nation (YFN) Final Agreements (Section 13.9.0) and the transboundary agreement with the Gwich'in Tribal Council (Tetlit Gwich'in) (Section 9.5) require the development of procedures to protect and manage YFN or TG burial sites, and specify certain actions when such sites are discovered.

Consistent with these obligations, these guidelines were developed at two workshops held jointly in March and October l998, involving First Nation Elders, heritage and implementation staff, the RCMP, Coroner and other Yukon and federal government officials.

Purpose

To provide direction on the reporting, identification, treatment and disposition of human remains found outside of recognized cemeteries in the Yukon, to ensure these remains are respected and protected consistent with legislation and Yukon land claims agreements.

Scope and Application

These guidelines apply to anyone who discovers human remains or grave goods outside of recognized cemeteries in the Yukon, and to the Yukon, Federal and First Nation government officials involved in protecting and caring for such sites.

The guidelines reflect existing practices in many ways. They do not replace legislation or regulations protecting burial sites, but are intended to integrate obligations contained in Yukon land claim agreements with land use permitting regimes and the Development Assessment Process . These guidelines may apply on Settlement Lands at the discretion of each First Nation. Government approval is required for management plans for sites on non-Settlement Land.

Existing known burial sites that are marked or otherwise recorded are protected by existing legislation. Management plans for these sites may be developed on a case by case basis.

Burial sites discovered within the boundaries of a designated heritage site may be subject to the management plan for that site.

The guidelines do not apply within National Historic Sites or National Parks. Parks Canada has its own guidelines respecting burial sites and human remains.

Evaluation and Revision of Guidelines

The implementation of these guidelines will be evaluated as necessary to ensure that they are fulfilling their purpose.

GUIDING PRINCIPLES

All human remains, and items found at graves (grave offerings, markers etc.) shall be treated with respect and dignity regardless of their cultural affiliation.

Actions taken following the discovery of sites will be consistent with Yukon and transboundary land claim agreement provisions respecting Yukon First Nation and Tetlit Gwich'in Burial Sites.

Each discovery will be handled on a case by case basis in consultation with the affected parties, in a coordinated and timely manner.

Definitions - see Appendix 1
References - see Appendix 2
Land claims provisions - see Appendix 3

Guidelines Respecting the Discovery of Human Remains and First Nation Burial Sites

See also Figure 1.

These guidelines cover five steps: discovery and notification; site protection and investigation; investigation and reporting; and site disposition or management agreements. A final step, arbitration, is provided for where no disposition agreement is reached.

1. Discovery and Notification

If human burial remains are accidentally discovered the following guidelines apply:

a) The finder will immediately cease any further activity at the site and report the site to the RCMP.

b) *If the finder is operating under a land use licence or permit*, the site must also be reported immediately to the land manager/permitting authority, as set out on the permit. The land manager/permitting authority shall confirm that the site is reported to the RCMP.

c) Based on the information it receives, the RCMP will notify: 1) the Coroner's office if the site is of a forensic or criminal nature; or 2) both the First Nation(s) in whose Traditional Territory the Site is located and the Heritage Branch, if the site is a suspected historic or First Nation burial site.

2. Site Protection and Identification

a) the land manager/permitting authority shall take reasonable measures to protect the site from environmental factors and any form of unauthorized interference or disturbance.

b) based on the evidence reported at the scene, the RCMP/Coroner will investigate the site and make a preliminary determination as to the nature of the remains.

c) *if the site is of a criminal or forensic nature* (potential crime scene or missing person), then the Coroner's office and police will assume authority over the site/remains.

d) Heritage Branch may recommend that an archaeologist assist police or coroner in the preliminary assessment of the site.

e) *If the site is **not** of police/coroner interest* then the Director, Heritage Branch, the affected First Nation(s) and the land manager will assume interim responsibility for protection and investigation of the site. If it's a suspected First Nation site, the Heritage Branch and First Nation would assume this responsibility.

f) the Director, Heritage Branch, the affected First Nation(s) and land manager shall take reasonable measures to restrict access and ensure that the human remains and any grave offerings are not further disturbed pending the investigation and identification of the remains. The RCMP may be consulted about protecting the site.

Figure 1

Guidelines respecting the Discovery of Human Remains and First Nation* Burial Sites

2. Site Protection and Investigation
-protection/no disturbance or access

If not a criminal matter, Heritage Branch takes lead with affected FN or transboundary group. RCMP may assist if requested.

- *First Nation, Minister*
- *permitting authority - person may continue activity with FN consent. If consent is not provided, proceed according to terms and conditions of arbitrator(UFA 26.7.0 TG Ch.18)*

or

- *rebury, relocate or remove remains*
- *restrict/specify access if necessary and possible*
- *may designate existing or new site as burial site/cemetery or heritage site*
- *management plan (jointly prepared/approved by FN and Government on Non-Settlement Lands)*

Maps, inventories, reports, plans, agreements.

**the Tetlit Gwich'in will be involved in steps to protect and manage Tetlit Gwich'in burial sites discovered within their Primary Use Area (Fort McPherson Group Trapping area within the Peel River Basin).*

g) Where human remains are at risk of being destroyed or damaged, the Minister of Tourism for Heritage may issue a stop work order prohibiting any further activities and may make an agreement with the First Nation or the Tetlit Gwich'in or land owner or user for any investigation, excavation, examination and preservation and removal of the remains, consistent with land claim provisions. (s.*72, Historic Resources Act- This would address concerns about unknown remains.)*

Existing site inventories, land use records, affected First Nations and community elders, and military authorities, should be consulted as soon as possible about possible identification of the remains.

Some examination of the site/remains may be required to determine its cultural affiliation and age, and whether or not the site is modern or historic.

3. Investigation and Reporting

a) The Heritage Branch/land manager will direct an archaeologist or qualified examiner to carry out an investigation under any required permits, in consultation with the affected First Nation and other affected parties, to make an initial report citing, if possible*, the cultural affiliation of the human remains.

b) Within a reasonable time to be specified by the Minister, and the affected First Nation(s), the archaeologist or qualified examiner shall deliver a written report and any notification not yet made, to:

- the Minister, and the affected First Nation(s) if appropriate;
- the Director of the Heritage Branch;
- the land manager/permitting authority;
- any other representative of the interred, if known.

c) The written report shall attempt *to identify:

- the representative group of the interred;
- the geographic boundaries of the site;
- the grave offerings or other heritage resources that may be associated with the remains or the site.

d) The archaeologist or examiner may, with the agreement of the proper authority and the representative of the interred, if known, remove all or part of the human remains for further analysis or for temporary custody where the remains may otherwise be at risk.

e) Any exhumation, examination and reburial of human remains from a YFN/TG burial site shall be at the discretion of the affected YFN/TG; and if ordered by an arbitrator pursuant to land claim provisions, will be done or supervised by the YFN or Tetlit Gwich'in.

*it is often difficult to determine the cultural ancestry or affiliation of fragmentary human remains

3.1 Reporting

a) If the site is determined to be a Yukon First Nation Burial Site, or Tetlit Gwich'in burial site, the appropriate representative will be contacted in writing to provide further direction on the disposition of the remains. *

b) A person carrying out Government or First Nation authorized activity where a First Nation site is discovered can continue that activity with the consent of the First Nation in whose Traditional Territory the Yukon site is located. The consent of the Tetlit Gwich'in is required if the site is in the Tetlit Gwich'in primary use area. If consent is denied, the person can seek terms and conditions from an arbitrator about continuing the activity (see Section 5).

c) If after the final report, the human remains are found to be those of a different aboriginal people than those mentioned previously, the proper authority of that group shall be notified in order that they may assume the role of the representative.

d) Where a site is **not** found to be a Yukon First Nation or Tetlit Gwich'in burial site, or a military or mariner's burial site, the Director, Heritage Branch may publish notice of the discovery in a newspaper or other public notice seeking information on the remains.

4. Site Disposition Agreement (Management Plan)

4.1 When the site or remains are identified

a) The site shall not be disturbed and the Director, Heritage Branch or First Nation if on Settlement Land, shall initiate discussions towards entering into a site disposition agreement with the representative of the interred.

b) If the site is a Yukon First Nation Burial Site or a Tetlit Gwich'in burial site on non-settlement land, there must be joint approval of the site management plan by the Yukon First Nation in whose Traditional Territory the site is located and the Government. If the site is a Tetlit Gwich'in burial site located off Tetlit Gwich'in land but in the primary use area, the management plan must be jointly approved by the Tetlit Gwich'in and the Government.

c) Decisions regarding reburial, relocation or other disposition should be determined on a case by case basis in consultation with those concerned and in a timely manner.

Site disposition agreements shall determine such things as:

1. the interim care of the human remains*;*

2. the scope and extent of analysis to be performed on the human remains, if any;
3. the exact location of the place where the human remains are to remain or to be interred;
4. the style and manner of disinterment, if applicable;
5. the style and manner of reinterment, if applicable;
6. the time period in which disinterment and reinterment is to take place;
7. the procedures relating to, and the final disposition of any grave offerings discovered with the human remains and any additional analysis of them;
8. the provision for future maintenance of the cemetery or site where the human remains are to be located;
9. access to the site and ways to prevent disturbance;
10. any other issue agreed upon.

*it is often difficult to determine the cultural ancestry or affiliation of fragmentary human remains

4.2 When no representative is identified or no disposition is specified:

If disposition is not specified by a representative, or the remains are not claimed or no affiliation is established within a reasonable time, the Minister, or First Nation if on Settlement Land, shall with the necessary permits and approvals provide for the following disposition:

a) cover and leave the remains where they were found and have the site recorded as a burial site/ heritage site, if on land suitable for a burial site; or
b) have the remains disinterred and reinterred in the nearest appropriate cemetery; or
c) remove the remains from the site for analysis and may have them reinterred in a recognized cemetery or;
d) may act as the temporary repository of the remains.

(Where the remains were found on Settlement Land but are not considered First Nations remains, the Government may remove the remains in consultation with the First Nation.)

5. Arbitration

a) If no disposition agreement or management plan is reached within a reasonable time the matter may be referred to arbitration for settlement. If this matter concerns a Yukon First Nation Burial Site, this shall be done pursuant to 26.7.0 of the UFA; or Chapter 18, if the matter concerns a Tetlit Gwich'in site in the primary use area.

6. Records

a) A record of the site and a report of the discovery and disposition plan shall by kept by the Government and the affected First Nation(s)/representative for future reference to protect the site.

b) Access to information about discovered sites will be addressed in any site management plan developed under these guidelines, and will be protected under the *Access to Information and Protection of Privacy Act*, and the *Historic Resources Act* or *any similar First Nations legislation.*

Appendix 1

Definitions

burial site

the location of any human grave or remains that have been interred, cremated or otherwise placed, and include ossuaries, single burials, multiple burials; rock cairns; cave or cache burials etc. not situated within a cemetery

First Nation Burial Site

This refers to a Yukon First Nation Burial Site or a Tetlit Gwich'in burial site, which is defined as: a place outside a recognized cemetery where the remains of a cultural ancestor of a Yukon Indian Person (or the Tetlit Gwich'in) have been interred, cremated or otherwise placed."

[from the Definitions section of the *Umbrella Final Agreement for the Council for Yukon Indians (now Council of Yukon First Nations) and the Transboundary Agreement between Canada and the Gwich'in Tribal Council*]

human remains

mean the remains of a dead human body and include partial skeletons, bones, cremated remains and complete human bodies that are found outside a recognized cemetery" *(adapted from Historic Resources Act)*

grave offering

any object or objects associated with the human remains which may reflect the religious practices, customs or belief system of the interred.

historic

under the Historic Resources Act this generally means something older than 45 years.

land manager

Agency responsible for the administration of the land on which the site is located. For example, currently territorial parks are managed by Yukon Parks and Outdoor Recreation; gravel pits and rural airports are administered by Community and Transportation Services. Settlement Land is administered by the First Nation. Private land is administered by the land owner. (Burial sites may not be disturbed on any land without proper authorization.)

Recognized cemetery

a defined area of land that is set aside for the burial of human bodies.

representative

means a descendant of the interred or of the person whose remains are found, or where no descendant survives or is identified, an official representative of the appropriate First Nation in whose Traditional Territory the burial site is located or the closest culturally affiliated group, religious denomination, military or marine authority as evidenced by the location or mode of burial.

Where no representative can be determined the Minister shall act as the representative on Non-Settlement Lands and on Settlement Lands at the discretion and with the consent of the First Nation

representative group

means the appropriate Yukon First Nation or the closest culturally affiliated group, religious denomination, military or marine authority as evidenced by mode and style of burial which is willing to act as a representative.

Site disposition agreement

means a written agreement to be reached between the Director of the Heritage Branch and the representative of the interred regarding the disposition of the remains, including any disinterment and reinterment, and management plan

Management plan

means a plan to identify the roles of the representative, Government and land owner or manager respecting the care and protection of the site, including a consideration of site records, site access, and ways to protect a site from disturbance.

Appendix 2

References

The following include requirements to protect burial sites and were considered in the development of these Guidelines.

Umbrella and Yukon First Nation Final Agreements, Sections 13.9.0 and 26.7.0, and Implementation Plans
Yukon Transboundary Agreement (Gwich'in Tribal Council), Sections 9 and 18, and Implementation Plan
Yukon Historic Resources Act, Part 6
Criminal Code
Cemeteries and Burial Sites Act
Coroner's Act
Territorial Land Use Regulations
Yukon Archaeological Sites Regulations
Yukon Quartz Mining Act, and Regulations
Yukon Placer Mining Act, and Regulations
Yukon Surface Rights Act
Vital Statistics Act

Appendix 3

Land Claims Provisions Relating to Burial Sites

13.9.0 Yukon First Nation Burial Sites*

13.9.1 Government and Yukon First Nations shall each establish procedures to manage and protect Yukon First Nation Burial Sites which shall:

13.9.1.1 restrict access to Yukon First Nation Burial Sites to preserve the dignity of the Yukon First Nation Burial Sites;

13.9.1.2 where the Yukon First Nation Burial Site is on Non-Settlement Land, require the joint approval of Government and the Yukon First Nation in whose Traditional Territory the Yukon First Nation Burial Site is located for any management plans for the Yukon First Nation Burial Site; and

13.9.1.3 provide that, subject to 13.9.2, where a Yukon First Nation Burial Site is discovered, the Yukon First Nation in whose Traditional Territory the Yukon First Nation Burial Site is located shall be informed, and the Yukon First Nation Burial Site shall not be further disturbed.

13.9.2 Where a Person discovers a Yukon First Nation Burial Site in the course of carrying on an activity authorized by Government or a Yukon First Nation, as the case may be, that Person may carry on the activity with the agreement of the Yukon First Nation in whose Traditional Territory the Yukon First Nation Burial Site is located.

13.9.3 In the absence of agreement under 13.9.2, the Person may refer the dispute to arbitration under 26.7.0 for a determination of the terms and conditions upon which the Yukon First Nation Burial Site may be further disturbed.

13.9.4 Any exhumation, examination, and reburial of human remains from a Yukon First Nation Burial Site ordered by an arbitrator under 13.9.3 shall be done by, or under the supervision of, that Yukon First Nation.

13.9.5 Except as provided in 13.9.2 to 13.9.4, any exhumation, scientific examination and reburial of remains from Yukon First Nation Burial Sites shall be at the discretion of the affected Yukon First Nation.

13.9.6 The management of burial sites of a transboundary claimant group in the Yukon shall be addressed in that Transboundary Agreement.

*This is an excerpt from the Umbrella Final Agreement between Canada, the Council for Yukon Indians and the Government of the Yukon (l993),Ch. 13, pp. 128-129, and subsequent Yukon First Nation Final Agreements.

9.5. Tetlit Gwich'in Burial Sites*

9.5.1 Government and Tetlit Gwich'in shall each establish procedures to manage and protect Tetlit Gwich'in burial sites which shall:

(a) restrict access to Tetlit Gwich'in burial sites to preserve the dignity of Tetlit Gwich'in burial sites;

(b) where the Tetlit Gwich'in burial site is outside the primary use area *(Fort McPherson Group Trapping Area)*, require the joint approval of government and the Yukon First Nation in whose traditional territory the Tetlit Gwich'in burial site is located for any management plans for the Tetlit Gwich'in burial site;

(c) where the Tetlit Gwich'in burial site is on land in the primary use area which is not Tetlit Gwich'in Yukon land, require the joint approval of government and the Tetlit Gwich'in for any management plans for the Tetlit Gwich'in burial site; and

(d) provide that, subject to 9.5.2, where a Tetlit Gwich'in burial site is discovered, the Yukon First Nation in whose traditional territory the Tetlit Gwich'in burial site is located or the Tetlit Gwich'in, if the Tetlit Gwich'in burial site is in the primary use area, shall be informed and the Tetlit Gwich'in burial site shall not be further disturbed.

9.5.2 Where a person discovers a Tetlit Gwich'in burial site in the course of carrying on an activity authorized by government, a Yukon First Nation or the Tetlit Gwich'in, as the case may be, that person may carry on the activity with the agreement of the Yukon First Nation in whose traditional territory the Tetlit Gwich'in burial site is located or the Tetlit Gwich'in if the Tetlit Gwich'in burial site is in the primary use area.

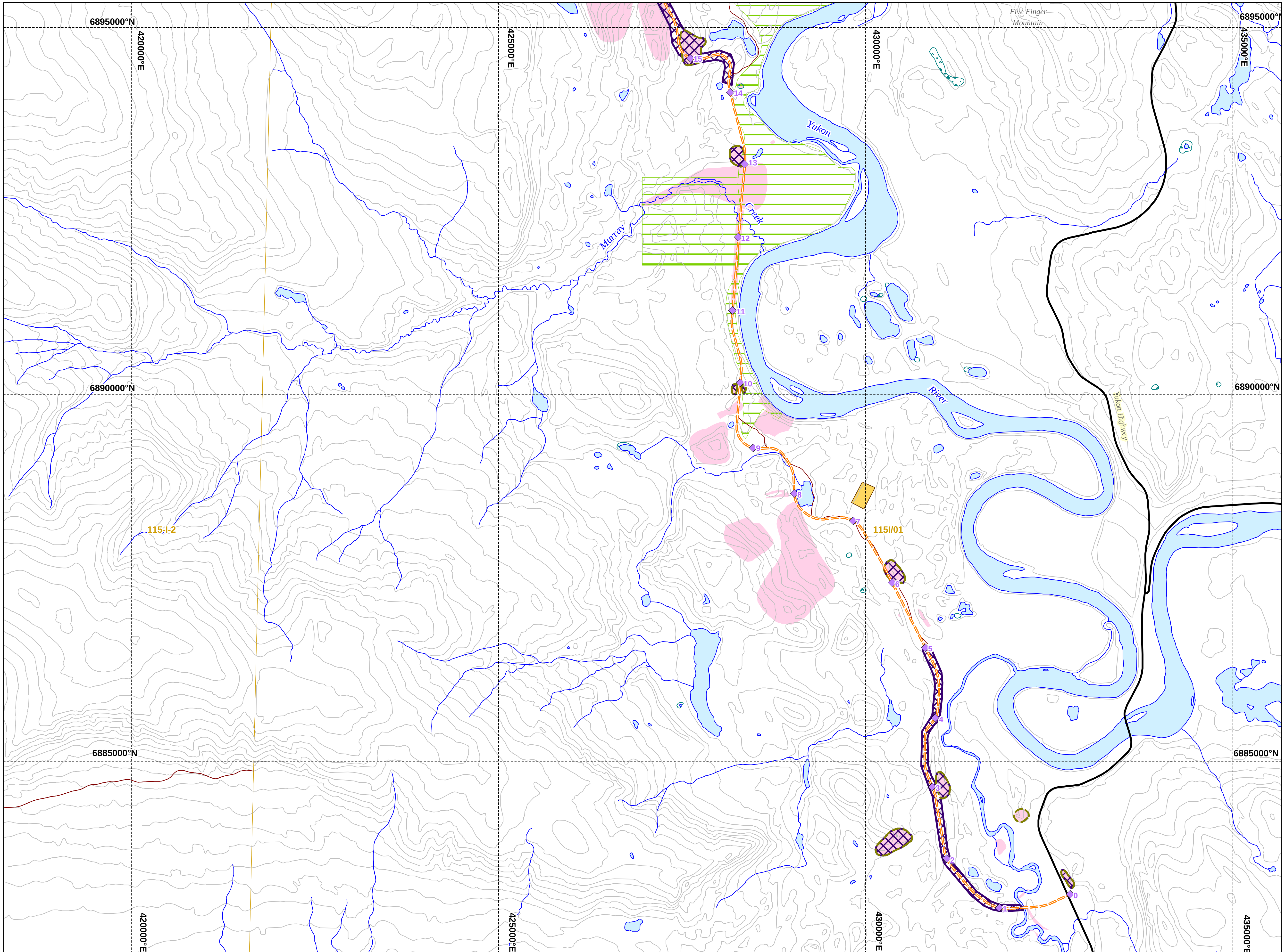
9.5.3 In the absence of agreement under 9.5.2, the person may refer the dispute to arbitration under chapter 18 of this appendix for a determination of the terms and conditions upon which the Tetlit Gwich'in burial site may be further disturbed.

9.5.4 Any exhumation, examination and reburial of human remains from a Tetlit Gwich'in burial site ordered by an arbitrator under 9.5.3 shall be done by, or under the supervision of, the Tetlit Gwich'in.

9.5.5. Except as provided in 9.5.2 to 9.5.4, any exhumation, scientific examination and reburial of remains from Tetlit Gwich'in burial sites shall be at the discretion of the Tetlit Gwich'in**.**

*This is an excerpt from Appendix C - Yukon Transboundary Agreement between Canada and the Gwich'in Tribal Council, (l992), p. 32.

APPENDIX III: PROJECT MAPPING



CASINO

PROPOSED EXTENSION OF FREEGOLD ROAD

ARCHAEOLOGICAL IMPACT ASSESSMENT MAP 1

Map Projection: NAD 83, UTM Zone 8
NTS Mapsheet: 115-I-1/2
Date: December 4, 2014

N
500 0 500 1000 1500
Meters
Scale: 1:50,000

LEGEND

- Waterbody
- Wetland
- Stream
- Contour
- Logging Road
- Proposed Road Alignment
- Propoed Borrow Pit
- Road Meter Marker
- Terrain Polygon

Archaeological Information

- Assessed Area
- Remaining Areas to be Assessed

Land Use Information

- First Nation Settlement Lands
- First Nation Settlements
- Little Salmon/Carmacks First Nation

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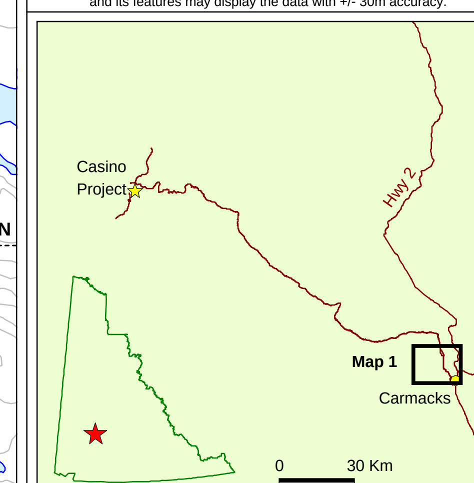

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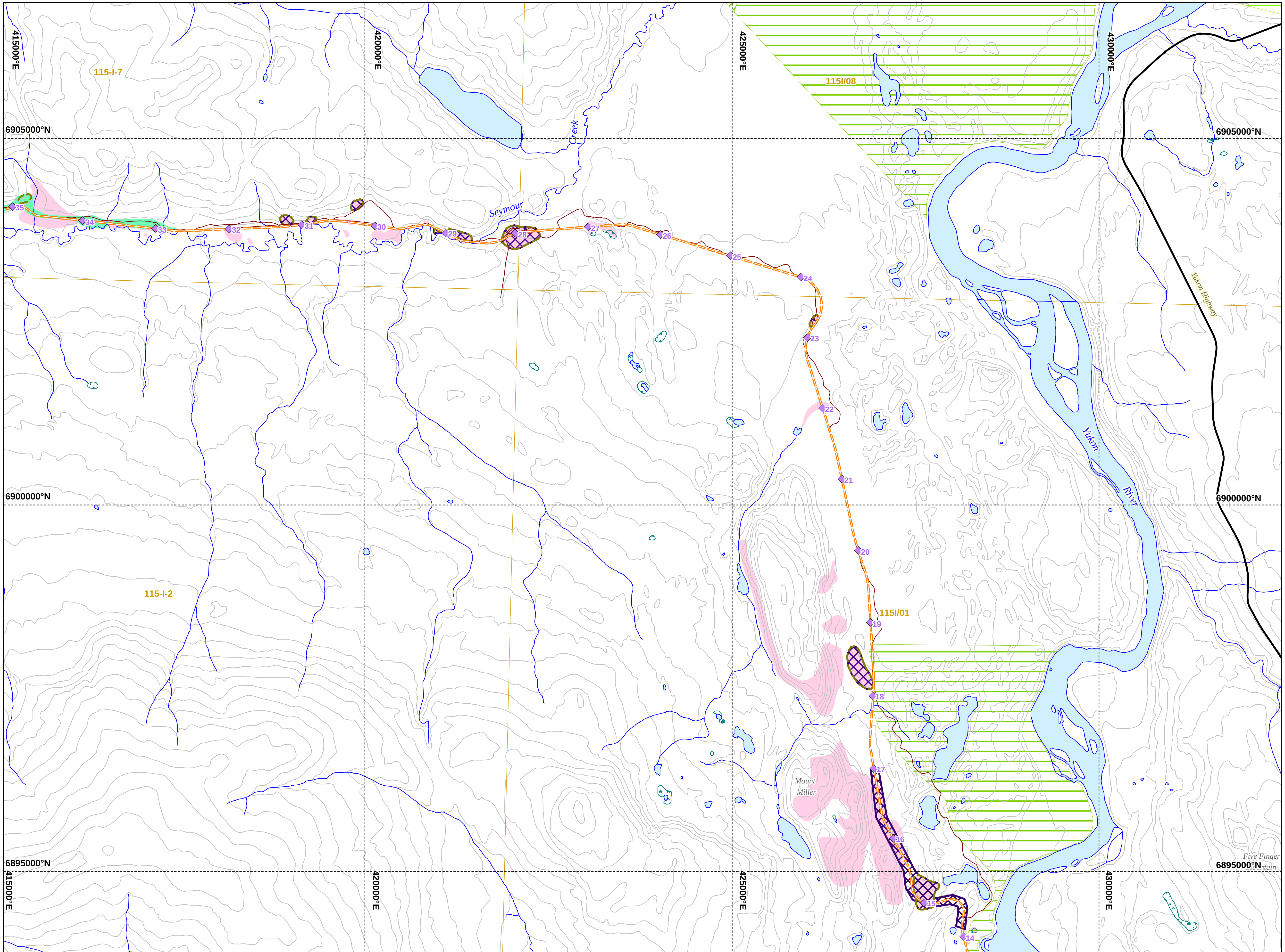

CASINO

PROPOSED EXTENSION OF FREEGOLD ROAD

ARCHAEOLOGICAL IMPACT ASSESSMENT MAP 2

Map Projection: NAD 83, UTM Zone 8
NTS Mapsheet: 115-I-1/2/7/8
Date: December 4, 2014

N

500 0 500 1000 1500
Meters
Scale: 1:50,000

LEGEND

- Waterbody
- Wetland
- Stream
- Contour
- Logging Road
- Proposed Road Alignment
- Proposed Borrow Pit
- Road Meter Marker
- Terrain Polygon

Archaeological Information

- Assessed Area
- Remaining Areas to be Assessed

Land Use Information

- First Nation Settlement Lands

First Nation Settlements

- Little Salmon/Carmacks First Nation

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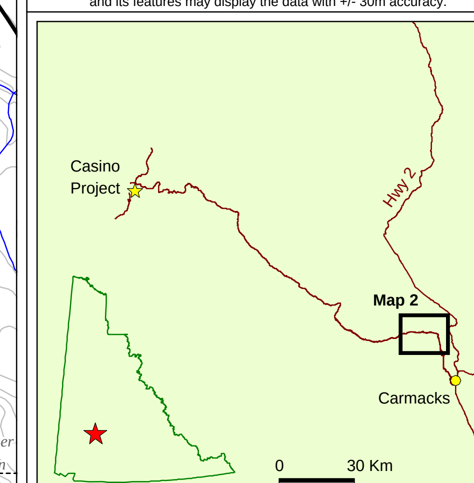

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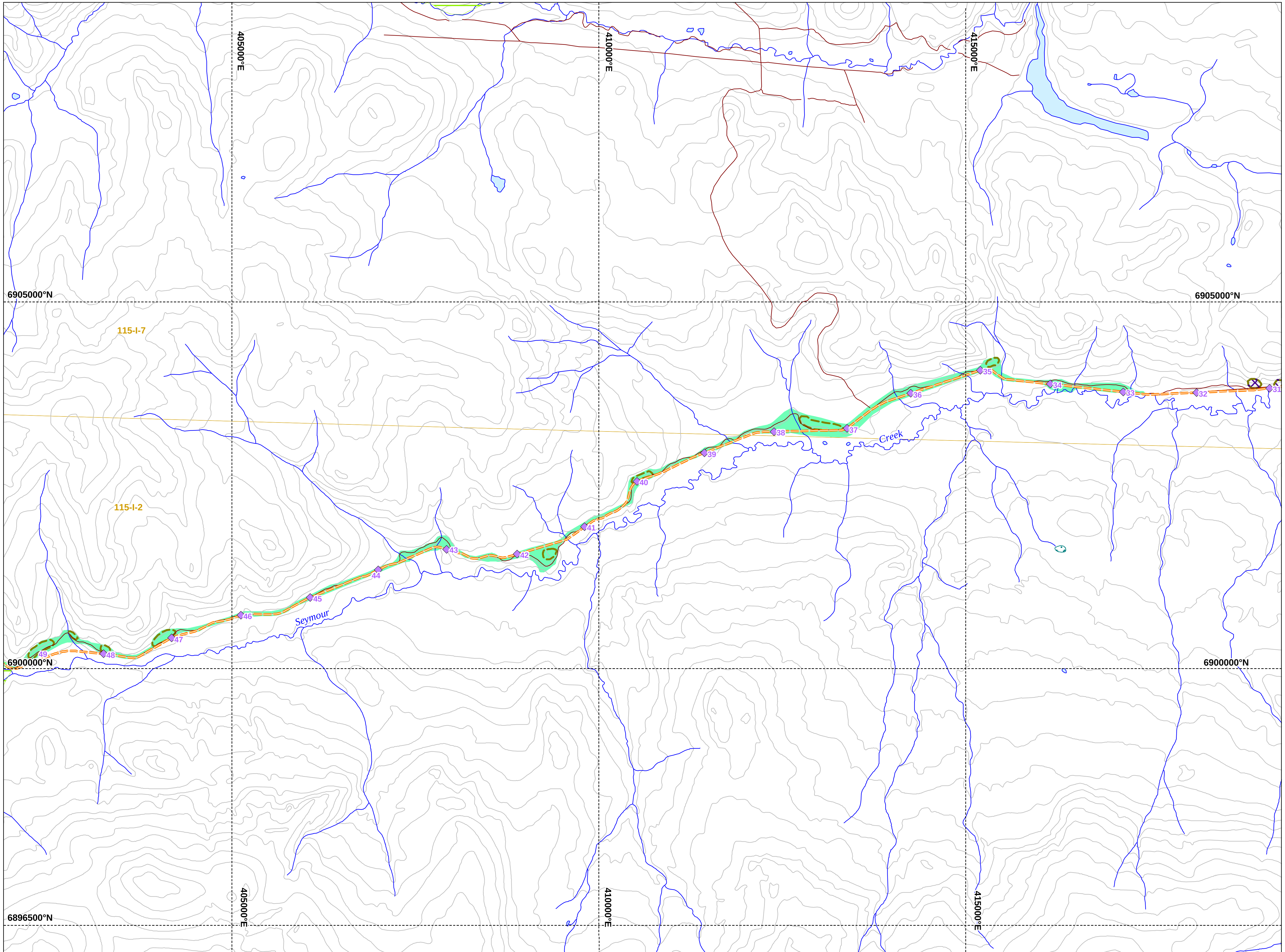

CASINO

PROPOSED EXTENSION OF FREEGOLD ROAD

ARCHAEOLOGICAL IMPACT ASSESSMENT MAP 3

Map Projection: NAD 83, UTM Zone 8
NTS Mapsheet: 115-I-2/7
Date: December 4, 2014

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500 0 500 1000 1500
Meters
Scale: 1:50,000

LEGEND

- Waterbody
- Wetland
- Stream
- Contour
- Road
- Proposed Road Alignment
- Proposed Borrow Pit
- Road Meter Marker

Archaeological Information

- Assessed Area
- Remaining Areas to be Assessed

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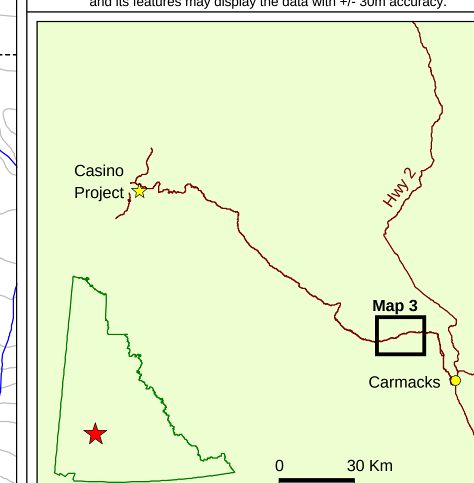

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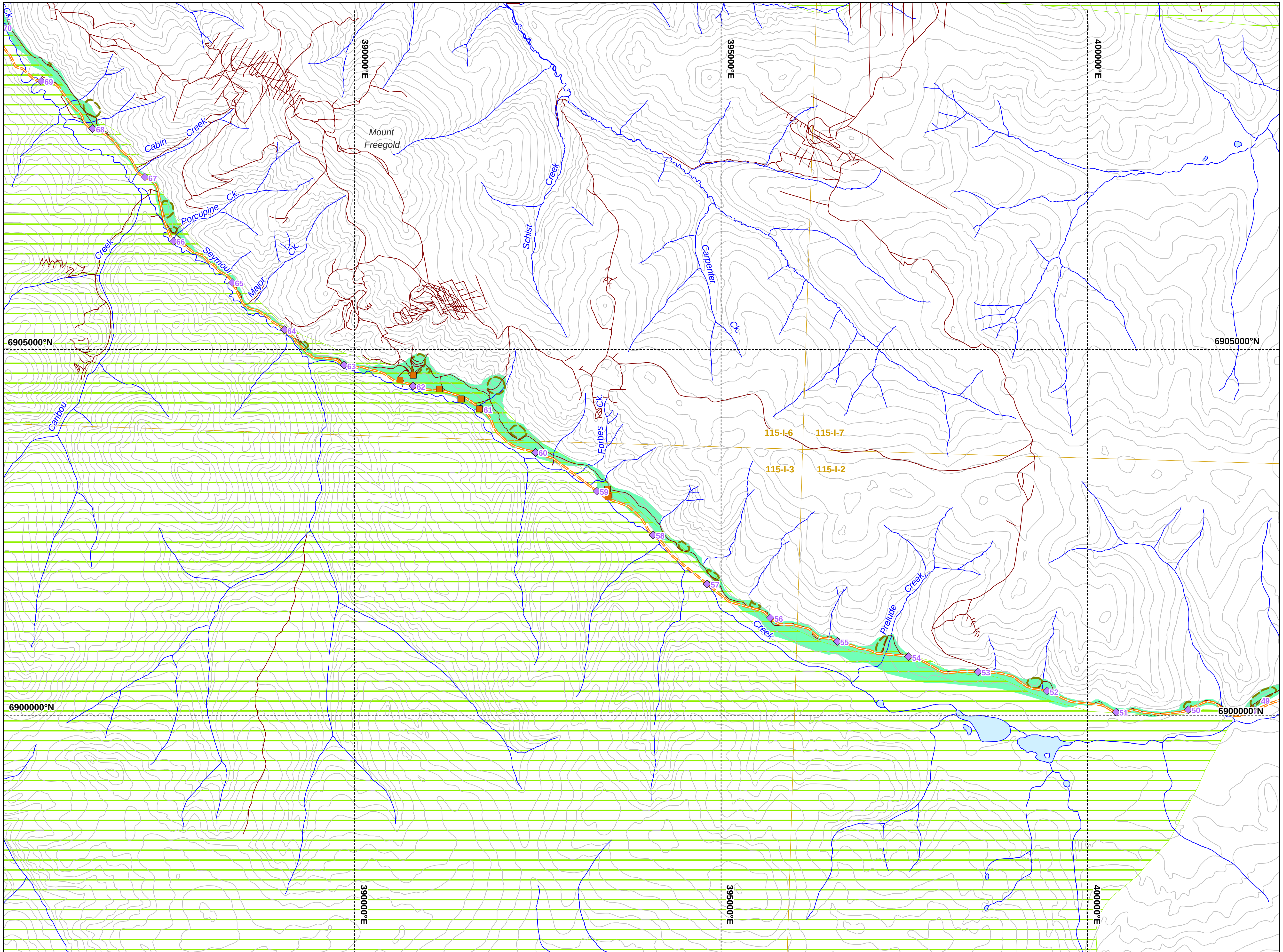

CASINO

PROPOSED EXTENSION OF FREEGOLD ROAD

ARCHAEOLOGICAL IMPACT ASSESSMENT MAP 4

Map Projection: NAD 83, UTM Zone 8
NTS Mapsheet: 115-I-2/3/6/7
Date: December 4, 2014

N
500 0 500 1000 1500
Meters
Scale: 1:50,000

LEGEND

- Waterbody
- Wetland
- Stream
- Contour
- Road
- Proposed Road Alignment
- Proposed Borrow Pit
- Road Meter Marker

Archaeological Information

- Assessed Area
- Historic Structure

Land Use Information

First Nation Settlements

- Little Salmon/Carmacks First Nation

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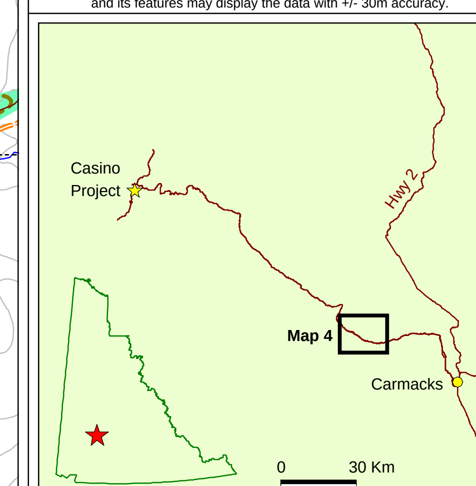

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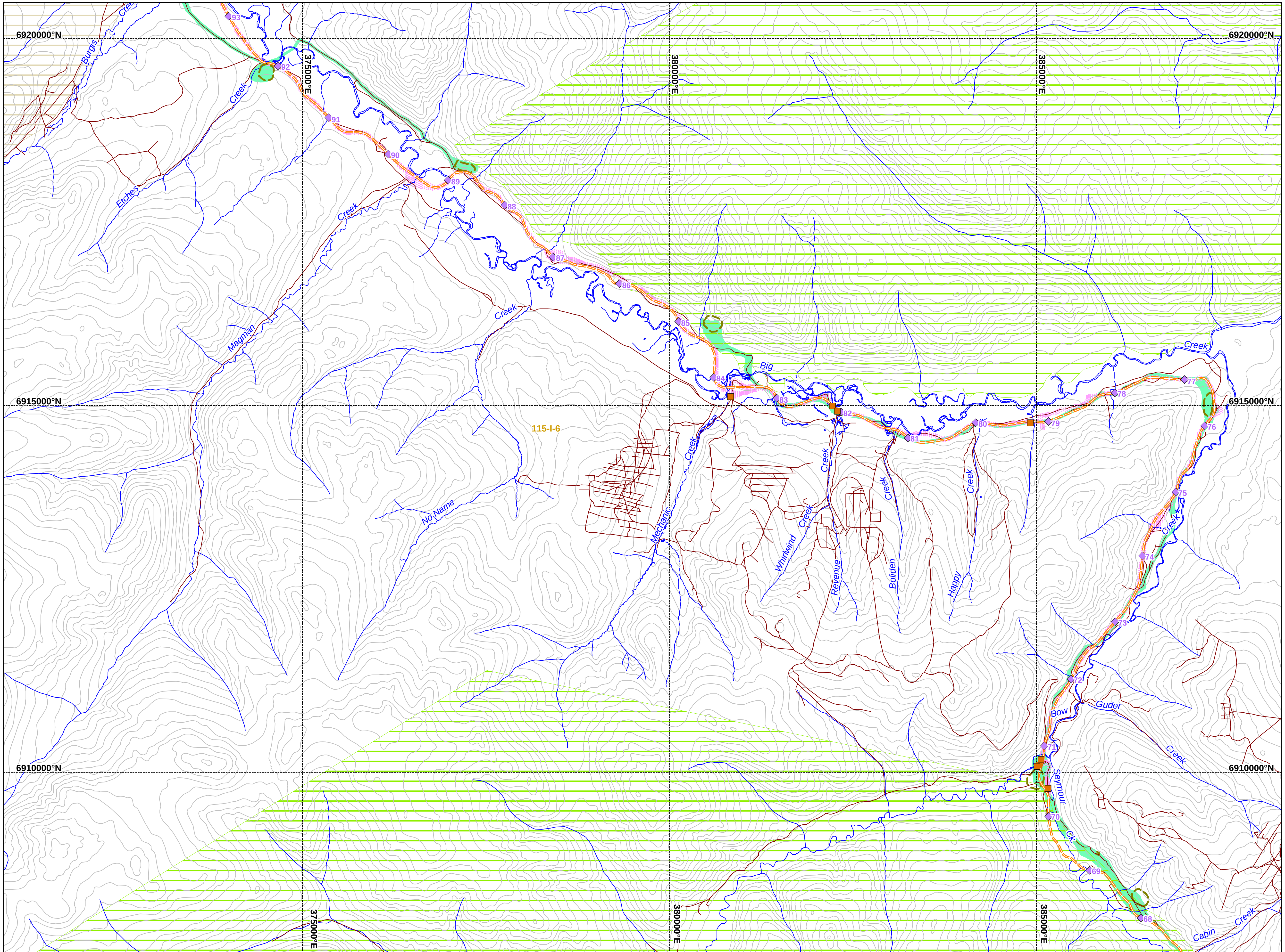

CASINO

PROPOSED EXTENSION OF FREEGOLD ROAD

ARCHAEOLOGICAL IMPACT ASSESSMENT MAP 5

Map Projection: NAD 83, UTM Zone 8
NTS Mapsheet: 115-I-6
Date: December 4, 2014

N

500 0 500 1000 1500
Meters
Scale: 1:50,000

LEGEND

- Waterbody
- Wetland
- Stream
- Contour
- Road
- Proposed Road Alignment
- Proposed Borrow Pit
- Road Meter Marker

Archaeological Information

- Assessed Area
- Previously Assessed Area
- Historic Structure

Land Use Information

First Nation Settlements

- Little Salmon/Carmacks First Nation
- Selkirk First Nation

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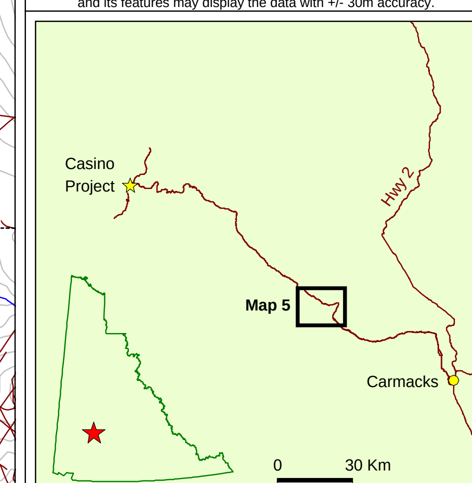

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PROPOSED EXTENSION OF FREEGOLD ROAD

ARCHAEOLOGICAL IMPACT ASSESSMENT MAP 6

Map Projection: NAD 83, UTM Zone 8
NTS Mapsheet: 115-I-5/6
Date: December 4, 2014

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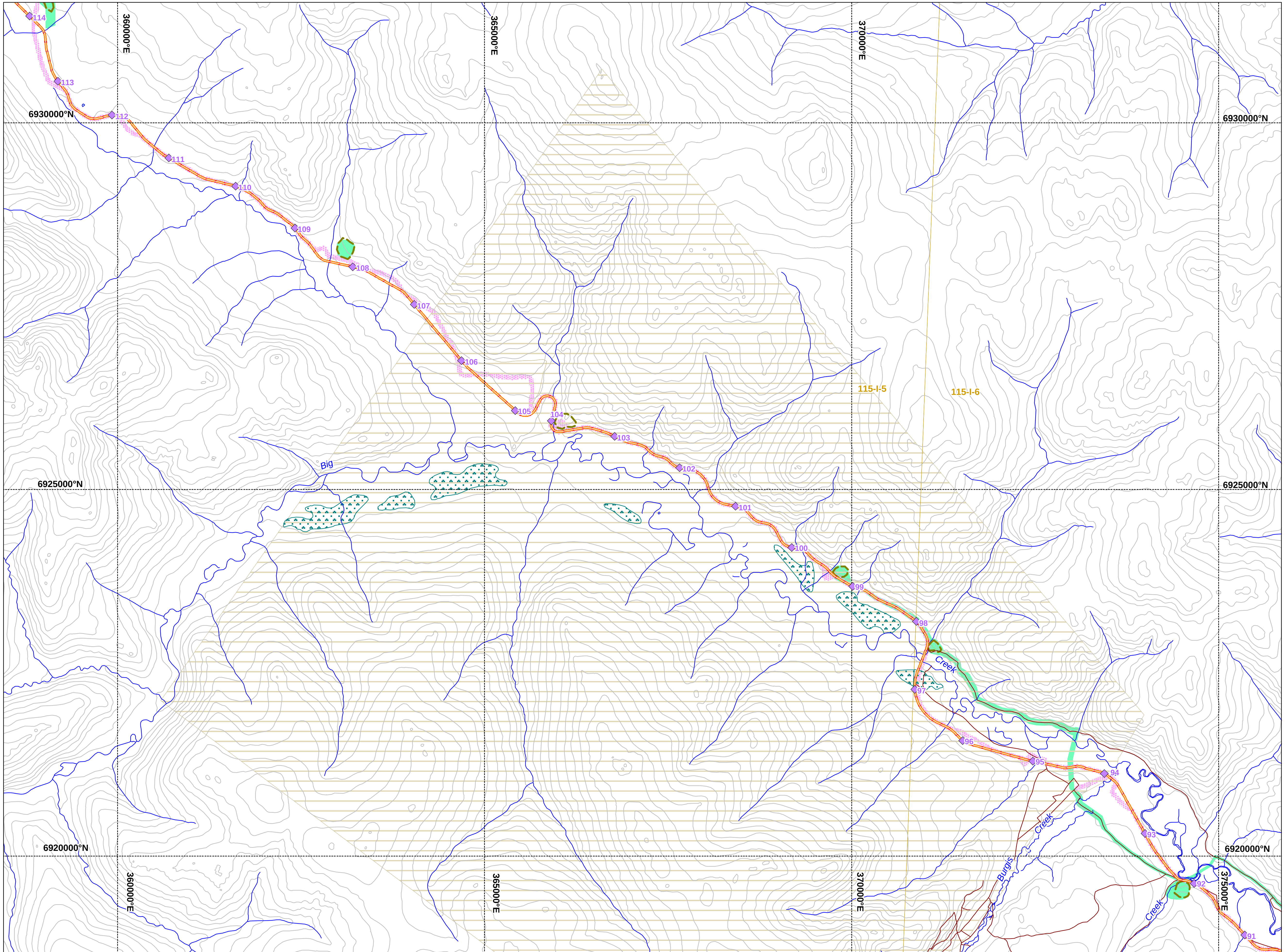
Meters
Scale: 1:50,000



LEGEND

- Waterbody
- Wetland
- Stream
- Contour
- Road
- Proposed Road Alignment
- Proposed Borrow Pit
- Road Meter Marker

Archaeological Information

- Assessed Area
- Previously Assessed Area

Land Use Information

First Nation Settlements

- Selkirk First Nation

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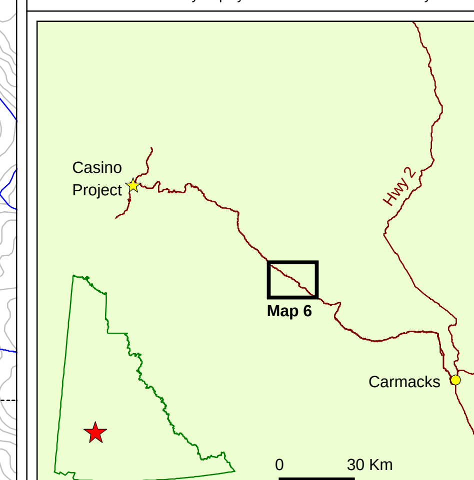

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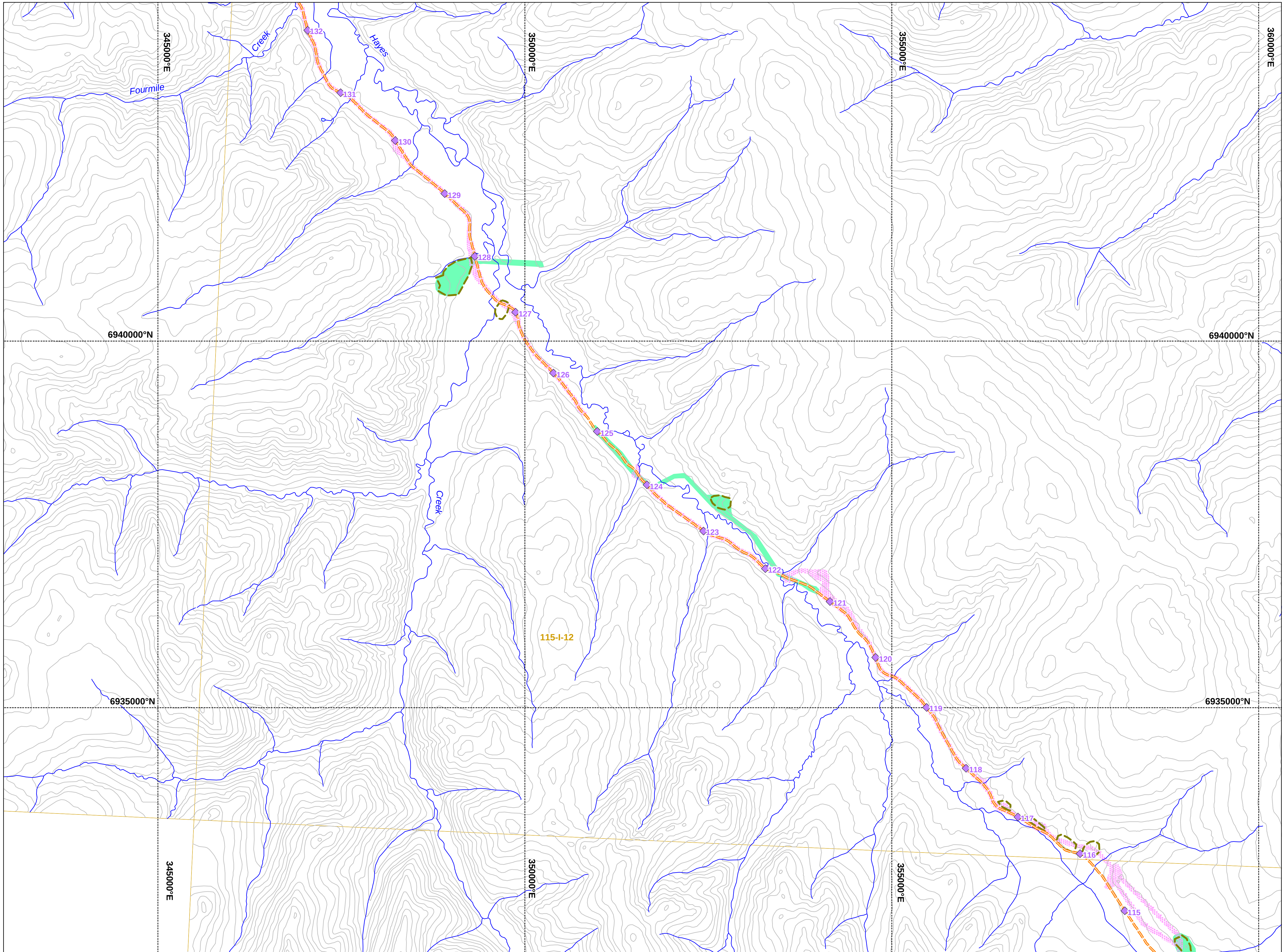

CASINO

PROPOSED EXTENSION OF FREEGOLD ROAD

ARCHAEOLOGICAL IMPACT ASSESSMENT MAP 7

Map Projection: NAD 83, UTM Zone 8
NTS Mapsheet: 115-I-12
Date: December 4, 2014

N

500 0 500 1000 1500
Meters
Scale: 1:50,000

LEGEND

Waterbody
Wetland
Stream
Contour
Road
Proposed Road Alignment
Proposed Borrow Pit
Road Meter Marker

Archaeological Information

Assessed Area
Previously Assessed Area
Historic Structure

Disclaimer:
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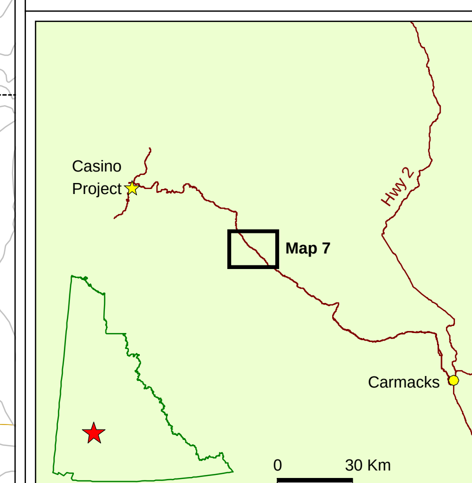

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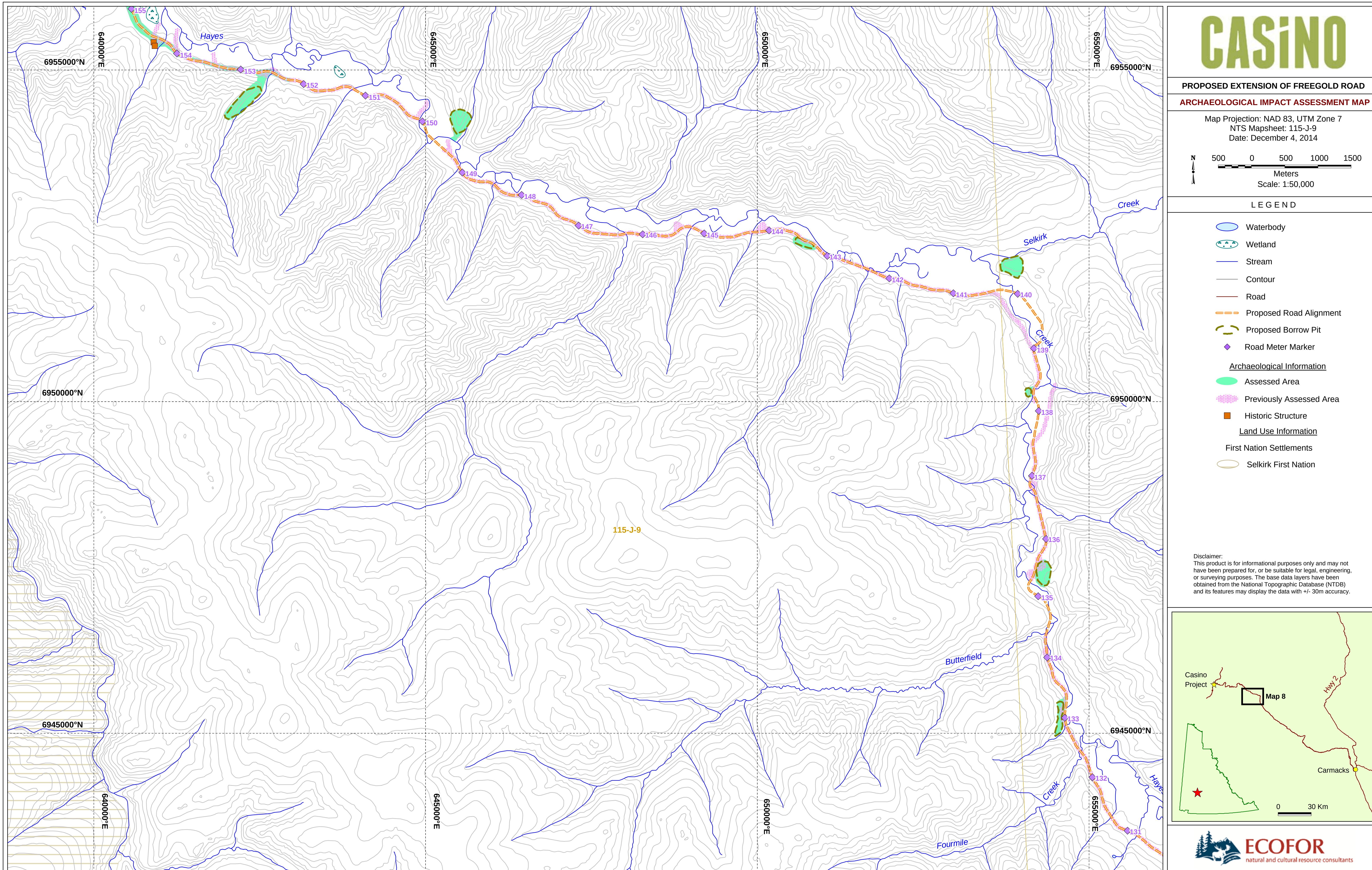
CASINO
PROPOSED EXTENSION OF FREEGOLD ROAD
ARCHAEOLOGICAL IMPACT ASSESSMENT MAP 8
Map Projection: NAD 83, UTM Zone 7
NTS Mapsheet: 115-J-9
Date: December 4, 2014
N
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Meters
Scale: 1:50,000
LEGEND
Waterbody
Wetland
Stream
Contour
Road
Proposed Road Alignment
Proposed Borrow Pit
Road Meter Marker
Archaeological Information
Assessed Area
Previously Assessed Area
Historic Structure
Land Use Information
First Nation Settlements
Selkirk First Nation
Disclaimer:
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Casino Project
Map 8
Hwy 2
Carmacks
0 30 Km
ECOFOR
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6955000°N
6950000°N
6945000°N
640000°E
645000°E
650000°E
655000°E
Hayes
Selkirk
Creek
Butterfield
Fourmile
115-J-9
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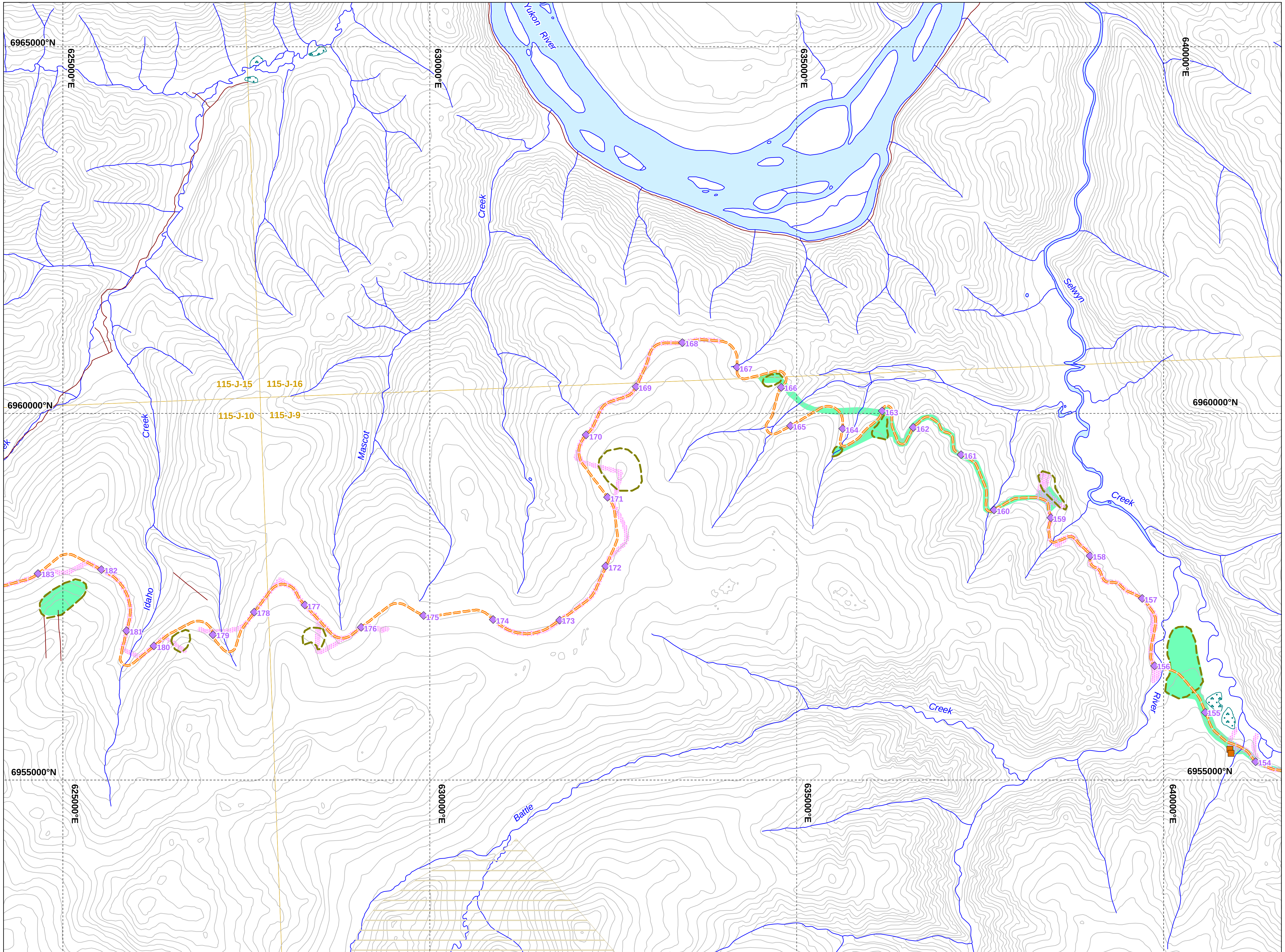

CASINO

PROPOSED EXTENSION OF FREEGOLD ROAD

ARCHAEOLOGICAL IMPACT ASSESSMENT MAP 9

Map Projection: NAD 83, UTM Zone 7
NTS Mapsheet: 115-J-9/10/15/16
Date: December 4, 2014

N

500 0 500 1000 1500
Meters
Scale: 1:50,000

LEGEND

- Waterbody
- Wetland
- Stream
- Contour
- Road
- 2013 Road Alignment
- 2013 Borrow Pit
- 2013 Road Meter Marker

Archaeological Information

- Assessed Area
- Previously Assessed Area
- Historic Structure

Land Use Information

First Nation Settlements

- Selkirk First Nation

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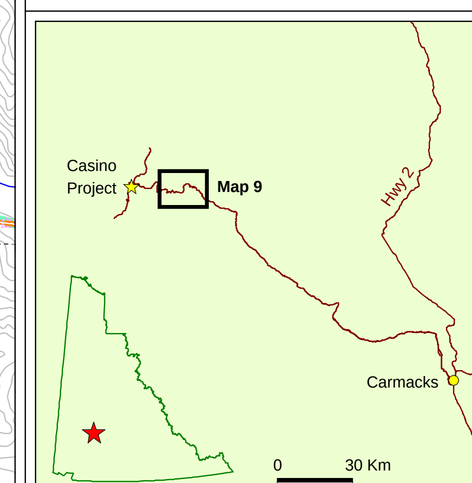

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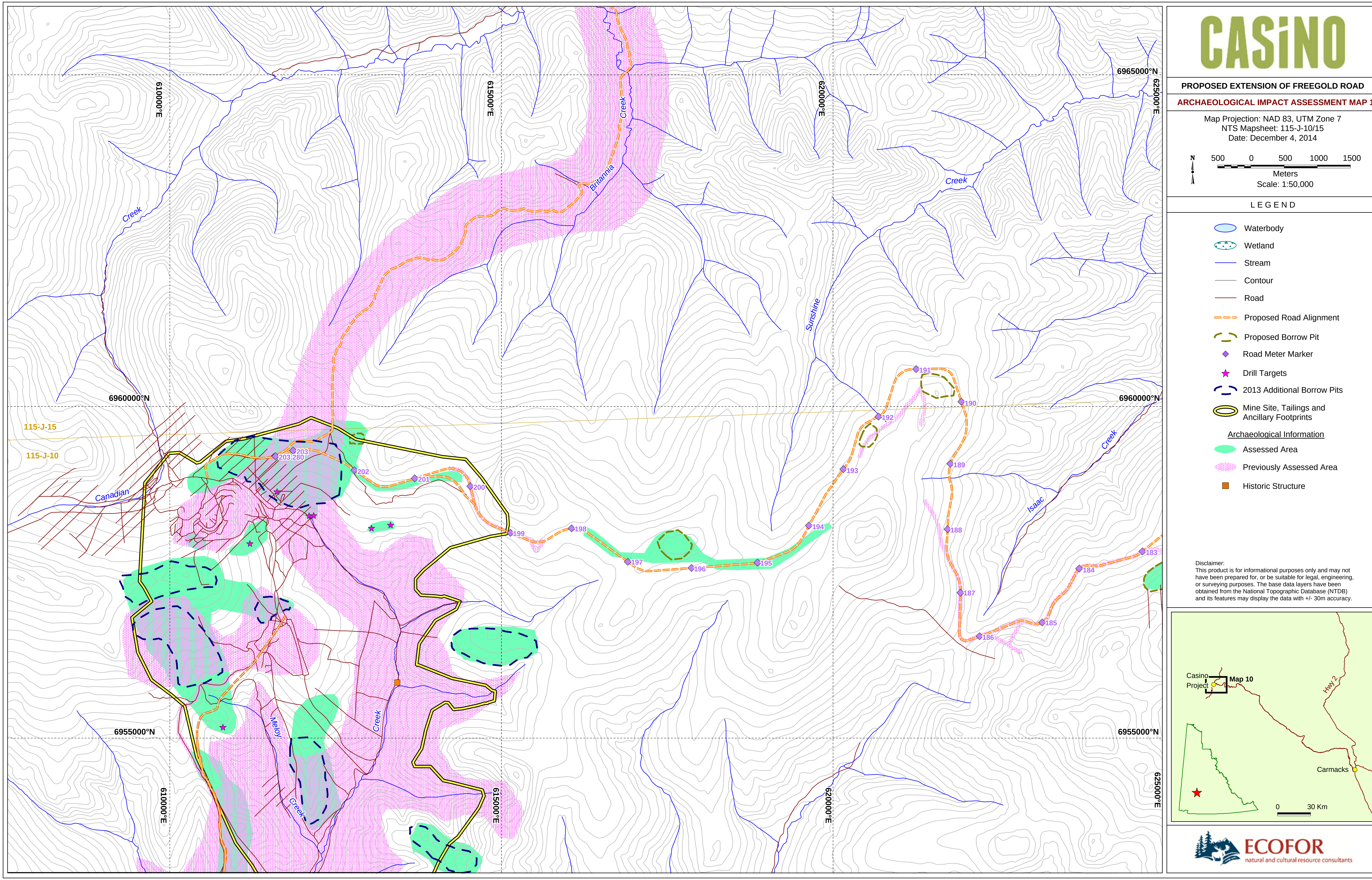

CASINO
PROPOSED EXTENSION OF FREEGOLD ROAD
ARCHAEOLOGICAL IMPACT ASSESSMENT MAP 10
Map Projection: NAD 83, UTM Zone 7
NTS Mapsheet: 115-J-10/15
Date: December 4, 2014
N
500 0 500 1000 1500
Meters
Scale: 1:50,000
LEGEND
Waterbody
Wetland
Stream
Contour
Road
Proposed Road Alignment
Proposed Borrow Pit
Road Meter Marker
Drill Targets
2013 Additional Borrow Pits
Mine Site, Tailings and Ancillary Footprints
Archaeological Information
Assessed Area
Previously Assessed Area
Historic Structure
Disclaimer:
This product is for informational purposes only and may not have been prepared for, or be suitable for legal, engineering, or surveying purposes. The base data layers have been obtained from the National Topographic Database (NTDB) and its features may display the data with +/- 30m accuracy.
Casino Project
Map 10
Hwy 2
Carmacks
0 30 Km
ECOFOR
natural and cultural resource consultants
6965000°N
6960000°N
6955000°N
610000°E
615000°E
620000°E
625000°E
115-J-15
115-J-10
Creek
Britannia
Sunshine
Canadian
Meloy
Isaac
191
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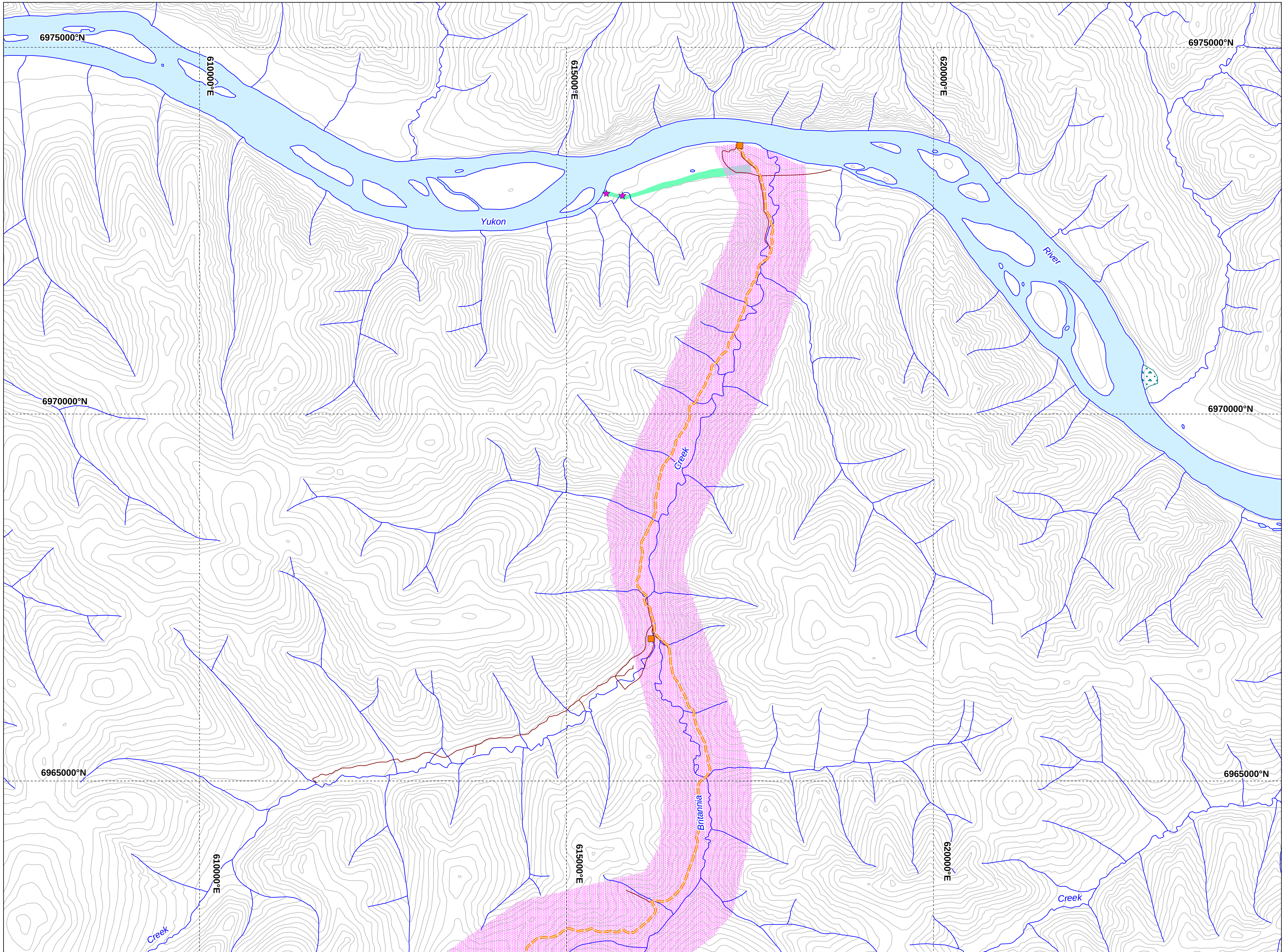


CASINO

PROPOSED EXTENSION OF FREEGOLD ROAD

ARCHAEOLOGICAL IMPACT ASSESSMENT MAP 11

Map Projection: NAD 83, UTM Zone 7
NTS Mapsheet: 115-J-10/15
Date: December 4, 2014

N
500 0 500 1000 1500
Meters
Scale: 1:50,000

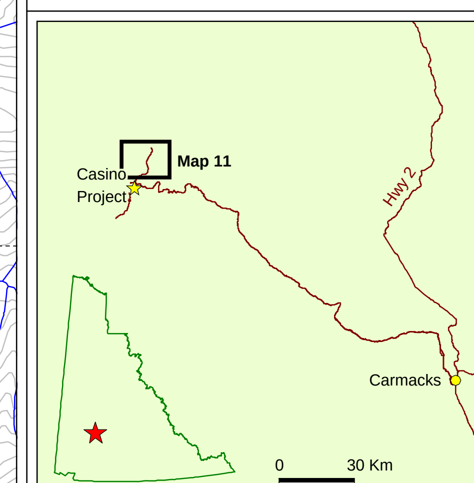
LEGEND

- Waterbody
- Wetland
- Stream
- Contour
- Road
- Proposed Road Alignment
- Proposed Borrow Pit
- 2013 Road Meter Marker
- Drill Targets

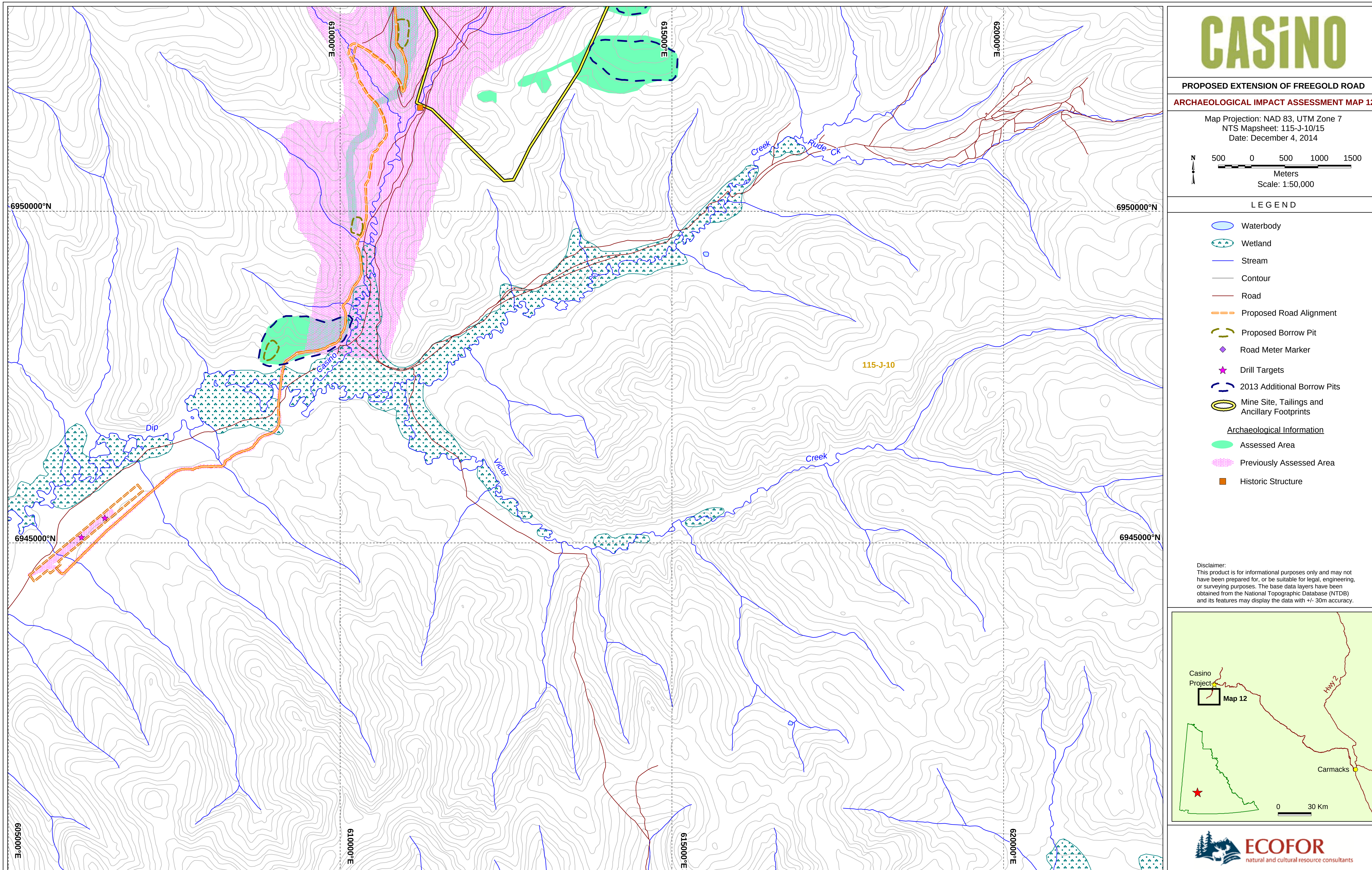
Archaeological Information

- Assessed Area
- Previously Assessed Area
- Historic Structure

Disclaimer:
This product is for informational purposes only and may not have been prepared for, or be suitable for legal, engineering, or surveying purposes. The base data layers have been obtained from the National Topographic Database (NTDB) and its features may display the data with +/- 30m accuracy.



ECOFOR
natural and cultural resource consultants


CASINO
PROPOSED EXTENSION OF FREEGOLD ROAD
ARCHAEOLOGICAL IMPACT ASSESSMENT MAP 12
Map Projection: NAD 83, UTM Zone 7
NTS Mapsheet: 115-J-10/15
Date: December 4, 2014
N
500 0 500 1000 1500
Meters
Scale: 1:50,000
LEGEND
Waterbody
Wetland
Stream
Contour
Road
Proposed Road Alignment
Proposed Borrow Pit
Road Meter Marker
Drill Targets
2013 Additional Borrow Pits
Mine Site, Tailings and Ancillary Footprints
Archaeological Information
Assessed Area
Previously Assessed Area
Historic Structure
Disclaimer:
This product is for informational purposes only and may not have been prepared for, or be suitable for legal, engineering, or surveying purposes. The base data layers have been obtained from the National Topographic Database (NTDB) and its features may display the data with +/- 30m accuracy.
Casino Project
Map 12
Hwy 2
Carmacks
0 30 Km
ECOFOR
natural and cultural resource consultants
605000°E
610000°E
615000°E
620000°E
6950000°N
6945000°N
115-J-10
Casino
Dip
Victor
Creek
Rude Ck
Creek

APPENDIX IV: SUMMARY TABLE

Borden Number or Temp Site #	Class	Features	Current Status of Site	Scope of Possible Impacts from Casino Project	Site Boundary Clearly Flagged	Management Recommendations and Proposed Mitigation Strategy	Report/ Permit number and Authors	Bibliographic Reference
Remaining HRIA Survey Fieldwork To Be Completed								
na	na	na	na	Area is a proposed borrow pit east side of Klondike Highway.	na	HRIA Assessment Required	na	na
na	na	na	na	Area is a proposed borrow pit west side of Klondike Highway.	na	HRIA Assessment Required - Proposed Borrow Pit may be dropped as near possible graves	na	na
na	na	na	na	Within the proposed Freegold Project ROW.	na	HRIA Assessment Required	na	na
na	na	na	na	Area is a proposed borrow pit west side of Proposed ROW and near Nansen Road.	na	HRIA Assessment Required	na	na
na	na	na	na	Area is a proposed borrow pit east side of ROW.	na	HRIA Assessment Required	na	na
na	na	na	na	Area is a proposed borrow pit west side of ROW.	na	HRIA Assessment Required	na	na
na	na	na	na	Area is a proposed borrow pit west side of ROW.	na	HRIA Assessment Required	na	na
na	na	na	na	Area is a proposed borrow pit east side of ROW.	na	HRIA Assessment Required	na	na
na	na	na	na	Area is a proposed borrow pit west side of ROW.	na	HRIA Assessment Required	na	na
na	na	na	na	Within the proposed Freegold Project ROW.	na	HRIA Assessment Required	na	na
na	na	na	na	Area is a proposed borrow pit both sides of ROW.	na	HRIA Assessment Required	na	na
na	na	na	na	Area is a proposed borrow pit west side of ROW.	na	HRIA Assessment Required	na	na
na	na	na	na	Area is a proposed borrow pit west side of ROW.	na	HRIA Assessment Required	na	na
na	na	na	na	Area is a proposed borrow pit both sides of ROW.	na	HRIA Assessment Required	na	na
na	na	na	na	Area is a proposed borrow pit north side of ROW.	na	HRIA Assessment Required	na	na
na	na	na	na	Area is a proposed borrow pit south side of ROW.	na	HRIA Assessment Required	na	na

Borden Number or Temp Site #	**Class**	**Features**	**Current Status of Site**	**Scope of Possible Impacts from Casino Project**	**Site Boundary Clearly Flagged**	**Management Recommendations and Proposed Mitigation Strategy**	**Report/ Permit number and Authors**	**Bibliographic Reference**
na	na	na	na	Area is a proposed borrow pit north side of existing road.	na	HRIA Assessment Required	na	na
na	na	na	na	Area is a proposed borrow pit north side of existing road.	na	HRIA Assessment Required	na	na
na	na	na	na	Area is a proposed borrow pit north side of existing road.	na	HRIA Assessment Required	na	na

Borden Number or Temp Site #	Class	Features	Current Status of Site	Scope of Possible Impacts from Casino Project	Site Boundary Clearly Flagged	Management Recommendations and Proposed Mitigation Strategy	Report/ Permit number and Authors	Bibliographic Reference
Archaeological Sites to be Managed Along Proposed Freegold Road Upgrade								
KaVa-17	prehistoric site; and cemetery	surface scatter (lithic)	Slighlty disturbed by dirt track and vehicle traffic.	This site and cemetery are not currently planned for impacts and are located upslope and to the east of the proposed ROW.	No	Avoidance of this site and cemetery are recommended.	N/A no permit just site form	Just KaVb-17 Site form YG Heritage Branch 2012
KaVa-3	prehistoric	surface scatter (lithic) and subsurface scatter (lithic and faunal)	disturbed	None planned	No	Avoidance (preferred) or mitigative excavations. If the existing bridge over the Nordenskiold River was upgraded and or replaced as part of the Freegold Project reconstruction, adverse impacts could be placed on the remaining buried cultural materials.	94-22ASR (Antiquus)	Handly and Rousseau 1995
KaVb-2	prehistoric	surface scatter (lithic) and subsurface scatter (lithic)	intact (1995)	Outside of the zone of impact of Freegold Project ROW.	No	Site avoidance.	95-1ASR (Yukon Govt)	Gotthardt 1995
KaVb-1	prehistoric	subsurface scatter (lithic).	disturbed	Within the proposed Freegold Project ROW, and proposed borrow pit.	No	Avoidance (preferred) or Mitigative Excavations(Handly and Rousseau); avoid impacts to the south edge of the terrace and maintain 30 m buffer along terrace edge. Access road should be routed along north side of the terrace (Hammer 1995).	94-22ASR (Antiquus); 95-2ASR (Hammerstone)	Hammer 1995; Handly and Rousseau 1995
KbVb-2	prehistoric	subsurface scatter (lithic)	excavated in 1995	Within proposed Freegold Project ROW.	No	Recommended that during construction for the upgrading of the Freegold Road, the surface soil (0-30 cm below surface) be removed in the vicinity of KbVb-2 and stockpiled so possible remaining cultural materials may be salvaged at a future date.	94-22ASR (Antiquus), 95-2ASR (Hammerstone)	Hammer 1995; Handly and Rousseau 1995
KbVb-4	prehistoric	subsurface scatter (lithic and faunal bone)	some intact portions of site remain	Within Freegold Project ROW.	No	Mitigative Excavations	95-1ASR (Yukon Govt)	Gotthardt 1995
KbVb-3	prehistoric	scatter (lithic)	No Evidence of Site Remains	Within Freegold Project ROW.	No	None required.	95-1ASR (Yukon Govt)	Gotthardt 1995

Borden Number or Temp Site #	Class	Features	Current Status of Site	Scope of Possible Impacts from Casino Project	Site Boundary Clearly Flagged	Management Recommendations and Proposed Mitigation Strategy	Report/ Permit number and Authors	Bibliographic Reference
KcVd-3	prehistoric	subsurface scatter (lithic)	intact	Within Freegold Project proposed borrow pit.	Yes	If avoidance is not possible then data recovery work under is recommended. Data recovery should include additional shovel testing to better determine artifact distribution and density followed by 1 x 1 m block excavation. Approximately 14 - 18 square meters of excavation would be recommended.	13-07ASR (Ecofor)	Mooney 2013a
KcVe-4	prehistoric	subsurface scatter (lithic)	intact	Very close to the proposed extension of Freegold Road.	Yes	Avoidance of the site is recommended. If avoidance is not possible then data recovery work is recommended to include in-fill shovel testing to better determine artifact densities followed by a series of 1 x 1 m unit block excavations in relation to the size and distribution of the site.	11-04ASR (Ecofor)	Mooney 2011
KcVf-2	prehistoric	subsurface scatter (lithic)	intact	On edge of Freegold Project proposed borrow pit.	Yes	If avoidance is not possible then data recovery work is recommended. Data recovery should include additional shovel testing to determine artifact distribution and density followed by 1 x 1 m block excavation. Approximately 12 - 15 square meters of excavation would be recommended.	13-07ASR (Ecofor)	Mooney 2013a
KcVf-3	prehistoric	subsurface scatter (lithic)	intact	Within Freegold Project proposed borrow pit.	Yes	If avoidance is not possible then data recovery work under is recommended. Data recovery should include additional shovel testing to determine artifact distribution and density followed by 1 x 1 m block excavation. Approximately 12 - 15 square meters of excavation would be recommended.	13-07ASR (Ecofor)	Mooney 2013a

Borden Number or Temp Site #	Class	Features	Current Status of Site	Scope of Possible Impacts from Casino Project	Site Boundary Clearly Flagged	Management Recommendations and Proposed Mitigation Strategy	Report/ Permit number and Authors	Bibliographic Reference
KeVf-1	prehistoric	subsurface scatter (lithic)	intact	Within Freegold Project proposed borrow pit as of 2013 (previously not in planned impacts 2011).	Yes	If avoidance is not possible then data recovery work under is recommended. Data recovery should include additional shovel testing to determine artifact distribution and density followed by 1 x 1 m block excavation. Approximately 12 - 15 square meters of excavation would be recommended.	11-04ASR (Ecofor)	Mooney 2011
KdVf-4	prehistoric	surface and subsurface scatter (lithic)	intact	Was planned to be impacted by the proposed borrow pit (2011) but now is not planned for impacts (2013).	Yes	Avoidance of the site is recommended. If avoidance is not possible then data recovery work is recommended to include in-fill shovel testing to better determine artifact densities followed by a series of 1x1m unit block excavations in relationship to the relation to the size and distribution of the site.	88-3ASR (Gotthardt); 11-04ASR (Ecofor)	Gotthardt 1988; Mooney 2011
KdVf-13	prehistoric	subsurface scatter (lithic)	intact	Will be directly impacted by the proposed borrow pit.	Yes	Avoidance of the site is recommended. If avoidance is not possible then data recovery work is recommended to include in-fill shovel testing to better determine artifact densities followed by a series of 1x1m unit block excavations in relationship to the size and distribution of the site.	11-04ASR (Ecofor)	Mooney 2011

Borden Number or Temp Site #	Class	Features	Current Status of Site	Scope of Possible Impacts from Casino Project	Site Boundary Clearly Flagged	Management Recommendations and Proposed Mitigation Strategy	Report/ Permit number and Authors	Bibliographic Reference
KdVf-7	Multi-component: Prehistoric and Proto-historic	subsurface scatter (lithic and Chinese coin)*	intact	The site is located within a proposed borrow pit and very close to the current proposed alignment of the road. This site may be directly impacted by the road construction.	Yes	Avoidance of the site is recommended. If avoidance is not possible then data recovery work is recommended to include in-fill shovel testing to better determine artifact densities followed by a series of 1x1m unit block excavations in relationship to the size and distribution of the site. Additional historical research in regards to possible Chinese placer mining in the project area is recommended.	11-04ASR (Ecofor)	Mooney 2011
KdVf-6	prehistoric	subsurface scatter (lithic) and possible cache	intact	Within the proposed extension of Freegold Road and potential borrow pits.	Yes	Avoidance of the site is recommended. If avoidance is not possible then data recovery work is recommended to include in-fill shovel testing to better determine artifact densities followed by a series of 1x1m unit block excavations in relationship to the size and distribution of the site.	11-04ASR (Ecofor)	Mooney 2011
KdVf-5	prehistoric	subsurface scatter (lithic)	intact	Was planned to be impacted by the proposed borrow pit (2011) but now borrow pit is dropped but site is within planned ROW impacts (2013).	Yes	Avoidance of the site is recommended. If avoidance is not possible then data recovery work is recommended to include in-fill shovel testing to better determine artifact densities followed by a series of 1x1m unit block excavations in relationship to the size and distribution of the site.	11-04ASR (Ecofor)	Mooney 2011
KdVf-8	prehistoric	subsurface scatter (lithic)	intact	This site will not be directly impacted by the road construction or borrow pit use.	Yes	No further work is recommended. However, if borrow pit construction impacts lead to upslope erosion then avoidance of the site is recommended. If avoidance is not possible then data recovery work under is recommended.	11-04ASR (Ecofor)	Mooney 2011

Borden Number or Temp Site #	Class	Features	Current Status of Site	Scope of Possible Impacts from Casino Project	Site Boundary Clearly Flagged	Management Recommendations and Proposed Mitigation Strategy	Report/ Permit number and Authors	Bibliographic Reference
KdVf-10	prehistoric	subsurface scatter (lithic)	intact	This site will not be directly impacted by the road construction or borrow pit use.	Yes	No further work is recommended. However, if borrow pit construction impacts lead to upslope erosion then avoidance of the site is recommended. If avoidance is not possible then data recovery work under is recommended.	11-04ASR (Ecofor)	Mooney 2011
KdVf-11	prehistoric	subsurface scatter (lithic)	intact	This site will not be directly impacted by the road construction or borrow pit use.	Yes	No further work is recommended. However, if borrow pit construction impacts lead to upslope erosion then avoidance of the site is recommended. If avoidance is not possible then data recovery work is recommended.	11-04ASR (Ecofor)	Mooney 2011
KdVf-9	prehistoric	subsurface scatter (lthic) and possible cache	intact	This site will be directly impacted by the road construction.	Yes	Avoidance of the site is recommended. If avoidance is not possible then data recovery work is recommended to include in-fill shovel testing to better determine artifact densities followed by a series of 1x1m unit block excavations in relationship to the size and distribution of each site.	11-04ASR (Ecofor)	Mooney 2011
KdVf-14 (aka KdVf-1)	prehistoric	subsurface scatter (lithic) and possible spirit house and grave site	intact	Outside of the zone of impact of Freegold Project ROW.	Yes	Avoidance of the site is recommended. If this area is planned for any future impacts then additional efforts are recommended to confirm possible grave or spirit house locations with First Nation representatives	88-3ASR (Gotthardt); 11-04ASR (Ecofor); 13-07ASR (Ecofor)	Gotthardt 1988; Mooney 2011, 2013a
KdVf-12	prehistoric	subsurface scatter (lithic)	intact	This site will be directly impacted by the Freegold road construction.	Yes	Avoidance of the site is recommended. If avoidance is not possible then data recovery work is recommended to include in-fill shovel testing to better determine artifact densities followed by a series of 1x1m unit block excavations in relationship to the size and distribution of the site.	11-04ASR (Ecofor)	Mooney 2011

Borden Number or Temp Site #	Class	Features	Current Status of Site	Scope of Possible Impacts from Casino Project	Site Boundary Clearly Flagged	Management Recommendations and Proposed Mitigation Strategy	Report/ Permit number and Authors	Bibliographic Reference
KeVf-3	prehistoric	subsurface scatter (lithic)	intact	Inside the zone of impact of a proposed borrow pit.	Yes	If avoidance is not possible then data recovery work under is recommended. Data recovery should include additional shovel testing to better determine artifact distribution and density followed by separate loci of 1 x 1 m block excavation. Approximately 20 – 28 square meters of excavation would be recommended.	13-07ASR (Ecofor)	Mooney 2013a
KeVg-5	prehistoric	subsurface scatter (lithic)	intact	This site will be directly impacted by road construction.	Yes	Avoidance of the site is recommended. If avoidance is not possible then data recovery work is recommended.	11-04ASR (Ecofor)	Mooney 2011
KeVg-4	prehistoric	subsurface scatter (lithic and bone)	intact	This site may be directly impacted by road construction.	Yes	Avoidance of the site is recommended. If avoidance is not possible then data recovery work under is recommended.	11-04ASR (Ecofor)	Mooney 2011
KeVg-9	prehistoric	subsurface scatter (lithic)	intact	Inside the zone of impact of the Freegold Road extension.	Yes	If avoidance is not possible then data recovery work under is recommended. Data recovery should include additional shovel testing to determine artifact distribution and density followed by 1 x 1 m block excavation. Approximately 8 - 10 square meters of excavation would be recommended.	13-07ASR (Ecofor)	Mooney 2013a
KeVg-7	prehistoric	subsurface scatter (lithic)	intact	Site may be impacted by road construction.	Yes	Avoidance of the site is recommended. If avoidance is not possible then data recovery work is recommended to include in-fill shovel testing to better determine artifact densities followed by a series of 1x1m unit block excavations in relationship to the size and distribution of the site.	11-04ASR (Ecofor)	Mooney 2011
KeVg-8	prehistoric	subsurface scatter (lithic isolate)	intact	Within Freegold Project proposed borrow pit.	Yes	None Recommended	13-07ASR (Ecofor)	Mooney 2013a

Borden Number or Temp Site #	Class	Features	Current Status of Site	Scope of Possible Impacts from Casino Project	Site Boundary Clearly Flagged	Management Recommendations and Proposed Mitigation Strategy	Report/ Permit number and Authors	Bibliographic Reference
KeVg-3	prehistoric	subsurface scatter (lithic)	intact	Within Freegold Project proposed borrow pit as of 2013 (previously not in planned impacts 2011).	No	Avoidance of the site is recommended. If avoidance is not possible then data recovery work is recommended to include in-fill shovel testing to better determine artifact densities followed by a series of 1x1m unit block excavations in relationship to the size and distribution of the site.	11-04ASR (Ecofor), 13-07ASR (Ecofor)	Mooney 2011, 2013
KeVg-6	prehistoric	subsurface scatter (lithic)	intact	Within Freegold Project proposed borrow pit as of 2013 (previously not in planned impacts 2011).	No	Avoidance of the site is recommended. If avoidance is not possible then data recovery work is recommended to include in-fill shovel testing to better determine artifact densities followed by a series of 1x1m unit block excavations in relationship to the size and distribution of the site.	11-04ASR (Ecofor), 13-07ASR (Ecofor)	Mooney 2011, 2013a
KeVh-3	prehistoric	subsurface scatter (lithic)	intact	This site will not be directly impacted.	Yes	Avoidance of the site is recommended. If avoidance is not possible then data recovery work is recommended to include in-fill shovel testing to better determine artifact densities followed by a series of 1x1m unit block excavations in relationship to the size and distribution of the site.	11-04ASR (Ecofor)	Mooney 2011
KeVh-4	prehistoric	subsurface scatter (lithic isolate)	intact	Within Freegold Project proposed borrow pit.	No	None Recommended	13-07ASR (Ecofor)	Mooney 2013a

Borden Number or Temp Site #	Class	Features	Current Status of Site	Scope of Possible Impacts from Casino Project	Site Boundary Clearly Flagged	Management Recommendations and Proposed Mitigation Strategy	Report/ Permit number and Authors	Bibliographic Reference
Archaeological Sites to be Managed Near Proposed Mine Site, Road to Yukon River, and Road to Proposed Airstrip								
KeVi-1	prehistoric	scatter (lithic) scatter (bone)	Destroyed (Soucey et al 2010a)	Supernatant pond area of Mine Site.	Yes	None Required (Handley et al 1994, Mooney 2013)	94-9ASR (Antiquus); 09-09ASR (Altamira); 13-07ASR (Ecofor)	Handly et al 1994 ; Mooney 2013a; Soucey et al 2010a
KeVi-2	prehistoric	scatter (lithic)	Destroyed (Soucey et al 2010a)	Supernatant pond area of Mine Site.	Yes	None Required (Handly et al 1994, Mooney 2013)	94-9ASR (Antiquus); 09-09ASR (Altamira); 13-07ASR (Ecofor)	Handly et al 1994; Mooney 2013; Soucey et al 2010a
KeVi-3	prehistoric	isolated lithic find	No Evidence of Site Remains	Mine Site Developments - within impact zone of Mine Site.	No - N/A	None Required (Mooney 2013)	94-9ASR (Antiquus); 09-09ASR (Altamira); 13-07ASR (Ecofor)	Handly et al 1994 ; Mooney 2013a; Soucey et al 2010a
KeVi-6	prehistoric	subsurface scatter (bone) subsurface scatter (lithic)	intact	Outside proposed project area.	Yes	No further work is recommended.	09-09ASR (Altamira); 13-06ASR (Altamira)	de Guzman et al 2014; Soucey et al 2010a
KeVi-12 Note: This Borden number was mistakenly assigned to two sites. This lithic site and an adze cut stump (Soucey et al 2010b). The stump is now part of Site KeVi-9 (Gotthardt personal communication 2014).	prehistoric	subsurface scatter (lithic) (Mooney 2011)	intact	Located within 50 m of the current proposed alignment of the road, not directly impacted.	Yes	Avoidance. The site appears to be within approximately 50 m the proposed access road to the airstrip. This site will not be directly impacted. No further work is recommended .	11-04ASR (Ecofor); 10-4ASR (Altamira)	Mooney 2011; Soucey et al 2010b
KeVi-13	prehistoric	subsurface scatter (lithic)	intact	Mine Site Developments	Yes	No further work is recommended.	13-07ASR (Ecofor)	Mooney 2013a

Borden Number or Temp Site #	Class	Features	Current Status of Site	Scope of Possible Impacts from Casino Project	Site Boundary Clearly Flagged	Management Recommendations and Proposed Mitigation Strategy	Report/ Permit number and Authors	Bibliographic Reference
KeVi-14	prehistoric	subsurface scatter (lithic)	intact	Mine Site Developments	Yes	Avoidance. If avoidance is not possible then data recovery work under is recommended. Data recovery should include additional shovel testing to better determine artifact distribution and density followed by 1 x 1 m block excavation. Approximately 4 - 6 square meters of excavation would be recommended.	13-07ASR (Ecofor)	Mooney 2013a
KeVi-15	prehistoric	subsurface scatter (lithic)	intact	Mine Site Developments	Yes	Avoidance. If avoidance is not possible then data recovery work under is recommended. Data recovery should include additional shovel testing to better determine artifact distribution and density followed by 1 x 1 m block excavation. Approximately 4 - 6 square meters of excavation would be recommended.	13-07ASR (Ecofor)	Mooney 2013
KdVi-1	prehistoric	surface and subsurface scatter (lithic)	intact - abundance and density of the remains appears low	Near Proposed Borrow Pit west of road to Proposed Airstrip.	Yes	Avoidance if possible. If not possible, then further excavation (up to 20 1-x-1 m units) at KdVi-1 is recommended (de Guzman et al 2014).	94-9ASR (Antiquus) 09-09ASR (Altamira); 13-06ASR (Altamira); 13-07ASR (Ecofor); 13-06ASR (Altamira)	de Guzman et al 2014; Handly et al 1994; Mooney 2013; Soucey et al 2010a; de Guzman 2014
KdVi-2	prehistoric	subsurface scatter (lithic)	intact	Within a proposed borrow pit.	Yes	Avoidance. If avoidance is not possible then data recovery work under is recommended. Data recovery should include additional shovel testing to better determine artifact distribution and density followed by separate loci of 1 x 1 m block excavation. Approximately 20 - 28 square meters of excavation would be recommended.	13-07ASR (Ecofor)	Mooney 2013a

Borden Number or Temp Site #	Class	Features	Current Status of Site	Scope of Possible Impacts from Casino Project	Site Boundary Clearly Flagged	Management Recommendations and Proposed Mitigation Strategy	Report/ Permit number and Authors	Bibliographic Reference
KdVi-3	prehistoric	subsurface scatter (lithic)	intact	Within a proposed borrow pit.	Yes	Avoidance. If avoidance is not possible then data recovery work under is recommended. Data recovery should include additional shovel testing to better determine artifact distribution and density followed by 1 x 1 m block excavation. Approximately 4 - 6 square meters of excavation would be recommended.	13-07ASR (Ecofor)	Mooney 2013a
KdVi-4	prehistoric	subsurface scatter (lithic)	intact	Within a proposed borrow pit.	Yes	Avoidance. If avoidance is not possible then data recovery work under is recommended. Data recovery should include additional shovel testing to better determine artifact distribution and density followed by 1 x 1 m block excavation. Approximately 8 - 10 square meters of excavation would be recommended.	13-07ASR (Ecofor)	Mooney 2013a
KdVi-5	prehistoric	subsurface scatter (lithic)	intact	Within a proposed borrow pit.	Yes	Avoidance. If avoidance is not possible then data recovery work under is recommended. Data recovery should include additional shovel testing to better determine artifact distribution and density followed by 1 x 1 m block excavation. Approximately 6 - 8 square meters of excavation would be recommended.	13-07ASR (Ecofor)	Mooney 2013a
KfVi-2	undetermined	subsurface hearth scatter (bone) scatter (fire cracked rock)	intact	Outside of the proposed project area.	Yes	No further work is recommended.	09-09ASR (Altamira); 13-06ASR (Altamira)	de Guzman et al 2014; Soucey et al 2010a

Borden Number or Temp Site #	Class	Features	Current Status of Site	Scope of Possible Impacts from Casino Project	Site Boundary Clearly Flagged	Management Recommendations and Proposed Mitigation Strategy	Report/ Permit number and Authors	Bibliographic Reference
KfVi-3	historic/prehistoric	house (building, outline) scatter (lithic)	intact	No planned impacts for this site.	Yes	Continued avoidance of KfVi-3 is recommended. If avoidance is not feasible, Stage 1 excavations of at least a 15% sample are recommended at KfVi-3; this would entail hand excavation of an additional 190 1-x-1 m units. If artifact recovery is limited, excavation could be halted upon discussion with the Heritage Resources Unit.	09-09ASR (Altamira); 13-06ASR (Altamira)	de Guzman et al 2014; Soucey et al 2010a
KfVi-4	prehistoric	subsurface scatter (bone) subsurface scatter (lithic)	intact	No planned impacts for this site.	Yes	No further work recommended.	09-09ASR (Altamira); 13-06ASR (Altamira)	de Guzman et al 2014; Soucey et al 2010a
KfVi-5	prehistoric	scatter (lithic)	Data Recovery Completed by Ecofor(13-18ASR)	No further planned Impacts.	Yes	Avoidance	09-09ASR (Altamira); 13-07ASR (Ecofor); 13-18ASR(Ecofor); 13-06ASR(Altamira)	de Guzman et al 2014; Mooney 2013a; Mooney 2014, Soucey et al 2010a

Borden Number or Temp Site #	Class	Features	Current Status of Site	Scope of Possible Impacts from Casino Project	Site Boundary Clearly Flagged	Management Recommendations and Proposed Mitigation Strategy	Report/ Permit number and Authors	Bibliographic Reference
Historic Structures and Resources to be Managed Along Proposed Freegold Road Upgrades								
H1: Whitehorse-Dawson Winter Road	historic	overland stage coach route	good	Outside of proposed ROW impact zone.	No - N/A	None Required	94-22ASR (Antiquus)	Handly and Rousseau 1995
H2: Log structure	historic	log structure	good	No impact due to road realignment around Carmacks.	No	Avoidance. Consultation between Community, Village of Carmacks, Community and Transportation Service prior to Project to determine historical significance and appropriate mitigation procedure.	94-22ASR (Antiquus)	Handly and Rousseau 1995
H3: Mink/Fox Fur Farm	historic	metal cages and burnt wood	highly disturbed	No impact due to road realignment around Carmacks.	No - N/A	None Required	94-22ASR (Antiquus)	Handly and Rousseau 1995
H4: Dalton Trail	historic	road/trail	disturbed	Outside of proposed ROW impact zone.	No - N/A	None Required	94-22ASR (Antiquus)	Handly and Rousseau 1995
H5: Place Mine Trench	historic	trench and sluice box	disturbed	Outside of proposed ROW impact zone.	No - N/A	None Required	94-22ASR (Antiquus)	Handly and Rousseau 1995
H6: Morrison Road House	historic	log structures	highly disturbed	Outside of proposed ROW impact zone.	No - N/A	None Required	94-22ASR (Antiquus)	Handly and Rousseau 1995
Tricker Cabin	historic cabin	log structure	unknown	Approximately 20 m south of proposed road realignment.	No	Avoidance. No further work is recommended.	95-1ASR (Yukon Govt)	Gotthardt 1995
Fallen Cache Cabin (YHSI 115I/03/002)	historic	cabin and two log pit features	poor	Within the proposed road realignment.	Yes	If these resources are not avoided then additional documentation is recommended prior to construction impacts. This should include additional on-site recording including site mapping and photodocumentationand interviews with First Nation informants and other stakeholders to better document the history and use of the structures.	13-07ASR (Ecofor)	Mooney 2013a

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Dog House Cabin (YHSI 115I/06/012)	historic	cabin	poor - mostly collapsed	Within the proposed road realignment.	Yes	If these resources are not avoided then additional documentation is recommended prior to construction impacts. This should include additional on-site recording including site mapping and photodocumentationand interviews with First Nation informants and other stakeholders to better document the history and use of the structures.	13-07ASR (Ecofor)	Mooney 2013a
Gas Can Cabin (YHSI 115I/06/010)	historic	cabin	Fair to Good	Within the proposed road realignment.	Yes	If these resources are not avoided then additional documentation is recommended prior to construction impacts. This should include additional on-site recording including site mapping and photodocumentationand interviews with First Nation informants and other stakeholders to better document the history and use of the structures.	13-07ASR (Ecofor)	Mooney 2013a
Melmac Cabin (YHSI 115I/06/011)	historic	cabin	poor - mostly collapsed	Within the proposed road realignment.	Yes	If these resources are not avoided then additional documentation is recommended prior to construction impacts. This should include additional on-site recording including site mapping and photodocumentationand interviews with First Nation informants and other stakeholders to better document the history and use of the structures.	13-07ASR (Ecofor)	Mooney 2013a

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Ketchup Cabin (YHSI 115I/06/009)	historic	cabin	poor - mostly collapsed	Within the proposed road realignment.	Yes	If these resources are not avoided then additional documentation is recommended prior to construction impacts. This should include additional on-site recording including site mapping and photodocumentationand interviews with First Nation informants and other stakeholders to better document the history and use of the structures.	13-07ASR (Ecofor)	Mooney 2013a
Three Room Cabin (YHSI 115J/06/013)	historic	cabin	good	Within the proposed road realignment.	Yes	If these resources are not avoided then additional documentation is recommended prior to construction impacts. This should include additional on-site recording including site mapping and photodocumentationand interviews with First Nation informants and other stakeholders to better document the history and use of the structures.	13-07ASR (Ecofor)	Mooney 2013a
Frenchman Cabin (YHSI 115I/06/005)	historic	cabin	intact	Near planned road construction but may not be impacted.	Yes	Avoidance and if not possible, relocation of structure.	11-04ASR (Ecofor)	Mooney 2011
Bow Creek Cabins	historic	three cabins	intact	Near planned road construction and borrow pit but may not be impacted.	Yes	Avoidance and if not possible, relocation of structures.	11-04ASR (Ecofor)	Mooney 2011
KcVd-2	historic cabin		unknown	None	No	None required.	88-3ASR (Gotthardt); 11-04ASR (Ecofor)	Gotthardt 1988; Mooney 2011, 2013a
KcVd-1	historic cabin		unknown	None	No	None required.	88-3ASR (Gotthardt); 11-04ASR (Ecofor)	Gotthardt 1988; Mooney 2011, 2013a
Five Course Cabin (YHSI 115I/06/001)	historic	cabin	intact	Near planned road construction but should not be impacted.	Yes	If these resources are not avoided then a limited amount of additional documentation is recommended prior to construction impacts.	11-04ASR (Ecofor)	Mooney 2011

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Garage by Big Creek	historic	cabin	intact	Near planned road construction but should not be impacted.	Yes	If these resources are not avoided then a limited amount of additional documentation is recommended prior to construction impacts.	11-04ASR (Ecofor)	Mooney 2011
High Cache Cabin	historic	cabin	intact	Near planned road construction but should not be impacted.	Yes	If these resources are not avoided then a limited amount of additional documentation is recommended prior to construction impacts, or possible relocation of structure.	11-04ASR (Ecofor)	Mooney 2011
Burl Cabin	historic	cabin	intact	Near planned road construction but should not be impacted.	Yes	If these resources are not avoided then a limited amount of additional documentation is recommended prior to construction impacts, or possible relocation of structure.	11-04ASR (Ecofor)	Mooney 2011
KcVe-3	historic/prehistoric	brush camp and possible grave site	unknown	None	No	No further work required.	88-3ASR (Gotthardt);	Gotthardt 1988
KcVe-1	possible grave		unknown	None	no	Avoidance of area	88-3ASR (Gotthardt);	Gotthardt 1988
KcVe-2	historic cabin		unknown	None	no	Avoidance of area.	88-3ASR (Gotthardt);	Gotthardt 1988
KdVf-3	historic	cabin	unknown	May be located near proposed borrow pit of borrow pit access road.	No	This cabin is recommended to be relocated and flagged for avoidance. If avoidance of possible borrow pit or access road is not feasible then additional documentation is recommended.	11-04ASR (Gotthardt); Mooney 2013 (Ecofor)	Gotthardt 1988; Mooney 2013
KdVf-2	historic	possible cache or cabin	unknown	Outside of the zone of impact of Freegold Project ROW.	No	No further work required.	88-3ASR (Gotthardt); 11-04ASR (Ecofor)	Gotthardt 1988; Mooney 2013a

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Steamers/Upright Boilers Site (YHSI 115J/09/002)	historic	boilers, pits, ladders	intact	Within the proposed alignment of Freegold Road (2013) previously listed within a proposed borrow pit (2011).	Yes	Avoidance and if not possible, relocation of resources where possible and additional documentation.	11-04ASR (Ecofor)	Mooney 2011
KeVg-1 (see YHSI 115J/09/001) AKA Hayes Creek Cabins	historic	two cabins & cache and trail AY09-19	poor	Outside of the zone of impact of Freegold Project ROW.	Yes	Avoidance. No further work is recommended. If planned impacts change then additional documentation.	09-09ASR (Altamira); 11-04ASR (Ecofor); 13-07ASR (Ecofor)	Mooney 2011; Soucey et al 2010a; Mooney 2013
AY09-19	ethnohistoric	trail	intact	Portions within Freegold Road ROW.	Yes - white CMT flagging	Impacts to the previously recorded ethno-historic trails are recommended to be avoided and/or minimized where possible. If impacts to these ethno-historic trails can't be avoided then additional background research, on-site recording, and informant interviews to document use of the trails is recommended.	09-09ASR (Altamira); 13-07ASR (Ecofor)	Mooney 2013a; Soucey et al 2010a
AY09-18	ethnohistoric	trail	intact	Portions within Freegold Road ROW.	Yes - white CMT flagging	Impacts to the previously recorded ethno-historic trails are recommended to be avoided and/or minimized where possible. If impacts to these ethno-historic trails can't be avoided then additional background research, on-site recording, and informant interviews to document use of the trails is recommended.	09-09ASR (Altamira); 13-07ASR (Ecofor)	Mooney 2013a; Soucey et al 2010a
KeVg-2	historic	adze-cut stump	intact	Outside of the zone of impact of Freegold Project ROW.	No	None Recommended	09-09ASR (Altamira); 13-07ASR (Ecofor)	Mooney 2013a; Soucey et al 2010b

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Historic Structures and Resources to be Managed Near the Proposed Mine Site, Road to the Yukon River, and Road to Proposed Airstrip								
KeVi-4	historic	cabin remains	partially collapsed	Within Tailings Management Facility. Mine Site Developments - within impact zone of Heap Leach Site #1.	Yes general area flagged	Additional survey and data collection is warranted to determine the age and ownership of the cabin (Soucey et al 2010a). Handly et al (1994) say avoidance if possible otherwise, no further work is recommended.	94-9ASR (Antiquus); 09-09ASR (Altamira); 13-07ASR (Ecofor)	Handly et al 1994; Mooney 2013a; Soucey et al 2010a
KeVi-5	historic	cabin remains	partially collapsed	Within Tailings Management Facility.	Yes	If site disturbance is likely to occur, it is recommended that additional research and test excavation be carried out (cabin is pre-1936) (Soucey et al 2010a). Handly et al (1994) recommend the site be avoided but if not feasible then no further work is recommended.	94-9ASR (Antiquus); 09-09ASR (Altamira)	Handly et al 1994; Soucey et al 2010a
KeVi-7	historic	cabin (log) depression	intact	No planned impacts for this site.	Yes	Avoidance. Additional testing at the site is recommended to augment the current knowledge of its placement and use within the Historic Time Period.	09-09ASR (Altamira)	Soucey et al 2010a
KeVi-8	historic	cabin (foundation)	partially collapsed	Mine Site Developments - possible impact.	Yes	Avoidance. If site disturbance is likely to occur, it is recommended that additional research and test excavation be carried out.	09-09ASR (Altamira)	Soucey et al 2010a
KeVi-9	indigenous historic	Culturally Modified Tree (knot); and possible adze cut stump formerly recorded by Altamira as KeVi-12 (Gotthardt personal communication 2014).	intact	No planned impacts for this site.	Yes	Avoidance. If site disturbance is likely to occur, additional consideration and research is warranted. Further consultation and research with local informants could provide additional information about the site and its association with an existing trail.	09-09ASR (Altamira); 11-04ASR (Ecofor); 10-4ASR (Altamira)	Soucey et al 2010a; Mooney 2011; Soucey et al 2010b

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KeVi-10	indigenous historic	platform or hunting blind	collapsed	No planned impacts for this site.	Yes	Avoidance. If site disturbance is likely to occur, additional consideration and research is warranted. Further consultation and research with local informants could provide additional information about the site and its association with an existing trail.	09-09ASR (Altamira)	Soucey et al 2010a
KeVi-11	indigenous historic	hide working rack	disturbed	Outside of zone of impact.	Yes	Avoidance. If site disturbance is likely to occur, additional consideration and research is warranted to determine site value.	09-09ASR (Altamira)	Soucey et al 2010a
KfVi-6	historic	cabin/depression/ dump/scatter (metal)	intact	No planned impacts for this site.	Yes	Avoidance. Additional investigation is warranted for this historic era site.	09-09ASR (Altamira); 10-4ASR (Altamira)	Soucey et al 2010a; Soucey et al 2010b
KfVi-7	indigenous historic	isolated find - bone tool	intact	No planned impacts for this site.	Yes	Avoidance. Additional investigation is warranted for this historic era site.	09-09ASR (Altamira); 10-4ASR (Altamira)	Soucey et al 2010a; Soucey et al 2010b
KfVi-8	historic	tent frame (log)	intact	No planned impacts for this site.	Yes	Avoidance. Additional consideration and research is warranted to determine site value and specific mitigation options.	09-09ASR (Altamira)	Soucey et al 2010a
KfVi-9	historic	partially buried wooden object	intact	No planned impacts for this site.	Yes	Avoidance. Additional consideration and research is warranted to determine site value and specific mitigation options.	09-09ASR (Altamira); 10-4ASR (Altamira)	Soucey et al 2010a; Soucey et al 2010b
KfVi-10	indigenous historic	hide working frame	intact	No planned impacts for this site.	Yes	Avoidance. Additional consideration and research could be undertaken to determine its value in terms of ownership and relationship to other sites or cultural activities in the area.	09-09ASR (Altamira); 10-4ASR (Altamira)	Soucey et al 2010a; Soucey et al 2010b

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KfVi-11	indigenous historic	Hide working stump and pole	intact	No planned impacts for this site.	Yes	Avoidance. Additional consideration and research is warranted to determine its value in terms of ownership and relationship to other sites or cultural activities in the area.	09-09ASR (Altamira)	Soucey et al 2010a
KfVi-12	indigenous historic	Culturally Modified Tree (bark stripping)	intact	No planned impacts for this site.	Yes	Avoidance. Further Consultation and Research.	10-4ASR (Altamira)	Soucey et al 2010b
KfVi-13	indigenous historic	Culturally Modified Tree (bark stripping)	intact	No planned impacts for this site.	Yes	Avoidance. Further Consultation and Research.	10-4ASR (Altamira)	Soucey et al 2010b
KfVi-14	indigenous historic	Culturally Modified Tree (bark stripping)	intact	No planned impacts for this site.	Yes	Avoidance. Further Consultation and Research.	10-4ASR (Altamira)	Soucey et al 2010b

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Previoulsy Noted First Nation Use Sites along the Proposed Upgrades to Freegold Road								
FN 1	indigenous historic	Brush Camp	unknown	No planned impacts for this site.	No	Keep access to area from old Freegold Road.	94-22ASR (Antiquus)	Handly and Rousseau 1995
FN 2	indigenous historic	natural spring	previously impacted	Adjacent to proposed ROW.	No	Keep access to area from old Freegold Road.	94-22ASR (Antiquus)	Handly and Rousseau 1995
FN 3	indigenous historic	trail	unknown	No planned impacts for this site.	No	Keep access to area from old Freegold Road.	94-22ASR (Antiquus)	Handly and Rousseau 1995
FN 4	indigenous historic	Caribou lookout	unknown	May be within a proposed borrow pit	No	Requires Heritage Assessment if in possible borrow pit	94-22ASR (Antiquus)	Handly and Rousseau 1995
FN 5	indigenous historic	fish camp	unknown	No planned impacts for this site.	No	Keep access to area.	94-22ASR (Antiquus)	Handly and Rousseau 1995
FN 6	indigenous historic	fish camp	unknown	None	No	Keep access to area.	94-22ASR (Antiquus)	Handly and Rousseau 1995
FN 7	indigenous historic	trail	unknown	Outside area of impact.	No	Keep access to area.	94-22ASR (Antiquus)	Handly and Rousseau 1995
FN 8	indigenous historic	hunting and trapping camp	unknown	Outside area of impact.	No	We strongly recommend that the First Nation traditional cultural material remaining at this site be systematically collected by representatives of the LSCFN prior to construction of the proposed Freegold Road.	94-22ASR (Antiquus)	Handly and Rousseau 1995
FN 9	indigenous historic	bush camp	previously impacted	Adjacent to proposed ROW.	No	No further work recommended.	94-22ASR (Antiquus)	Handly and Rousseau 1995
FN 10	indigenous historic	trappers camp	unknown	Adjacent to proposed ROW.	No	We strongly recommend that the First Nation traditional cultural material remaining at this site be systematically collected by representatives of the LSCFN prior to construction of the proposed Freegold Road (1995). Materials may no longer exist.	94-22ASR (Antiquus)	Handly and Rousseau 1995