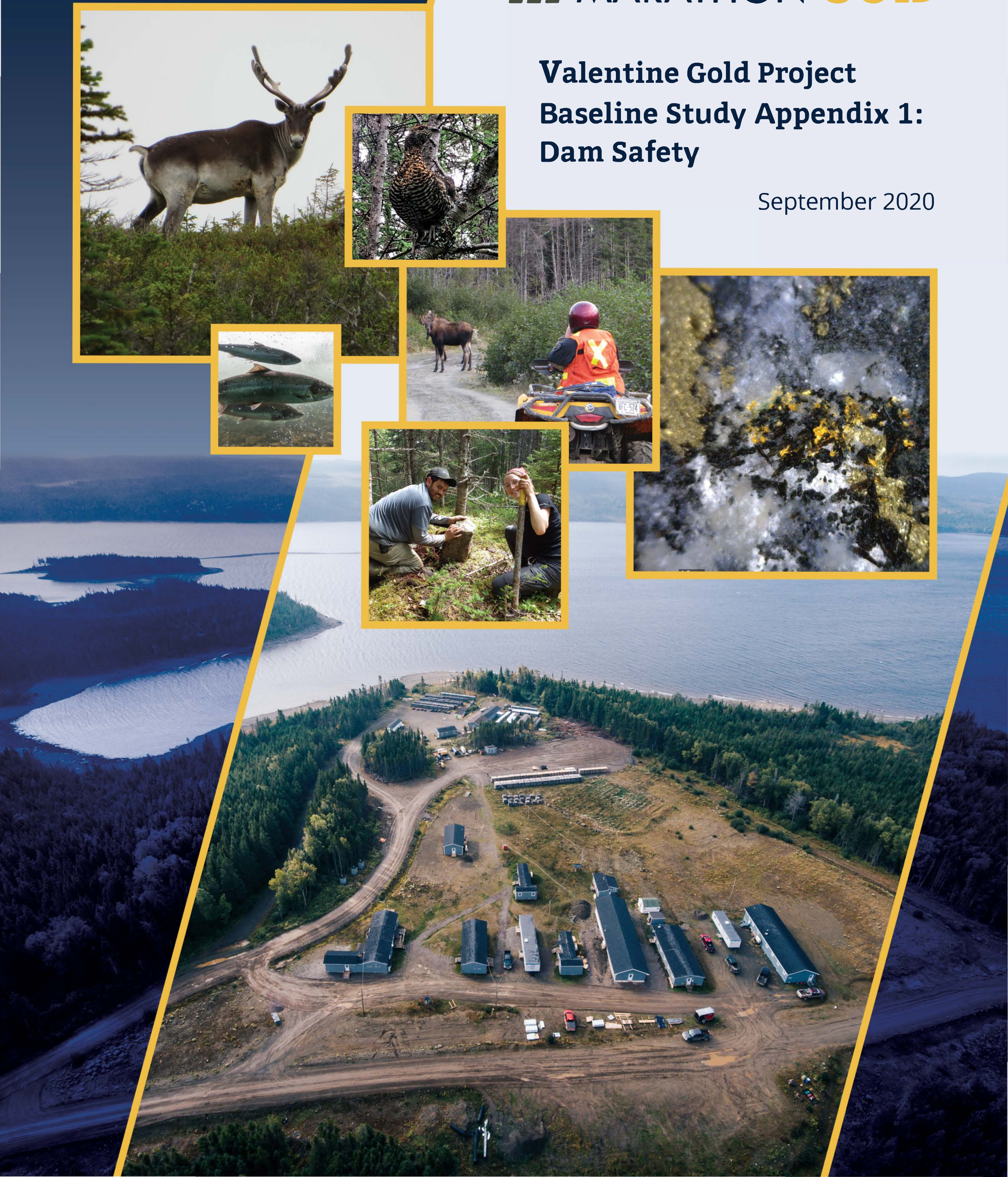
MARATHON GOLD

Valentine Gold Project Baseline Study Appendix 1: Dam Safety

September 2020



Valentine Gold Project
Environmental Impact Statement

Final Report

Baseline Study Appendix 1: Dam Safety (BSA.1)

Prepared for:

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September 25, 2020

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Abbreviations and Acronyms

ARD/ML	Acid Rock Drainage / Metal Leaching
BSA	Baseline Study Appendix
CCME	Canadian Council of Ministers of the Environment
EIS	Environmental Impact Statement
km	kilometre
Marathon	Marathon Gold Corporation
NL	Newfoundland and Labrador
NLDECCM	Newfoundland and Labrador Department of Environment, Climate Change and Municipalities
NLEPA	Newfoundland and Labrador *Environmental Protection Act*
PMF	Probable Maximum Flood
mm/s	millimetres per second
PPV	Peak Particle Velocity
SAR	Species At Risk
SOCC	Species Of Conservation Concern
Stantec	Stantec Consulting Inc.
TMF	Tailings Management Facility
VC	Valued Component

1.0 INTRODUCTION

Marathon Gold Corporation (Marathon) is planning to develop an open pit gold mine south of Valentine Lake, located in the Central Region of the Island of Newfoundland, approximately 60 kilometres (km) southwest of the town of Millertown, Newfoundland and Labrador (NL) (Figure 1-1). The Valentine Gold Project (the Project) will consist primarily of open pits, waste rock piles, crushing and stockpiling areas, conventional milling and processing facilities (the mill), a tailings management facility, personnel accommodations, and supporting infrastructure including roads, on-site power lines, buildings, and water and effluent management facilities. The mine site is accessed by an existing public access road that extends south from Millertown approximately 88 km to Marathon's existing exploration camp. Marathon will upgrade and maintain the access road from a turnoff approximately 8 km southwest of Millertown to the mine site, a distance of approximately 76 km.

The Minister of the Department of Environment, Climate Change and Municipalities (NLDECCM) has determined that the Project will require preparation of an Environmental Impact Statement (EIS) under the provincial *Environmental Protection Act* (NLEPA). The Provincial EIS Guidelines require the preparation of a number of baseline studies to describe and provide data on specific components of the environment; to address baseline data requirements to support the assessment of one or more Valued Components (VCs); and to support the development of mitigation measures and follow-up monitoring programs. Each has been prepared as a stand-alone Baseline Study Appendix (BSA) to the EIS:

- BSA.1: Dam Safety
- BSA.2: Woodland Caribou
- BSA.3: Water Resources
- BSA.4: Fish, Fish Habitat and Fisheries
- BSA.5: Acid Rock Drainage / Metal Leaching (ARD/ML)
- BSA.6: Atmospheric Environment
- BSA.7: Avifauna, Other Wildlife and Their Habitats
- BSA.8: Species at Risk / Species of Conservation Concern (SAR / SOCC)
- BSA.9: Community Health, Services and Infrastructure / Employment and Economy
- BSA.10: Historic Resources

Table 1.1 outlines the organization for BSA.1: Dam Safety.

Table 1.1 BSA.10: Dam Safety

Number	Baseline Study Appendix	Attachment Number	Attachment Name
BSA.1	Dam Safety	1-A	Dam Breach Assessment and Inundation Study – Valentine Gold Tailings Management Facility (2020)
		1-B	Dam Breach Assimilative Capacity Study for the Valentine Gold Tailings Management Facility (2020)
		1-C	Valentine Gold Project Blast Impact Assessment (2020)

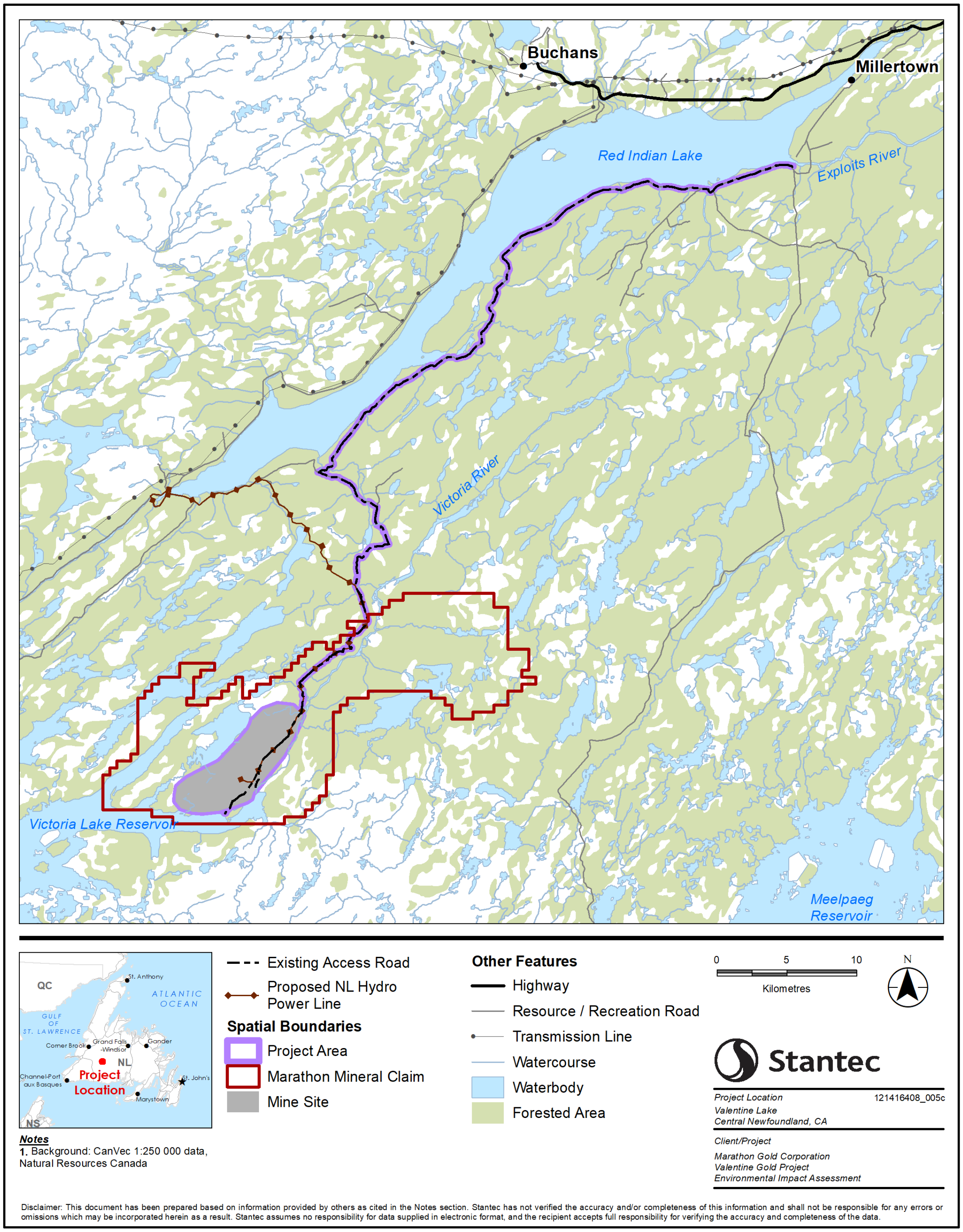

Figure 1-1 Project Area

Note that the BSAs consist of data reports that have been prepared for Marathon over several years (i.e., 2011 to 2020), during which the Project has gone through a series of refinements. The study areas and Project references in these data reports reflect the Project description at the time of preparation of these reports. The current Project description for the purposes of environmental assessment is found in Section 2 of the EIS.

2.0 SUMMARY OF DAM SAFETY BSA ATTACHMENTS

Three assessments were completed by Golder Associates Ltd. (Golder) in support of the assessment of dam safety for the Project. Table 2.1 provides a summary of the objectives, study areas, methods and results of each of these studies.

Table 2.1 Summary of Dam Safety BSA Attachments

Rationale / Objectives and Study Area	Methods	Results
Attachment 1-A - Dam Breach Assessment and Inundation Study – Valentine Gold Tailings Management Facility (2020)		
Objectives – The assessment of the flooding impacts of a dam breach included the following objectives: • Review of various dam failure mechanisms and determine the plausible failure scenarios • Estimate the volume of tailings and water released from a dam breach • Determine the areal extent of the flooding impact in the event of a dam failure • Determine peak flood wave water levels resulting from the hypothetical dam failure **Study Area** – The Study Area was the Victoria River from the downstream toe of Victoria Dam to 1 km upstream of the inlet of Red Indian Lake (Figure 1-1).	The numerical modelling in support of the dam breach analysis included: • Breach Parameters – estimation of the breach formation parameters (e.g., geometry, development time) to be used in the hydrologic model • Hydrologic Modelling – estimation of the pond's release volumes and breach outflow hydrographs • Flood Routing – estimation of the movement of the peak flood wave along the downstream path	The assessment found that: • For the Tailings Management Facility (TMF) East / South Dam under fair-weather conditions, the most plausible mode of failure is piping • Under the probable maximum flood (PMF) conditions, the assumed mode of failure is piping for the TMF East and South Dams, as higher breach outflows were predicted compared to the overtopping failure mode • Under both the fair-weather and PMF conditions for the TMF East Dam failure, the polishing pond containment volume was incorporated into the release volume • Under both the fair-weather and PMF conditions, the breach outflow hydrograph undergoes substantial attenuation within the first 2 km (> 60%) • The incremental impact of the breach of the TMF East Dam under PMF conditions is not significant as the runoff volume generated by the PMF storm is substantially larger. The incremental impact of the breach of the TMF East Dam is negligible with respect to dwellings and major crossings such as Crossing 2 • A breach failure of the TMP South Dam will release the impounded water and tailings towards Victoria River, where the flood wave will propagate both upstream as well as downstream. While the upstream flood wave propagation will reach the downstream toe of Victoria Dam, its impact on the structure is unlikely. • No potential loss of life or critical infrastructure is anticipated due to the breach failure of the TMF East and South Dams under fair-weather conditions or incrementally under the PMF scenario. • The tailings runout analysis conducted for the TMF West Dam failure predicted that the tailings will runout eastwards towards the Victoria River, and will impact the process plant and any personnel within the runout path. It is likely, however, that the downstream toe of the TMF South Dam will not be impacted due to tailings runout.

Table 2.1 Summary of Dam Safety BSA Attachments

Rationale / Objectives and Study Area	Methods	Results
Attachment 1-B - Dam Breach Assimilative Capacity Study for the Valentine Gold Tailings Management Facility (2020)		
Objectives – The overall objective of this analysis was to assess the water quality impacts downstream of the TMF and polishing pond in the event of a failure. The results were used to confirm hazard classification for the TMF dams and to provide information crucial for effective emergency preparedness planning. **Study Area** –The Study Area was the Victoria River from the downstream toe of Victoria Dam to 1 km upstream of the inlet of Red Indian Lake (Figure 1-1).	The approach for the assimilative capacity study included generating estimates of water quality resulting from dam failure using a mass-conservative spreadsheet model that evaluated resultant water quality for two scenarios: the fair-weather ("sunny day") conditions and a PMP event. The breach was assumed to occur at the TMF East Dam with piping as the breach failure mechanism as these conditions result in the maximum release of water from the TMF.	A hypothetical failure of the TMF East Dam would release the impounded water and suspended tailings into Victoria River and would ultimately reach Red Indian Lake. This would have the potential to result in adverse environmental effects to aquatic life as a result of increased concentrations of dissolved constituents. The duration of a dam breach event into a river system would be short (e.g., less than a day), for which acute water quality guidelines (i.e., Canadian Council of Ministers of the Environment [CCME] Acute guidelines) are appropriate. For Red Indian Lake, the appropriate guidelines differ depending on flow conditions. During low flow conditions, the CCME Chronic guidelines would be more applicable due to the longer retention time of the lake during low flow conditions. However, during high flow events (e.g., spring freshet), the CCME Acute guidelines would be more applicable due to the increased flow rates. Short-duration concentrations of up to ten constituents are anticipated to be greater than CCME Chronic guidelines at one or more locations in Victoria River. No concentrations greater than CCME Acute guidelines are anticipated for parameters with acute exposure criteria. The magnitude of concentrations is typically greater closer to the breach and in the fair-weather scenario. Duration of concentrations greater than applicable criteria is typically greater further from the breach, due to attenuation of peak flow rates over distance. The modeled conditions are considered to be fully reversible over a relatively short period of time once all inundated areas have returned to ambient water levels. The modeled water chemistry in Victoria River is not anticipated to result in adverse environmental effects, subject to confirmation that TMF water does not present the potential for acute toxicity. In Red Indian Lake, there is the potential for chromic toxicity as a result of a dam breach. Confirmation of mixing zone volume would provide verification and greater assurance as to the duration of concentrations greater than chronic exposure criteria.

Table 2.1 Summary of Dam Safety BSA Attachments

Rationale / Objectives and Study Area	Methods	Results
Attachment 1-C - Valentine Gold Project Blast Impact Assessment (2020)		
Objective – Determine if open pit blasting could impact the stability of the Victoria Dam or the Project TMF. **Study Area** – The Study Area was the Project Area (Figure 1-1) and surrounding area.	The effect of blasting was assessed by modelling the potential blast vibrations including ground vibrations (measured as Peak Particle Velocity [PPV]). The model included several variables including blast parameters (e.g., delay timing, type of explosive), topography of the site, distance from the blast source, maximum explosive charge, and characteristics of the in situ material (bedrock and/or soil materials). Modelling was completed for both the Leprechaun and Marathon pits.	The blast-induced vibrations predicted for the Victoria Dam and the TMF are well below the assumed limits. The maximum estimated PPV levels for the proposed mine blasts are: 1.14 mm/s at the TMF (at a minimum separation distance of 1,100 m from the Marathon pit), and 0.16 mm/s at the Victoria Dam (at a minimum separation distance of 3,740 m from the Leprechaun pit). PPV levels are likely to change due to changes in the mine plan and blast design, and with recommended calibration of the vibration attenuation model. While a PPV of 50 mm/s is considered an appropriate limit for the toe of the embankment of the TMF and Victoria Dam, a trigger point of 35 mm/s (70% of the recommended threshold) should be considered as the ground vibration level at which the potential blast impacts are to be reassessed. Due to the inherent variability in site specific conditions, caution must be exercised when assessing the potential damage from blast-induced vibration. Actual vibrations will need to be monitored during the ongoing blasting operations. The potential blast impacts should be reassessed prior to implementing considerable changes to the mine design, blast design, TMF location, or TMF embankment design.

ATTACHMENT 1-A

Dam Breach Assessment and Inundation Study – Valentine Gold Tailings Management Facility (2020)

GOLDER

REPORT

Dam Breach Assessment and Inundation Study

Valentine Gold Tailings Management Facility

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04 August 2020

Distribution List

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FIGURES

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by Marathon Gold Corp. (Marathon) to complete a dam breach and inundation assessment for the proposed Tailings Management Facility (TMF) for the proposed Valentine Gold Project. The TMF perimeter dam if breached has the potential to affect the downstream environment. The analysis and results are documented in this report.

2.0 SITE DESCRIPTION

The proposed Valentine Gold Project is located approximately 57 km south of Buchans, 340 km northwest of St John's and within the Central Uplands of Newfoundland as shown in Figure 1. The mine is accessed by a 73 km long, well-maintained gravel road from Millertown to the northeast of the site. The site is situated amidst gentle to moderately steep, hilly terrain and the ground surface elevation ranges from approximately 320 m to 480 m above sea level (masl). A distinct northeast trending ridge occurs along the length of the property. The ground cover consists of a mixture of boggy ground, spruce and fir forests, and grassy clearings with many small ponds and streams. Victoria Lake is located south of the site and is contained by Victoria Dam which is a hydroelectric reservoir. Valentine Lake lies north of the site. Below are background data governing site operations:

- Life of mine: 12 years
- Mill throughput: Ramps up from 1.875 Mtpa in Year 1 to 4.0 Mtpa in Year 5
- Total tonnage of tailings produced: 40.68 million tonnes
- Mining method: Open Pit
- Disposal method: Thickened tailings, sub-aerial
- Tailings disposal location: Year 1 to 9 TMF, Year 10 to 12 Leprechaun Pit
- Total tonnage of tailings to TMF: 30.13 million tonnes
- Tailings specific gravity: 2.68
- Tailings discharge solids content: 65% (by mass)

The proposed Valentine Gold Project containment facilities consist of a TMF for tailings storage and a Polishing Pond for water management and effluent polishing. Figure 2 and Figure 3 show the general arrangements of the overall site plan and TMF's for the Ultimate Stage (Year 9). Table 1 shows the catchments areas of the proposed Valentine Gold Project site facilities (Golder 2020a). The ponds are described below.

Table 1: Site Drainage Areas (Golder 2020a)

Site Facility	Collecting Area (ha)	Surface Type	Collecting Area (ha)
Tailings Storage Facility	223	Natural Ground	22
		Prepared Ground	22
		Pond and wet tailings	100
		Dry tailings beach	78
Leprechaun Pit	54	Prepared Ground	11
		Pond and wet tailings	24
		Dry tailings beach	19
Polishing Pond	5	Pond	5
Total	**282**		

2.1 Tailings Management Facility (TMF)

The proposed TMF dam is a downstream raised rockfill embankment with upstream filter zones and an inclined HDPE liner as a seepage barrier. The TMF is bound by embankments on west, south and east faces. Throughout the operating period, tailings deposition will occur on the north and west side of the TMF with the tailings pond maintained on the eastern side of the facility. The foundation beneath the containment facility is granular till and/or bedrock. The TMF's crest elevation varies between 408.3 masl at the western portion of the dam and 390.5 masl at the northeast portion. Downstream and upstream slopes are 2 horizontal (H): 1 vertical (V) and 3H:1V, respectively.

The emergency spillway, located on the northeastern abutment of the dam, is an open cut channel with an invert elevation of 389.5 masl and a width of 6 m at the spillway channel inlet. The TMF collects runoff and process water. Water is reclaimed from the tailings pond for processing. Excess water is treated in a water treatment plant and Polishing Pond prior to discharge to the environment.

The maximum operating water level in the TMF is 1 m below the spillway invert, providing sufficient storage for the Environmental Design Flood (EDF). Under the inflow design flood (IDF) scenario, which has been selected as the flood generated under the probable maximum precipitation (PMP), it is assumed that the mill will remain operational and tailings slurry and reclaim water pumping will continue. The maximum water surface elevation in the TMF under the PMP is 390.3 masl prior to closure when the tailings pond surface area is smallest. It is assumed that the pond would be full to the spillway invert prior to the PMP event.

The main characteristics of the TMF dams and dykes is summarized in Table 2.

Table 2: Tailings Management Facility Perimeter Dam Characteristics – Ultimate Stage

Dam Characteristic	East Dam[1]	South Dam	West Dam
Dam Design Section	Downstream raised rockfill embankment with upstream filter zones		
Crest Elevation at Breach Location (masl) [2]	390.5		404.0
Dam Crest Length (m)[3]	3,325		
Dam Crest Width (m)	10		
Elevation of Dam Foundation (m)	342.0	353.0	384.0
Maximum Dam Height Above Foundation (m)	48.5	37.5	20.0
Overall Downstream Dam Side Slope (H:V)	2H:1V		
Overall Upstream Dam Side Slope (H:V)	3.5H:1V[4]		
Maximum Tailings Elevation (masl)	416.0[5]		
Spillway Invert (masl)	389.5		
Maximum Operating Water Level (masl)	388.5		
Probable Maximum Flood Level (masl)	390.3		

Notes:

1) Tailings pond accumulates on eastern side of the facility
2) Crest elevation ranges from 390.5 masl to 408.3 masl. The values presented in the table are the approximate crest elevation at the selected breach location.
3) Corresponds to the length of the entire perimeter
4) Intermediate slope (between benches) is 3H:1V
5) Highest tailings elevation is at the northside of the TMF

The TMF will be constructed in stages, with the ultimate dam lift occurring in Year 7, and operated in Years 8 and 9. The analysis was carried out for the maximum tailings dam section prior to closure to assess the maximum potential impacts of downstream inundation. Following the lowering of the tailings pond at closure, the potential impacts of dam breach will be less. Consequently, the Ultimate Stage was the selected setup upon which the breach analysis was conducted from two points-of-view: the volume of impounded water at the tailings pond and the volume of tailings against the TMF West Dam.

2.2 Polishing Pond

The Polishing Pond is located downstream of the TMF and has a footprint area of 4.1 hectares and has an operational capacity of 44,000 m^3. The pond is lined with a geomembrane, similar to the upstream slope of the TMF embankment. A failure of the TMF East Dam is assumed to cause a complete washout of the Polishing Pond.

3.0 OBJECTIVES OF DAM BREACH ANALYSIS

The overall objective of this analysis is to assess the flooding impacts downstream of the TMF and Polishing Pond in the event of a failure of a dam impounding tailings and/or water. This is a sensitivity study, which will be used to also confirm hazard classification for the TMF dams, and to provide information crucial for effective emergency preparedness planning.

Specific objectives include the following:

- Review various dam failure mechanisms and determine the plausible failure scenarios
- Estimate the volume of tailings and water released from a dam breach
- Determine the areal extent of the flooding impact in the event of a dam failure
- Determine peak flood wave water levels resulting from the hypothetical dam failure

The TMF will be developed over five stages, including start-up. A tailings pond will form at the toe of the deposited tailings towards the east end of the TMF. With continued tailings deposition, the size of the TMF Pond remains approximately the same. At the Ultimate Stage configuration, the potential magnitude of water and liquefied tailings discharged from site in the event of a breach is considered to be the greatest. This configuration was therefore used in this dam breach assessment and inundation study. Tailings storage in the Leprechaun Pit is not considered in this analysis.

Figure 5 shows the flow paths associated with the two potential breach failures.

A breach of the TMF East or South Dams could either result in ponding at the toe of the Victoria Dam, or more likely, discharge into the Victoria River, which ultimately discharges to Red Indian Lake, approximately 60 km northeast of the site. Red Indian Lake discharges to Bay of Exploits via the Exploits River. Depending on the location, a breach in the dam could also potentially cause the Polishing Pond, which is adjacent to the TMF, to fail and ultimately discharge its impoundment towards Victoria River.

The simulations of the flood wave resulting from a hypothetical failure of the TMF and Polishing Ponds dams were conducted along the flow path as shown in Figure 5 as follows:

- A failure of the TMF East or South Dams would release the impounded water and tailings with the surge wave travelling along the headwater subwatershed of Victoria River reaching the confluence with Red Cross Lake approximately 5.1 km downstream of the TMF; then through the confluence with Valentine Lake and Long Lake a further 1.7 km downstream.
- The surge wave will then propagate through the downstream subwatershed along several confluences of Victoria River including Quinn Lake, Kelly's Pond and Bobby's Pond approximately 14.3 km, 40.3 km and 45.5 km downstream the TMF respectively, before reaching the inlet to Red Indian Lake approximately 60.0 km downstream the TMF.

The inhabited areas and relevant infrastructure along the flood wave path resulting from a breach in the TMF East or South Dams are the following:

- The main point of interest along the flood wave path in the headwater subwatershed is an abandoned railroad (referred to as Crossing 1 herein), located approximately 6.3 km downstream of the TMF.
- The main points of interest along the flood wave path in the downstream subwatershed include a gravel forestry access road used for forestry operations and recreational use (referred to as Crossing 2 herein), located 59.8 km downstream the TMF (less than 200 m upstream the inlet to Red Indian Lake) and dwellings and a hunting lodge at 39.7 km downstream the TMF.

There is no water ponded on the western portion of the TMF (even during extreme events); therefore a breach of the dam would release tailings and potentially impact site facilities (i.e. the Process Plant and the Truck Shop, ROM

Pad and the exploration camp on the shores of Lake Victoria as shown in Figure 3) before flowing into Victoria River.

4.0 EAST AND SOUTH DAM BREACH NUMERICAL ANALYSES (TOWARDS VICTORIA RIVER)

The numerical modelling in support of the dam breach analyses is a three-stage process:

1) **Breach Parameters** - Estimation of the breach formation parameters (geometry, development time) to be used in the hydrologic model as described on Section 4.1.3. The Hydrologic Engineering Center – Hydrologic Modeling System (HEC-HMS) model (HEC-HMS, 2018) software Version 4.3, developed by the U.S. Army Corps of Engineers (USACE), was used to develop the hydrologic model.

2) **Hydrologic Modelling** – This step estimates the pond's release volumes and the consequential breach outflow hydrographs. The volume of fluid released is discussed in Subsection 4.2.1 while the development of the hydrograph is described below in Subsection 4.2.2. The consequences of dam failure depend on the potential for release of the impounded water and tailings. The volume of water retained by the dam will govern the impact on the downstream area. HEC-HMS was used to generate the breach outflow hydrographs. The outflow hydrographs were then used as inputs to model the flood wave routing in the next step.

   The dam breach analysis was carried out based on the following assumptions:

   - The initial water level in the TMF is assumed to be at maximum operating water level (MOWL) of 388.5 masl for fair-weather (sunny conditions). During the Probable Maximum Flood (PMF) event, assuming initial water levels at the invert of the spillway (389.5 masl) the water level will rise to 390.3 masl. In this scenario both piping and overtopping failures were considered for the TMF East Dam. The inclusion of overtopping as a potential failure mode is to account for a reduction in the spillway discharge capacity due to blockage.

   - For the purpose of flood routing, the emergency spillway was considered unobstructed at the time of dam failure.

3) **Flood Routing** - The movement of the peak flood wave along the downstream path was simulated using the Hydrologic Engineer Center – River Analysis System (HEC-RAS) software Version 5.0.7 (HEC-RAS, 2016). This model performs the channel flood routing and calculates the potential inundation area and travel time. This version of the software can perform two-dimensional (2D) unsteady hydrodynamic routing. The outflow hydrographs generated by HEC-HMS were used as volumetric source terms at the breach locations to perform the flood routing. The flood routing is described further in Section 4.3.

4.1 Dam Breach Parameters

4.1.1 Failure Modes

The intent of the dam breach study is to identify credible, but conservative scenarios for dam failure for the purpose of emergency planning and confirmation of existing dam classifications. Several failure mechanisms have historically resulted in dam breaks (i.e., earthquakes, landslides, overtopping, internal erosion or piping, foundation failure and slope failures). Overtopping and piping failures are the most common causes of recorded dam failures (ICOLD 1995).

Geotechnical slope instability leading to a dam breach is unlikely as the TMF dams are expected to be founded on competent foundations, and the downstream slopes have been designed to meet the minimum target factors of safety (CDA 2013 and 2014). The compacted rockfill and foundation soils are also not considered susceptible to liquefaction during an extreme seismic event. Geotechnical investigation at the TMF is required to confirm the subsurface conditions during the next stage of design.

Piping is the internal erosion of the embankment material due to the flow of water. While it is primarily a design and construction issue, piping can also develop over time due to burrowing animals, decaying root systems below the pond reservoir level, deterioration of the liner material or cracking caused by deformation. Piping manifests in the form of concentrated seepage and erosion of the dam fill, which can progress and cause a collapse of the dam crest.

Dam overtopping occurs when the inflow to the pond exceeds its storage and discharge capacities resulting in a rise of water level higher than the dam crest. Rapid down cutting would ensue as the dam fill is eroded by the flowing water. Both overtopping and piping, if not identified and corrected, could lead to a rapid breach of the dam section through progressive erosion of the fill materials and an uncontrolled release of the impounded water.

The failure modes used for the proposed Valentine Gold Project dam breach analysis were selected based on the following considerations:

- The piping failure mode is considered as a plausible mechanism of failure for the TMF East Dam under fair-weather and Probable Maximum Flood (PMF) conditions. Under the PMF, an overtopping failure is plausible, due to wave action or wind setup, or in the event of a spillway failure, the maximum water surface elevation in the TMF pond could potentially reach the dam crest; piping was selected as it results in a larger released flow.
- The piping failure mode is considered as the plausible mechanism of failure for the TMF South Dam under the PMF event.
- A cascading failure of the TMF and Polishing Pond under both fair-weather and PMF conditions is plausible. However, its likelihood is dependent on the selected location where the breach is assumed to initiate and propagate. This is discussed in the next subsection.
- Failure in the above cases was assumed to occur where the volume of the released tailings would be highest and the consequences most significant (i.e. at the maximum height dam section).

These failure modes were analysed for three main scenarios as follows:

- Scenario A – Under fair-weather (“sunny day”) conditions for the TMF East Dam by the piping failure mode, with the MOWL at 388.5 masl.
- Scenario B – Under the flood-induced (“rainy day”) scenario for the TMF East Dam, by the piping (Scenario B1) and overtopping failure modes (Scenario B2) with the PMF level at 390.5 masl, obtained by routing the PMF.
- Scenario C – Under the flood-induced (“rainy-day”) scenario for the TMF South Dam by the piping failure mode, with the PMF level at 390.5 masl, obtained by routing the PMP storm.

4.1.2 Location of Breach

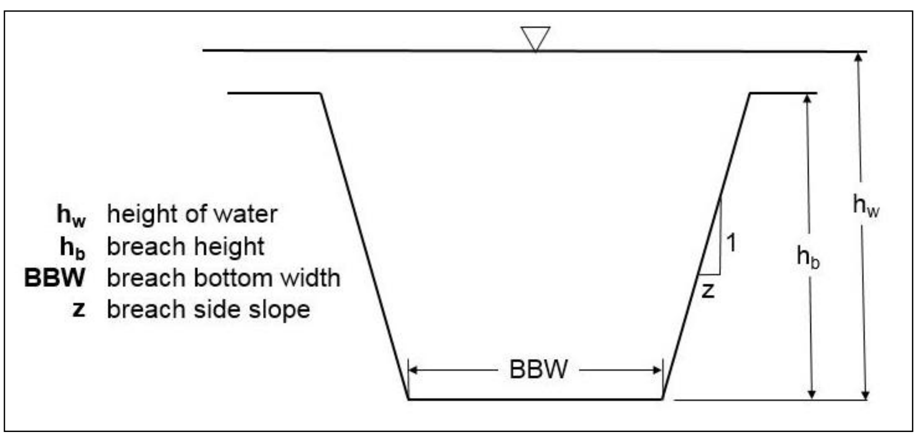
Embankments and dams can potentially fail at any location. For the purpose of this study, dam breach locations have been selected based on dam configurations and the topography to represent the worst-case scenarios. The largest dam height location was selected, which corresponds to the location where the difference in elevation between the dam crest and the toe of the dam is the greatest. This breach location results in the largest plausible breach outflow volume for that dam.

For Scenarios A and B, the location of the breach which corresponds to the largest volumetric release of both tailings and water (defined as CASE 1A in ICOLD 2019) towards Victoria River is the eastern corner of the TMF dam where the foundation is at 353 masl and the water surface level is 388.5 masl and 390.5 masl for fair-weather and PMF conditions, respectively. This location also coincides with the Polishing Pond. A rupture of the Polishing Pond was assumed in the event of a breach failure of the TMF East Dam.

While the location upstream of the Polishing Pond provides the largest potential release, it does not necessarily pose the largest risk to the Victoria Lake Dam. Therefore, for Scenario C, the location of the breach closest to the Victoria Lake Dam was selected. Given the pond depth at this location, the potential volume of tailings released is less, but it has a greater potential to flow towards the dam.

4.1.3 Estimation of Breach Parameters

Every dam breach scenario requires unique dam breach parameters, as these are based on the physical characteristics specific to each breach (i.e., dam geometry, dam construction, and volume of impounded water and tailings) and the failure mechanism. The parameters necessary to characterize a dam breach are the breach geometry (breach bottom width, breach height, and breach side slope) as demonstrated in Schematic 1, as well as the breach development time (i.e., time of failure).

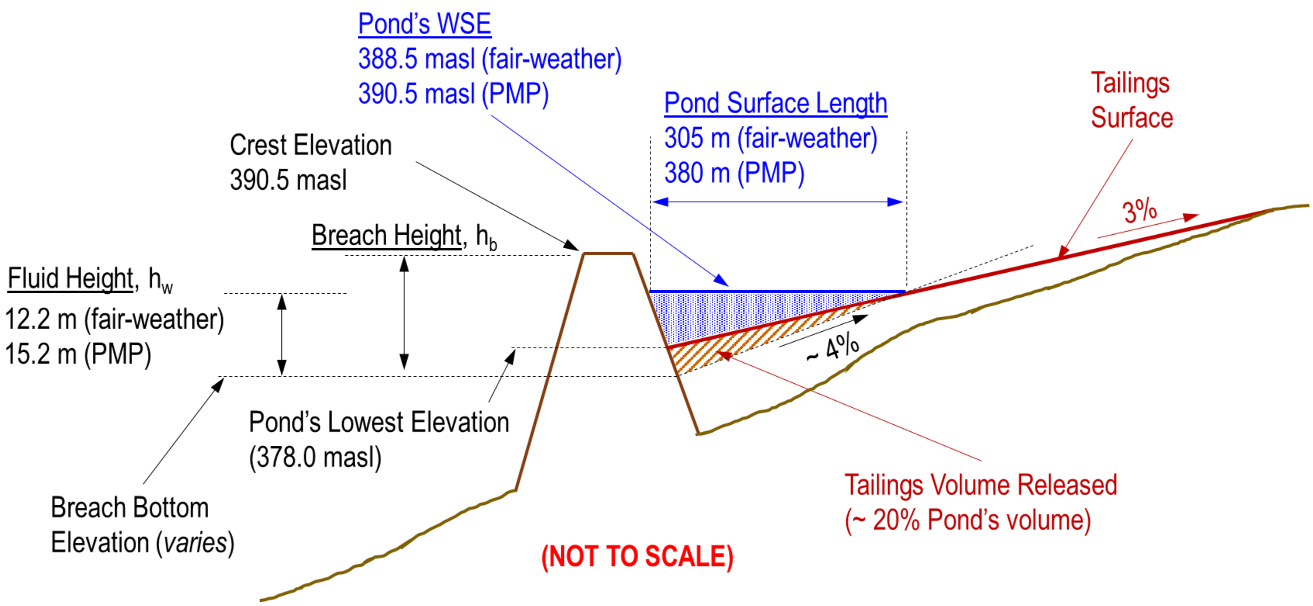


Schematic 1: Parameters of an Idealized Dam Breach

In the current study, the breach height h_b is considered to be the height from the dam crest to the breach channel's invert as a consequence to the erosive force of the released water.

Dam breach parameters for this study have been estimated using empirical relationships and methods developed from historic water dam failures as presented on Table 3. The various empirical equations typically result in a large variation in estimated values of the breach parameters. Because the equations vary widely, several available relationships have been used to develop an appropriate range of dam breach geometry values and development times. The range of values are used to perform the sensitivity analysis of the breach outflow hydrographs. During a dam failure event in which water is released some of the impounded tailings will become entrenched and flow with the water. For the current study, the effective water storage was increased by 20% to account for tailings flow as slurry. Treating slurry flow as water will yield conservative estimates for flood inundation levels and time of travel.

In the event that a tailings dam is breached, the erosive forces of the mobilised tailings will erode the tailings beneath such that the breach channel bottom (invert) will be lower than the bottom of the tailings pond. The breach bottom under the fair-weather and PMF conditions was predicted as 1.7 and 2.7 m below the pond bottom, respectively (Schematic 2). This estimate is reasonable given the relatively small volume of the tailings pond, the low erodibility of rockfill and the thickened state of the tailings.



Schematic 2: Conceptual Breach Channel Profile

Table 3: Regression Equations for Predicting Breach Parameters in Embankments Dams

Breach Width and Formation Time Equations		Notes
Average Breach Width (B) Equations		
U.S. Bureau of Reclamation (1988)	$B = 3h_w$	This equation is not intended to yield accurate predictions of peak breach outflows, but rather intended to produce conservative, upper bound values that will introduce a factor of safety into the hazard classification procedure. Dependent on dam height only.
Von Thun and Gillette (1990)	$B = 2.5h_w + C_b$	The offset parameter C_b is a function of reservoir size (e.g. $C_b = 6.1$ where reservoir size < 1.23 Mm^3). This relationship was developed from Froehlich (1987) - subsequently updated by MacDonald & Langridge-Monopolis (1984) - useful mostly as a check for other derived geometries. Does not take specific reservoir volume into account.
Froehlich (1995a)	$B = 0.1803K_0V_wH_b$	Dependent on volume and height (overtopping). Where $K_0 = 1.4$ for overtopping and $K_0 = 1.0$ for other failure modes.
Froehlich (2008)	$B = 0.27K_0V_w^{0.32}H_b^{0.04}$	Equation developed in 2008 based on 74 embankment dam failures, it is an updated version of the 1995 equation. Where dimensionless coefficient $K_0 = 1.3$ for overtopping failure and $K_0 = 1.0$ for other failure modes.
Fread (2001)	$B = 9.5K_0(V_rH)^{0.25}$	Dependent on volume and height.
MacDonald & Langridge-Monopolis (1984) – earthfill dam	$V_{er} = 0.0261(V_wh_w)^{0.769}$	Useful as a check of the geometries of other predictions. Based on breach formation factor defined as the product of the volume of breach outflow and the depth of water above the breach invert at the time of failure.
MacDonald/Langridge-Monopolis (1984) – Non-earthfill dam	$V_{er} = 0.0261(V_wh_w)^{0.852}$	Non-earthfill (e.g., rockfill).
Breach Formation Time (t_f) Equations		
U.S. Bureau of Reclamation (1988)	$t_f = 0.011B$	This equation is not intended to yield accurate predictions of peak breach outflows, but rather is intended to reduce conservative, upper bound values that will introduce a factor of safety into the hazard classification procedure. Dependent on height only.
Von Thun and Gillette (1990) - highly erodible soils	$t_f = 0.015h_w$	It is assumed that the embankment is highly erodible, as embankments mostly consist of materials such as coarse rejects. Sands and other small materials are also mixed in.
	$t_f = B \div (4h_w + 61)$	Dependent on height and breach width. However, breach width is not dependent on a specific volume, but rather on a range. Equation for embankments with highly erodible material, e.g., coarse rejects, sands and other small materials mixed in.
Von Thun and Gillette (1990) - erosion resistant soils	$t_f = 0.020h_w + 0.25$	Dependent on height only. More relevant for rockfill, erosion resistant cores, etc.
	$t_f = B \div 4h_w$	Dependent on height and breach width.
Froehlich (1995b)	$t_f = 0.00254(V_w)^{0.53}h_b^{-0.9}$	Dependent on volume and height.
Froehlich (2008)	$t_f = 63.2(V_w \div gH_b^2)^{0.5}$	Dependent on volume and height.
Fread (2001)	$t_f = 0.3\ V_r^{0.53}/H^{0.9}$	Dependent on volume and height.

Sensitivity Analysis

Sensitivity analyses were performed for the outflow hydrographs using a range of dam breach parameters evaluated for each dam breach scenario under CASE 1A in ICOLD 2019 (i.e. Scenarios A, B1, B2 and C) using the equations presented in Table 3. These analyses were performed using HEC-HMS software.

The Monte Carlo method was used to estimate the uncertainty in the outflow hydrographs given the uncertainty in each of the dam breach parameters. The Monte Carlo method works by creating several alternative models of the dam breach using an automated sampling procedure. Each breach model is created by sampling the model parameters according to their individual Probability Density Function (PDF). Each model is simulated to obtain an outflow hydrograph response corresponding to the sampled parameter values. The outflow hydrograph results were analyzed statistically to evaluate the uncertainty in the simulated breach response. Golder selected representative dam breach parameters leading to realistic but conservative outflow hydrographs for each scenario based on the sensitivity analysis results. The breach parameters that led to a peak flow corresponding to the mean plus one standard deviation results of the sensitivity analysis were selected.

The key failure characteristics including the estimated dam breach parameters are summarized in Table 4 and Table 5.

Table 4: Dam Breach Parameters, TMF East Dam – Fair Weather Conditions

Dam / Breach Parameter	Scenario A
Breach Location[1]	East Dam
Breach Failure Mechanism	Piping
Pond Water Elevation (masl)	388.5
Volume of Water Released from Pond (x 1,000 m^3)	906.9
Tailings Elevation Against the Dam (masl)	378.0
Estimate of Volume of Tailings Released[2] (x 1,000 m^3)	181.4
Final Bottom Breach Width (m)	19.0
Final Top Width of Breach (m)	45.6
Pond Bottom Elevation (masl)	378.0
Bottom Elevation of Breach (masl)	376.3
Foundation Elevation (masl)	353.0
Ultimate Breach Height (m)	14.2
Piping Elevation (masl)	385.4
Breach Side Slope (H:1V)	0.7
Depth of Water behind Breach (m)	12.2
Breach Formation Time (hr)	0.44
Peak Outflow (m^3/s)	1,137

Notes:

1) Breach location chosen to maximize the volume of fluid released.

2) Tailings volume represents the amount of tailings released due to dynamic liquefaction and erosion of tailings as described in Subsection 4.2.1. This volume is added to the free pond volume as effective storage in assessing breaching parameters.

Table 5: Dam Breach Parameters, TMF East Dam – PMF Event

Dam / Breach Parameter	Scenario B1	Scenario B2	Scenario C
Breach Location[1]	East Dam		South Dam
Breach Failure Mechanism	Piping	Overtopping	Piping
Pond Water Elevation (masl)	390.5[2]		
Volume of Water Released from Pond (x 1,000 m³)	1,617.5		1,337.5
Tailings Elevation Against the Dam (masl)	378.0[3]		389.0
Estimates of Volume of Tailings Released[4] (x 1,000 m³)	323.5		267.5
Final Bottom Breach Width (m)	24.8	28.6	21.1
Final Top Width of Breach (m)	46.1	59.0	28.8
Pond Bottom Elevation (masl)	378.0		386.0
Bottom Elevation of Breach (masl)	375.3		385.0
Foundation Elevation (masl)	353.0		342.0
Ultimate Breach Height (m)	15.2		5.5
Piping Elevation (masl)	379.2	-	386.5
Breach Side Slope (H:1V)	0.7	1.0	0.7
Depth of Water behind Breach (m)	15.2		5.5
Breach Formation Time (hr)	0.56	0.53	0.58
Peak Outflow (m³/s)	2,049	1,851	540

Notes:

1) Breach location chosen to maximize the volume of fluid released.

2) Maximum estimated water elevation in pond was 390.3 masl under PMF event. Water surface elevation at the time of breach was imposed at the same elevation as the crest (i.e. 390.5 masl).

3) Coincides with the bottom of the TMF pond.

4) Tailings volume represents the amount of tailings released due to dynamic liquefaction and erosion of tailings as described in Subsection 4.2.1.

4.2 Hydrologic Modelling and Dam Breach Simulations

4.2.1 Volume of Water Released and Tailings Mobilized

The proposed TMF dam impounds both water and tailings. In this study, the total volume of 'water only' considers the "free" water, defined as the water above the tailings surface. The pore water within the tailings is accounted for in the mobilized tailings volume.

The volume of "free" water released from the TMF Pond was calculated based on the pond volume above this level up to the MOWL for the fair-weather scenario (388.5 masl) and maximum water level in the pond under the PMF scenario (390.5 masl). The pond volume was calculated from stage-storage curves developed from the CAD model pertaining to the prefeasibility study (PFS) (Golder 2020a). The estimates of water volume to be released are presented in Table 4 and Table 5 for both weather scenarios, respectively. The Polishing Pond's containment volume (i.e., 44,000 m^3) was incorporated in the water volume estimate for Scenarios A, B1 and B2; but not Scenario C, as it is not plausible that a breach in the southernmost location of the TMF will cause a cascading failure of the Polishing Pond. It is worthy to note that the elevation of the bottom of the pond at the TMF South Dam (Scenario C) is 8 m higher than the TMF East Dam location, hence the calculated peak outflow was much lower.

There are several physical mechanisms that contribute to the mobilizing of tailings including static and dynamic liquefaction (flow of tailings from sudden loss of strength), erosion of the tailings due to the turbulent flow exiting the breach, and erosion of the tailings surface due to the shear force on the tailings surface from the flow velocity as the water level in the tailings area drops. The estimation of the volume of mobilized tailings due to these mechanisms is very complex considering the spatial variability of tailings surface slopes and elevations, as do the tailings properties and the flow velocities. Instead, Golder used a simplified but conservative estimate where the approach based on the post failure tailings surface following the dam breach.

The volume of tailings mobilized due to liquefaction and erosion for a hypothetical breach of the TMF East and South Dams of the TMF containing a supernatant pond (i.e. CASE 1A in ICOLD, 2019) was assumed to be 20% of the volume of the “free” water.

4.2.2 Breach Outflow Modelling

A HEC-HMS hydrologic model was developed to simulate the hydrological response in a watershed and to simulate a reservoir dam failure either by overtopping or piping failure modes.

The hydrologic model inputs are as follows:

- Piping failure mode for both fair-weather and flood-induced (PMF) scenarios
- Overtopping failure mode for flood-induced (PMF) scenario
- Initial water level in the TMF Pond assumed at MOWL 388.5 masl under fair-weather conditions
- Initial water level in the TMF Pond at the start of the PMP storm is assumed at the spillway invert level 389.5 masl. The maximum water level in the TMF Pond 13 hours and 20 minutes into the PMP storm was estimated at 390.3 masl. In the hydrologic model, the dam breach was triggered at 390.5 masl, corresponding to the maximum water surface level in the pond
- 24-hr Probable Maximum Precipitation (PMP) depth used for the Stephenville Environment and Climate Change Canada (ECCC) meteorological station (ID: 8403800) is 309 mm (Golder 2020b)
- Breach parameters as listed in Table 4 and Table 5
- Stage-Storage curve developed for the TMF Pond and tailings
- Emergency Spillway stage-discharge rating curve

The breach geometry was estimated assuming the failure would occur where the tailings pond accumulation coincides with the Polishing Pond and where the tailings surface against the dam is at its lowest as a conservative approach. This assumption provides the maximum plausible breach size and consequently the largest outflow. The breach geometry presented in Table 4 and Table 5 was estimated for the maximum dam height for each flood wave path direction, as it generates the largest peak outflow and largest inundation consequences.

The peak outflows resulting from the hypothetical failure simulation corresponding to the fair-weather scenario are presented in Table 4 and the flood-induced scenario presented in Table 5. The peak discharge from the breach is governed mostly by the volume of water in the TMF Pond.

Under fair-weather conditions (Scenario A), the breach peak outflow from a piping failure at the TMF East Dam reporting to Victoria River is 1,137 m^3/s. Under the flood-induced failure at the TMF East Dam (Scenario B), the peak breach outflows are 2,049 and 1,851 m^3/s for the piping and overtopping failure modes (Scenarios B1 and B2), respectively. The outflow hydrograph for piping failure (Scenario B1) was selected for being routed downstream as it results in a larger release volume. Under the flood-induced failure at the TMF South Dam by the piping failure mode (Scenario C), the peak breach outflow is 540 m^3/s. The generated outflow hydrographs are presented on Figure 6 through Figure 8.

4.2.3 Baseline Flows in Downstream Watersheds

The baseline hydrological conditions of the downstream watersheds refer to the downstream water levels and flows along the flood path prior to dam failure. The hydrological conditions are dependent on the proposed initial conditions (i.e., fair-weather or flood events including PMF weather conditions). Canadian Dam Association (CDA) recommends evaluating incremental dam breach failure consequences taking into consideration initial conditions that are most likely to occur coincident with the breach event (CDA 2014).

A HEC-HMS model was developed for the Victoria River watershed, downstream the TMF dam. Subwatershed delineation was conducted using 2 m topographic contour data assisted by available online cartographic resources (NHN 2020). For modeling purposes, the watershed was divided into the following two subwatershed areas:

- From the headwaters at Victoria Lake Dam up to the confluence of Quinn Lake with an area of 583 km², including approximately 84 km² of lake surface
- From the confluence of Quinn Lake up to the inlet of Red Indian Lake with an area of 314 km², including approximately 15 km² of lake surface

Figure 10 shows a map of the two delineated sub-watersheds as well as the encompassing watershed of Red Indian Lake.

Fair-weather stream flows in the downstream flow paths were prorated based on the unit flow rate for the Great Rattling Brook above Tote River Confluence Water Survey of Canada (WSC) hydrometric station (ID: 02YO010) for the month of August (0.008 $m^3/s/km^2$), as presented in the 2020 hydrology baseline report (Stantec 2020). The 24-hour PMP was used to generate the baseline hydrological conditions in the downstream catchments for the flood-induced scenario.

Table 6 shows the 24-hour precipitation for return periods from 2-year to 100-year, extracted from Intensity-Duration-Frequency (IDF) information for the Stephenville ECCC meteorological station developed by Conestoga-Rovers & Associates (CRA 2015) and which were presented in the 2020 hydrology baseline study (Stantec, 2020). Golder selected to use IDF curves adjusted for climate change corresponding to the 2011-2040 time horizon, during which the volume of water in the TMF is at its maximum. The 1,000-year rainfall was extrapolated from the 2- to 100-year rainfalls and the PMP rainfall of 309 mm was extracted from the Rainfall Frequency Atlas for Canada (Hogg and Carr, 1985).

Table 6: 24-hr Rainfall Events for Stephenville ECCC Meteorological Station (ID: 8403800)

Duration (hr)	Return Period (Years)							
	2	5	10	25	50	100	1,000[1]	PMP (Hogg and Carr, 1985)
	Rainfall (mm)							
24-hr	65.1	86.4	100.7	118.6	131.8	144.8	192.5	309

Notes:

1) 1,000-Yr rainfall depth extrapolated from lower return periods (i.e. 2- to 100-year)

The initial conditions downstream of the dams under the PMF event were generated and assessed using a hydrological model. The following is a simplified description of the approach adopted:

1) Watershed characteristics such as drainage area, average length of stream channels and channel slopes from the delineated sub-watersheds were extracted from mapping software and input into the hydrological model.

2) A high-level calibration of a hydrologic input parameter representing precipitation losses was performed for the 24-hr 100-year storm event hydrographs. This input parameter was adjusted by matching the computed 100-year peak flow to an estimate derived from the regional regression equation defined in the 2020 baseline hydrology report (Stantec, 2020) for the North East hydrologic region of Newfoundland.

3) The PMF hydrographs were generated using the calibrated precipitation loss derived for the 24-hr 100-year storm and by applying the 24-hr PMP value of 309 mm. The Soil Conservation Service (SCS) Type-II distribution was applied for the PMP event.

4) The flood hydrographs under the PMP event and for the Victoria River watershed were estimated at three locations along the Victoria River as part of the downstream routing:

    i) Confluence of Red Cross Lake: Runoff at this location represents 10% of the runoff generated in the headwater subwatershed.

    ii) Confluence of Quinn Lake: Runoff at this location represents the remainder (i.e. 90%) of the runoff generated in the headwater subwatershed.

    iii) Confluence of Kelly’s Pond: Runoff at this location represents the entire runoff generated in the downstream subwatershed.

The generated PMF hydrographs, shown in Figure 11, were used as lateral inflows (i.e., natural watershed inflows to the waterways) in conjunction with the simulated dam breach flood wave to assess incremental consequences of a dam breach.

The setup of the hydrological model setup during the PMP event assumes that the flow through the dams along the Victoria River are unregulated. It is also assumed that no outflow from Victoria Lake into Victoria River will occur during the PMP event.

Under fair-weather conditions, the prorated baseline flows estimated for the two subwatershed was apportioned according to the same ratios defined for the PMP baseline conditions (10% and 90% of runoff from the headwater subwatershed at the confluence of Red Cross Lake and Quinn Lake, respectively, and 100% of runoff from the downstream subwatershed at the confluence of Kelly’s Pond).

4.3 Flood Wave Routing

The HEC-RAS program used for the present analysis was the most recent version (5.0.7). HEC-RAS is a computer program that models the hydraulics of water flowing through natural rivers and other channels. This version of the program (Version 5.0) can perform two-dimensional (2D) unsteady flow analysis, making it more suitable to support flood map development. The flood model has found wide acceptance by many since its public release in 2016. HEC-RAS was used to simulate the movement of the flood wave downstream of the breached dam to define the duration and spatial extent of the inundation area.

The hydraulic modelling using HEC-RAS involves the following steps:

- Preparation of the geometric model from the DEM generated based on available topographic data as described in the section below.
- Definition of model inputs.
- Definition of boundary conditions.
- Simulation of unsteady flow analysis.

4.3.1 Geometric Model

An accurate terrain model is required for the development of a two-dimensional (2D) hydraulic model. The data source for the Project area are 10 m interval contours developed by the Government of Newfoundland. A 2 m DEM was then created by interpolating this contour dataset.

Challenges Encountered

The resolution of the downstream topographic information provides low accuracy as there were both sudden and gradual increases of up to 3 m in bottom elevation along a 20 km reach of the Victoria River approximately 4 km downstream of Crossing 1 (Figure 12). Although it is not unusual to encounter adverse slopes (uphill) in digital terrain data (especially where crossings are present), this particular case does not coincide with crossings. This resulted in severe ponding within the river, event during low flow scenarios.

Several attempts were made to correct the issue regarding the sudden increases and adverse slopes. The terrain was updated by lowering the ground elevation along this reach by means of a 5 m wide channel at the river’s thalweg with 1:1 average side-slopes in order to facilitate the propagation of the flood wave in the hydraulic model. This practice is acceptable for the case of a prefeasibility study. However, for future studies, a site survey is recommended to verify the bathymetric and drainage characteristics of the Victoria River. Detailed topographic data is important for more accurate estimations of the potential flooding extent.

4.3.2 Flow Domain / Model Boundaries

Red Indian Lake is a large freshwater body located approximately 60 km downstream of the TMF, with the largest drainage area in Central Newfoundland – 5,580 km^2 – approximately 7 times the drainage area at its inlet with Victoria River. Red Indian Lake receives runoff from 10 riverine systems including Victoria River and has a surface area of 187 km^2, nearly 500 times the size of the TMF Pond by area. It is therefore anticipated that the water and tailings released from the TMF in the event of a dam breach will have negligible impacts on Red Indian Lake.

The flow domain for the TMF East Dam failure simulations (Scenarios A and B1) extended from the downstream toe of Victoria Dam up to a station 1 km upstream of the inlet to Red Indian Lake. The reason for truncating the downstream model boundary is to avoid imposing a water surface level that is dependent on inflow from other sub-watersheds within the Red Indian Lake watershed. The downstream boundary for the TMF South Dam failure was extended a sufficient distance along the Victoria River to ensure no backwater effects from boundary conditions. Figure 13 and Figure 14 illustrate the flow domain of the hydraulic model for the TMF East and South Dams failure simulations, respectively. Also Illustrated within the flow domains are the coarse and fine meshes as well as the axes representing the flow path from the hypothetical breach failures.

4.3.3 Model Inputs

The following key inputs were required to simulate the movement of the dam breach flood hydrograph:

- Inflow hydrographs (dam breach flood hydrograph) immediately downstream of the dams which were generated by a hydrologic model using HEC-HMS. A total of three hydrographs, one under fair-weather and two under the PMF scenarios were input.
- Lateral inflow hydrographs under the PMF event for the TMF East Dam failure by piping (Scenario B1) were assigned at locations of confluences of the flood paths with the main streams. A total of three lateral inflows for the flood wave path were considered. The generation of these hydrographs is described on Subsection 4.2.3. Since the main purpose of the dam breach analysis for the TMF South Dam failure by piping under the PMF event (Scenario C) is to assess the risk on Victoria Dam, no lateral inflow was considered along the Victoria River.
- Lateral inflow under fair-weather conditions was input based on the average streamflow rate estimated for the month of August from the Great Rattling Brook above Tote River Confluence WSC hydrometric station (ID: 02YO010) as described in Subsection 4.2.3.
- Two roughness (Manning's) coefficients of 0.035 and 0.06 was used for the river channel and floodplain, respectively.

4.3.4 Flow Domain and Boundary Conditions

The upstream boundary conditions were defined by the dam breach hydrographs and the lateral inflows scenarios at the locations described in Section 4.2.3. The downstream boundary conditions were defined as the slope of the energy grade line (EGL) assuming normal flow depth estimated for all cases.

4.3.5 Simulations Results

Maximum flood wave depth, peak flow, maximum flow velocity, maximum of the product of flood wave depth and flow velocity and peak flood wave travel time since initiation of the breach for the fair-weather and flood-induced conditions, respectively, were estimated using the HEC-RAS software for the following three simulations (Figure 15 through Figure 31):

- Dam breach at the TMF East Dam under fair-weather (Scenario A)
- Dam breach at the TMF East Dam under flood-induced conditions (Scenario B1)
- Baseline condition under a PMF event (no dam breach).

Tables summarizing the results at specific stations of interest are shown on the Flood Inundation Map figures for the TMF East Dam breach failures under the fair-weather and flood-induced conditions on Figure 15 and Figure 26, respectively. Values at select points of interest such as trail/road crossings, dwellings/lodges and confluences along the flow path are shown on these figures. The critical points of interest within the model boundary are the dwellings and hunting lodge upstream of Station 6 and the forestry access road immediately upstream the inlet to Red Indian Lake (i.e. Crossing 2). Both have been identified as critical infrastructure as they hold a strong potential for loss of life if they are inundated with a high enough velocity.

The Flood Inundation Maps also include the maximum water depth multiplied by flow velocity, which is an indicator of potential loss of life. The critical threshold is 0.37 m^2/s (0.6 m depth multiplied by 0.6 m/s stream velocity), OMNR (2002).

As the main purpose of the dam breach analysis for the TMF South Dam failure under the PMF event (Scenario C) is to assess the risk on Victoria Dam, only velocities and water flood wave depth within the vicinity of Victoria Dam are presented as post-processing outputs of the hydraulic model. The results for this scenario are discussed in Subsection 4.3.5.3.

4.3.5.1 Red Indian Lake Impacts: Qualitative Analysis

The breach of the TMF Pond and Polishing Pond have the potential to release water and tailings through the flood wave path shown on Figure 5. Based on the release volume of water and tailings estimated, it is predicted that the increase in water surface elevation of Red Indian Lake as a result of a breach in the TMF dam will be in the order of millimetres, which justifies the downstream extent in the model. The Assimilative Capacity study, issued under separate cover as part of this Project (Golder 2020c), describes the water quality downstream.

4.3.5.2 TMF East Dam Breach

A hypothetical failure of the TMF East Dam (Scenarios A and B1) would release the impounded water and suspended tailings, potentially rupturing the Polishing Pond walls and releasing its containment. The consequential surge wave from both breaches will propagate downstream the Victoria River towards Red Indian Lake.

PMF With and Without Breach

Results of inundation, maximum flow depth, maximum flow velocity and maximum depth multiplied by velocity along the flood wave flow path for the flood-induced failure by piping (Scenario B1) are presented in Figure 15 through Figure 25. Based on the model results, no critical infrastructure will be inundated under the dam breach PMF event except Crossing 2. Crossing 2 will be inundated under the PMF event with or without a dam breach. Based on the model results, the dwellings and hunting lodge upstream of Station 6, as shown in more detail in Figure 22 and Figure 23, will be inundated under the PMF event regardless of if there is a breach. The following results can also be interpreted for this scenario:

- The release volume for the PMF dam breach is 1.99 Mm^3, which represents approximately 1.1% of the PMF baseline no-dam failure runoff volume (189.5 Mm^3) at the Red Indian lake inlet.
- The peak water flow at the inlet of Red Indian Lake under a dam breach is about 2,311 m^3/s compared to a no-dam failure flow of 2,280 m^3/s (an incremental increase of 31 m^3/s).
- The peak outflow from the PMP breach scenario will attenuate by 67% after having traveled a distance of 1.6 km.
- The arrival time of the flood wave at the dwellings and hunting lodge is 13 hours from the time of the breach. The arrival time of the flood wave at the Red Indian Lake is less than 14 hours from the time of the breach.
- The maximum incremental water depth of 8.8 m occurs immediately downstream the TMF at Section 1.
- The incremental maximum depth multiplied by velocity always exceeded the threshold value of 0.37 m^2/s at locations within the river’s flow boundary and was not coincidental with critical points of interest.

Based on the incremental impact analysis outlined above, no additional potential loss of life is anticipated due to a flood-induced breach failure in the TMF East or South Dams.

Fair-Weather Breach

Results of inundation, flow depth, velocity and depth multiplied by velocity along the flood wave flow path for the fair-weather failure by piping (Scenario A) are presented in Figure 26 through Figure 31. Based on the model results, none of the crossings would be inundated under this scenario. Detailed topographic data is recommended to accurately estimate the extent of the potential flooding. The following results can also be interpreted from this scenario:

- The peak outflow from the fair-weather breach scenario will attenuate by 68% after having traveled a distance of 1.6 km.
- The peak flow at Station 1 is 480 m^3/s above base conditions.
- The peak of the flood wave at the inlet of Red Indian lake is 14 m^3/s (3.2 m^3/s above baseline conditions).
- The maximum water depth of 5 m occurs downstream of Station 2.

- Maximum stream velocity is 4.7 m/s in downstream Section 6 where rapids are present.
- The incremental maximum depth multiplied by velocity always exceeded the threshold value of 0.37 m^2/s at locations within the river's flow boundary and was not coincidental with critical points of interest.

Based on the analysis outlined above, no potential loss of life is anticipated for this scenario.

4.3.5.3 TMF South Dam Breach

A potential failure of the TMF South Dam would release the impounded water and tailings with the surge wave travelling towards the upstream reach of Victoria River just south of the facility. The flood routing simulation revealed that the flood wave resulting from the dam breach would mostly propagate downstream in the Victoria River with a peak flow equal to 320 m^3/s, and only a peak flow equal to 3.5 m^3/s would propagate towards the downstream toe of Victoria Dam. Figure 32 and Figure 33 show the maximum velocity and maximum depth within the flow domain. At the downstream toe of Victoria Dam, the maximum depth and velocity reached is 0.5 m and 0.3 m/s, respectively. At this depth and velocity, there would be no adverse impacts on the dam. The supporting figures for locations further downstream are not presented as the effects of the TMF East Dam failure which shares the same flood wave path are more critical.

5.0 WESTERN DAM BREACH QUALITATIVE ANALYSIS

5.1 Dam Breach Parameters

5.1.1 Failure Modes

As with the TMF East Dam breach, geotechnical slope instability leading to a dam breach is unlikely as the dams are expected to be founded on competent foundations, and the downstream slopes have been designed to meet the minimum target factors of safety (CDA 2013 and 2014).

Although the foundation is not subject to liquefaction, given that piping and overtopping are not credible modes of failure due to the fact that there is no water against the dam (even under an extreme storm scenario), it is assumed that the most plausible cause for a geotechnical failure would be seismic loading coupled by poor construction or defective materials resulting in slope instability. This sequence of events was assumed to occur at the western portion of the TMF leading to liquefaction of the tailings and their runout downstream (Scenario D).

Failure was assumed to occur where the volume of the released tailings would be highest and the consequences most significant (i.e. at the maximum height dam section).

5.1.2 Location of Breach

Embankments and dams can potentially fail at any location. For the purpose of this study, dam breach locations have been selected based on dam configurations and the topography to represent the worst-case scenarios. The largest dam height location was selected, which corresponds to the location where the difference in elevation between the dam crest and the toe of the dam is the greatest. This breach location results in the largest plausible breach outflow volume for that dam.

The location of the breach which corresponds to the largest release volume of liquefiable tailings (defined as CASE 2A in ICOLD 2019) is the western portion of the TMF. At this location, the dam's foundation and crest are at 384.0 and 404.0 masl, respectively.

It is also important to note that the TMF West Dam is only constructed for the Ultimate Stage in Year 7. Therefore, before that year, there is no risk of a breach in this area of the TMF.

5.2 Tailings Runout Modeling

5.2.1 Estimation of Volume of Tailings Mobilized

The volume of tailings mobilized due to liquefaction and erosion for a hypothetical breach of the western portion of the TMF and which does not contain a supernatant pond (i.e. CASE 2A in ICOLD, 2019) was estimated based on an approximate geometrical configuration of the post-failure profile of the tailings surface in the failure scar area after its release downstream. Golder selected conservative post failure geometrical parameters in order to construct the projected tailings surface following the dam breach. A post failure slope equal to 6% within the TMF, corresponding to the lower limit of post liquified residual angles (ICOLD 2019), was adopted. The width of the breach control section (breach entrance) was taken as 3 times the dam height at that location.

The key failure characteristics including the estimated dam breach parameters are summarized in Table 7.

Table 7: Dam Breach Parameters – West Dam (Scenario D)

Dam / Breach Parameter	West Dam
Breach Failure Mechanism	Slope Instability
Pond Water Elevation (masl)	-
Volume of Water Released (Mm^3)	-
Tailings Elevation Against the Dam (masl)	404.0
Estimate of Volume of Tailings Released[2] (m^3)	860,000
Final Bottom Breach Width (m)	60[1]
Final Top Width of Breach (m)	120
Bottom Elevation of Breach (masl)	384.0
Foundation Elevation (masl)	384.0
Ultimate Breach Height (m)	20
Piping Elevation (masl)	-
Breach Side Slope[3] (H:1V)	1
Depth of Water behind Breach (m)	-

Notes:

1) Assumed as three times breach height.

2) Hydrograph characteristics not estimated as flow properties of liquefiable tailings are characterised as mudflow.

3) Assumed.

5.2.2 Results

The liquefied tailings will flow like a slurry. The fair-weather tailings liquefaction failure at the western portion of the TMF dam was not simulated using a hydrological model, instead it was simulated as a tailings runout by estimating the post failure tailings profile. The tailings runout centreline was defined based on the available 1 m interval topographic contour data. The maximum slope of the 860,000 m^3 of tailings deposited downstream was taken at the minimum grade suggested in ICOLD 2019 (2%) to yield conservative estimates.

The tailings runout model is based on the current natural topography as represented by the available 1 m interval contours. The tailings will runout eastwards towards the Victoria River. The extent of the runout tailings and consequential inundation depths are shown in Figure 34. It is predicted that the Process Plant could be partially inundated as a result of the tailings runout. The maximum predicted inundation depths immediately downstream the dam and within the Process Plant are approximately 6 m and 2 m, respectively. It is estimated that the released tailings will be deposited southwest of the TMF, where the runout distance is approximately 950 m. The runout model does not consider the future grading plan of the Process Plant site nor the design elevation of the Mill pad. It is expected that the grading and configuration of the Process plant site will impact the ultimate inundation extent and depth within the plant site area. A relocation of the Process Plant 200 m southwest or 500 m northwest could prevent it from being inundated, assuming that the local topography coinciding with the inundated area remains unchanged. It is important to note that while the location of the runout analysis was selected based on the largest potential tailings release, a failure north of the selected location will likely impact the Truck Shop and ROM Pad. The topographic characteristics of the site also indicate that some tailings will flow along the downstream toe of the TMF's South Dam. The depth of tailings at the toe of the TMF's South Dam is approximately 0.5 m. Given the slope and gross width of the rockfill dam, the net effect of any scour in the vicinity as tailings are deposited is expected to be minor. Consequently, the rockfill dam shell is unlikely to be affected.

6.0 DAM BREACH SUMMARY

This dam breach assessment provides useful information to identify hazards and consequences from a hypothetical failure of water and tailings containment dams in the proposed Valentine Gold Project TMF. The present study will support the emergency response planning and verify the Failure Consequence Classification of the dams following CDA guidelines, as presented in Section 7.0, below.

Subsection 4.3.5 provides a summary of the inundation characteristics for all scenarios analysed in this study. The conclusions are as follows:

- TMF East / South Dam the fair-weather conditions, the most plausible mode of failure is piping.
- Under the PMF conditions, the assumed mode of failure is piping for the TMF East and South Dams, as higher breach outflows were predicted in comparison to the overtopping failure mode.
- Under both the fair-weather and PMF conditions for the TMF East Dam failure, the Polishing Pond containment volume was incorporated into the release volume.
- Under both the fair-weather and PMF conditions, the breach outflow hydrograph undergoes substantial attenuation within the first 2 km (> 60%).
- The incremental impact of the breach of the TMF East Dam under PMF conditions is not significant as the runoff volume generated by the PMP storm is substantially larger. The incremental impact of the breach of the TMF East Dam is negligible with respect to dwellings and operational crossings such as Crossing 2.
- A breach failure of the TMF South Dam will release the impounded water and tailings towards Victoria River, where the flood wave will propagate both upstream as well as downstream. While the upstream flood wave propagation will reach the downstream toe of Victoria Dam, its impact on the structure is unlikely. The flood inundation due to downstream propagation was not outlined in this analysis as the effects of the TMF East Dam failure, which shares the same path, are considered more critical.
- No potential loss of life or critical infrastructure is anticipated due to the breach failure of the TMF East and South Dams under fair-weather conditions or incrementally under the PMF scenario.

TMF West Dam

- The tailings runout analysis conducted for the TMF West Dam failure is assumed to occur following a geotechnical failure, such as seismic loading coupled by poor construction or defective materials resulting in slope instability.
- The runout analysis is based on the existing topographic features of the site. The tailings are predicted to runout eastwards towards the Victoria River, and will impact the Process Plant and any personnel within the runout path. It is likely, however, that the downstream toe of the TMF South Dam will not be impacted due to of the tailings runout.

7.0 VERIFICATION OF THE HAZARD POTENTIAL CLASSIFICATION

The results from the hypothetical dam breach were used to review the existing Hazard Potential Classifications (HPC) for the proposed Valentine Gold Project TMF dam. The dams were classified based on anticipated impacts of hypothetical dam failure in terms of loss of life, financial loss, and environmental and cultural damage in accordance with CDA Dam Safety Guidelines (CDA 2013). Table 8 serves as the basis for establishing the classification of dams according to the CDA Dam Safety Guidelines.

The dam safety program established in Newfoundland and Labrador requires that dams must be designed, operated and maintained to meet the requirements of CDA Dam Safety Guidelines

Table 8: Dam Classification (CDA 2013)

Dam Class	Population at Risk	Incremental Losses		
		Loss of Life	Environmental and Cultural Values	Infrastructure and Economics
Low	None	Nil	Minimal short-term 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 is highly possible	High economic losses affecting infrastructure, public transportation, and commercial facilities

Dam Class	Population at Risk	Incremental Losses		
		Loss of Life	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 possible but impractical	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 in kind impossible	Extreme losses affecting critical infrastructure or services (e.g., hospital, major industrial complex, major storage facilities for dangerous substances)

The incremental consequences of dam failure are higher in the Sunny Day scenario for all cases. Based on the analysis completed for the PMF, such a conclusion remains for a flood event with a return period less than the PMF.

The analyses herein indicate that the proposed TMF West Dam failure poses a life safety risk for the population downstream in the Process Plant at the Ultimate Stage. The dwellings and hunting lodge along the Victoria River and the communities along Red Indian lake are located about 40 km and 60 km downstream of the TMF, respectively. The analyses herein indicate that the breach failure of the proposed TMF East and South Dams poses no life safety risks for populations downstream at the Ultimate Stage.

Economic losses are LOW, as there is no damage expected to the critical infrastructure identified as a result of a dam breach failure.

Environmental consequences from the breach failures of the TMF East, South and West Dams are assessed as part of the Assimilative Capacity study for this Project (Golder 2020c). The Assimilative Capacity assessment determined environmental effects related to water chemistry are moderate and alone would only correspond to a SIGNIFICANT classification. However, while not assessed directly in either assessments, environmental effects related to habitat destruction as a result of erosion and tailings deposition are assumed to correspond to a HIGH dam classification. A VERY HIGH dam classification is not selected as the affected habitat is not considered “critical” habitat.

On the basis of the assumed 100 or fewer lives at risk during the operating period, a VERY HIGH dam classification is appropriate (Table 8).

The prefeasibility study design criteria adopted for the proposed TMF dams are appropriate for the VERY HIGH dam classification.

8.0 RECOMMENDATIONS FOR FUTURE WORK

- As stated in Section 4.3.1, issues with the topographic data added a level of uncertainty to the analysis. The model was adjusted and successfully used for the assessment. However, for future studies, ground surveys are recommended to confirm the actual ground conditions. In addition to the river reach described in Section 4.3.1, it is also recommended to verify the bathymetric and drainage characteristics of the Victoria River, particularly near crossings, confluences and dwellings and in narrow reaches where rapids and overfalls are often encountered.
- The hydrologic inputs are based on regional data (Section 4.2.3). For more accurate estimations of flow in the Victoria River, a flow monitoring program could be considered for the purpose of fulfilling hydraulic model calibration requirements. Continuous flow monitoring during periods of rainfall will improve estimates of loss parameters that govern hydrologic processes in downstream receivers and consequently estimates of baseline flows.
- While a relocation of the Process Plant 200 m southwest or 500 m northwest could potentially avert a potential inundation due to a tailings runout from the TMF West Dam, the lives of the personnel conducting operations nearby the Process Plant remain at risk.
- It is recommended that the grading plan for the plant site west of the TMF West Dam be designed to avoid runout of tailings into Victoria Lake in the event of a TMF West Dam failure. It is recommended that the runout assessment for the TMF West Dam be validated once the plant site grading plant is finalized.
- While a dam breach poses no threat to the dwellings along the Victoria River and to the communities along Red Indian Lake, it is still recommended to put in place a comprehensive emergency preparedness plan to ensure that there is a failure detection system and that all downstream stakeholders are notified expeditiously during a dam incident and that the appropriate evacuation requirements are met.

9.0 CLOSING

We trust the above meets your present requirements. If you have any questions, please contact the undersigned.

SIGNATURE PAGE

Golder Associates Ltd.

<Original signed by>

<Original signed by>

Adwoa Cobbina, P.Eng. ON
Water Resource Specialist

Peter Merry, P.Eng. NL
Principal, Project Director

<Original signed by>

Shiu Kam, P.Eng. ON
Principal, Senior Consultant

https://golderassociates.sharepoint.com/sites/126654/project files/5 technical work/05 reports/dam breach assessment/final (rev 1)/doc files/20141194 (400) marathon gold_dam breach assessment_rev1_04august2020.docx

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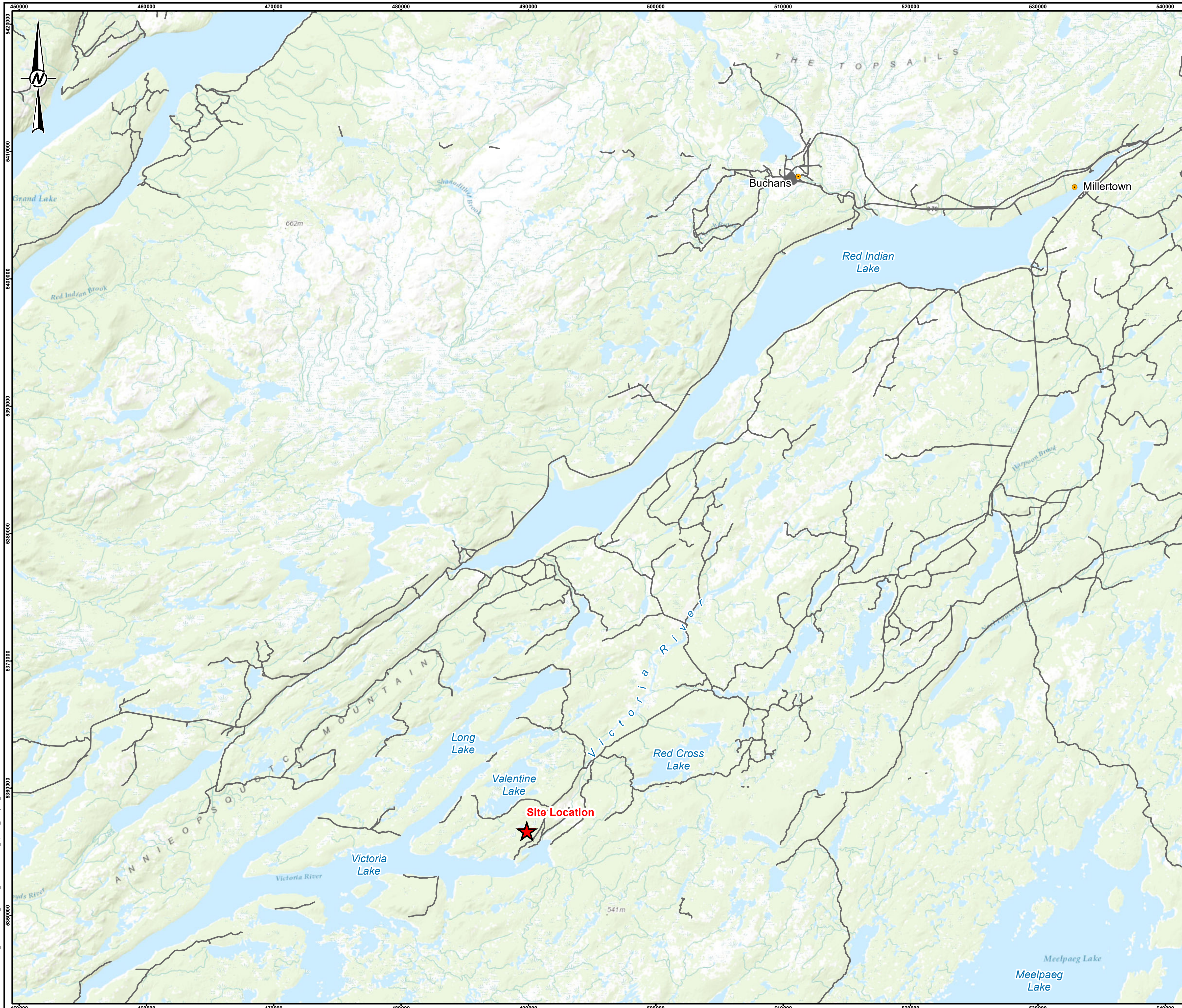
FIGURES



LEGEND

- ★ Site Location
- Roads
- Waterbody

0 7,500 15,000

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NOTE(S)

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT NO. 19130660

REFERENCE(S)

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CLIENT

MARATHON GOLD CORPORATION

PROJECT

DAM BREACH ASSESSMENT AND INUNDATION STUDY
VALENTINE GOLD TAILINGS MANAGEMENT FACILITY

TITLE

SITE LOCATION PLAN

CONSULTANT

GOLDER

YYYY-MM-DD	2020-06-25
DESIGNED	---
PREPARED	RRD
REVIEWED	---
APPROVED	---

PROJECT NO.	PHASE	REV.	FIGURE
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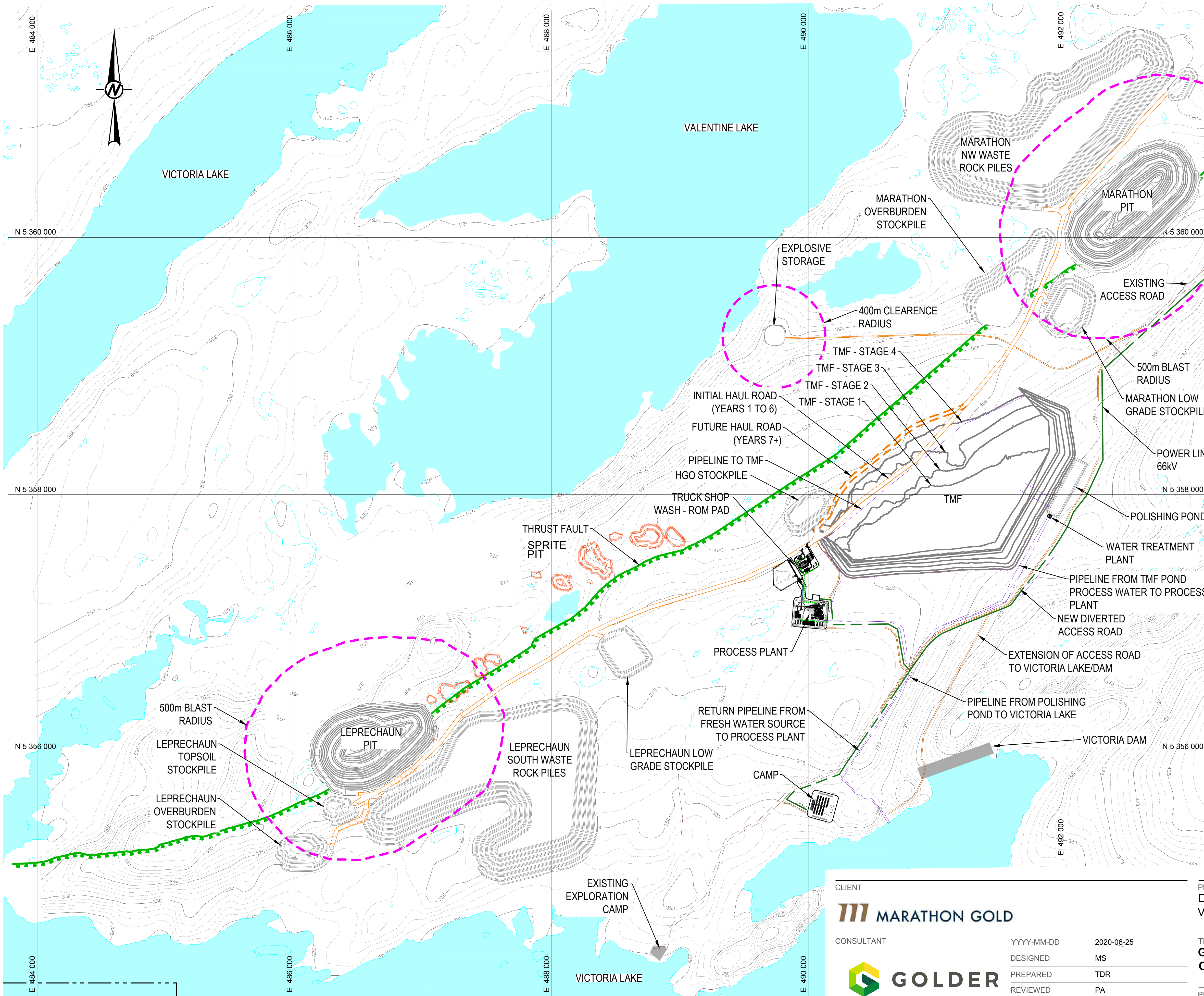

LEGEND

PROPERTY BOUNDARY

THRUST FAULT

NOTE(S):
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REFERENCE:
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NOT FOR CONSTRUCTION

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CLIENT
MARATHON GOLD

CONSULTANT
GOLDER

YYYY-MM-DD	2020-06-25
DESIGNED	MS
PREPARED	TDR
REVIEWED	PA
APPROVED	WPM

PROJECT
DAM BREACH ASSESSMENT AND INUNDATION STUDY
VALENTINE GOLD TAILINGS MANAGEMENT FACILITY

TITLE
GENERAL ARRANGEMENT
OVERALL SITE PLAN

PROJECT NO.	PHASE	REV.	FIGURE
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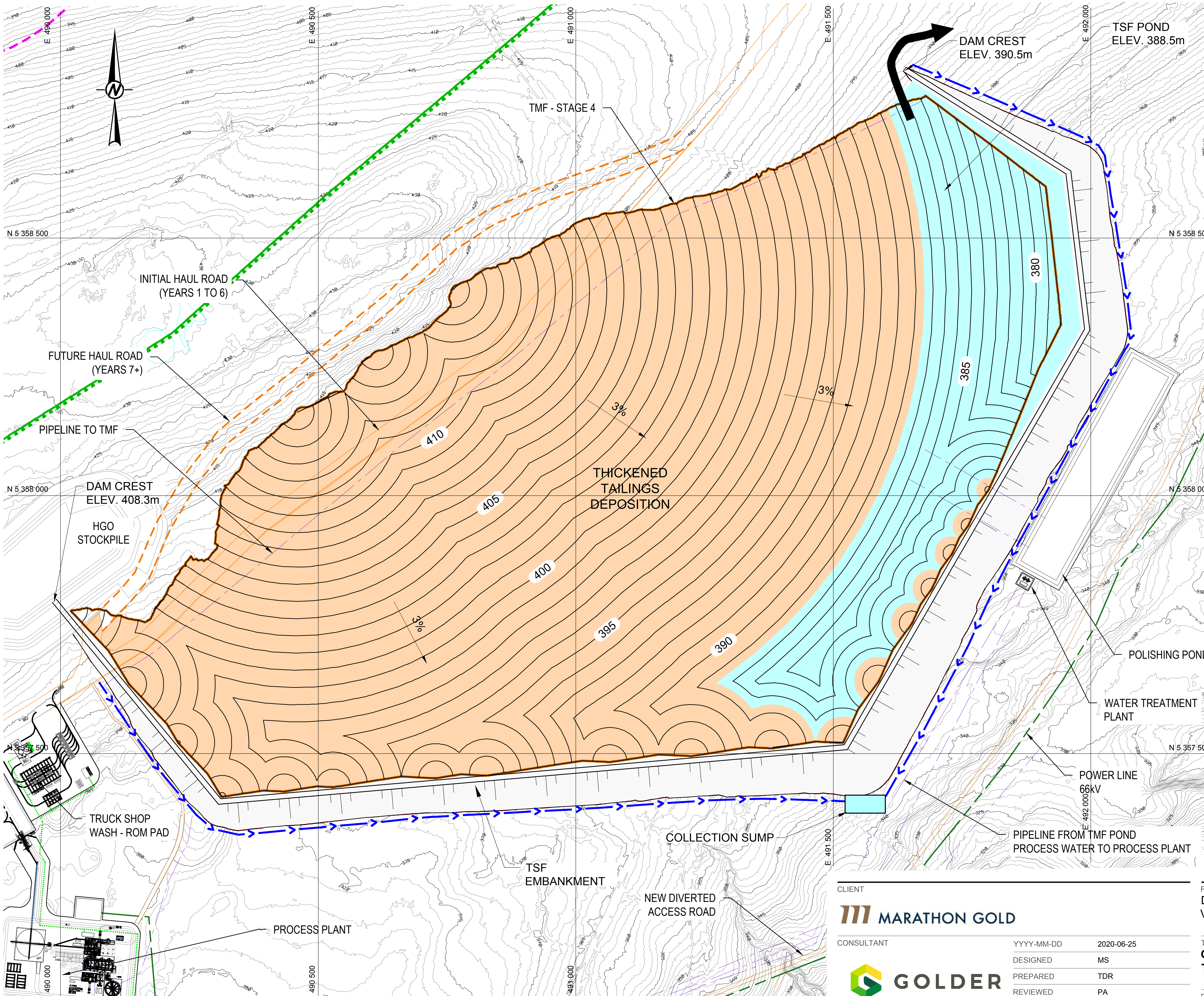

LEGEND

- THRUST FAULT
- SEEPAGE AND RUN-OFF COLLECTION DITCH
- TMF EMERGENCY SPILLWAY
- WATERCOURSE

NOTES:

1. ALL ELEVATIONS, GRID COORDINATES AND DIMENSIONS ARE IN METRES. GRID D COORDINATES ARE REFERENCE TO NAD83 UTM ZONE 21 DATUM.
2. GROUND CONTOURS INTERVALS AT 1m.

REFERENCES

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GROUND CONTOURS PROVIDED BY CLIENT. FILENAME MRG_01_Valentine_Mine_Survey_Data_Delivery.ZIP, DATED 11/6/2019.

NOT FOR CONSTRUCTION

0 125 250
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CLIENT
MARATHON GOLD

CONSULTANT
GOLDER

YYYY-MM-DD	2020-06-25
DESIGNED	MS
PREPARED	TDR
REVIEWED	PA
APPROVED	WPM

PROJECT
DAM BREACH ASSESSMENT AND INUNDATION STUDY
VALENTINE GOLD TAILINGS MANAGEMENT FACILITY

TITLE
GENERAL ARRANGEMENT
TMF ULTIMATE CONFIGURATION

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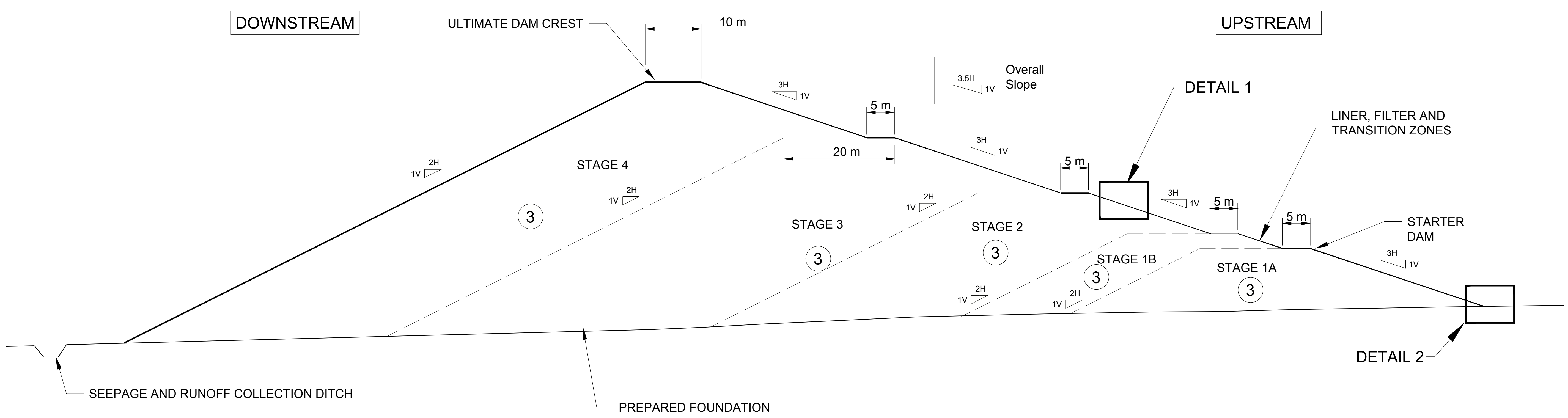
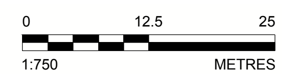
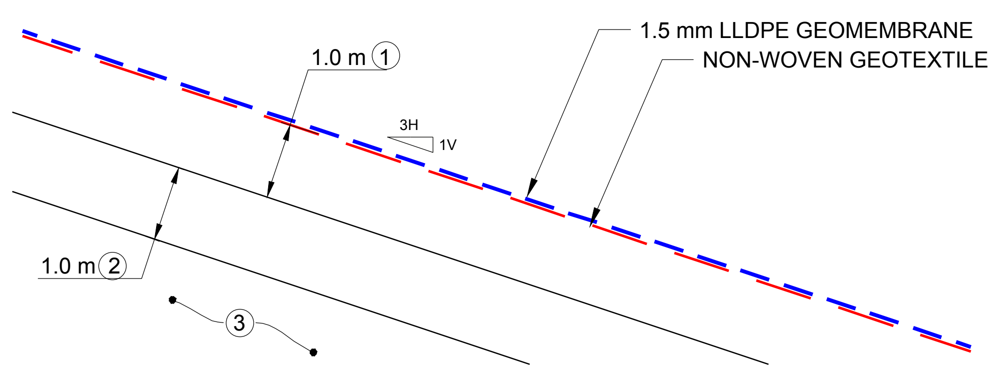


TYPICAL CROSS-SECTION





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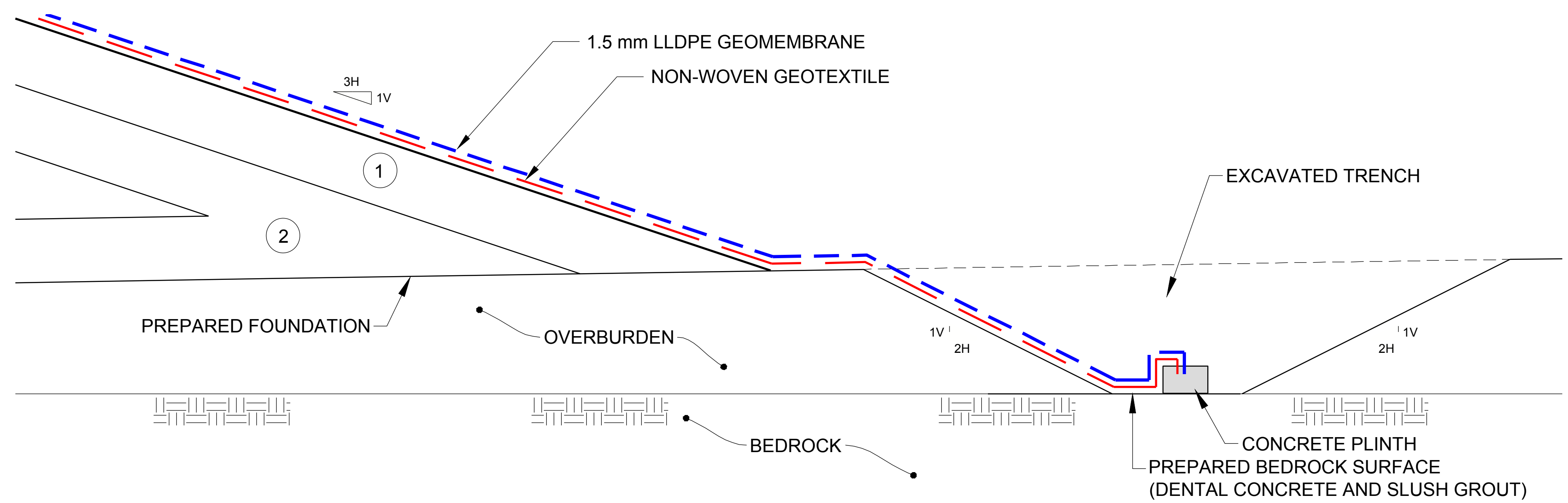

SCALE 1:100 2 - DETAIL 2: GEOMEMBRANE ANCHOR DETAIL

FILL MATERIALS		
ZONE	1	SAND BEDDING / FILTER SAND
ZONE	2	COARSE FILTER
ZONE	3	ROCKFILL

NOT FOR CONSTRUCTION

CLIENT
MARATHON GOLD

CONSULTANT
GOLDER

YYYY-MM-DD	2020-06-25
DESIGNED	MS
PREPARED	TDR
REVIEWED	PA
APPROVED	WPM

PROJECT
DAM BREACH ASSESSMENT AND INUNDATION STUDY
VALENTINE GOLD TAILINGS MANAGEMENT FACILITY

TITLE
TYPICAL DAM SECTION

PROJECT NO.	PHASE	REV.	FIGURE
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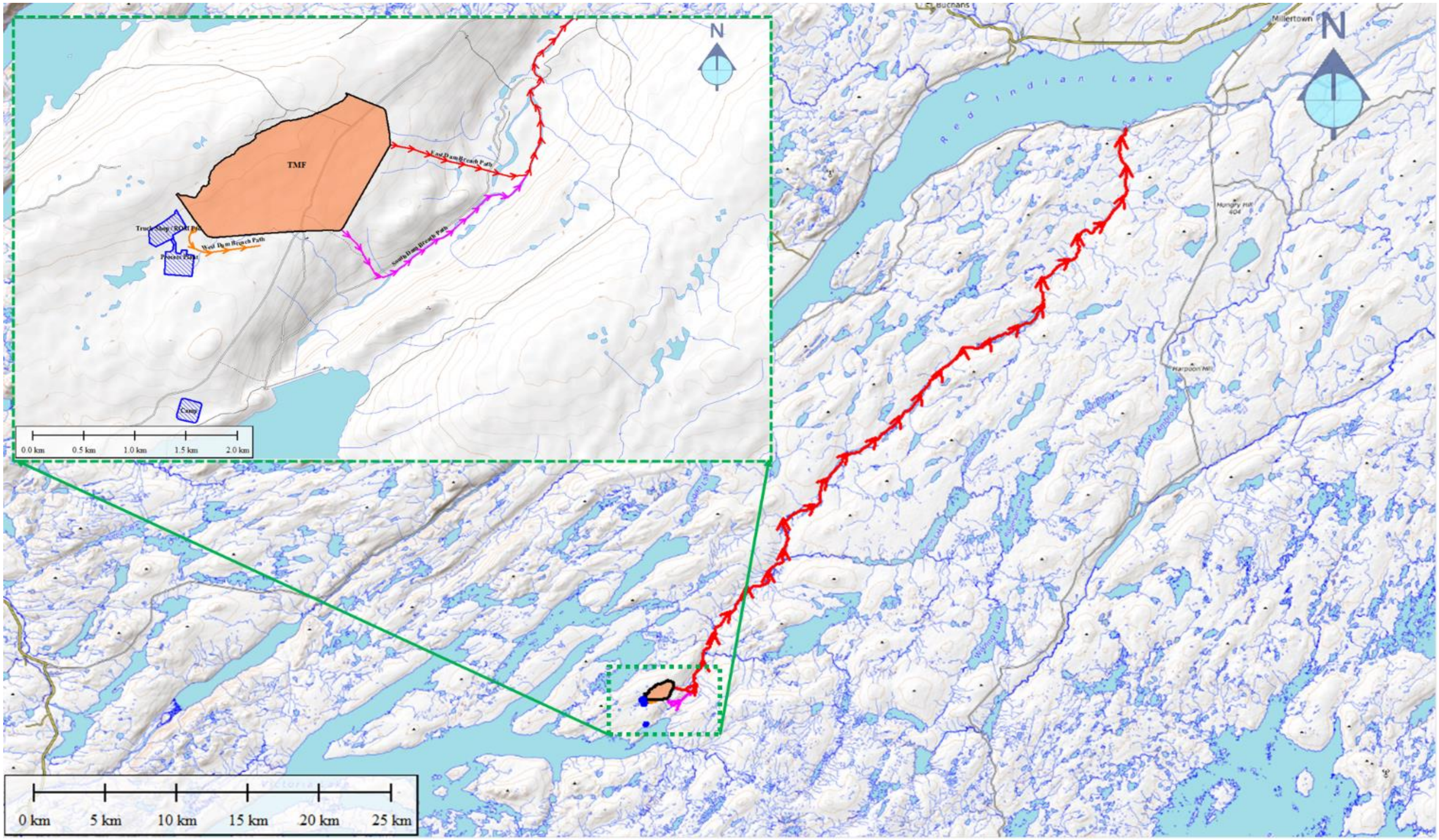


Figure 5 TMF East/South/West Dam Breach – Flood Wave Paths

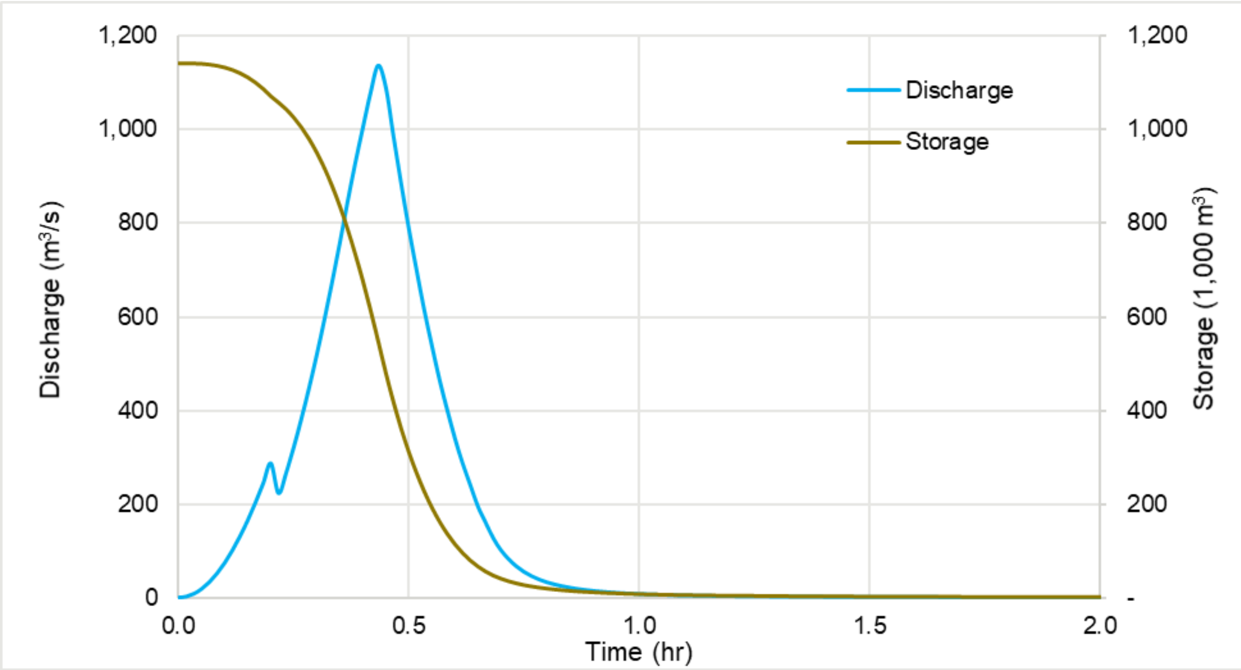


Figure 6: HEC-HMS TMF East Dam Breach Outflow Under Fair-Weather Conditions – Piping Failure (Scenario A)

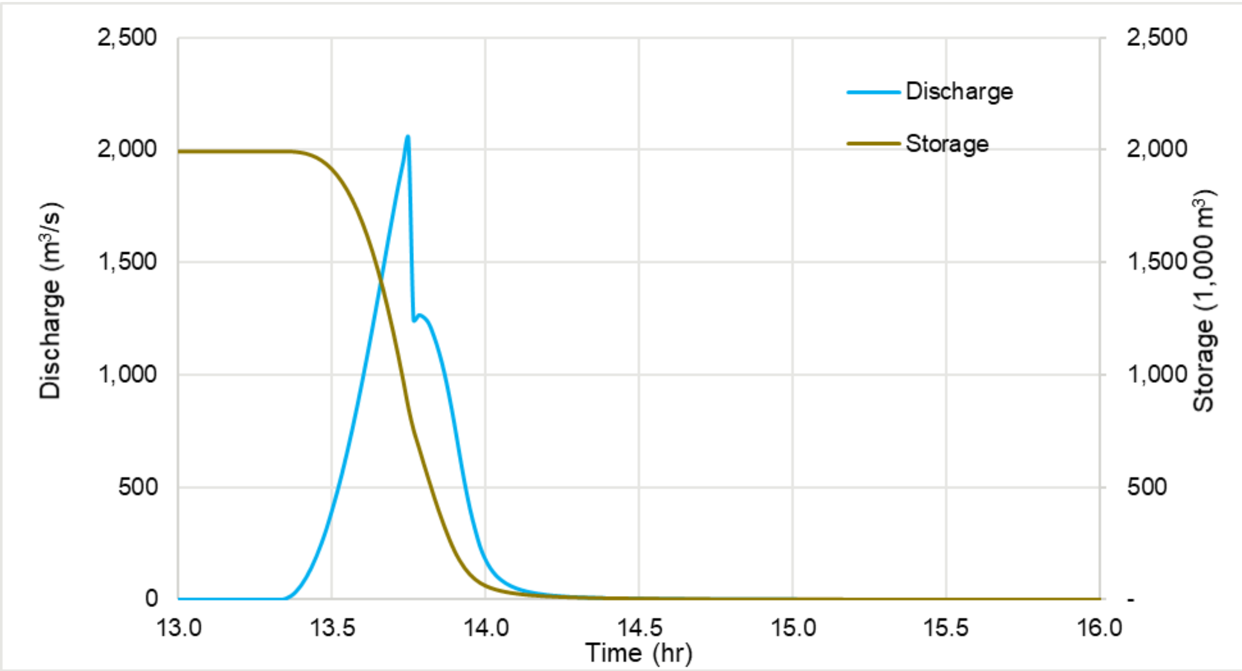


Figure 7: HEC-HMS TMF East Dam Breach Outflow Under PMF Event – Piping Failure (Scenario B1)

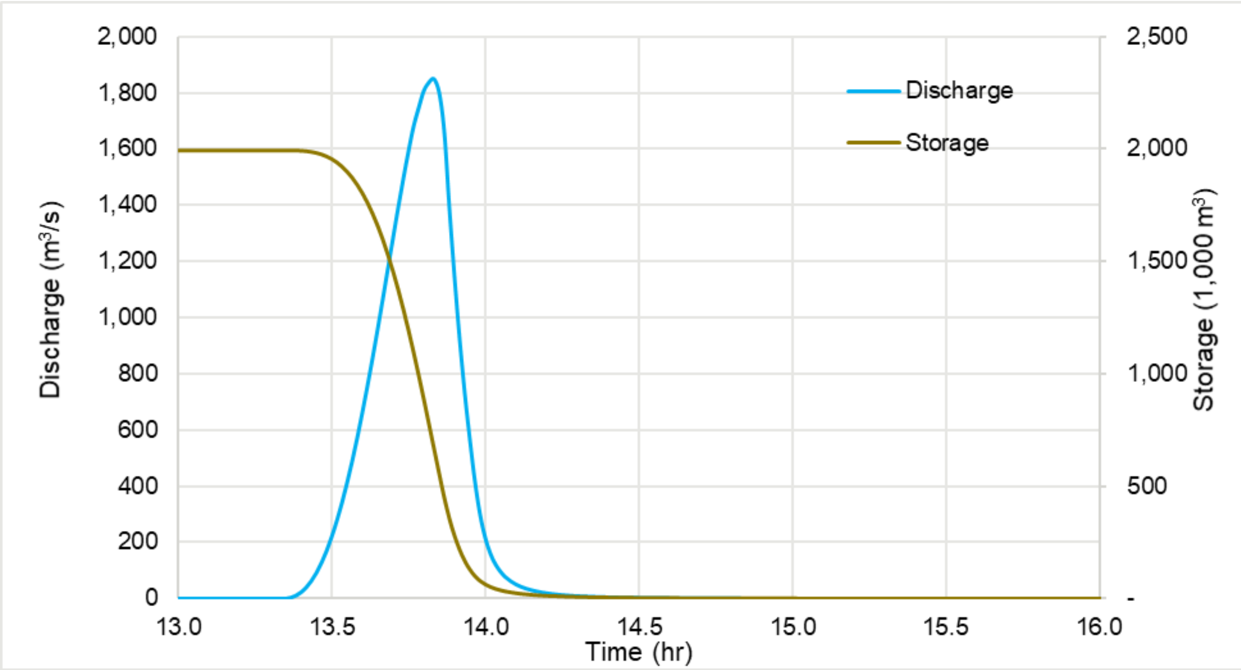


Figure 8: HEC-HMS TMF East Dam Breach Outflow Under PMF Event – Overtopping Failure (Scenario B2)

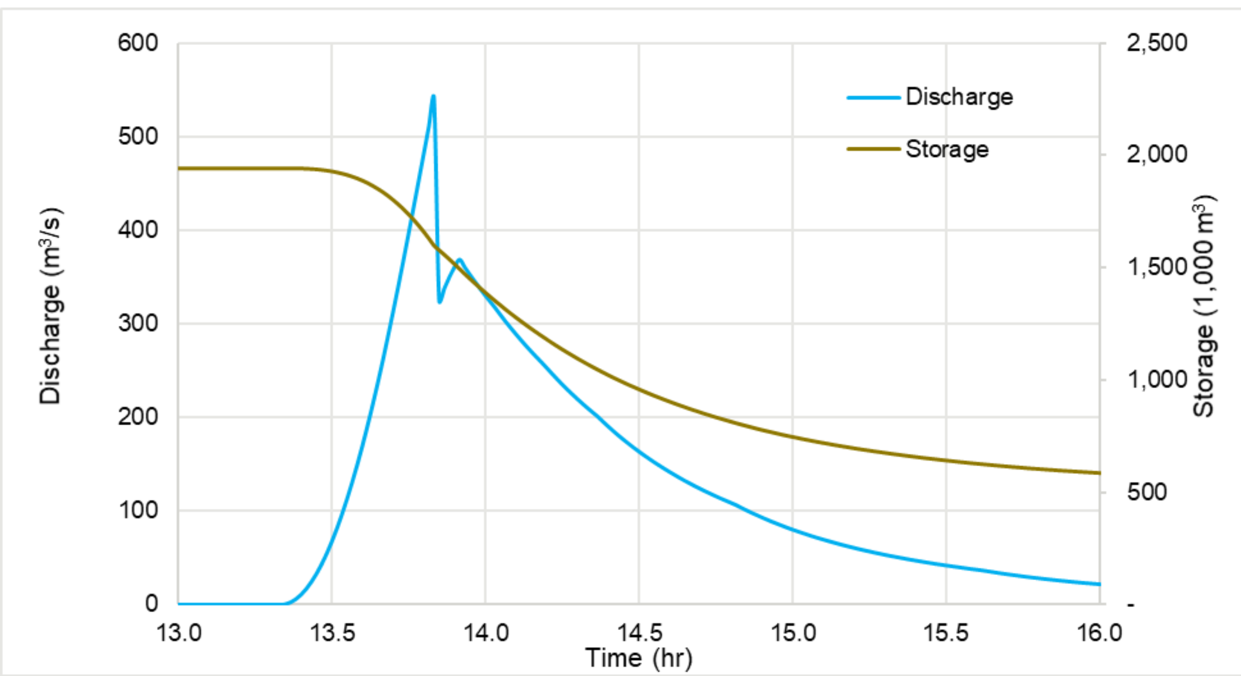


Figure 9: HEC-HMS TMF South Dam Breach Outflow Under PMF Event – Piping Failure (Scenario C)

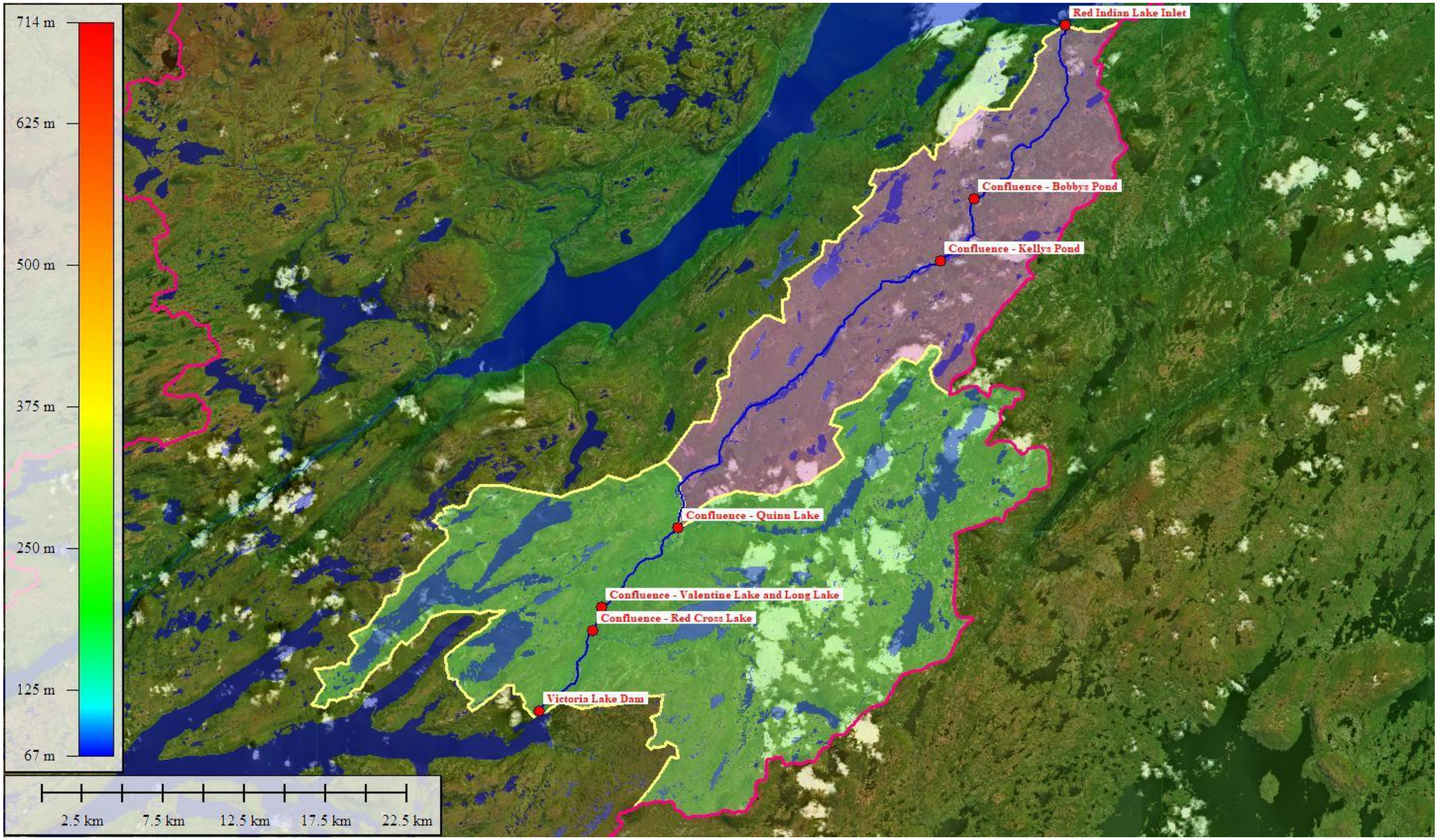


Figure 10: Victoria River subwatershed Areas

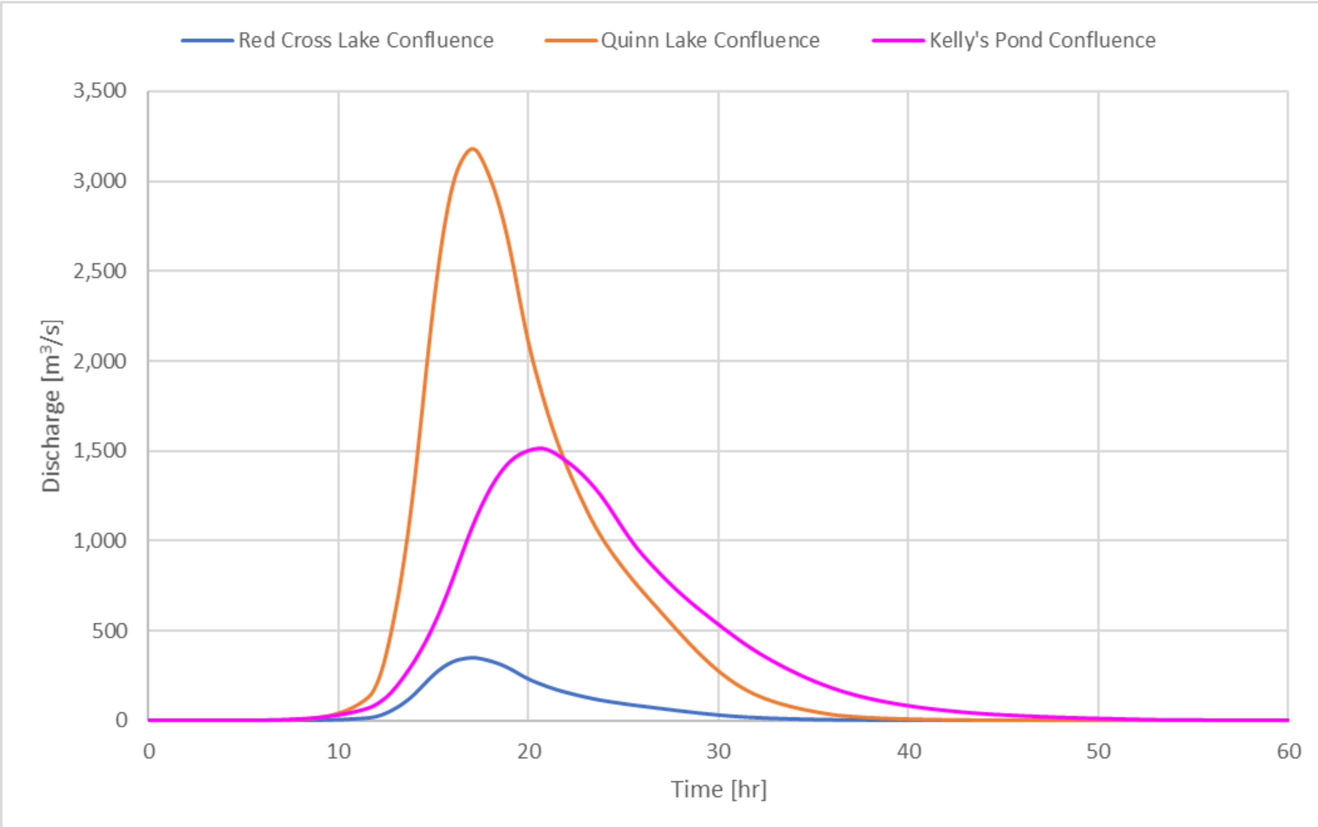


Figure 11: PMF Lateral Inflow Hydrographs Routed at Downstream Locations Along Victoria River

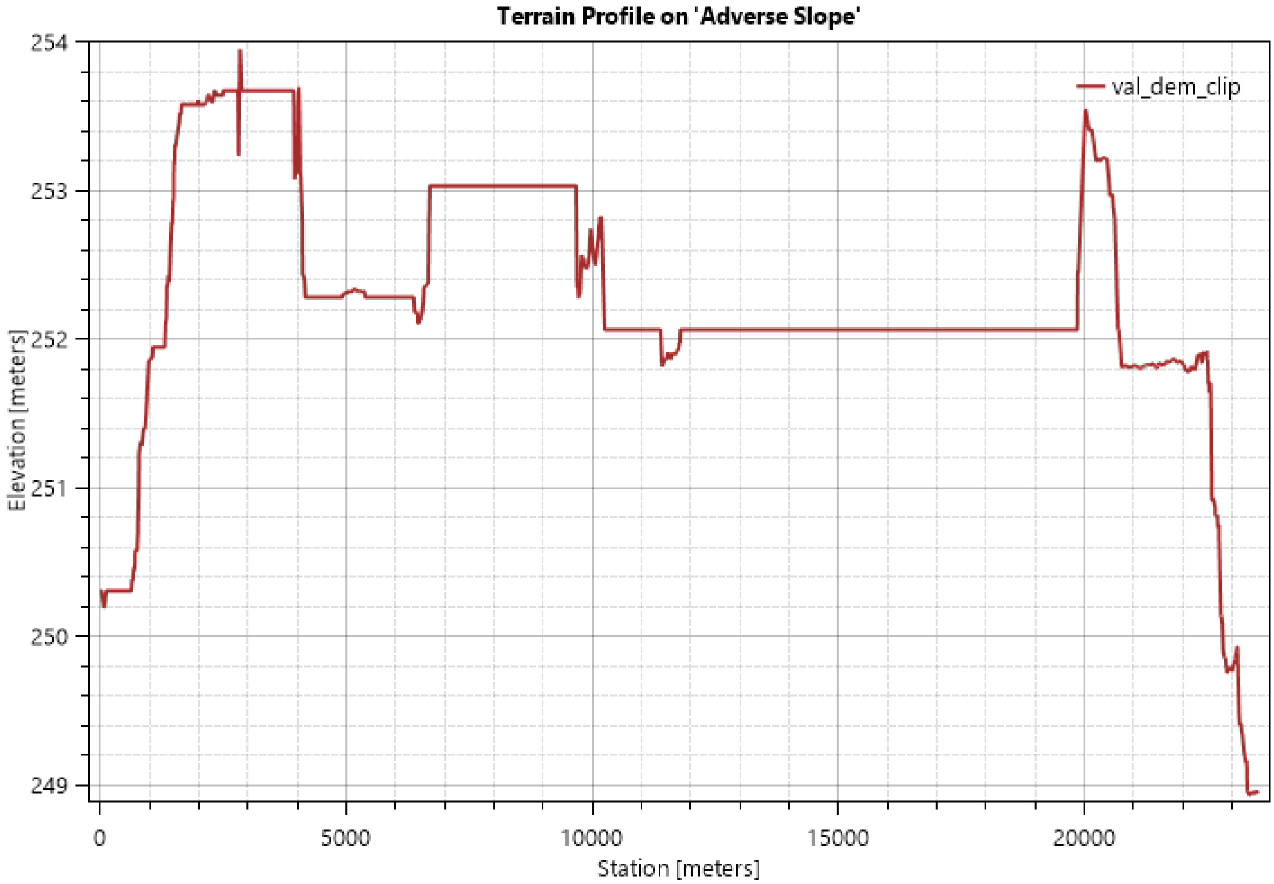


Figure 12: Adverse Slopes in Terrain Data

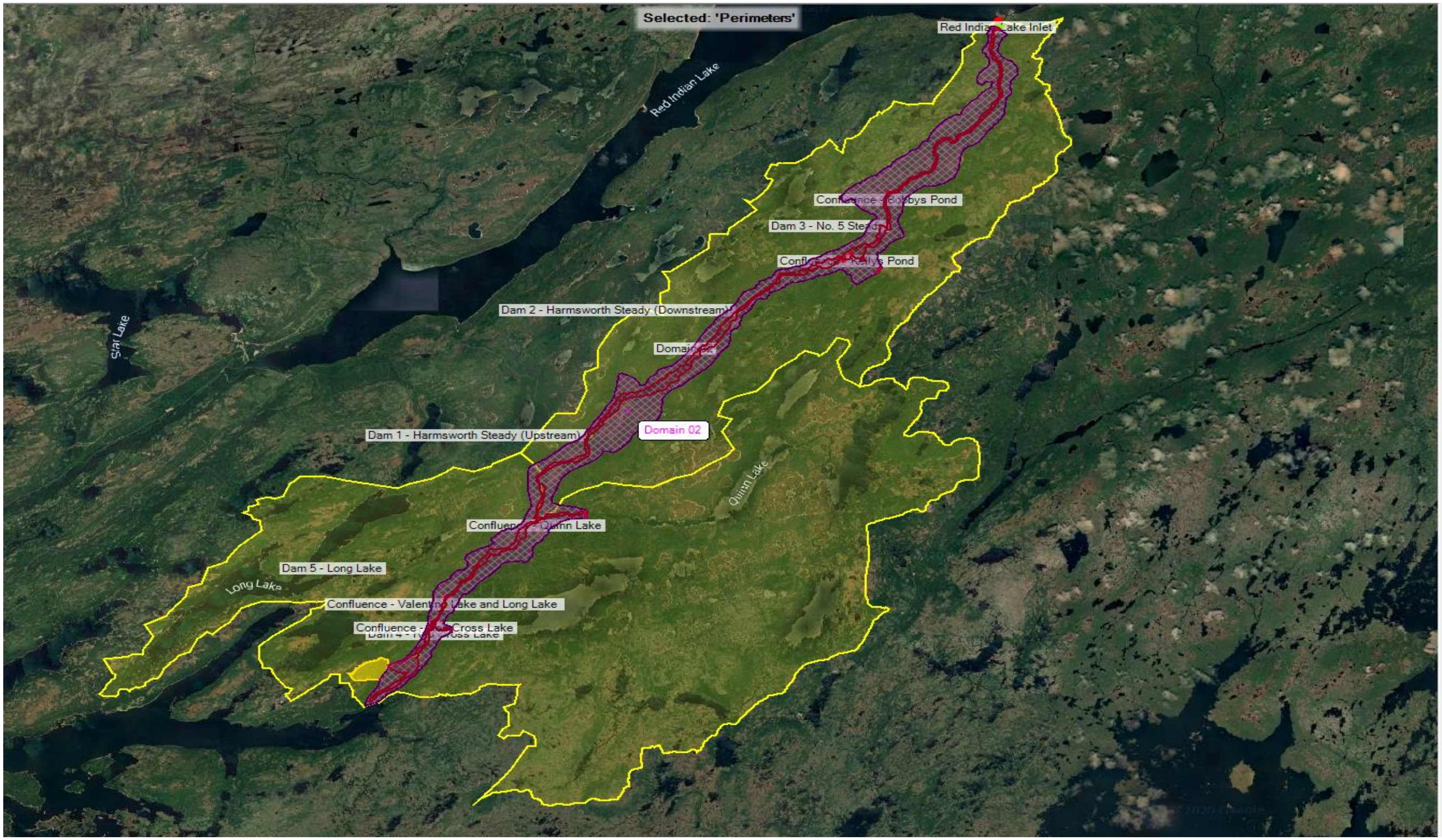


Figure 13: Hydrologic and Hydraulic Model Boundary for the TMF East Dam Failure Simulations (Scenarios A and B1)

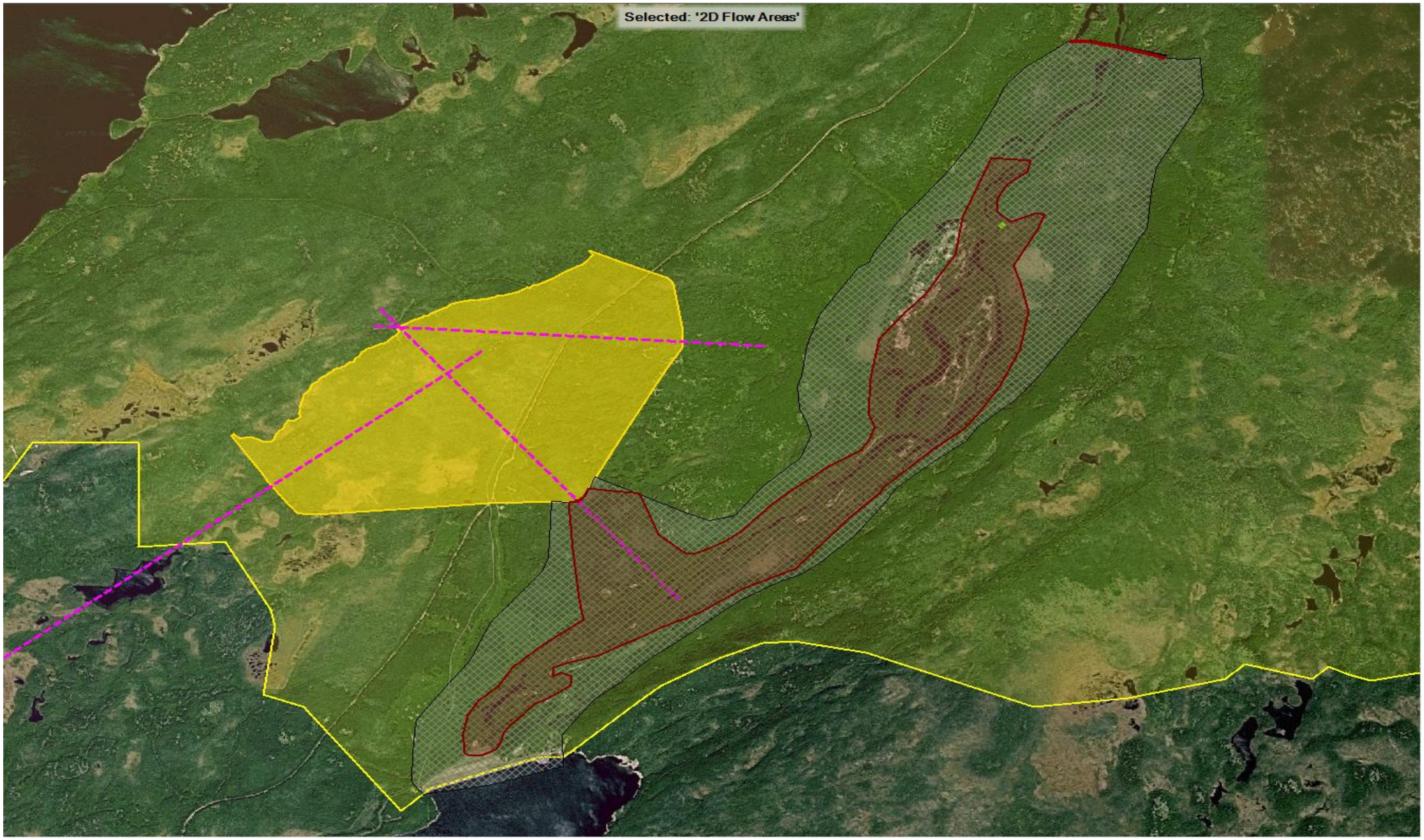
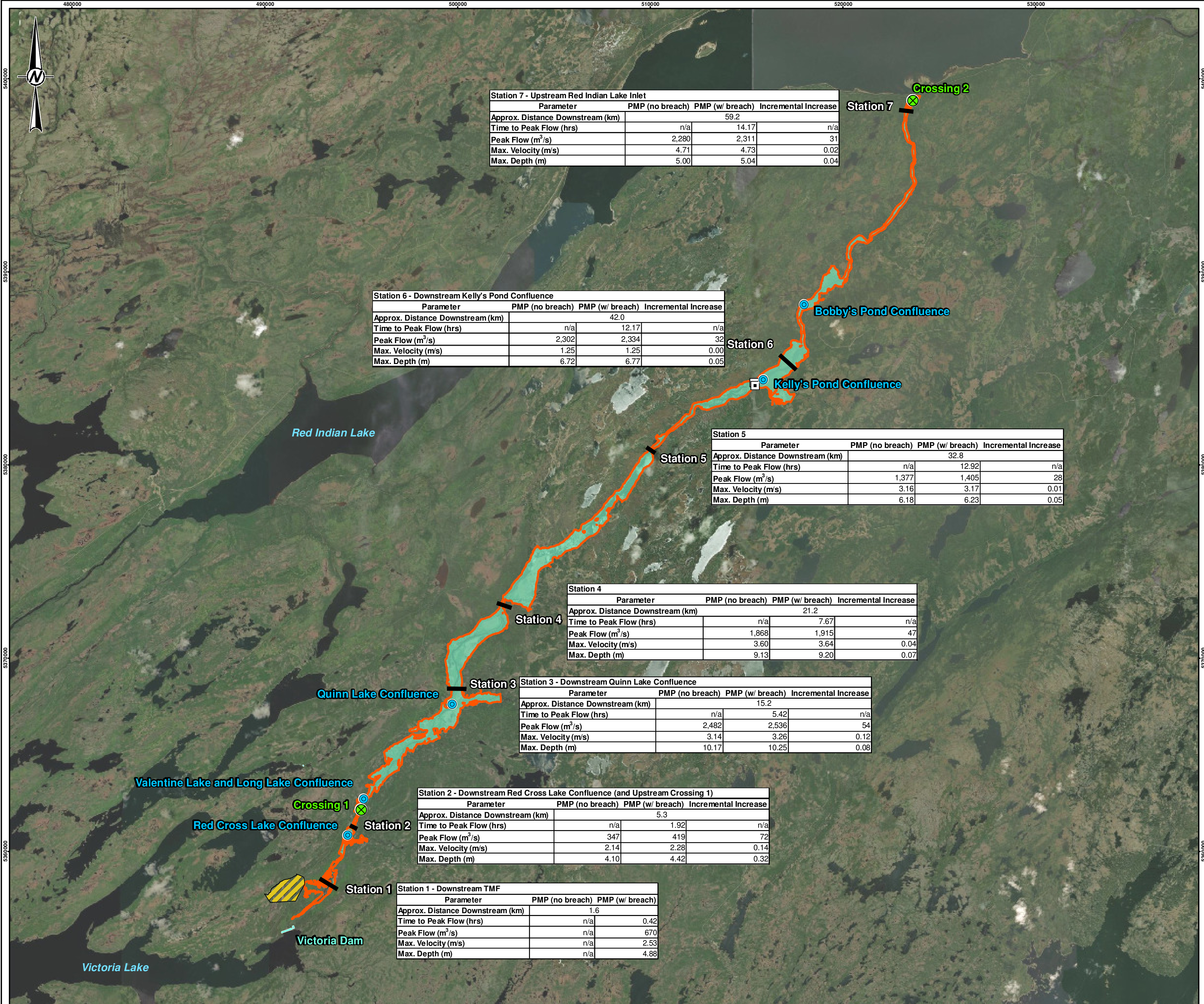


Figure 14: Hydrologic and Hydraulic Model Boundary for the TMF South Dam Failure Simulations (Scenario C)



Station 7 - Upstream Red Indian Lake Inlet			
Parameter	PMP (no breach)	PMP (w/ breach)	Incremental Increase
Approx. Distance Downstream (km)		59.2	
Time to Peak Flow (hrs)	n/a	14.17	n/a
Peak Flow (m^3/s)	2,280	2,311	31
Max. Velocity (m/s)	4.71	4.73	0.02
Max. Depth (m)	5.00	5.04	0.04

Station 6 - Downstream Kelly's Pond Confluence			
Parameter	PMP (no breach)	PMP (w/ breach)	Incremental Increase
Approx. Distance Downstream (km)		42.0	
Time to Peak Flow (hrs)	n/a	12.17	n/a
Peak Flow (m^3/s)	2,302	2,334	32
Max. Velocity (m/s)	1.25	1.25	0.00
Max. Depth (m)	6.72	6.77	0.05

Station 5			
Parameter	PMP (no breach)	PMP (w/ breach)	Incremental Increase
Approx. Distance Downstream (km)		32.8	
Time to Peak Flow (hrs)	n/a	12.92	n/a
Peak Flow (m^3/s)	1,377	1,405	28
Max. Velocity (m/s)	3.16	3.17	0.01
Max. Depth (m)	6.18	6.23	0.05

Station 4			
Parameter	PMP (no breach)	PMP (w/ breach)	Incremental Increase
Approx. Distance Downstream (km)		21.2	
Time to Peak Flow (hrs)	n/a	7.67	n/a
Peak Flow (m^3/s)	1,868	1,915	47
Max. Velocity (m/s)	3.60	3.64	0.04
Max. Depth (m)	9.13	9.20	0.07

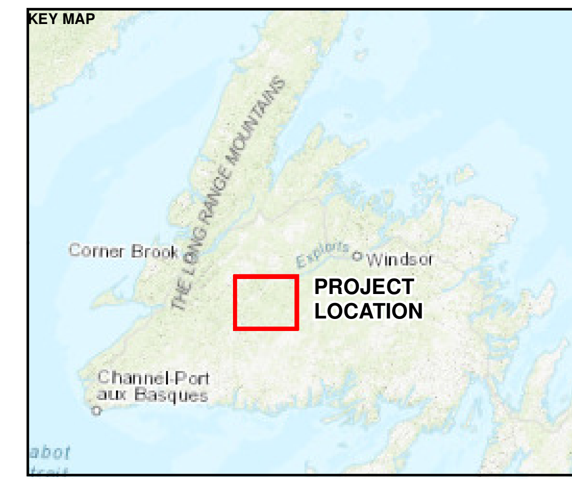
Station 3 - Downstream Quinn Lake Confluence			
Parameter	PMP (no breach)	PMP (w/ breach)	Incremental Increase
Approx. Distance Downstream (km)		15.2	
Time to Peak Flow (hrs)	n/a	5.42	n/a
Peak Flow (m^3/s)	2,482	2,536	54
Max. Velocity (m/s)	3.14	3.26	0.12
Max. Depth (m)	10.17	10.25	0.08

Station 2 - Downstream Red Cross Lake Confluence (and Upstream Crossing 1)			
Parameter	PMP (no breach)	PMP (w/ breach)	Incremental Increase
Approx. Distance Downstream (km)		5.3	
Time to Peak Flow (hrs)	n/a	1.92	n/a
Peak Flow (m^3/s)	347	419	72
Max. Velocity (m/s)	2.14	2.28	0.14
Max. Depth (m)	4.10	4.42	0.32

Station 1 - Downstream TMF		
Parameter	PMP (no breach)	PMP (w/ breach)
Approx. Distance Downstream (km)	1.6	
Time to Peak Flow (hrs)	n/a	0.42
Peak Flow (m^3/s)	n/a	670
Max. Velocity (m/s)	n/a	2.53
Max. Depth (m)	n/a	4.88

LEGEND

- DWELLING/LODGE
- CROSSING
- VICTORIA RIVER CONFLUENCE
- STATION PROFILE LOCATION
- TAILINGS MANAGEMENT FACILITY
- INUNDATION BOUNDARY (PMF BREACH)
- INUNDATION BOUNDARY (PMF NO BREACH)



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NOTE(S)

REFERENCE(S)

1. BASE IMAGERY - SOURCE: ESRI, DIGITALGLOBE, GEOEYE, EARTHSTAR GEOGRAPHICS, CNES/AIRBUS DS, USDA, USGS, AEROGRID, IGN, AND THE GIS USER COMMUNITY SOURCES: ESRI, HERE, GARMIN, INTERMAP, INCREMENT P CORP., GEBCO, USGS, FAO, NPS, NRCAN, GEOBASE, IGN, KADASTER NL, ORDNANCE SURVEY, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), (C) OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY
2. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 21

CLIENT
MARATHON GOLD COROPORATION

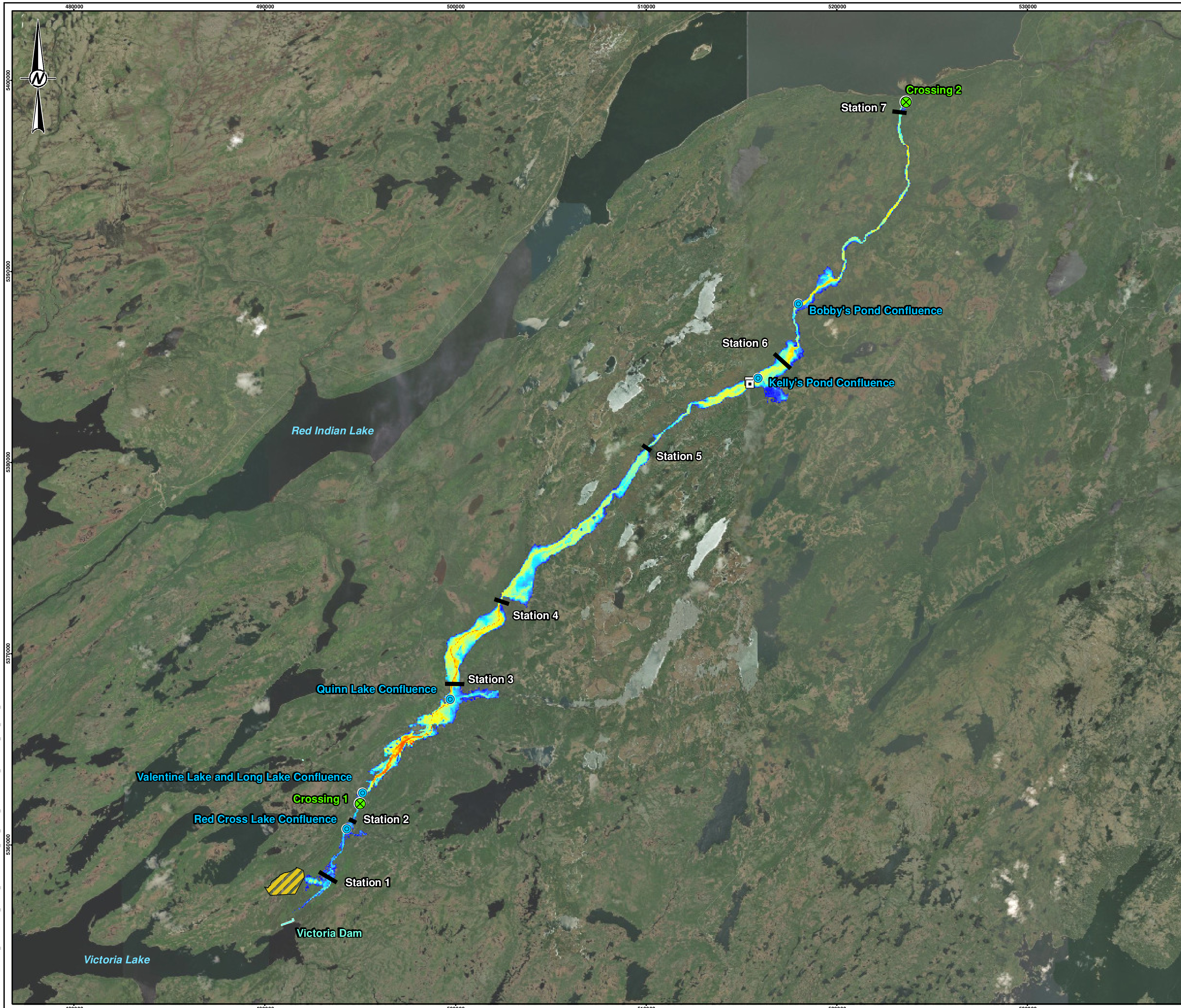
PROJECT
DAM BREACH ASSESSMENT AND INUNDATION STUDY
VALENTINE GOLD TAILINGS MANAGEMENT FACILITY

TITLE
INUNDATION AREA OF SIMULATED PMF BREACH AND NO BREACH SCENARIOS

CONSULTANT
GOLDER

YYYY-MM-DD	25-JUN-20
DESIGNED	CGE
PREPARED	CGE
REVIEWED	MAR
APPROVED	SK

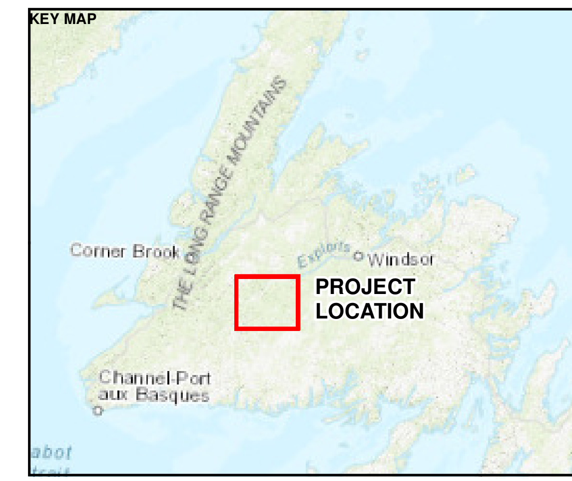
PROJECT NO.	CONTROL	REV.	FIGURE
20141194	0001	1	15



LEGEND

- DWELLING/LODGE
- CROSSING
- VICTORIA RIVER CONFLUENCE
- STATION PROFILE LOCATION
- TAILINGS MANAGEMENT FACILITY

MAXIMUM DEPTH (m)
HIGH : 11.5
LOW : 0



0 5,000 10,000
1:200,000 METRES

NOTE(S)

REFERENCE(S)

1. BASE IMAGERY - SOURCE: ESRI, DIGITALGLOBE, GEOEYE, EARTHSTAR GEOGRAPHICS, CNES/AIRBUS DS, USDA, USGS, AEROGRID, IGN, AND THE GIS USER COMMUNITY SOURCES: ESRI, HERE, GARMIN, INTERMAP, INCREMENT P CORP., GEBCO, USGS, FAO, NPS, NRCAN, GEOBASE, IGN, KADASTER NL, ORDNANCE SURVEY, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), (C) OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY
2. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 21

CLIENT
MARATHON GOLD COROPORATION

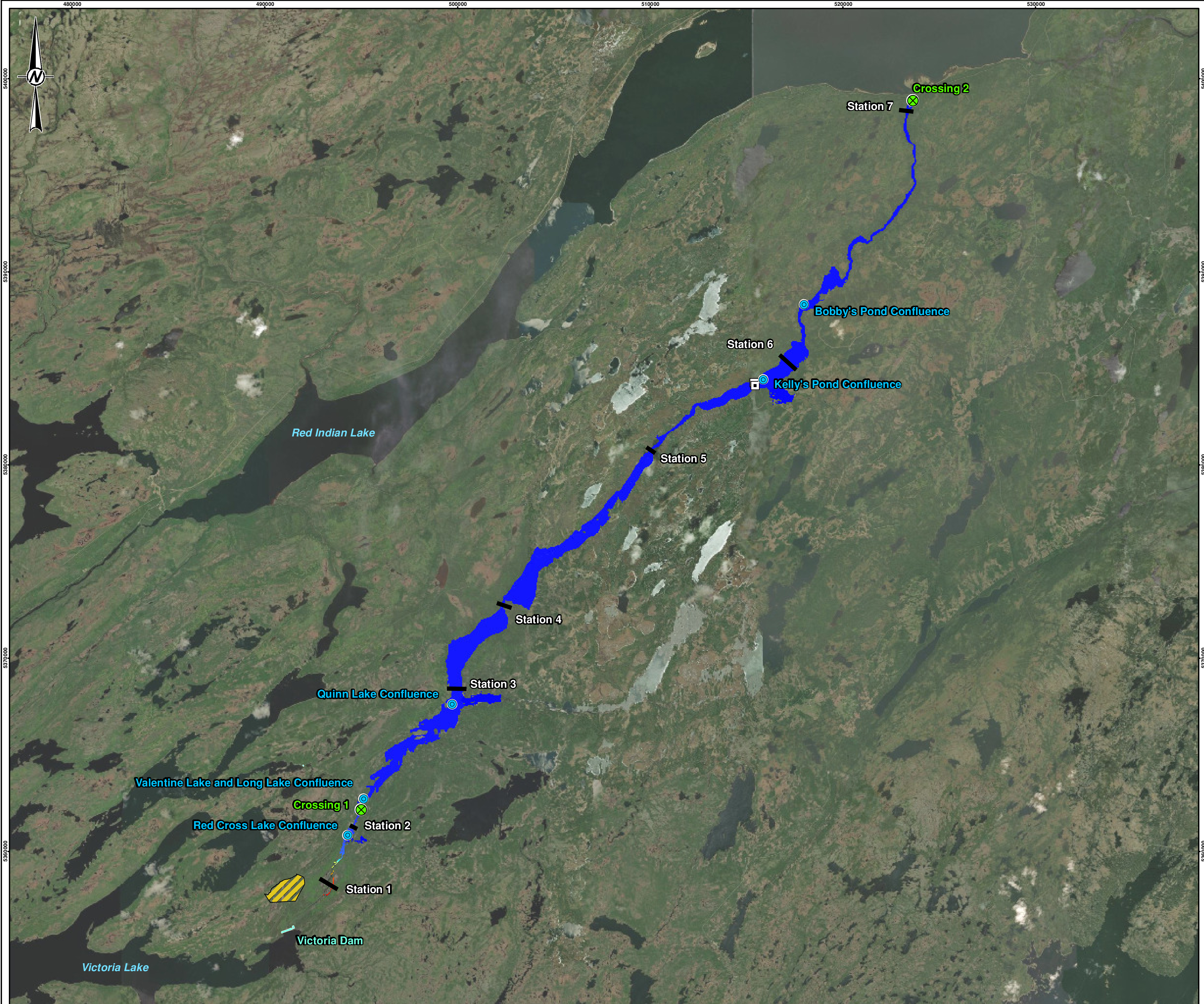
PROJECT
DAM BREACH ASSESSMENT AND INUNDATION STUDY
VALENTINE GOLD TAILINGS MANAGEMENT FACILITY

TITLE
MAXIMUM DEPTH FOR PMF BREACH SCENARIO

CONSULTANT
GOLDER

YYYY-MM-DD	25-JUN-20
DESIGNED	CGE
PREPARED	CGE
REVIEWED	MAR
APPROVED	SK

PROJECT NO.	CONTROL	REV.	FIGURE
20141194	0001	1	16



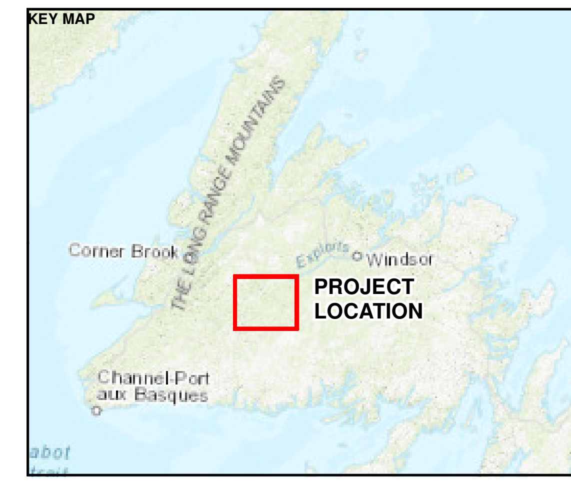
LEGEND

- DWELLING/LODGE
- CROSSING
- VICTORIA RIVER CONFLUENCE
- STATION PROFILE LOCATION
- TAILINGS MANAGEMENT FACILITY

INCREMENTAL DIFFERENCE, MAXIMUM DEPTH (m)

HIGH : 5

LOW : 0



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1:200,000 METRES

NOTE(S)

REFERENCE(S)

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2. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 21

CLIENT

MARATHON GOLD COROPORATION

PROJECT

DAM BREACH ASSESSMENT AND INUNDATION STUDY
VALENTINE GOLD TAILINGS MANAGEMENT FACILITY

TITLE

INCREMENTAL DIFFERENCE IN MAXIMUM INUNDATION DEPTH BETWEEN THE PMF BREACH AND PMF NO BREACH SCENARIOS

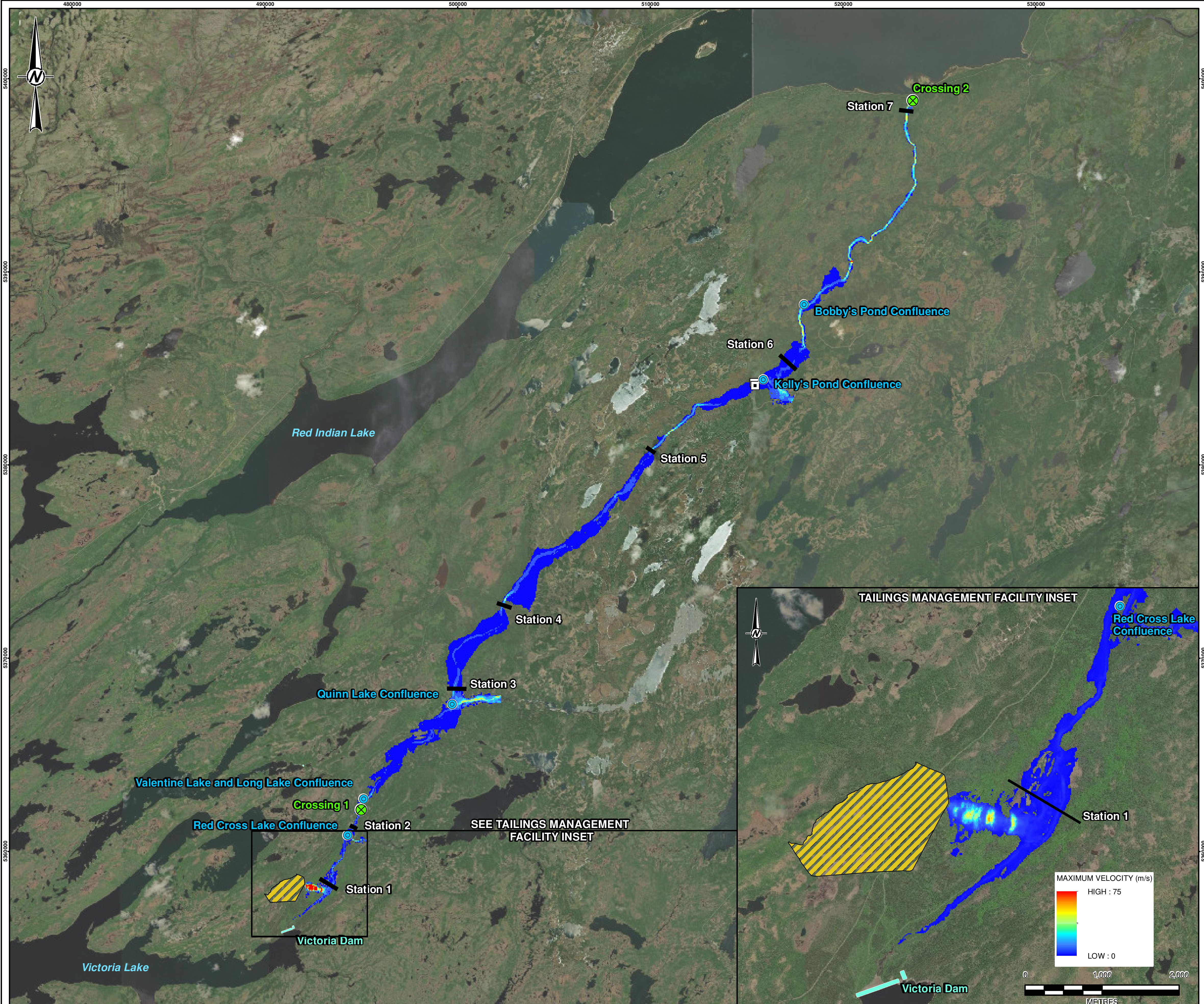
CONSULTANT

GOLDER

YYYY-MM-DD	25-JUN-20
DESIGNED	CGE
PREPARED	CGE
REVIEWED	MAR
APPROVED	SK

PROJECT NO.	CONTROL	REV.	FIGURE
20141194	0001	1	17

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

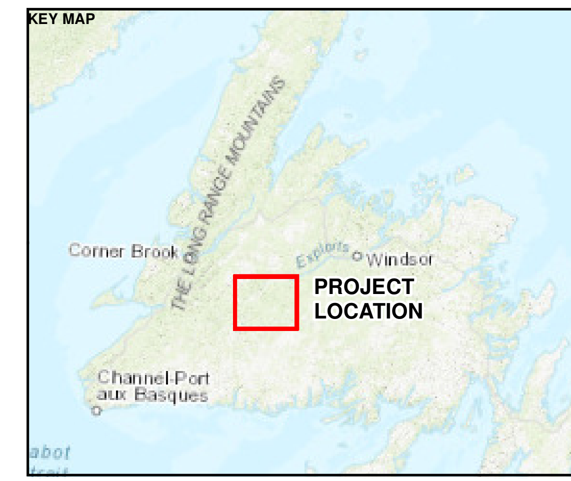


LEGEND

- DWELLING/LODGE
- CROSSING
- VICTORIA RIVER CONFLUENCE
- STATION PROFILE LOCATION
- TAILINGS MANAGEMENT FACILITY

MAXIMUM VELOCITY (m/s)

- 0 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- 5 - 6
- 6 - 7
- 7 - 8
- 8 - 9
- 9 - 10
- 10 - 75



0 5,000 10,000

1:200,000 METRES

NOTE(S)

REFERENCE(S)

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2. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 21

CLIENT

MARATHON GOLD COROPORATION

PROJECT

DAM BREACH ASSESSMENT AND INUNDATION STUDY
VALENTINE GOLD TAILINGS MANAGEMENT FACILITY

TITLE

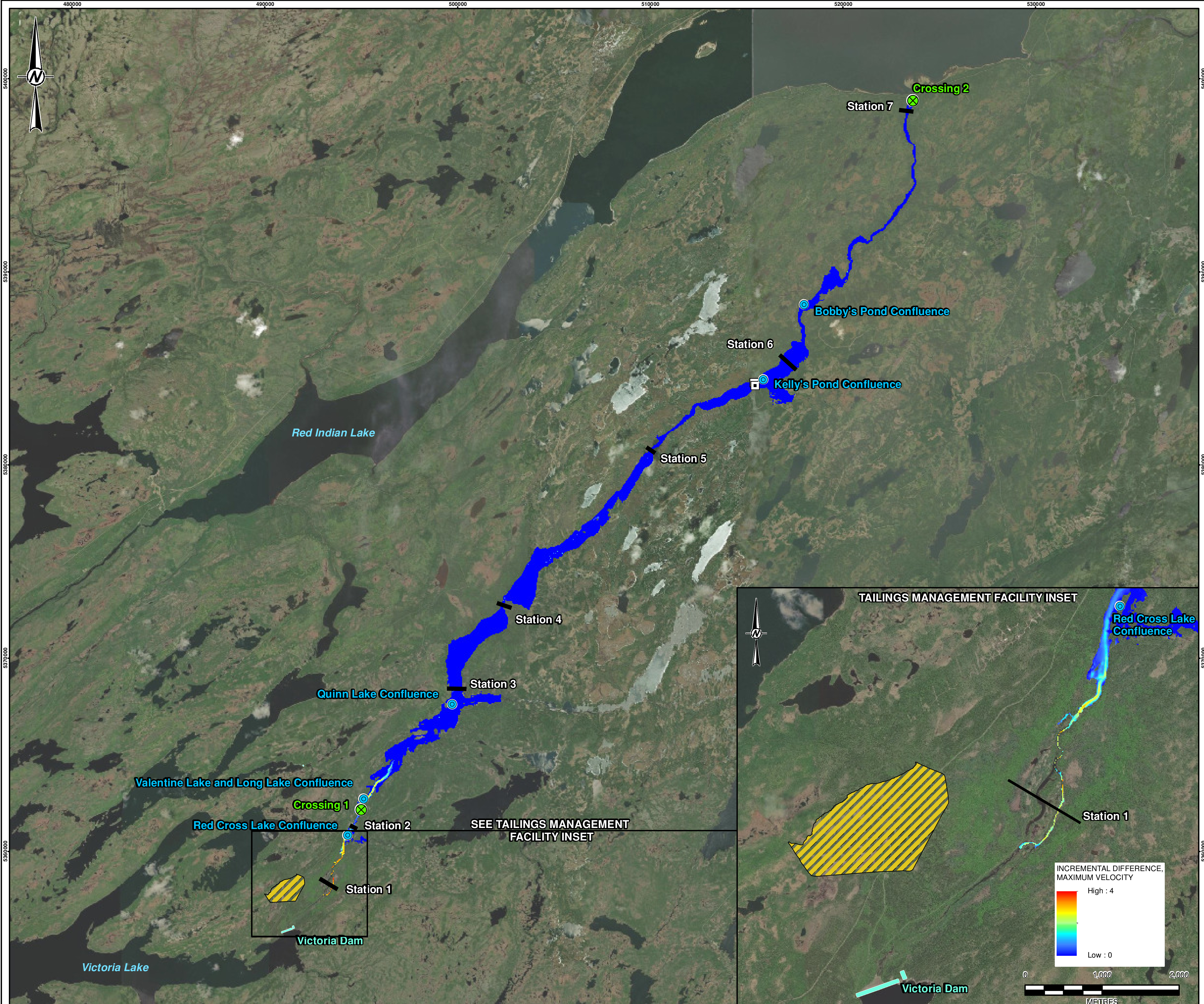
MAXIMUM VELOCITY FOR PMF BREACH SCENARIO

CONSULTANT

GOLDER

YYYY-MM-DD	25-JUN-20
DESIGNED	CGE
PREPARED	CGE
REVIEWED	MAR
APPROVED	SK

PROJECT NO.	CONTROL	REV.	FIGURE
20141194	0001	1	18

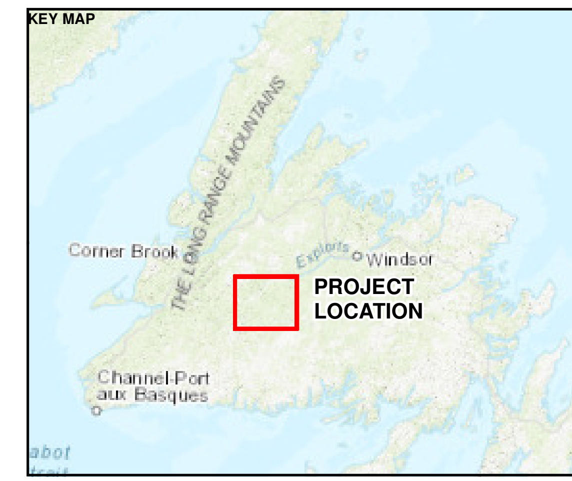


LEGEND

- DWELLING/LODGE
- CROSSING
- VICTORIA RIVER CONFLUENCE
- STATION PROFILE LOCATION
- TAILINGS MANAGEMENT FACILITY

INCREMENTAL DIFFERENCE, MAXIMUM VELOCITY

- 0 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.4
- 0.4 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 4



0 5,000 10,000

1:200,000 METRES

NOTE(S)

REFERENCE(S)

1. BASE IMAGERY - SOURCE: ESRI, DIGITALGLOBE, GEOEYE, EARTHSTAR GEOGRAPHICS, CNES/AIRBUS DS, USDA, USGS, AEROGRID, IGN, AND THE GIS USER COMMUNITY SOURCES: ESRI, HERE, GARMIN, INTERMAP, INCREMENT P CORP., GEBCO, USGS, FAO, NPS, NRCAN, GEOBASE, IGN, KADASTER NL, ORDNANCE SURVEY, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), (C) OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY
2. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 21

CLIENT

MARATHON GOLD COROPORATION

PROJECT

DAM BREACH ASSESSMENT AND INUNDATION STUDY
VALENTINE GOLD TAILINGS MANAGEMENT FACILITY

TITLE

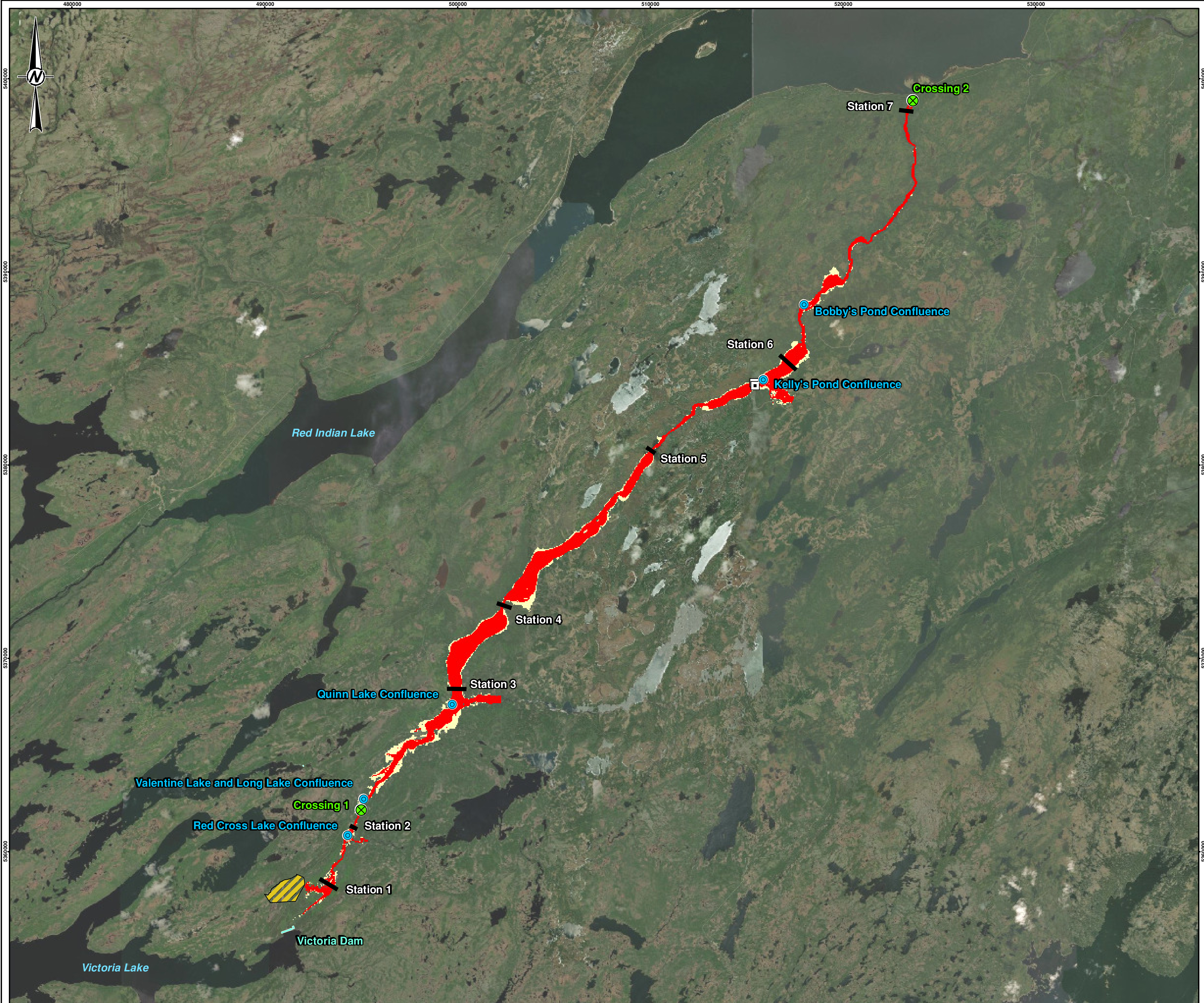
INCREMENTAL DIFFERENCE IN MAXIMUM VELOCITY BETWEEN THE PMF BREACH AND PMF NO BREACH SCENARIOS

CONSULTANT

GOLDER

YYYY-MM-DD	25-JUN-20
DESIGNED	CGE
PREPARED	CGE
REVIEWED	MAR
APPROVED	SK

PROJECT NO.	CONTROL	REV.	FIGURE
20141194	0001	1	19

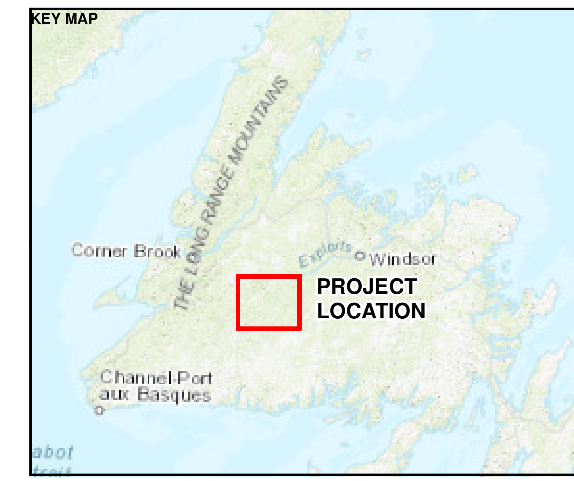


LEGEND

- DWELLING/LODGE
- CROSSING
- VICTORIA RIVER CONFLUENCE
- STATION PROFILE LOCATION
- TAILINGS MANAGEMENT FACILITY

MAXIMUM DEPTH * VELOCITY

- 0 - 0.37
- GREATER THAN OR EQUAL TO 0.37



0 5,000 10,000

1:200,000 METRES

NOTE(S)

REFERENCE(S)

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2. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 21

CLIENT

MARATHON GOLD COROPORATION

PROJECT

DAM BREACH ASSESSMENT AND INUNDATION STUDY
VALENTINE GOLD TAILINGS MANAGEMENT FACILITY

TITLE

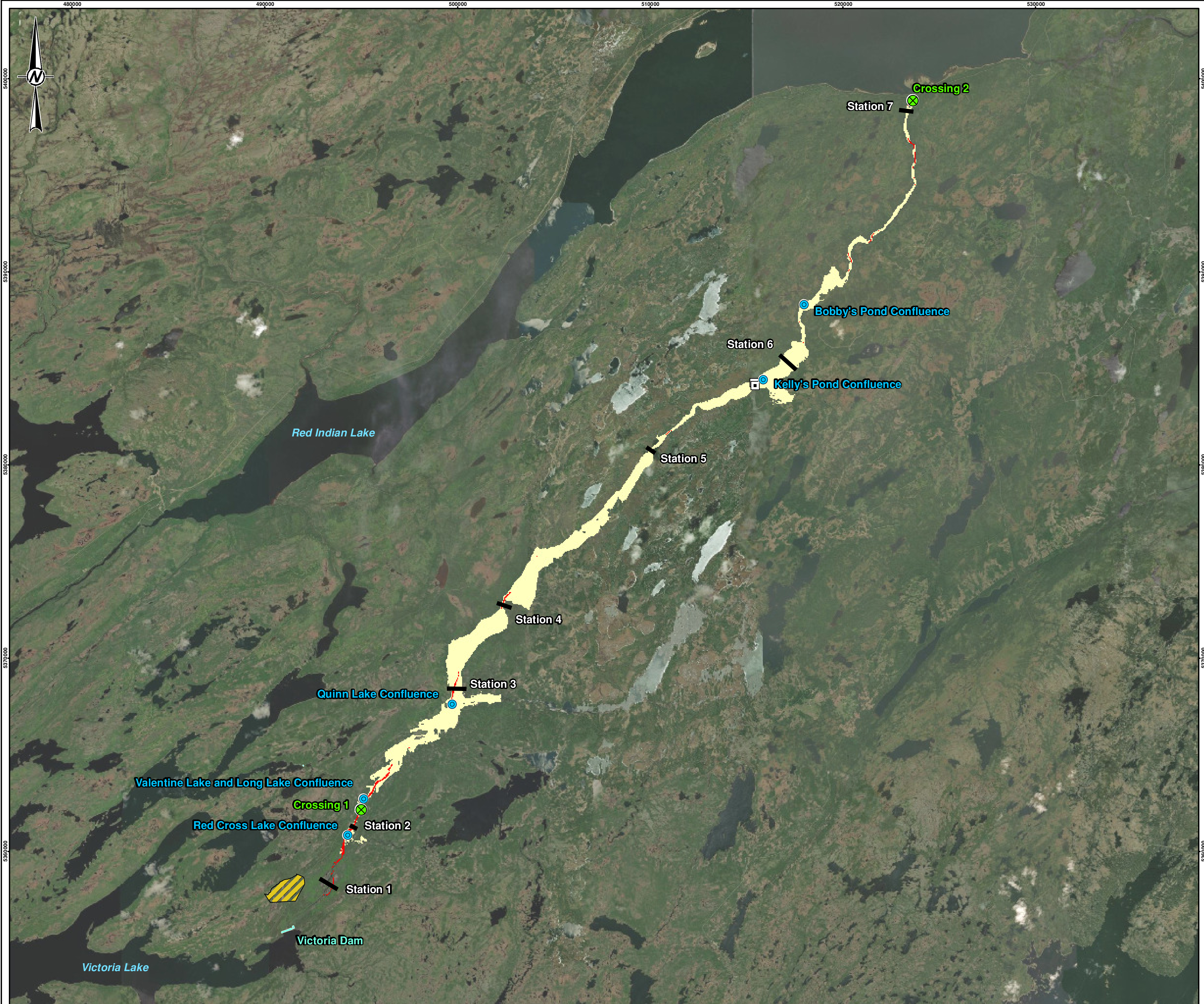
MAXIMUM DEPTH X VELOCITY FOR PMF BREACH SCENARIO

CONSULTANT

GOLDER

YYYY-MM-DD	25-JUN-20
DESIGNED	CGE
PREPARED	CGE
REVIEWED	MAR
APPROVED	SK

PROJECT NO.	CONTROL	REV.	FIGURE
20141194	0001	1	20



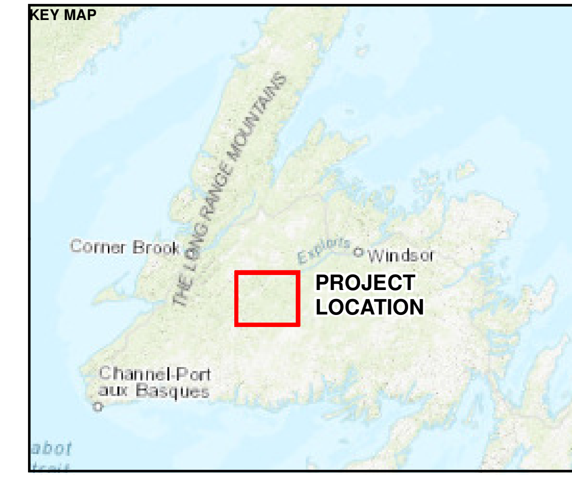
LEGEND

- DWELLING/LODGE
- CROSSING
- VICTORIA RIVER CONFLUENCE
- STATION PROFILE LOCATION
- TAILINGS MANAGEMENT FACILITY

INCREMENTAL DIFFERENCE, MAXIMUM DEPTH*VELOCITY

- 0 - 0.37
- GREATER THAN OR EQUAL TO 0.37

KEY MAP



0 5,000 10,000

1:200,000 METRES

NOTE(S)

REFERENCE(S)

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2. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 21

CLIENT

MARATHON GOLD COROPORATION

PROJECT

DAM BREACH ASSESSMENT AND INUNDATION STUDY
VALENTINE GOLD TAILINGS MANAGEMENT FACILITY

TITLE

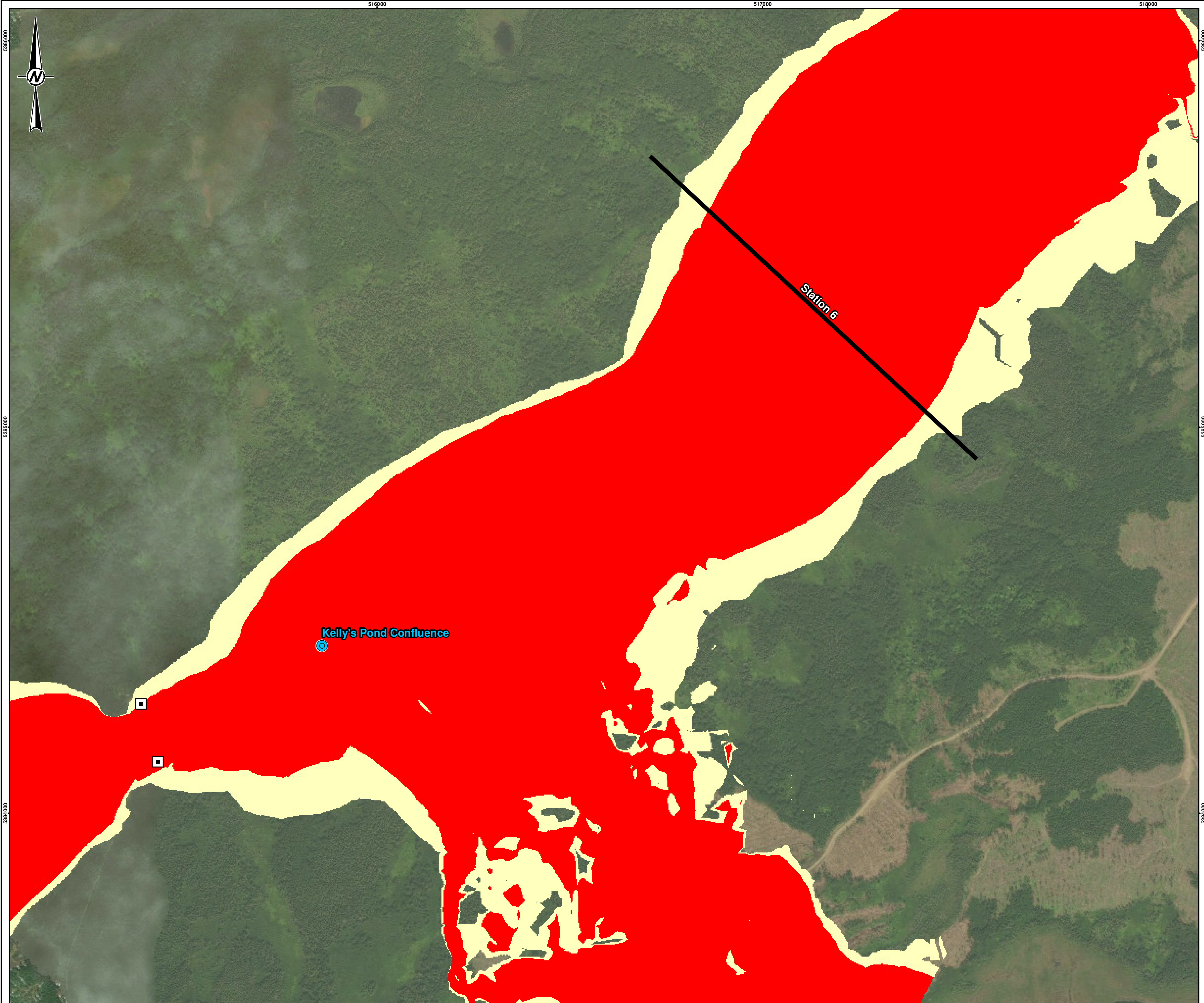
INCREMENTAL DIFFERENCE IN MAXIMUM DEPTH X VELOCITY BETWEEN THE PMF BREACH AND PMF NO BREACH SCENARIOS

CONSULTANT

GOLDER

YYYY-MM-DD	25-JUN-20
DESIGNED	CGE
PREPARED	CGE
REVIEWED	MAR
APPROVED	SK

PROJECT NO.	CONTROL	REV.	FIGURE
20141194	0001	1	21



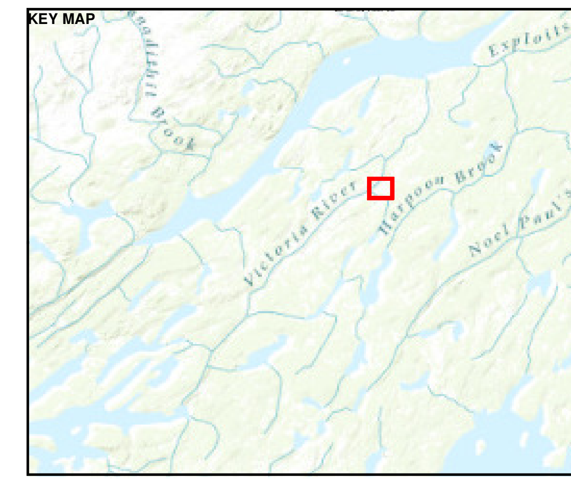
LEGEND

- DWELLING/LODGE
- VICTORIA RIVER CONFLUENCE
- STATION PROFILE LOCATION

MAXIMUM DEPTH * VELOCITY

- 0 - 0.37
- GREATER THAN OR EQUAL TO 0.37

KEY MAP



0 250 500

1:10,000 METRES

NOTE(S)

REFERENCE(S)

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2. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 21

CLIENT

MARATHON GOLD COROPORATION

PROJECT

DAM BREACH ASSESSMENT AND INUNDATION STUDY
VALENTINE GOLD TAILINGS MANAGEMENT FACILITY

TITLE

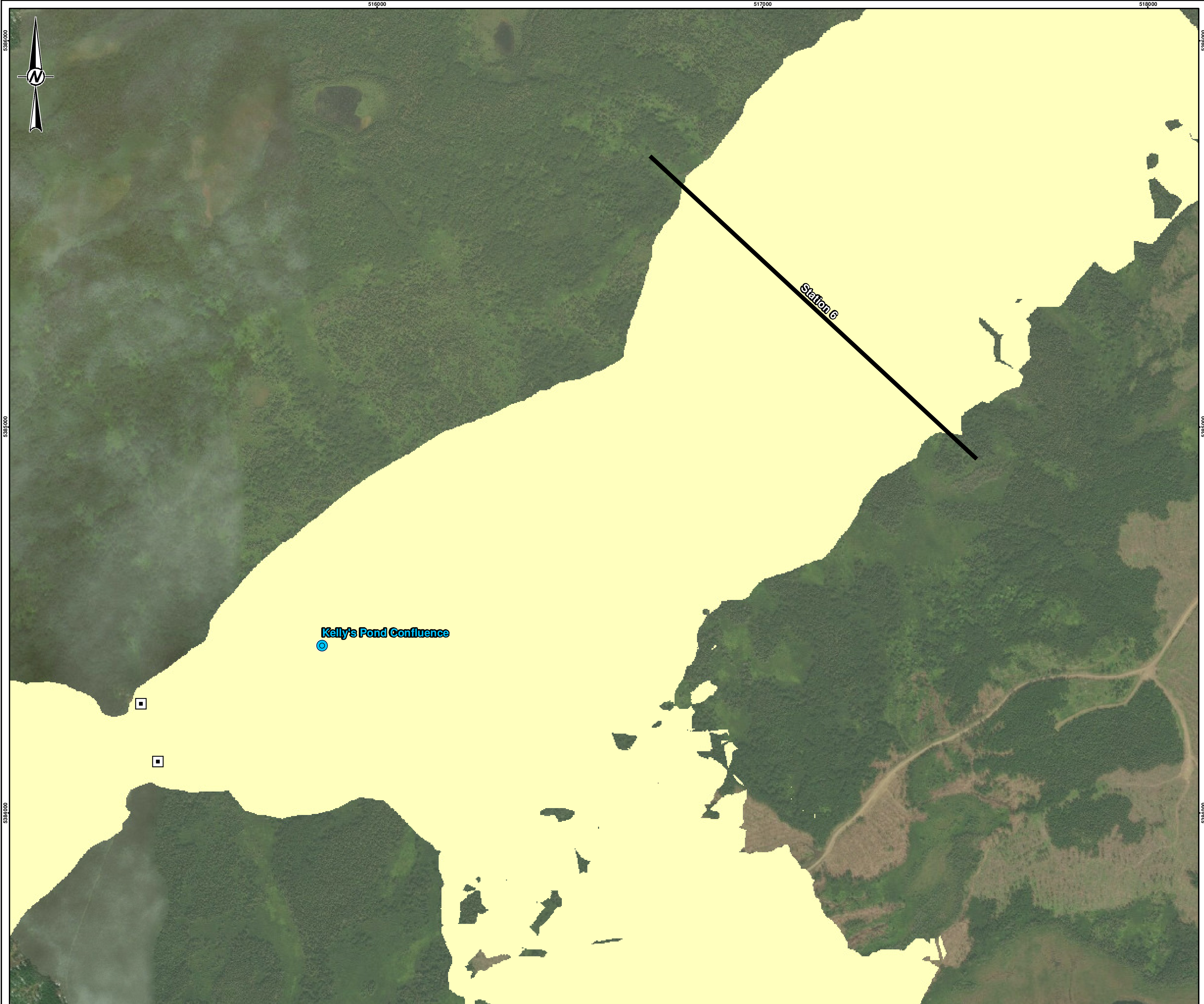
MAXIMUM DEPTH X VELOCITY FOR PMF BREACH SCENARIO AROUND DWELLINGS / LODGE

CONSULTANT

GOLDER

YYYY-MM-DD	25-JUN-20
DESIGNED	CGE
PREPARED	CGE
REVIEWED	MAR
APPROVED	SK

PROJECT NO.	CONTROL	REV.	FIGURE
20141194	0001	1	22



LEGEND

- DWELLING/LODGE
- VICTORIA RIVER CONFLUENCE
- STATION PROFILE LOCATION

INCREMENTAL DIFFERENCE, MAXIMUM DEPTH*VELOCITY

- 0 - 0.37
- GREATER THAN OR EQUAL TO 0.37

0 250 500

1:10,000 METRES

NOTE(S)

REFERENCE(S)

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2. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 21

CLIENT

MARATHON GOLD COROPORATION

PROJECT

DAM BREACH ASSESSMENT AND INUNDATION STUDY
VALENTINE GOLD TAILINGS MANAGEMENT FACILITY

TITLE

INCREMENTAL DIFFERENCE IN MAXIMUM DEPTH X VELOCITY BETWEEN THE PMF BREACH AND PMF NO BREACH SCENARIOS AROUND DWELLINGS / LODGE

CONSULTANT

GOLDER

YYYY-MM-DD	25-JUN-20
DESIGNED	CGE
PREPARED	CGE
REVIEWED	MAR
APPROVED	SK

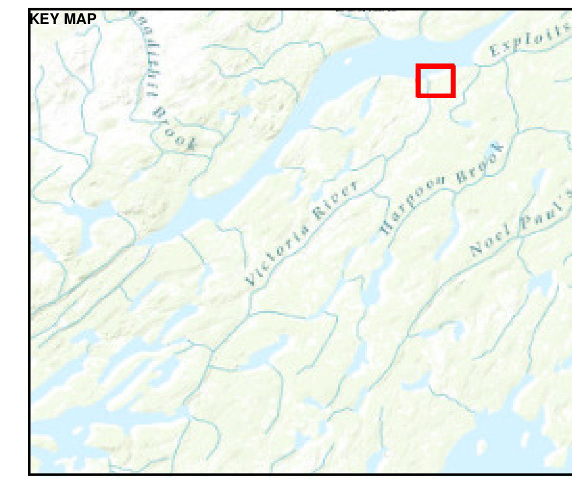
PROJECT NO.	CONTROL	REV.	FIGURE
20141194	0001	1	23

LEGEND

- CROSSING
- STATION PROFILE LOCATION
- EXPECTED INUNDATION DOWNSTREAM

MAXIMUM DEPTH * VELOCITY

- 0 - 0.37
- GREATER THAN OR EQUAL TO 0.37



0 500 1,000

1:15,000 METRES

NOTE(S)

REFERENCE(S)

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2. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 21

CLIENT

MARATHON GOLD COROPORATION

PROJECT

DAM BREACH ASSESSMENT AND INUNDATION STUDY
VALENTINE GOLD TAILINGS MANAGEMENT FACILITY

TITLE

MAXIMUM DEPTH X VELOCITY FOR PMF BREACH SCENARIO NEAR CROSSING 2

CONSULTANT

GOLDER

YYYY-MM-DD	25-JUN-20
DESIGNED	CGE
PREPARED	CGE
REVIEWED	MAR
APPROVED	SK

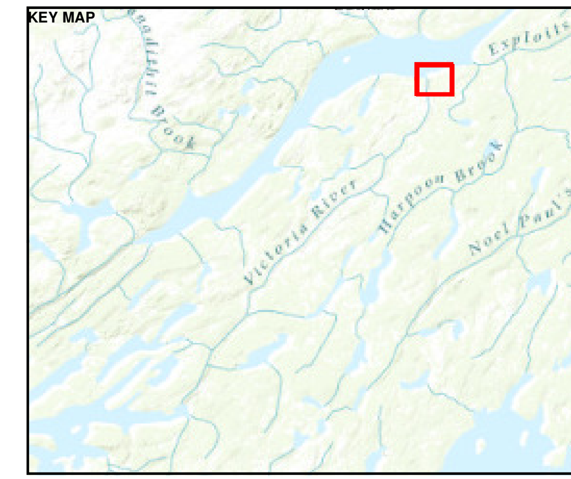
PROJECT NO.	CONTROL	REV.	FIGURE
20141194	0001	1	24

LEGEND

- CROSSING
- STATION PROFILE LOCATION
- EXPECTED INUNDATION DOWNSTREAM

INCREMENTAL DIFFERENCE, MAXIMUM DEPTH*VELOCITY

- 0 - 0.37
- GREATER THAN OR EQUAL TO 0.37



0 500 1,000

1:15,000 METRES

NOTE(S)

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2. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 21

CLIENT
MARATHON GOLD COROPORATION

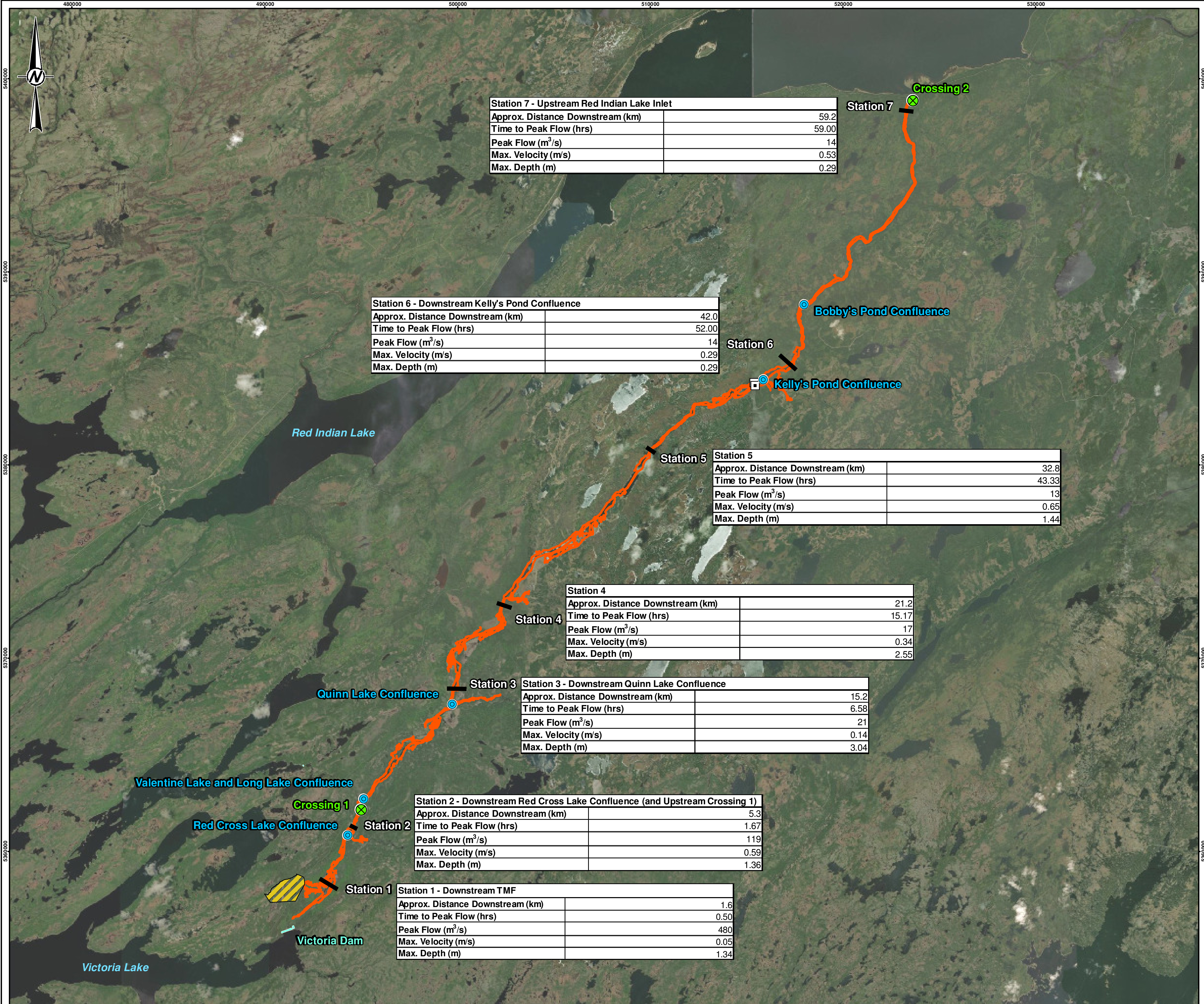
PROJECT
DAM BREACH ASSESSMENT AND INUNDATION STUDY
VALENTINE GOLD TAILINGS MANAGEMENT FACILITY

TITLE
INCREMENTAL DIFFERENCE IN MAXIMUM DEPTH X VELOCITY BETWEEN THE PMF BREACH AND PMF NO BREACH SCENARIOS NEAR CROSSING 2

CONSULTANT
GOLDER

YYYY-MM-DD	25-JUN-20
DESIGNED	CGE
PREPARED	CGE
REVIEWED	MAR
APPROVED	SK

PROJECT NO.	CONTROL	REV.	FIGURE
20141194	0001	1	25



Station 7 - Upstream Red Indian Lake Inlet	
Approx. Distance Downstream (km)	59.2
Time to Peak Flow (hrs)	59.00
Peak Flow (m^3/s)	14
Max. Velocity (m/s)	0.53
Max. Depth (m)	0.29

Station 6 - Downstream Kelly's Pond Confluence	
Approx. Distance Downstream (km)	42.0
Time to Peak Flow (hrs)	52.00
Peak Flow (m^3/s)	14
Max. Velocity (m/s)	0.29
Max. Depth (m)	0.29

Station 5	
Approx. Distance Downstream (km)	32.8
Time to Peak Flow (hrs)	43.33
Peak Flow (m^3/s)	13
Max. Velocity (m/s)	0.65
Max. Depth (m)	1.44

Station 4	
Approx. Distance Downstream (km)	21.2
Time to Peak Flow (hrs)	15.17
Peak Flow (m^3/s)	17
Max. Velocity (m/s)	0.34
Max. Depth (m)	2.55

Station 3 - Downstream Quinn Lake Confluence	
Approx. Distance Downstream (km)	15.2
Time to Peak Flow (hrs)	6.58
Peak Flow (m^3/s)	21
Max. Velocity (m/s)	0.14
Max. Depth (m)	3.04

Station 2 - Downstream Red Cross Lake Confluence (and Upstream Crossing 1)	
Approx. Distance Downstream (km)	5.3
Time to Peak Flow (hrs)	1.67
Peak Flow (m^3/s)	119
Max. Velocity (m/s)	0.59
Max. Depth (m)	1.36

Station 1 - Downstream TMF	
Approx. Distance Downstream (km)	1.6
Time to Peak Flow (hrs)	0.50
Peak Flow (m^3/s)	480
Max. Velocity (m/s)	0.05
Max. Depth (m)	1.34

LEGEND

- DWELLING/LODGE
- CROSSING
- VICTORIA RIVER CONFLUENCE
- STATION PROFILE LOCATION
- TAILINGS MANAGEMENT FACILITY
- INUNDATION BOUNDARY (FW BREACH)

0 5,000 10,000
1:200,000 METRES

NOTE(S)

REFERENCE(S)
1. BASE IMAGERY - SOURCE: ESRI, DIGITALGLOBE, GEOEYE, EARTHSTAR GEOGRAPHICS, CNES/AIRBUS DS, USDA, USGS, AEROGRID, IGN, AND THE GIS USER COMMUNITY SOURCES: ESRI, HERE, GARMIN, INTERMAP, INCREMENT P CORP., GEBCO, USGS, FAO, NPS, NRCAN, GEOBASE, IGN, KADASTER NL, ORDNANCE SURVEY, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), (C) OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY
2. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 21

CLIENT
MARATHON GOLD COROPORATION

PROJECT
DAM BREACH ASSESSMENT AND INUNDATION STUDY
VALENTINE GOLD TAILINGS MANAGEMENT FACILITY

TITLE
INUNDATION AREA OF SIMULATED FAIR-WEATHER BREACH SCENARIO

CONSULTANT
GOLDER

YYYY-MM-DD	25-JUN-20
DESIGNED	CGE
PREPARED	CGE
REVIEWED	MAR
APPROVED	SK

PROJECT NO.	CONTROL	REV.	FIGURE
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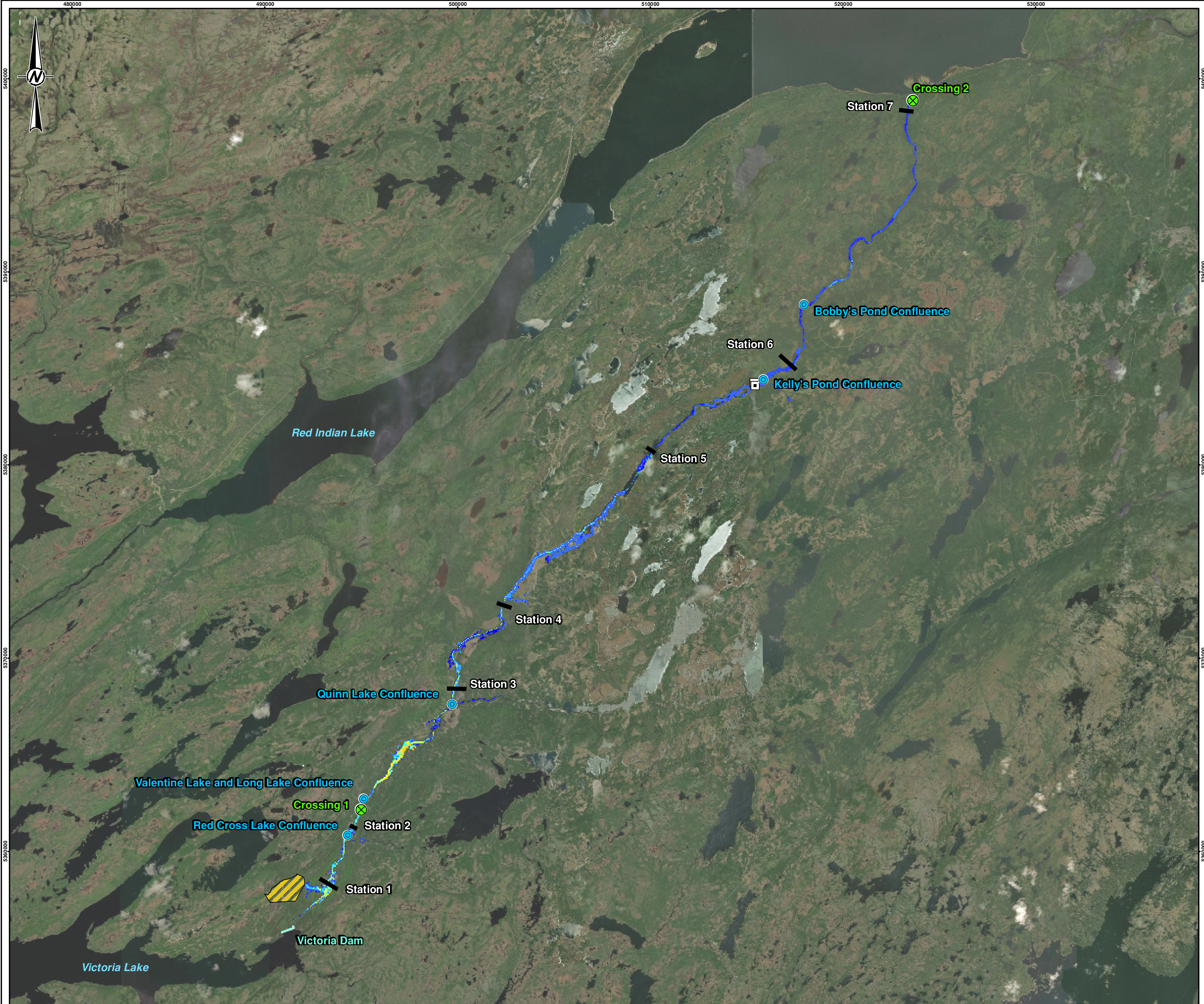
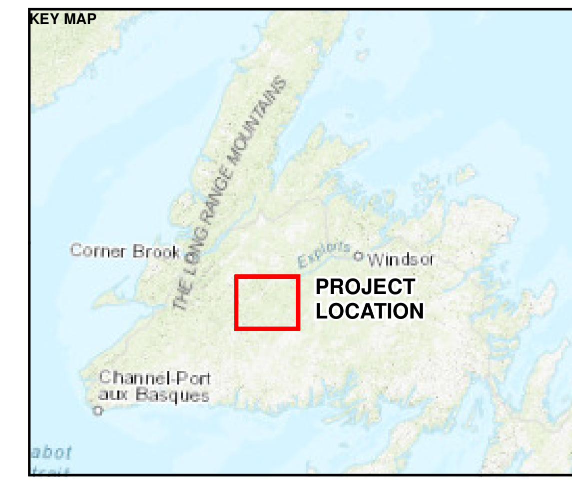


LEGEND

- DWELLING/LODGE
- CROSSING
- VICTORIA RIVER CONFLUENCE
- STATION PROFILE LOCATION
- TAILINGS MANAGEMENT FACILITY

MAXIMUM DEPTH (m)
HIGH : 5
LOW : 0



0 5,000 10,000
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NOTE(S)

REFERENCE(S)
1. BASE IMAGERY - SOURCE: ESRI, DIGITALGLOBE, GEOEYE, EARTHSTAR GEOGRAPHICS, CNES/AIRBUS DS, USDA, USGS, AEROGRID, IGN, AND THE GIS USER COMMUNITY SOURCES: ESRI, HERE, GARMIN, INTERMAP, INCREMENT P CORP., GEBCO, USGS, FAO, NPS, NRCAN, GEOBASE, IGN, KADASTER NL, ORDNANCE SURVEY, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), (C) OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY
2. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 21

CLIENT
MARATHON GOLD COROPORATION

PROJECT
DAM BREACH ASSESSMENT AND INUNDATION STUDY
VALENTINE GOLD TAILINGS MANAGEMENT FACILITY

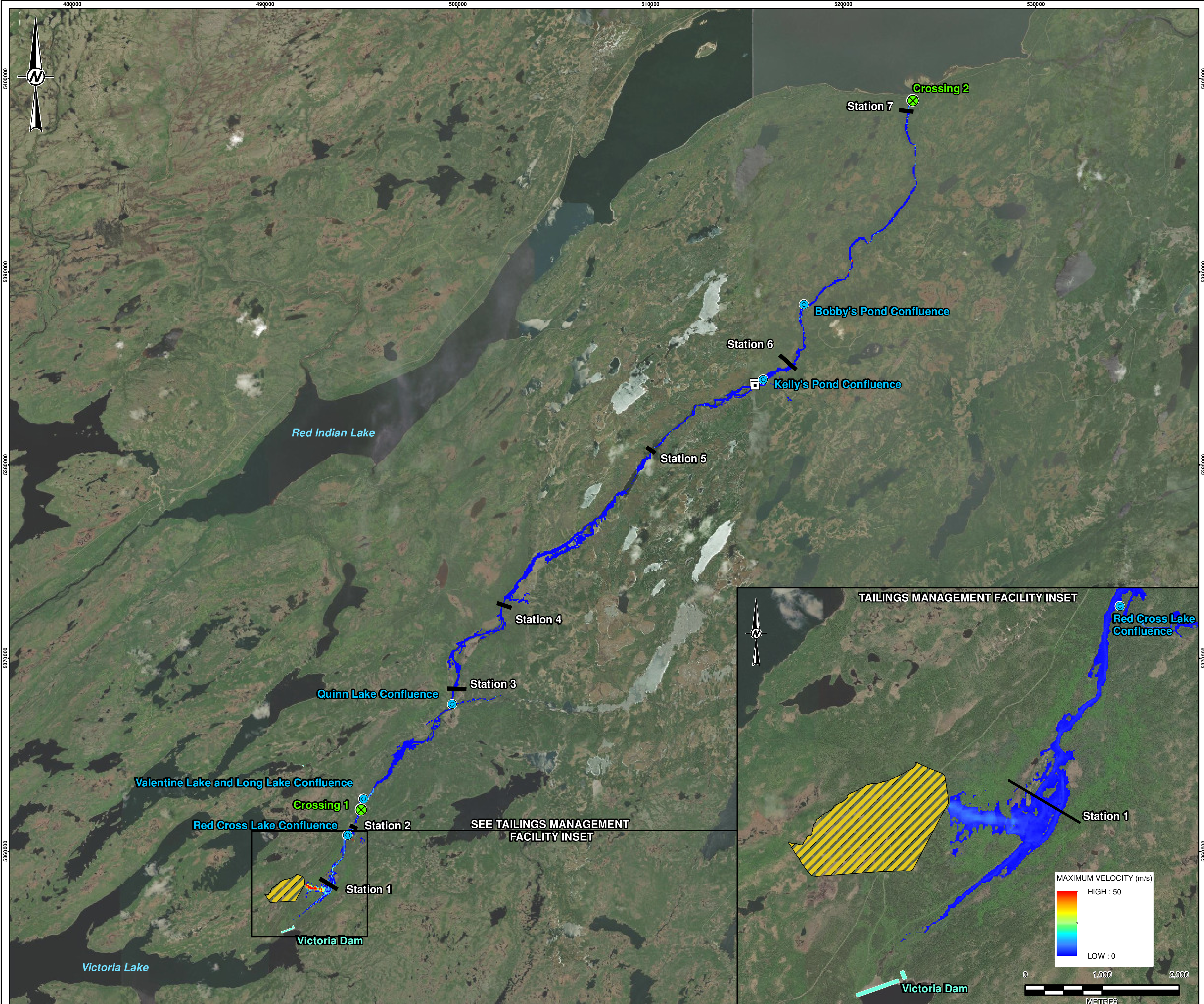
TITLE
MAXIMUM DEPTH FOR FAIR-WEATHER BREACH SCENARIO

CONSULTANT
GOLDER

YYYY-MM-DD	25-JUN-20
DESIGNED	CGE
PREPARED	CGE
REVIEWED	MAR
APPROVED	SK

PROJECT NO.	CONTROL	REV.	FIGURE
20141194	0001	1	27

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

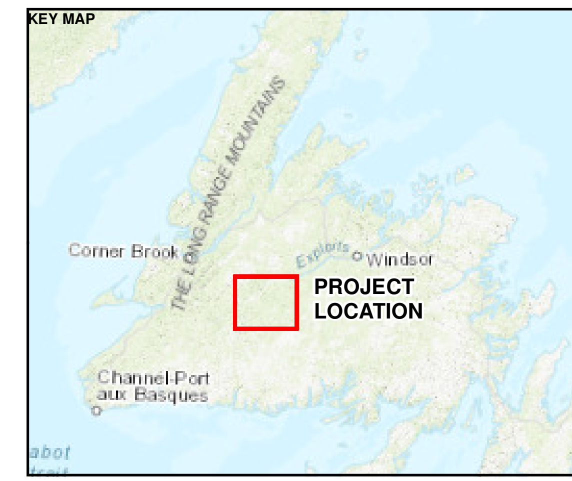


LEGEND

- DWELLING/LODGE
- CROSSING
- VICTORIA RIVER CONFLUENCE
- STATION PROFILE LOCATION
- TAILINGS MANAGEMENT FACILITY

MAXIMUM VELOCITY (m/s)

- 0 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- 5 - 50



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NOTE(S)

REFERENCE(S)
1. BASE IMAGERY - SOURCE: ESRI, DIGITALGLOBE, GEOEYE, EARTHSTAR GEOGRAPHICS, CNES/AIRBUS DS, USDA, USGS, AEROGRID, IGN, AND THE GIS USER COMMUNITY SOURCES: ESRI, HERE, GARMIN, INTERMAP, INCREMENT P CORP., GEBCO, USGS, FAO, NPS, NRCAN, GEOBASE, IGN, KADASTER NL, ORDNANCE SURVEY, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), (C) OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY
2. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 21

CLIENT
MARATHON GOLD COROPORATION

PROJECT
DAM BREACH ASSESSMENT AND INUNDATION STUDY
VALENTINE GOLD TAILINGS MANAGEMENT FACILITY

TITLE
MAXIMUM VELOCITY FOR FAIR-WEATHER BREACH SCENARIO

CONSULTANT
GOLDER

YYYY-MM-DD	25-JUN-20
DESIGNED	CGE
PREPARED	CGE
REVIEWED	MAR
APPROVED	SK

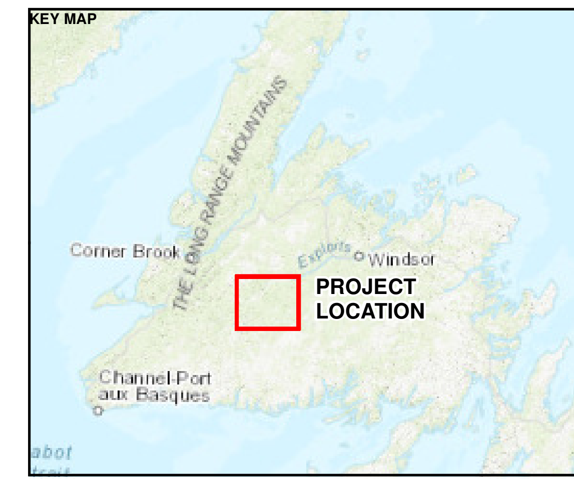
PROJECT NO.	CONTROL	REV.	FIGURE
20141194	0001	1	28

LEGEND

- DWELLING/LODGE
- CROSSING
- VICTORIA RIVER CONFLUENCE
- STATION PROFILE LOCATION
- TAILINGS MANAGEMENT FACILITY

MAXIMUM DEPTH * VELOCITY

- 0 - 0.37
- GREATER THAN OR EQUAL TO 0.37



0 5,000 10,000

1:200,000 METRES

NOTE(S)

REFERENCE(S)

1. BASE IMAGERY - SOURCE: ESRI, DIGITALGLOBE, GEOEYE, EARTHSTAR GEOGRAPHICS, CNES/AIRBUS DS, USDA, USGS, AEROGRID, IGN, AND THE GIS USER COMMUNITY SOURCES: ESRI, HERE, GARMIN, INTERMAP, INCREMENT P CORP., GEBCO, USGS, FAO, NPS, NRCAN, GEOBASE, IGN, KADASTER NL, ORDNANCE SURVEY, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), (C) OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY
2. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 21

CLIENT

MARATHON GOLD COROPORATION

PROJECT

DAM BREACH ASSESSMENT AND INUNDATION STUDY
VALENTINE GOLD TAILINGS MANAGEMENT FACILITY

TITLE

MAXIMUM DEPTH X VELOCITY FOR FAIR-WEATHER BREACH SCENARIO

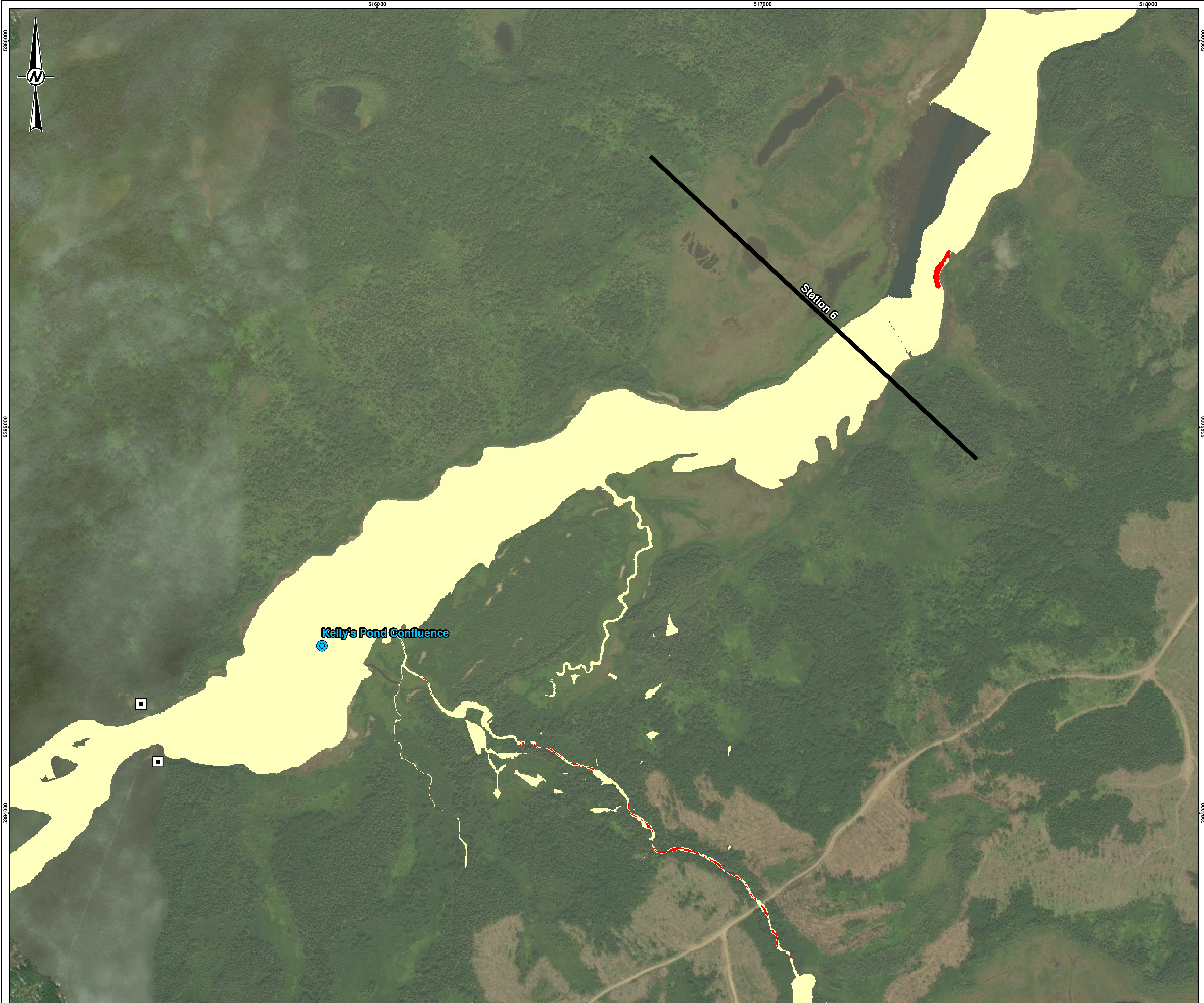
CONSULTANT

GOLDER

YYYY-MM-DD	25-JUN-20
DESIGNED	CGE
PREPARED	CGE
REVIEWED	MAR
APPROVED	SK

PROJECT NO.	CONTROL	REV.	FIGURE
20141194	0001	1	29

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B



LEGEND

- DWELLING/LODGE
- VICTORIA RIVER CONFLUENCE
- STATION PROFILE LOCATION

MAXIMUM DEPTH * VELOCITY

- 0 - 0.37
- GREATER THAN OR EQUAL TO 0.37

0 250 500
1:10,000 METRES

NOTE(S)

REFERENCE(S)
1. BASE IMAGERY - SOURCE: ESRI, DIGITALGLOBE, GEOEYE, EARTHSTAR GEOGRAPHICS, CNES/AIRBUS DS, USDA, USGS, AEROGRID, IGN, AND THE GIS USER COMMUNITY SOURCES: ESRI, HERE, GARMIN, INTERMAP, INCREMENT P CORP., GEBCO, USGS, FAO, NPS, NRCAN, GEOBASE, IGN, KADASTER NL, ORDNANCE SURVEY, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), (C) OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY
2. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 21

CLIENT
MARATHON GOLD COROPORATION

PROJECT
DAM BREACH ASSESSMENT AND INUNDATION STUDY
VALENTINE GOLD TAILINGS MANAGEMENT FACILITY

TITLE
MAXIMUM DEPTH X VELOCITY FOR FAIR-WEATHER BREACH SCENARIO AROUND DWELLINGS / LODGE

CONSULTANT
GOLDER

YYYY-MM-DD	25-JUN-20
DESIGNED	CGE
PREPARED	CGE
REVIEWED	MAR
APPROVED	SK

PROJECT NO.	CONTROL	REV.	FIGURE
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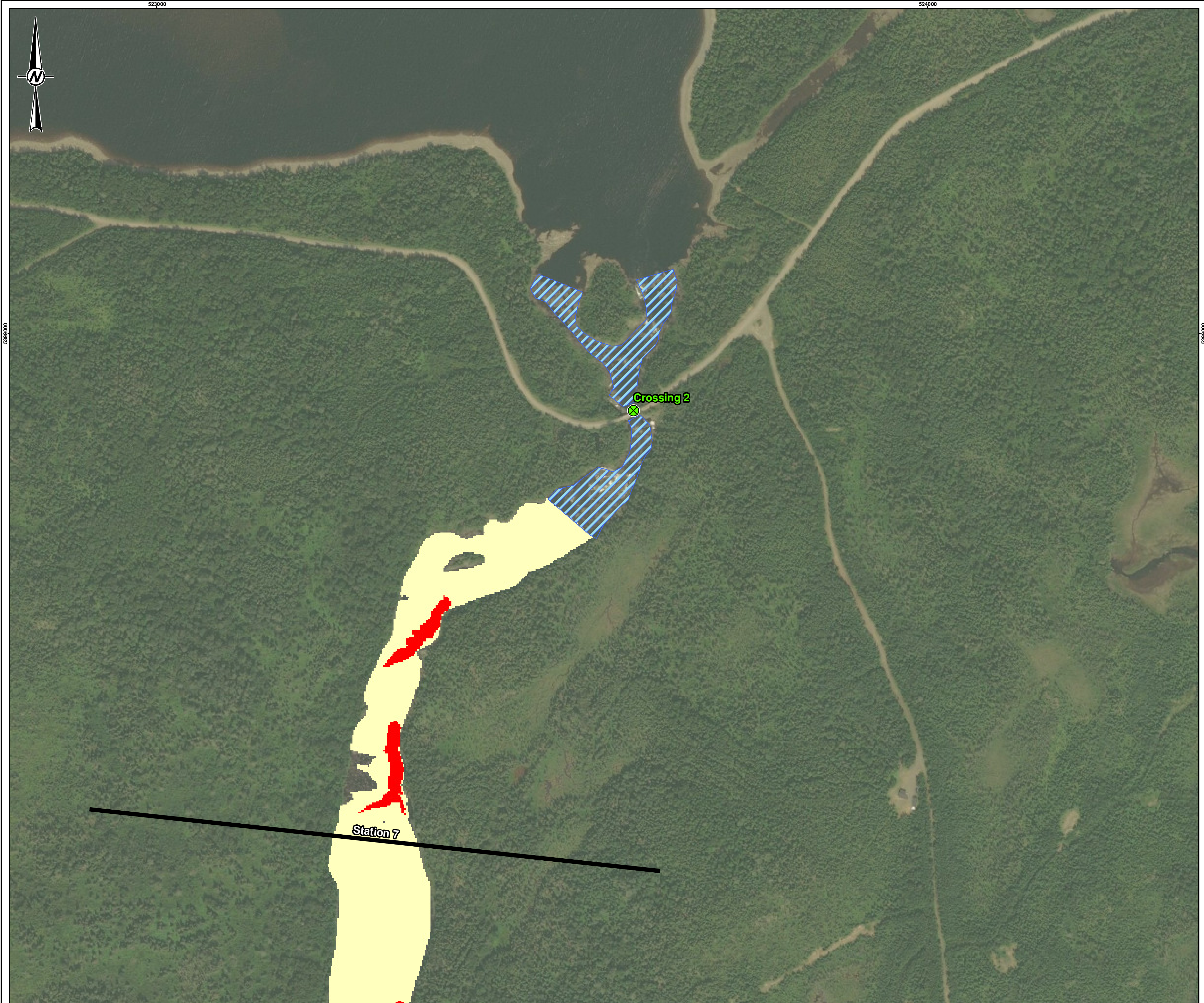
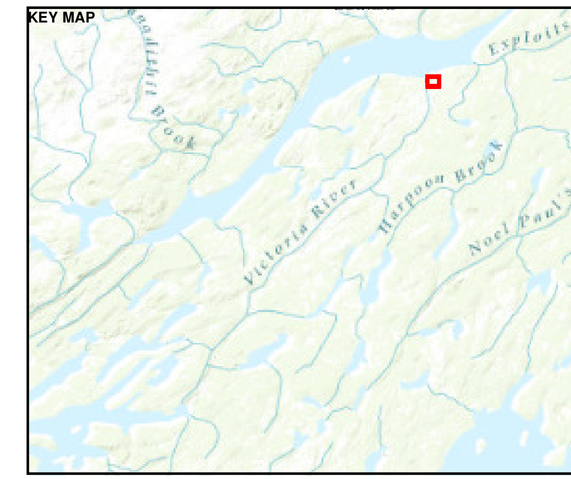


LEGEND

- CROSSING
- STATION PROFILE LOCATION
- EXPECTED INUNDATION DOWNSTREAM

MAXIMUM DEPTH * VELOCITY

- 0 - 0.37
- GREATER THAN OR EQUAL TO 0.37



0 150 300

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NOTE(S)

REFERENCE(S)

1. BASE IMAGERY - SOURCE: ESRI, DIGITALGLOBE, GEOEYE, EARTHSTAR GEOGRAPHICS, CNES/AIRBUS DS, USDA, USGS, AEROGRID, IGN, AND THE GIS USER COMMUNITY SOURCES: ESRI, HERE, GARMIN, INTERMAP, INCREMENT P CORP., GEBCO, USGS, FAO, NPS, NRCAN, GEOBASE, IGN, KADASTER NL, ORDNANCE SURVEY, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), (C) OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY
2. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 21

CLIENT

MARATHON GOLD COROPORATION

PROJECT

DAM BREACH ASSESSMENT AND INUNDATION STUDY
VALENTINE GOLD TAILINGS MANAGEMENT FACILITY

TITLE

MAXIMUM DEPTH X VELOCITY FOR FAIR-WEATHER BREACH SCENARIO AROUND CROSSING 2

CONSULTANT

GOLDER

YYYY-MM-DD	25-JUN-20
DESIGNED	CGE
PREPARED	CGE
REVIEWED	MAR
APPROVED	SK

PROJECT NO.	CONTROL	REV.	FIGURE
20141194	0001	1	31

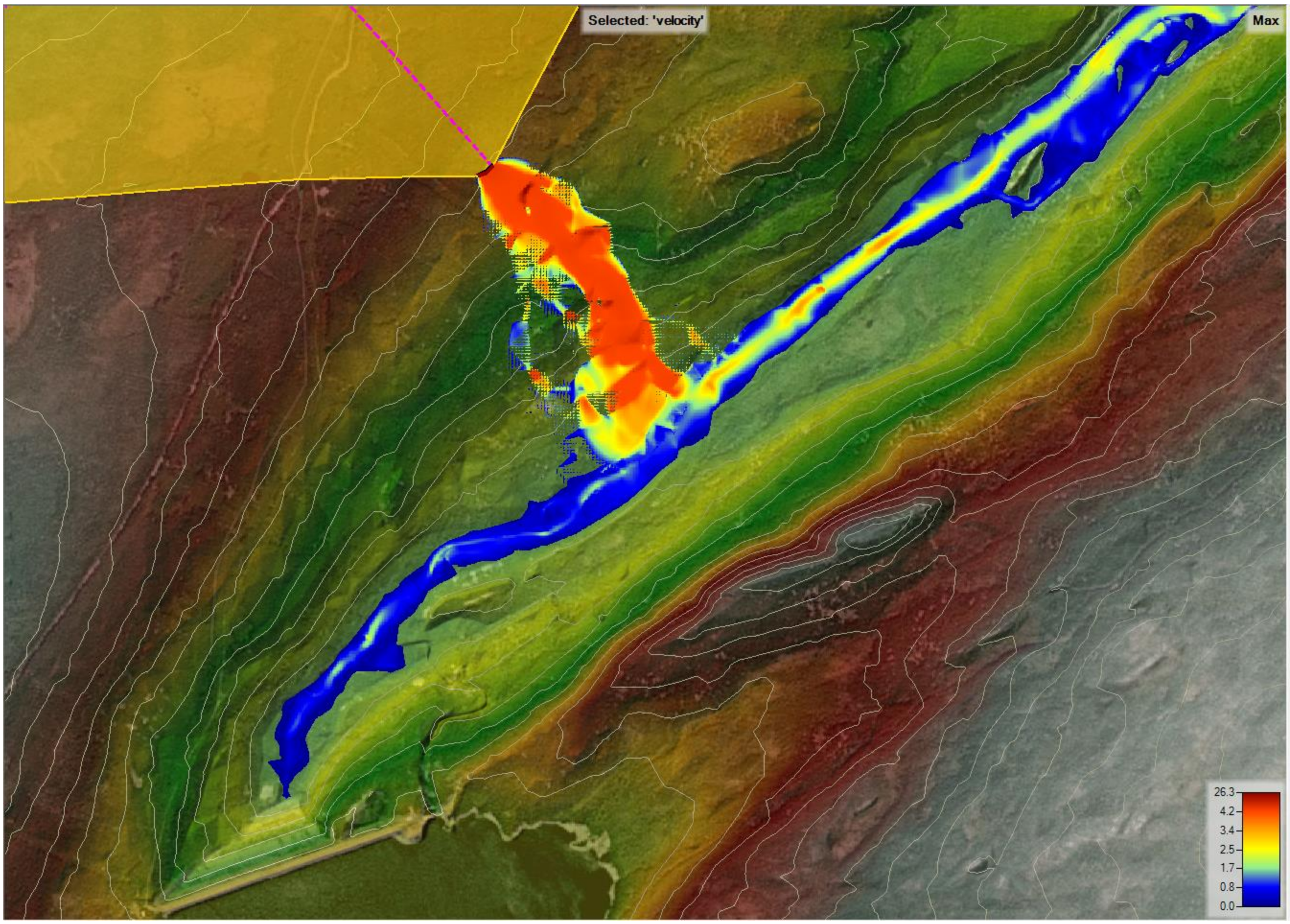


Figure 32: Processed Results showing Maximum Velocities (m/s) Immediately Downstream the TMF –South Dam Breach Failure (Scenario C)

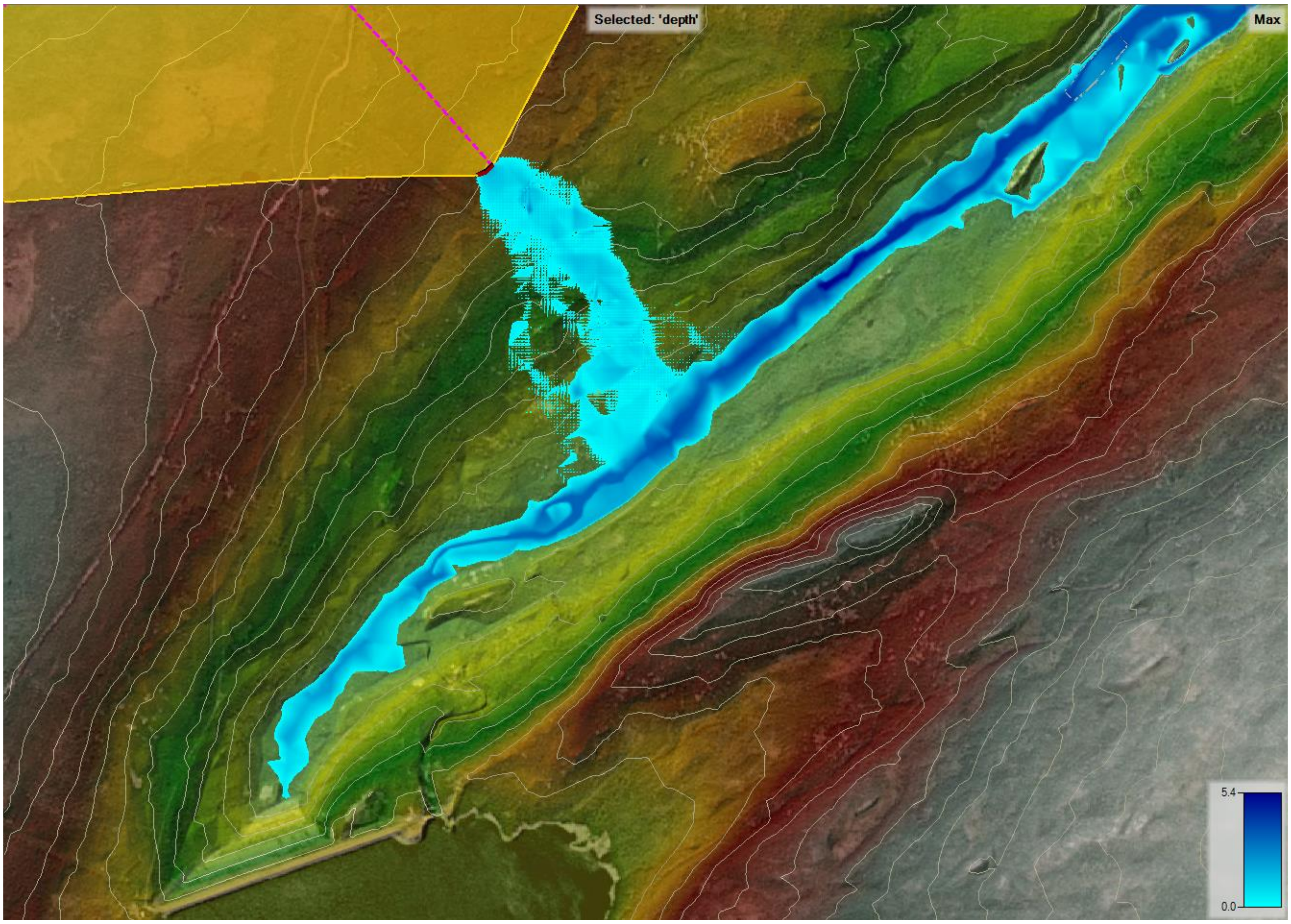


Figure 33: Processed Results showing Maximum Water Depths (m) Immediately Downstream the TMF – South Dam Breach Failure (Scenario C)

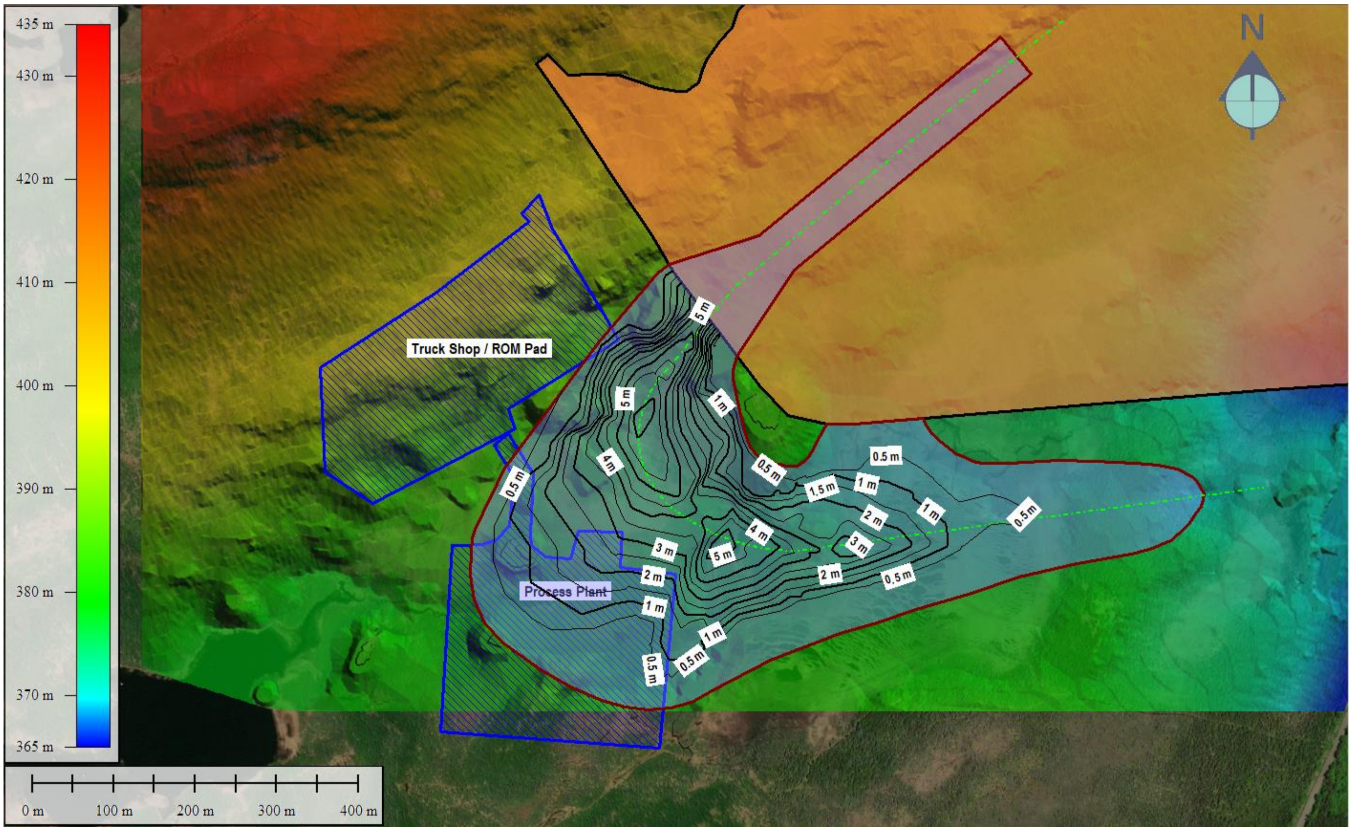


Figure 34: Tailings Runout Deposition for the TMF West Dam Failure (Scenario D) with Process Plant Inundated

GOLDER

golder.com

ATTACHMENT 1-B

Dam Breach Assimilative Capacity Study for the Valentine Gold Tailings Management Facility (2020)

REPORT

Dam Breach Assimilative Capacity Study

Valentine Gold Tailings Management Facility

Submitted to:

Marathon Gold Corporation

10 King Street, Suite 501
Toronto, Ontario, Canada
M5C 1C3

Submitted by:

Golder Associates Ltd.

11 Austin Street - Suite 101, St. John’s, Newfoundland and Labrador, A1B 4C1, Canada

+1 709 722 2695

20141194 (300) – Rev 0

06 August 2020

Distribution List

E-copy: Marathon Gold Corp.

E-copy: Golder Associates Ltd.

Table of Contents

FIGURES

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by Marathon Gold Corp. (Marathon) to complete an assimilative capacity assessment related to a potential dam breach for the proposed Tailings Management Facility (TMF) for the Valentine Gold Project (the Project). The TMF perimeter dam, if breached, has the potential to adversely affect water quality in the downstream environment. The analysis and results of the assimilative capacity assessment are documented in this report. This report should be read in conjunction with the related Dam Breach and Inundation Modelling report (Golder, 2020a) which forms the basis for hydrologic assumptions in this report and contains additional site background information.

2.0 SITE DESCRIPTION

The proposed Valentine Gold Project is located approximately 57 km south of Buchans, 340 km northwest of St. John's and within the Central Uplands of Newfoundland as shown in Figure 1. The mine is accessed by a 73 km long, well-maintained gravel road from Millertown to the northeast of the site. The site is situated amidst gentle to moderately steep, hilly terrain and the ground surface elevation ranges from approximately 320 m to 480 m above sea level (masl). A distinct northeast trending ridge occurs along the length of the property. The ground cover consists of a mixture of boggy ground, spruce and fir forests, and grassy clearings with many small ponds and streams. Victoria Lake, which is a hydroelectric reservoir, is adjacent to the south of the site and is contained by Victoria Dam. Red Indian Lake is located approximately 20 km to north (closest point) or approximately 60 km to the north (following Victoria River channel).

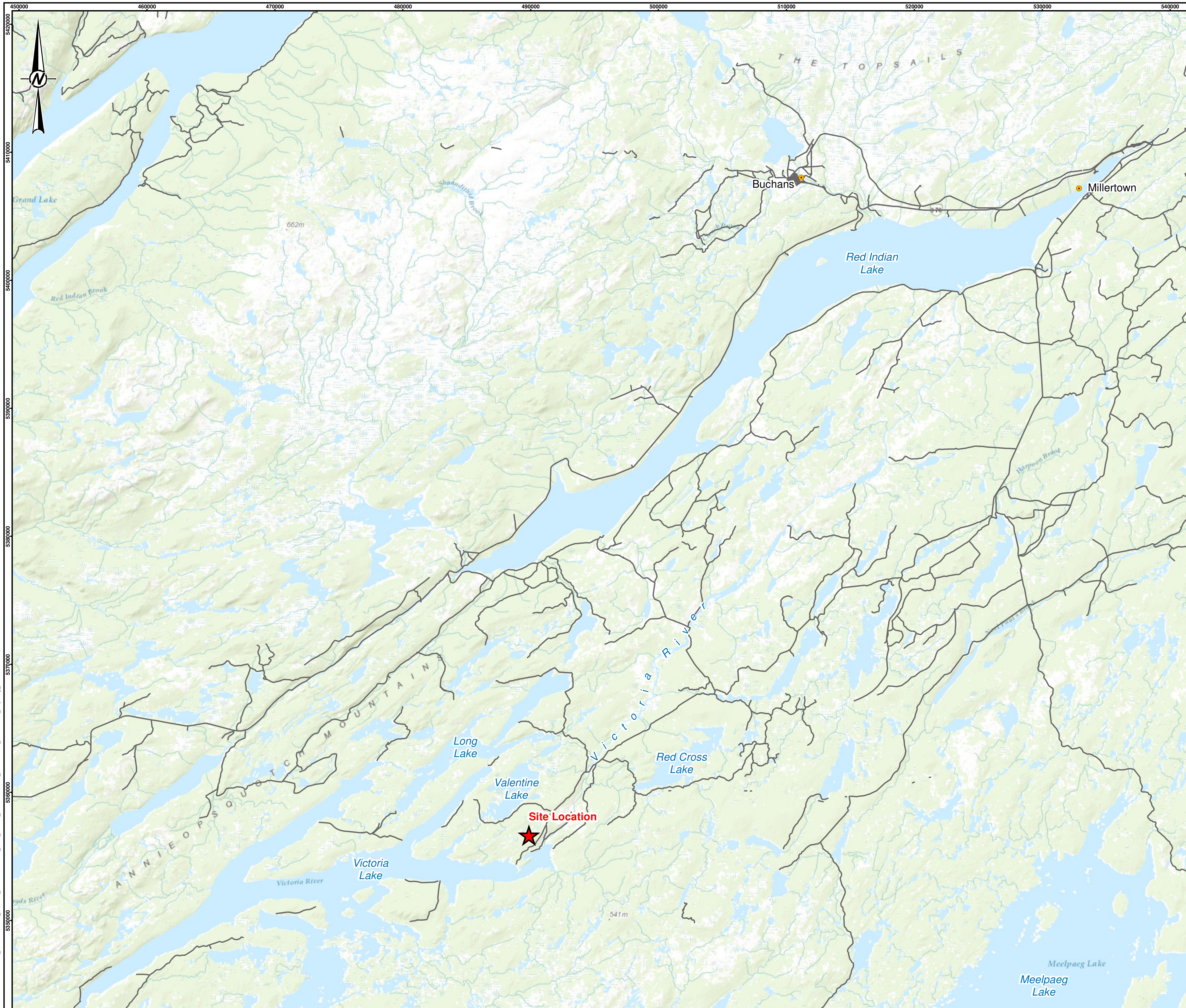
3.0 OBJECTIVES OF ASSIMILATIVE CAPACITY ANALYSIS

The overall objective of this analysis is to assess the water quality impacts downstream of the TMF and Polishing Pond in the event of a failure of a dam impounding tailings and/or water. Changes in water quality have the potential to result in adverse environmental effects to aquatic life. This is a sensitivity study, which will be used to also confirm hazard classification for the TMF dams, and to provide information crucial for effective emergency preparedness planning.

The TMF will be developed over five stages, including start-up. The pond will form at the east end of the TMF. With continued tailings deposition, the size of the TMF Pond remains approximately the same. At the Ultimate Stage configuration, the potential magnitude of water and liquefied tailings discharged from site in the event of a breach is considered to be the greatest. This configuration was therefore used in this dam assessment study.

It should be noted that the nature of a dam breach event into a river system is a temporary event of short duration (e.g., less than a day), for which acute water quality guidelines are appropriate. Canadian Council of Ministers of the Environment (CCME) for the Protection of Aquatic Life (Freshwater) guidelines are the applicable water quality guidelines for natural surface water bodies in Newfoundland and Labrador. However, relatively few constituents are assigned a CCME Acute guideline as compared to those assigned a CCME Chronic guideline value. To evaluate the potential for environmental effects, a numerical threshold value is required to interpret the model results. Therefore, CCME Chronic guidelines were used as the primary threshold for evaluation of the potential for environmental effects (in addition to available CCME Acute guidelines); however, elevated concentrations in the Victoria River occurring as a result of a dam breach are not expected to persist over the long exposure period for which chronic toxicity guidelines are intended to be applied.

Should elevated concentrations occur in Red Indian Lake during low flow conditions, the CCME Chronic guidelines are likely more applicable as the potential effects of the dam breach may persist for an extended period of time (e.g., more than 30 days) due to longer retention time of the lake during low flow conditions. However, during high flow events (e.g., spring freshet), the increased flow rates likely reduce the retention time and make the CCME Acute guidelines more applicable. Given the uncertainties associated with the bathymetry of Red Indian Lake and the resulting retention time, the CCME Chronic guidelines should be used for a conservative screening of the potential effects in Red Indian Lake.

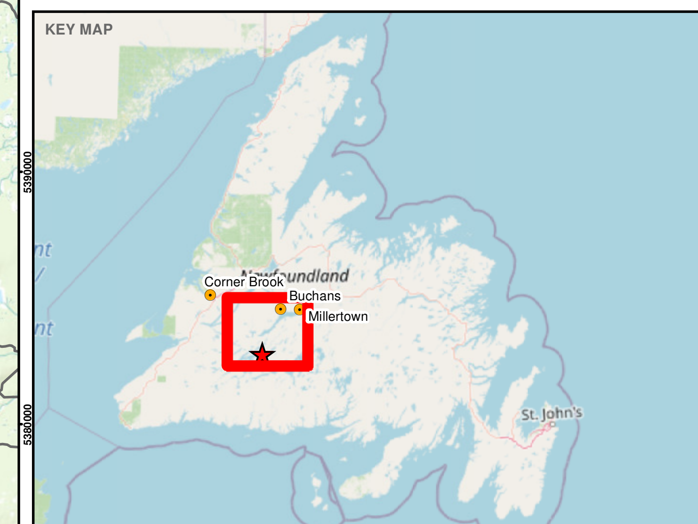


LEGEND

★ Site Location

Roads

Waterbody



DRAFT

0 7,500 15,000

1:300,000 METRES

NOTE(S)

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT NO. 19130660

REFERENCE(S)

SERVICE LAYER CREDITS: © OPENSTREETMAP (AND) CONTRIBUTORS, CC-BY-SA
SOURCES: ESRI, HERE, GARMIN, INTERMAP, INCREMENT P CORP., GEBCO, USGS, FAO, NPS, NRCAN, GEOBASE, IGN, KADASTER NL, ORDNANCE SURVEY, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), (C) OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY

CLIENT

MARATHON GOLD COROPORATION

PROJECT

ASSIMILATIVE CAPACITY ASSESSMENT
VALENTINE GOLD TAILINGS MANAGEMENT FACILITY

TITLE

SITE LOCATION PLAN

CONSULTANT

GOLDER

YYYY-MM-DD	2020-06-17
DESIGNED	RRD
PREPARED	RRD/CGE
REVIEWED	BT
APPROVED	SK

PROJECT NO.	CONTROL	REV.	FIGURE
20141194(300)	0002	0	1

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

25mm

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4.0 ANALYTICAL METHODS

4.1 General Approach

Estimates of water quality resulting from dam failure were generated using a mass-conservative spreadsheet model which evaluated resultant water quality for two scenarios. The scenarios evaluated considered variability including the proportions of water from ambient flow versus water derived from failure of the upstream dam, under two breach conditions. Breach conditions included in the analyses are the fair-weather (“sunny day) and probable maximum precipitation event (PMP) (“rainy day”) scenarios. In both scenarios, the breach was assumed to occur at the TMF East Dam with piping as the breach failure mechanism, as these conditions result in the maximum release of water from the TMF. All hydrologic inputs were provided as outputs from dam breach modelling completed by Golder (2020a), and the reader is referred to this report for additional details on the hydrologic data used in this assessment. Prior to modelling breach scenarios, a spreadsheet mixing model was developed to estimate TMF water quality.

The predictions generated through this evaluation were completed as a screening level evaluation for risk classification, including a limited set of chemical constituents, evaluate a limited range of hydrologic conditions, and do not incorporate any geochemical processes such as mineral precipitation, solubility limits, and sorption. The results generated should be treated as order-of-magnitude estimates of the potential range of receiving environment concentrations, rather than absolute values. Model results are compared to the Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guidelines (CWQG) for the protection of aquatic life (freshwater) (CCME, 2019).

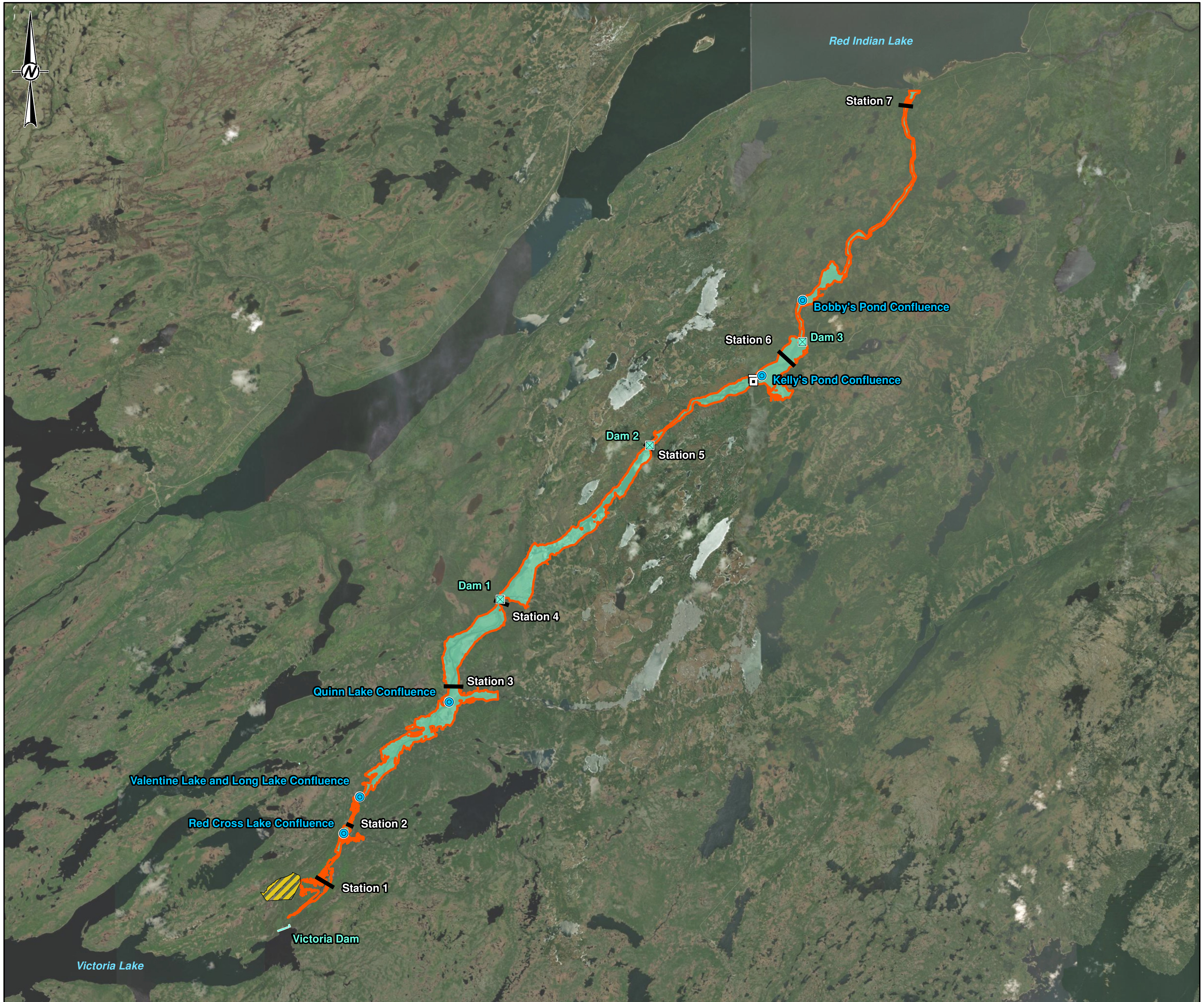
4.2 Model Boundaries

As noted in Golder (2020a), the flow domain for the TMF East Dam failure simulations extended from the downstream toe of Victoria Dam up to a station 1 km upstream of the inlet to Red Indian Lake. The reason for truncating the downstream boundary of the model was to avoid imposing a water surface level in Red Indian Lake. The water level in Red Indian Lake is dependent on inflow from other watersheds and management of downstream flow for hydroelectric generation.

Red Indian Lake is a large freshwater body located approximately 60 km downstream of the TMF and has the largest drainage area in Central Newfoundland (5,580 km^2) which is approximately 7 times the drainage area of Victoria River. Red Indian Lake receives runoff from 10 riverine systems including Victoria River and has a surface area of 187 km^2, nearly 500 times the size of the TMF Pond by area.

Predictions were generated for seven nodes in the Victoria River and one node in Red Indian Lake (Figure 2); these nodes are described in Table 1. Elevated uncertainty exists in predictions generated for Red Indian Lake as a result of several limitations; therefore, conservative assumptions were used to develop estimates of upper bound conditions. These limitations include:

- Lack of bathymetric data for Red Indian Lake precludes determination of the mixing zone volume.
- Lack of data on flows and residence time of water within Red Indian Lake.
- Current model approach assumes instantaneous mixing within a defined volume. Dispersion of dissolved constituents within a large water body will occur over an extended period of time as influenced by multiple physical and chemical processes.



LEGEND

- DWELLING/LODGE
- DAM
- VICTORIA RIVER CONFLUENCE
- STATION PROFILE LOCATION
- TAILINGS MANAGEMENT FACILITY
- INUNDATION BOUNDARY (PMF BREACH)
- INUNDATION BOUNDARY (PMF NO BREACH)

DRAFT

0 5,000 10,000

1:200,000 METRES

NOTE(S)

REFERENCE(S)

1. BASE IMAGERY - SOURCE: ESRI, DIGITALGLOBE, GEOEYE, EARTHSTAR GEOGRAPHICS, CNES/AIRBUS DS, USDA, USGS, AEROGRID, IGN, AND THE GIS USER COMMUNITY SOURCES: ESRI, HERE, GARMIN, INTERMAP, INCREMENT P CORP., GEBCO, USGS, FAO, NPS, NRCAN, GEOBASE, IGN, KADASTER NL, ORDNANCE SURVEY, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), (C) OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY
2. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 21

CLIENT
MARATHON GOLD COROPORATION

PROJECT
ASSIMILATIVE CAPACITY ASSESSMENT
VALENTINE GOLD TAILINGS MANAGEMENT FACILITY

TITLE
INUNDATION AREA OF SIMULATED PMF BREACH AND NO BREACH SCENARIOS

CONSULTANT

GOLDER

YYYY-MM-DD	17-JUN-20
DESIGNED	CGE
PREPARED	CGE
REVIEWED	MAR
APPROVED	SK

PROJECT NO.	CONTROL	REV.	FIGURE
20141194(300)	0002	0	2

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

25mm

Table 1: Model Nodes

Station #	Approx. Distance Downstream of TMF	Description
1	1.6	Downstream of TMF
2	5.3	Downstream of Red Cross Lake confluence
3	15.2	Downstream of Quinn Lake confluence
4	21.2	Upstream of dam 1
5	32.8	Upstream of dam 2
6	42.0	Downstream of Kelly's Pond confluence
7	59.2	Red Indian Lake inlet
N/A	60	Red Indian Lake

Note: Station 1 not carried forward to Assimilative Capacity Assessment as this location does not constitute aquatic habitat and only carries measurable flow as a result of a breach.

4.3 Water Quality Inputs

The following key inputs were required to simulate water quality in Victoria River and Red Indian Lake following a dam failure event:

- Natural runoff to TMF water chemistry (Stantec, 2020a; stations LP05, R01, R02, VL-01)
- Process water chemistry (Ausenco, 2020)
- Tailings leachate water quality (Stantec, 2020b)
- Chemistry of direct precipitation to pond surface (assumed values)
- Victoria River water chemistry (Stantec, 2020a; station VICRV-01)
- Red Indian Lake water chemistry (ECCC, 2020; station NF02YO0107)

4.4 Water Chemistry Mixing Calculations

Predictions of water quality were completed using a spreadsheet-based approach to calculate concentrations of constituents in a conservative mass transport model. Potential attenuation of constituents due to precipitation, partitioning, or absorption to soil particles was not modelled. At a given modelled location (or node), concentrations of a given constituent were predicted by adding all upstream loads and dividing by the total flow using the following equation:

$$C_x = \frac{\sum_{i=1}^{n} C_i Q_i}{\sum_{i=1}^{n} Q_i}$$

where:
C_x = predicted concentration of constituent ‘x’ at a given location;
C_i = concentration of constituent ‘x’ in inflow ‘i’ discharging to a given location;
Q_i = flow rate of inflow ‘i’; and
n = number of inflows to the location in question.

4.4.1 TMF

To complete the assimilative capacity assessment for Victoria River and Red Indian Lake, estimation of the TMF water quality was required as a preliminary step, as predictive modelling of the TMF pond water quality has not previously been completed. A spreadsheet-based mixing model was developed to mix the chemistry and volume of unique flows entering the TMF on an annual basis. Hydrologic inputs were extracted from the TMF water balance (Golder, 2020b). Unique flows to the TMF incorporated in the mixing model include:

- Natural runoff
- Process water chemistry
- Tailings beach runoff
- Direct precipitation to pond

The mixing model included a suite of anions, metals, and metalloids (Table 2). pH was not modeled given that pH cannot be accurately calculated in a spreadsheet-based model; however, pH measurements of process water and tailings leachate were found to be near-neutral and within the CCME acceptable range for pH.

Results were compared to CCME criteria to identify constituents of potential concern (COPCs) to be carried forward in the assimilative capacity assessment. It should be noted that CCME criteria are not applicable to water in a TMF; rather, these thresholds were used to identify constituents with the potential to be elevated relative to receiving environment criteria (CCME) in aquatic habitat which may be impacted as a result of a dam failure.

Table 2: Constituents Included in TMF Mixing Model

General Parameters	Metals and Metalloids		
Nitrate	Aluminum	Chromium	Sodium
Nitrate	Silver	Copper	Nickel
Total Ammonia	Arsenic	Iron	Lead
Sulphate	Boron	Mercury	Antimony
	Calcium	Potassium	Selenium
	Cadmium	Magnesium	Thallium
	Chloride	Manganese	Uranium
	Cobalt	Molybdenum	Zinc

4.4.2 Victoria River

The mixing model calculations for the Victoria River assumed that baseline water quality was mixed with TMF water quality according to the peak breach flow rates determined in dam breach modelling (Golder, 2020a) for each of Probable Maximum Precipitation (PMP) event and fair-weather scenarios. Peak flow rates were used to determine the maximum concentrations which may occur, while noting that the duration of those concentrations will be short for constituents influenced strongly by the release of TMF water. Estimates of water quality during maximum breach flow were completed for stations 2 through 7 listed in Table 1.

4.4.3 Red Indian Lake

The mixing model calculations for Red Indian Lake assumed that all water released from the TMF as a result of the breach was transported to Red Indian Lake without attenuation. The breach volume (using TMF water chemistry) was assumed to mix completely within a defined mixing zone in the eastern basin of Red Indian Lake in the vicinity of the Victoria River outlet and Red Indian Lake outlet (Exploits Dam). The Red Indian Lake mixing zone was assigned water chemistry as measured immediately downstream of Exploits Dam at station NF02YO0107 (ECCC, 2020).

Determination of the volume of the mixing zone in Red Indian Lake was limited by the lack of bathymetry for Red Indian Lake. A literature review was completed; however, it was unsuccessful in identifying reliable data on water depths in Red Indian Lake. To permit evaluation of potential environmental effects, an average water depth of 5 meters was assumed as a lower bound based on professional judgement. Due to the influence of this assumption on the calculations, field verification is required for any reliance to be placed upon the calculations for Red Indian Lake. Golder assumes no responsibility for the reliability of these calculations if the actual average water depth is determined to be less than 5 meters. If the average water depth is greater than 5 meters, greater assimilative capacity can be assumed to exist in Red Indian Lake, and concentrations of parameters influenced by the breach are expected to be lower than those presented in this assessment.

The conceptual Red Indian Lake mixing zone that would be anticipated to receive the majority of water discharged from Victoria River and flow towards the outlet at Exploits Dam is defined by the yellow perimeter in Figure 3. The perimeter is based on professional judgement and reflects a relatively small segment of Red Indian Lake. The mixing zone is extended slightly to the west of Victoria River outlet (i.e. opposite the direction of dominant flow) based on anticipated turbulent mixing and river discharge flow rates exceeding that of the lake water. Depending on physical mixing characteristics (i.e. flow towards outlet, wave action, etc.) the actual mixing zone may be smaller or larger.

The mixing zone volume was calculated based on the surface area within the perimeter identified in Figure 3 and the assumed depth of 5 m (assuming littoral zone areas less than 5 m depth are balanced by deeper areas in the centre of the lake). Mixing calculations assumed complete mixing of TMF water with the water in the mixing zone; however, in reality this will not occur instantaneously, and concentrations estimated at Victoria River Station 7 may occur within Red Indian Lake near the river outlet. A hydrodynamic model would be required to evaluate the time to achieve complete mixing within Red Indian Lake; however, at present inadequate data is available to support such a model.

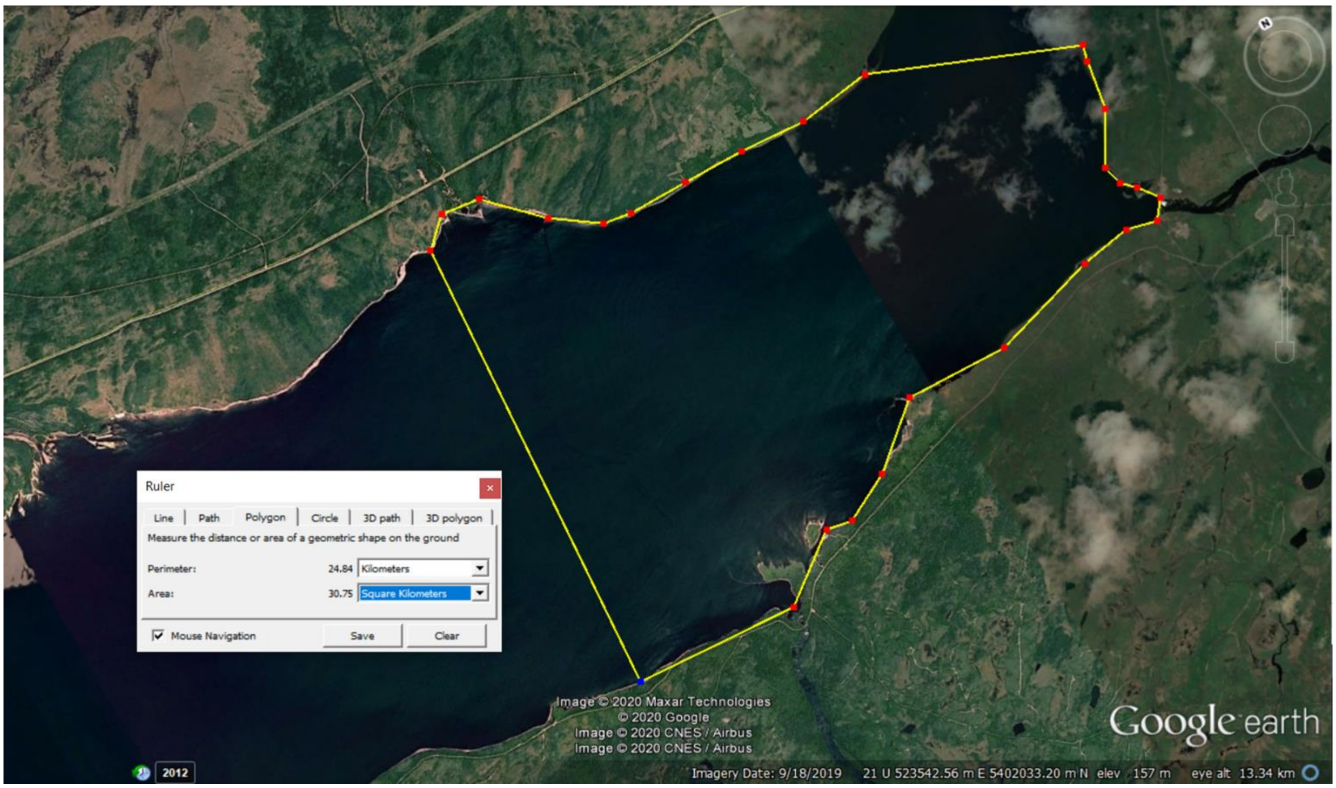


Figure 3: Red Indian Lake Mixing Zone (image via Google Earth).

5.0 RESULTS

A hypothetical failure of the TMF East Dam would release the impounded water and suspended tailings, and the consequential surge wave from the breach will propagate downstream the Victoria River towards Red Indian Lake. As a result, loading of chemical mass from the TMF to Victoria River and Red Indian Lake will occur. Estimated concentrations in the TMF and receiving environment under PMP and fair-weather breach scenarios are presented herein.

5.1 TMF Water Quality

The TMF mixing model evaluated the influence of several inflows to the TMF to estimate an overall TMF pond water quality. The results were compared to CCME criteria for freshwater aquatic life (CCME, 2019) to identify COPCs. The COPCs estimated in TMF pond water to exceed CCME criteria, and the estimated concentrations of each used as inputs to the Victoria River and Red Indian Lake mixing models are defined in Table 3.

Table 3: COPCs in TMF Water that Exceed CCME Chronic Criteria

Constituent	Units	CCME Freshwater Chronic	CCME Freshwater Acute	Simulated TMF
Nitrite (NO_2)	mg/L as N	0.060	-	0.117
Aluminum (Al)	mg/L	0.0050 [1]	-	0.0450
Silver (Ag)	mg/L	0.00025	-	0.00067
Arsenic (As)	mg/L	0.0050	-	0.0066
Cadmium (Cd)	mg/L	0.000040 [2]	0.001 [2]	0.000044
Cobalt (Co)	mg/L	0.00078 [2]	-	0.07916
Copper (Cu)	mg/L	0.0020 [2]	-	0.398
Iron (Fe)	mg/L	0.30	-	0.57
Mercury (Hg)	mg/L	0.000026	-	0.000235
Selenium (Se)	mg/L	0.0010	-	0.0016

Notes:
[1] Guideline is variable and dependent on pH values.
[2] Guideline is variable and dependent on hardness concentrations.

5.2 Victoria River

Water released from the TMF was mixed with each of the seven stations on Victoria River described in Section 4.2. Estimated peak concentrations at each station are presented in Table 4 and Table 5 and represent the maximum concentrations anticipated to occur as a result of a breach under each breach scenario. As noted in Section 4.4.1, only those constituents identified as COPCs were carried forward to the Victoria River mixing model. The nature of a dam breach event is a temporary event of short duration, for which acute water quality guidelines are most applicable. However, of the COPCs identified in Section 5.1, only cadmium has a corresponding CCME Freshwater Acute guideline. Therefore, CCME Freshwater Chronic guidelines were used, at a screening level, to identify constituents of potential concern and are not intended to indicate a potential for toxicity to aquatic life.

It should be noted that baseline water quality for Victoria River (as measured at station VICRV-01) is greater than the CCME chronic criteria for aluminum, at an average concentration of 0.077 mg/L. As this baseline concentration is greater than the TMF water and all predicted concentrations in Victoria River, the dam breach results in lower concentrations of aluminum than under ambient conditions.

The results presented in Table 4 indicate that under the fair-weather scenario, limited assimilative capacity results in concentrations at Station 2 above CCME criteria for all COPCs identified in TMF water. Attenuation of peak breach water flow rates and additional assimilative capacity at downstream stations results in a progressive decline in concentrations, with aluminum, cobalt, and copper remaining above the CCME criteria at Station 7.

The results presented in Table 5 indicate that under the PMP scenario, additional assimilative capacity results in only aluminum, copper, cobalt, and mercury being estimated to occur at concentrations greater than CCME criteria at Station 2. Mercury is estimated to be less than CCME criteria beyond Station 2, while aluminum, cobalt, and copper concentrations remain above CCME criteria at all stations, reflecting the baseline condition for aluminum, and highly elevated concentration of cobalt and copper in TMF water.

Values greater than CCME criteria are only identified for the chronic guidelines, with no values greater than acute guidelines (among parameters presented in Table 4, only cadmium has a corresponding CCME Freshwater Acute guideline value, of 0.001 mg/L). Due to the nature of a dam breach event, which results in surge of flow over a relatively short-duration, the estimated concentrations are not expected to persist over the long exposure period for which chronic toxicity guidelines are intended. Additional details on duration of inundation are presented in Golder (2020a).

Table 4: Modeled Concentrations in Victoria River – Fair-weather Scenario

Constituent	Units	CCME Freshwater Chronic	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7
Nitrite (NO_2)	mg/L as N	0.06	0.1161	0.0801	0.0727	0.0578	0.0323	0.0325
Aluminum (Al)	mg/L	0.0050 [1]	0.0452	0.0557	0.0578	0.0622	0.0696	0.0695
Silver (Ag)	mg/L	0.00025	0.00067	0.00046	0.00042	0.00033	0.00019	0.00019
Arsenic (As)	mg/L	0.005	0.00656	0.00453	0.00411	0.00328	0.00184	0.00185
Cadmium (Cd)	mg/L	0.000040 [2]	0.000044	0.000031	0.000028	0.000023	0.000014	0.000014
Cobalt (Co)	mg/L	0.00078 [2]	0.07870	0.05239	0.04702	0.03618	0.01754	0.01772
Copper (Cu)	mg/L	0.0020 [2]	0.3957	0.2633	0.2363	0.1817	0.0879	0.0888
Iron (Fe)	mg/L	0.3	0.564	0.431	0.404	0.349	0.255	0.256
Mercury (Hg)	mg/L	0.000026	0.000234	0.000158	0.000142	0.000111	0.000057	0.000057
Selenium (Se)	mg/L	0.001	0.00156	0.00112	0.00103	0.00085	0.00054	0.00054

Notes:
1.00 Value is greater than CCME Freshwater Chronic criteria.
[1] Guideline is variable and dependent on pH values.
[2] Guideline is variable and dependent on hardness concentrations.
As no constituents were greater than CCME Acute criteria in TMF water, comparisons to CCME Acute criteria are not presented.

Table 5: Modeled Concentrations in Victoria River – PMP Scenario

Constituent	Units	CCME Freshwater Chronic	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7
Nitrite (NO_2)	mg/L as N	0.06	0.1161	0.0801	0.0727	0.0578	0.0323	0.0325
Aluminum (Al)	mg/L	0.0050 [1]	0.0452	0.0557	0.0578	0.0622	0.0696	0.0695
Silver (Ag)	mg/L	0.00025	0.00067	0.00046	0.00042	0.00033	0.00019	0.00019
Arsenic (As)	mg/L	0.005	0.00656	0.00453	0.00411	0.00328	0.00184	0.00185
Cadmium (Cd)	mg/L	0.000040 [2]	0.000044	0.000031	0.000028	0.000023	0.000014	0.000014
Cobalt (Co)	mg/L	0.00078 [2]	0.07870	0.05239	0.04702	0.03618	0.01754	0.01772
Copper (Cu)	mg/L	0.0020 [2]	0.3957	0.2633	0.2363	0.1817	0.0879	0.0888
Iron (Fe)	mg/L	0.3	0.564	0.431	0.404	0.349	0.255	0.256
Mercury (Hg)	mg/L	0.000026	0.000234	0.000158	0.000142	0.000111	0.000057	0.000057
Selenium (Se)	mg/L	0.001	0.00156	0.00112	0.00103	0.00085	0.00054	0.00054

Notes:
1.00 Value is greater than CCME Freshwater Chronic criteria.
[1] Guideline is variable and dependent on pH values.
[2] Guideline is variable and dependent on hardness concentrations.
As no constituents were greater than CCME Acute criteria in TMF water, comparisons to CCME Acute criteria are not presented.

5.3 Red Indian lake

Water released from the TMF was mixed with the Red Indian Lake mixing zone as described in Section 4.4.3. As noted in Section 4.4.3, the mixing zone volume is unknown and estimated using assumptions which may over-estimate the concentrations that are predicted for the mixing zone.

Estimated concentrations after complete mixing are presented in Table 6. Predicted concentrations in Red Indian Lake do not differ between scenarios; this is because the total breach volume is the same in both scenarios, and the effects of regional runoff to Red Indian Lake in a PMP event were not evaluated. Prior to achieving equal mixing throughout the mixing zone, concentrations similar to Victoria River Station 7 may exist in the vicinity of the Victoria River outlet. As noted in Section 4.4.1, only those constituents identified as COPCs were carried forward to the Red Indian Lake mixing model., Since elevated concentrations can persist for longer periods in lake environments, the CCME Freshwater Chronic guidelines were used, at a screening level, to identify constituents of potential concern and are not intended to indicate a potential for toxicity to aquatic life.

It should be noted that baseline water quality for Red Indian Lake (as measured at station NF02YO0107) is greater than the CCME chronic criteria for aluminum and cadmium, at average concentrations of 0.061 mg/L and 0.000046 mg/L, respectively. As these baseline concentrations are slightly greater than the TMF water, the dam breach results in no significant change relative to ambient conditions.

The results presented in Table 6 indicate that copper concentrations are estimated to occur at concentrations greater than CCME criteria as a result of the dam breach. Concentrations of copper are slightly below CCME criteria at baseline, resulting in minimal assimilative capacity. As a result of the additional mass loading of copper associated with the breach, the concentration after breach is greater than the CCME criteria.

Values greater than CCME criteria are only identified for the chronic guidelines, with no values greater than acute guidelines (among parameters presented in Table 4, only cadmium has a corresponding CCME Freshwater Acute guideline value, of 0.001 mg/L). Due to the nature of a dam breach event, in which chemical loading occurs as a single event (rather than ongoing release over time) the estimated concentrations are not expected to persist over the long exposure period for which chronic toxicity guidelines are intended to be applied.

In the PMP breach scenario, increased regional runoff to Red Indian Lake would be anticipated to result in additional assimilative capacity which is not incorporated into the model. Additionally, a PMP event would facilitate increased flow rates through the mixing zone, resulting in displacement of TSF water with natural runoff.

Greater uncertainty exists with regard to the longevity of elevated concentrations of copper in Red Indian Lake in the fair-weather scenario, as the residence time of water in Red Indian Lake is not known.

Table 6: Modeled Concentrations in Red Indian Lake

Constituent	Units	CCME Freshwater Chronic	Red Indian Lake – Baseline	Red Indian Lake – After Breach
Nitrite (NO_2)	mg/L as N	0.06	0.0200	0.0207
Aluminum (Al)	mg/L	0.0050 [1]	0.0610	0.0609
Silver (Ag)	mg/L	0.00025	0.000003	0.000010
Arsenic (As)	mg/L	0.005	0.00027	0.00032
Cadmium (Cd)	mg/L	0.000040 [2]	0.000046	0.000046
Cobalt (Co)	mg/L	0.00078 [2]	0.00002	0.00060
Copper (Cu)	mg/L	0.0020 [2]	0.0017	0.0046
Iron (Fe)	mg/L	0.3	0.065	0.068
Mercury (Hg)	mg/L	0.000026	0.000005	0.000007
Selenium (Se)	mg/L	0.001	0.00005	0.00006

Notes:
1.00 Value is greater than CCME Freshwater Chronic criteria.
[1] Guideline is variable and dependent on pH values.
[2] Guideline is variable and dependent on hardness concentrations.
As no constituents were greater than CCME Acute criteria in TMF water, comparisons to CCME Acute criteria are not presented.

6.0 ASSIMILATIVE CAPACITY SUMMARY

A hypothetical failure of the TMF East Dam would release the impounded water and suspended tailings into Victoria River and ultimately reaching Red Indian Lake. Such a failure has the potential to result in adverse environmental effects to aquatic life as a result of increased concentrations of dissolved constituents. Alternative environmental effects pathways (i.e. suspended solids, habitat destruction, effects to terrestrial organisms, etc.) are outside the present scope of work.

It should be noted that the nature of a dam breach event into a river system is a temporary event of short duration (e.g., less than a day), for which acute water quality guidelines are appropriate. Canadian Council of Ministers of the Environment (CCME) for the Protection of Aquatic Life (Freshwater) guidelines are the applicable water quality guidelines for natural surface water bodies in Newfoundland and Labrador. However, relatively few constituents are assigned a CCME Acute guideline as compared to those assigned a CCME Chronic guideline value. To evaluate the potential for environmental effects, a numerical threshold value is required to interpret the model results. Therefore, CCME Chronic guidelines were used as the primary threshold for evaluation of the potential for environmental effects (in addition to available CCME Acute guidelines); however, elevated concentrations in the Victoria River occurring as a result of a dam breach are not expected to persist over the long exposure period for which chronic toxicity guidelines are intended to be applied.

Should elevated concentrations occur in Red Indian Lake during low flow conditions, the CCME Chronic guidelines are likely more applicable as the potential effects of the dam breach may persist for an extended period of time (e.g., more than 30 days) due to longer retention time of the lake during low flow conditions. However, during high flow events (e.g., spring freshet), the increased flow rates likely reduce the retention time and make the CCME Acute guidelines more applicable. Given the uncertainties associated with the bathymetry of Red Indian Lake and the resulting retention time, the CCME Chronic guidelines should be used for a conservative screening of the potential effects in Red Indian Lake.

Where estimated concentrations are greater than CCME Chronic guidelines, and where a CCME Acute guideline is not available, further evaluation of the potential for toxicity to aquatic life may be appropriate to determine the potential for environmental effects. Values greater than CCME Chronic guidelines alone should not be interpreted as indicative of potential for environmental effects, given the short duration of these concentrations.

As described in Section 5.2, short-duration concentrations of up to ten constituents are anticipated to be greater than CCME Chronic water quality guidelines at one or more locations in Victoria River. No concentrations greater than applicable water quality criteria for acute exposure are anticipated for parameters with acute exposure criteria.

The magnitude of concentrations is typically greater closer to the breach and in the fair-weather scenario, while duration of concentrations greater than applicable criteria is typically greater further from the breach, as a result of attenuation of peak flow rates over distance. The modeled conditions are considered to be fully reversible over a relatively short period of time once all inundated areas have drained to ambient water levels.

In summary, modeled water chemistry in Victoria River is not anticipated to result in adverse environmental effects, subject to confirmation that TMF water does not present the potential for acute toxicity. While environmental effects associated with physical water quality (i.e. suspended solids), tailings deposition, and habitat loss have not been evaluated within the present scope, the significance of those effects in Victoria River is anticipated to be greater than short-duration effects to water chemistry.

In Red Indian Lake, a potential for chronic toxicity exists as a result of a dam breach; however, confirmation of mixing zone volume would provide verification and greater assurance as to the duration of concentrations greater than chronic exposure criteria.

Recommendations:

- Retain an aquatic toxicologist to assess potential for acute toxicity in TMF water among those constituents for which no acute CCME criteria exists, and specifically those constituents estimated to occur at two orders of magnitude above the CCME criteria (i.e. cobalt and copper).
- Conduct investigation of water depths in Red Indian Lake (within the perimeter of the assuming mixing zone) to refine estimates of the mixing zone volume. The primary objective should be to confirm the average depth exceeds the 5 m assumed value used herein to determine that the estimates are conservative and that no additional COPCs should be identified.
- While a bathymetric survey to determine actual basin volume may support a reduction in estimated concentrations of copper in the assumed mixing zone; copper is anticipated to continue to exceed CCME criteria due to elevated baseline concentrations for a portion of Red Indian Lake. A hydrodynamic modelling study supported by additional field measurements would be needed to estimate the actual extents of the mixing zone in Red Indian Lake.

7.0 LIMITATIONS OF STUDY

The following limitations should be considered when evaluating the results presented in this assessment:

- The evaluation of environmental effects in this study is limited to estimation of changes in water quality affecting aquatic species resulting from water released from the TMF entering aquatic habitat. The following possible pathways for environmental effects were not assessed in the present scope of work:
  - Habitat smothering resulting from tailings deposition.
  - Effects to aquatic life resulting from increased suspended solids.
  - For terrestrial organisms, loss of life or destruction of habitat within the inundation zone.
  - Effects to terrestrial organisms resulting from consumption of impacted water.
- The predictions generated through this evaluation were completed as a screening level evaluation for risk classification, including a limited set of chemical constituents, evaluate a limited range of hydrologic conditions, and do not incorporate any geochemical processes such as mineral precipitation, solubility limits, and sorption.
- Only two precipitation scenarios were evaluated. An actual dam breach may differ from the scenarios presented, depending on actual hydrologic conditions at the time of a breach and the volume of water stored in the TMF at the time of failure. However, the analyses conducted herein are conservative with respect to potential conditions over the life of the TMF.
- To permit evaluation of potential environmental effects, an average water depth of 5 meters was assumed as a lower bound, based on professional judgement. Due to the influence of this assumption on the calculations, field verification is required for any reliance to be placed upon the calculations for Red Indian Lake. Golder assumes no responsibility for the reliability of these calculations if the actual average water depth is determined to be less than 5 meters.

- Environmental effects evaluation has been completed primarily relative to chronic toxicity exposure guidelines as a result of no CCME acute toxicity exposure guidelines for the majority of constituents. As recommended in Section 6.0, the potential for acute toxicity should be reviewed by an aquatic toxicologist based on the magnitude of estimated concentrations for certain constituents in TMF water.
- Mixing calculations assumed complete mixing of TMF water with the water in the mixing zone in Red Indian Lake; however, in reality this will not occur instantaneously, and concentrations estimated at Victoria River Station 7 may occur within Red Indian Lake near the river outlet. A hydrodynamic model would be required to evaluate the time to achieve complete mixing within Red Indian Lake; however, at present inadequate data is available to support such a model.

8.0 CLOSING

We trust the above meets your present requirements. If you have any questions, please contact the undersigned.

Golder Associates Ltd.

<Original signed by>

<Original signed by>

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https://golderassociates.sharepoint.com/sites/126654/project files/5 technical work/05 reports/assimilative capacity/final/20141194 (300) marathon gold_assimilative capacity_reva_06aug2020.docx

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ATTACHMENT 1-C

Valentine Gold Project Blast Impact Assessment (2020)

REPORT

Marathon Gold Corporation
Valentine Gold Project

Blast Impact Assessment

Submitted to:

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19130660-R-Rev0

18 September 2020

Distribution List

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E-copy: Golder Associates Ltd.

Table of Contents

Abbreviations, Acronyms and Initialisms

The abbreviations, acronyms and initialisms used in this document are defined as follows:

Name/Acronym	Definition
cc	cubic centimetre
FoS	Factor of Safety
g	gram
Golder	Golder Associates Ltd
Hz	hertz
ISEE	International Society of Explosives Engineers
kg	kilogram
km	kilometre
m	metre
Marathon	Marathon Gold Corporation
mm	millimetre
ms	millisecond
PFS	Pre-Feasibility Study
PGA	peak ground acceleration
PPV	peak particle velocity
Project	Valentine Gold Project
s	second
SD	scaled distance
TMF	tailings management facility

1.0 INTRODUCTION

As part of a National Instrument 43-101 compliant Pre-Feasibility Study (PFS) for the Valentine Gold Project (the Project), Marathon Gold Corporation (Marathon) has retained Golder Associates Ltd (Golder) to provide a risk assessment of the potential impacts, caused by mining activities, to the Victoria Dam and tailings management facility (TMF).

The Project site is located in central western Newfoundland approximately 54 km south of the Town of Buchans. Four significant gold deposits, known as the Leprechaun, Sprite, Marathon and Victory have been discovered on the property. The Marathon and Leprechaun resource estimates are the primary targets for the PFS and are, therefore, the focus of this impact assessment. The proposed Marathon and Leprechaun pits, Victoria Dam and the footprint of the proposed TMF are shown in Figure 1.

This assessment is intended to determine whether open pit blasting could impact the stability of the Victoria Dam or the TMF.

2.0 CRITICAL STRUCTURES

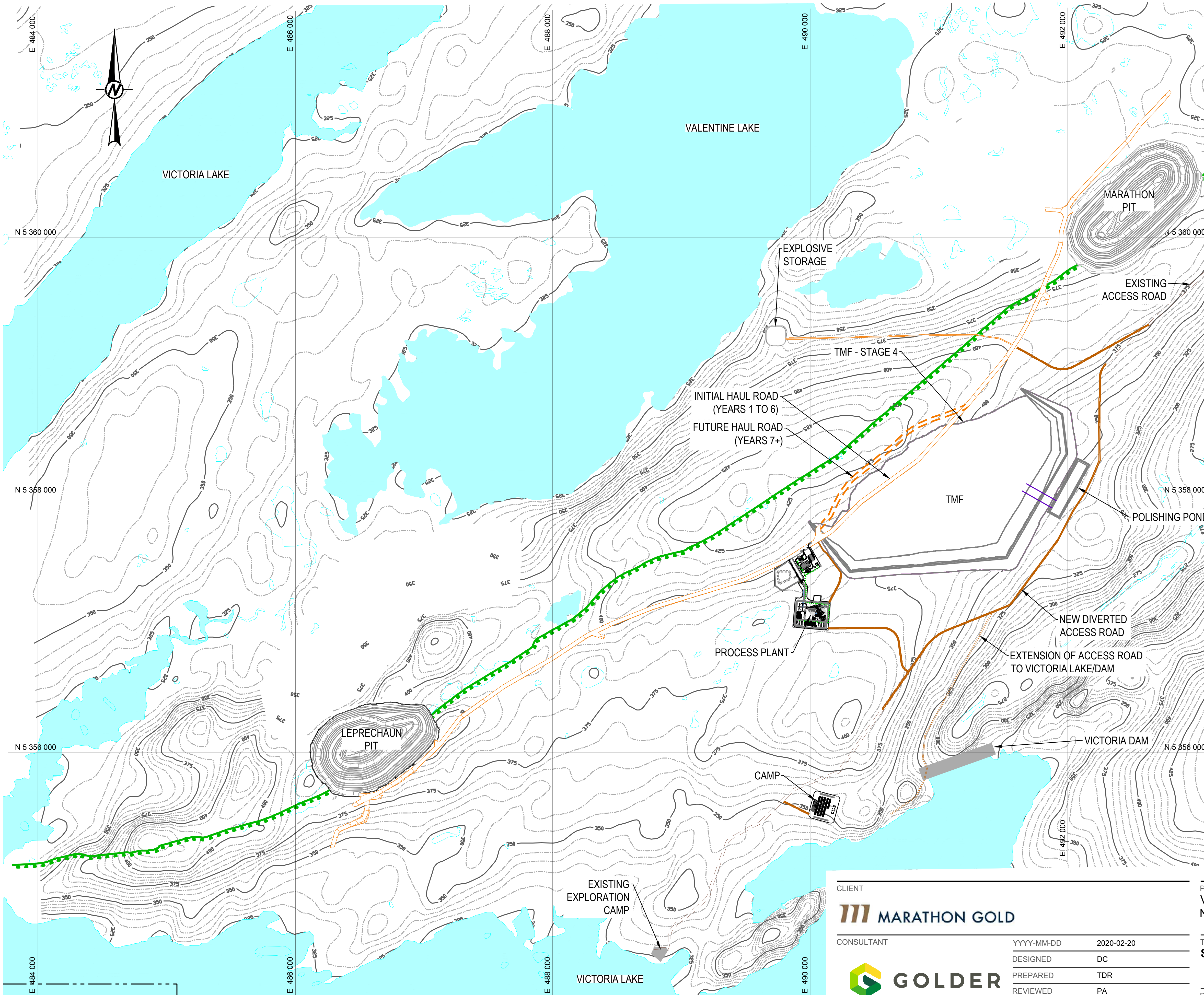
The critical structures included in this assessment, which have the potential to be impacted by the open pit blasts, are the existing Victoria Dam and the proposed TMF (see Figure 1). The approximate nearest distances between the proposed blasting operations and these critical structures are shown in Table 1.

Table 1: Separation Distance Between the Proposed Pits and the Critical Structures Studied

Open Pit	Structure	Separation Distance[a] (m)
Leprechaun Pit	Victoria Dam	3,800
	Valentine TMF	3,400
Marathon Pit	Victoria Dam	3,800
	Valentine TMF	1,100

a) Nearest distances between the proposed open pits and the structures studied.

The Victoria Dam and the Proposed Valentine TMF are described below.



LEGEND

PROPERTY BOUNDARY

THRUST FAULT

NOTE(S):
1. PROJECTION: NAD83 UTM ZONE 21.

REFERENCE:
BASEPLAN PROVIDED BY AUSENCO. FILENAME 104319-0000-G-001_20200130.DWG. REVISION C, DATED 20/01-29

0 500 1,000
1:30,000 METRES

CLIENT	MARATHON GOLD	PROJECT	VALENTINE GOLD PROJECT NEWFOUNDLAND
CONSULTANT	GOLDER	TITLE	SITE PLAN
YYYY-MM-DD	2020-02-20		
DESIGNED	DC		
PREPARED	TDR		
REVIEWED	PA		
APPROVED	WPM		

PROJECT NO.	CONTROL	REV.	FIGURE
19130660	0003	A	1

25 mm IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

2.1 Victoria Dam

The Victoria Dam was constructed as a diversion dam and is part of the river diversion infrastructure to support the Bay D'Espoir Hydroelectric Development. The dam diverts water from the Victoria River watershed into the White Bear drainage basin (Read and Cole 1972). According to Read and Cole (1972), the dam was constructed as a zoned rolled earth fill type with a central impervious core and a cutoff trench sealed on cleaned and where necessary grouted bedrock. The maximum height of the dam above the river level is 58 m and the crest length is approximately 400 m.

Golder did not receive information regarding testing on the seismic stability or the potential for seismically induced liquefaction on the Victoria Dam.

2.2 Valentine Tailings Management Facility

The proposed tailings management facility (TMF) is located between Valentine Lake and the northeast end of Victoria Lake (see Figure 1). The proposed pre-feasibility level design by Golder Associates has an ultimate dam height of 49 m. It is proposed to consist of a rockfill embankment with an upstream liner consisting of the following:

- 1.0 m thick coarse filter;
- 1.0 m thick fine filter; and,
- 1.5 mm linear low-density geomembrane.

The design calls for the geomembrane to be tied into the bedrock at the toe of the main embankment. The TMF will be founded on bedrock/till.

3.0 BLAST DESIGN

The open pit blasts for the Marathon and Leprechaun open pits are anticipated to vary depending on the grade control requirements. The proposed blast design parameters provided by Marathon are summarised in Table 2.

Table 2: Blast Design Parameters for the Marathon and Leprechaun Open Pits

Parameter	Values	
	Production	Tight Grade Control
Hole Diameter (mm)	165	155
Bench Height (m)	12.0	6.0
Sub-drill (m)	1.0	0.9
Hole Depth (m)	13.0	6.9
Stemming Length (m)	4.0	3.0
Explosive Charge Length (m)	9.0	3.9
Explosive Type	Bulk Emulsion	Bulk Emulsion
Explosive Density (g/cc)	1.10	1.10
Explosives Per Hole (kg)	215	80

4.0 POTENTIAL BLAST VIBRATIONS

The intensity of ground vibrations, which is an elastic effect measured in units of Peak Particle Velocity (PPV), is defined as the speed of excitation of particles within the ground resulting from vibratory motion. The PPV is the most commonly used measure of the intensity of the ground vibration caused by blasting. For the purposes of this report, PPV is measured in mm/s.

When assessing the effects on structures, such as earth embankments and TMFs, one must consider both the elastic effect (ground vibration) as well as the plastic (non-elastic) effect produced locally by each detonation. The detonation of an explosive produces a very rapid and dramatic increase in volume due to the rapid conversion of the explosive from one state to another. When this occurs within the confines of a borehole, it has the following effects:

- The bedrock in the area immediately adjacent to the explosive product is crushed.
- As the energy from the detonation radiates outward from the borehole, the bedrock between the borehole and blast face becomes fragmented and is displaced while there is minimal fracturing of the bedrock behind the borehole.
- Energy not used in the fracturing and displacement of the bedrock dissipates in the form of ground vibrations, sound and airblast. This energy attenuates rapidly from the blast site due to geometric spreading and natural damping.

4.1 Blasting Near Dams and Embankments

Ground vibration guidelines are typically established for blasting sites to prevent damage to adjacent facilities or infrastructure. Exceeding the guidance levels does not in itself imply that damage will occur but only increases the potential that damage may occur.

Liquefaction is the process wherein, following a trigger, the structure exhibits a rapid loss of strength. In cyclic liquefaction failure (most applicable to blasting), repeated loading during a seismic/blast event results in excess pore pressure generation in a material. If material is in a loose state, the loading could result in brittle strength loss and potential failure of the structure.

The designed seismic ground vibration limit for tailings embankments is typically based on a peak ground acceleration (PGA). A PGA based method is commonly used to assess the earthquake-induced liquefaction potential of soils and consequently embankments with the “simplified procedure” (Youd and Idriss 2001). However, there are fundamental differences between blast-induced ground vibrations from construction or mining operations and ground vibrations caused by earthquakes. Earthquake-induced vibrations are typically very low frequency, very large displacement and long duration. Ground vibrations initiated by open-cut blasts typically contain less energy, have a higher spectral frequency content, and have significantly shorter time duration (less than one second) compared to earthquake-induced ground vibrations (approximately 30 seconds to several minutes). The dominant frequency of blast-induced ground vibrations depends on the site geology, distance to the blast and delay sequencing of the blast. The dominant frequency from surface mine blasts typically range from 10 Hz to 50 Hz. Thus, although the PGA of the blast-induced ground vibrations may exceed the designed seismic limits, the PPV and displacements may be a small fraction of those anticipated for an earthquake induced event. Table 3 shows the PPV, displacement, and wavelength for a range of frequencies at a constant acceleration. We have considered an example PGA limit of 0.07 g (1 g = 9.8 m/s^2).

Table 3: Vibration Parameters at Constant Acceleration[a]

Acceleration (g)	Frequency (Hz)	Velocity (mm/s)	Displacement (mm)	Wavelength[b] (m)
0.07	0.1	1 100	1 700	25 000
0.07	1.0	110	17	2 500
0.07	10	11	0.17	250
0.07	100	1.1	0.002	25
0.07	1 000	0.11	0.00002	2.5

a) After Oriard, 2002.

b) Assuming a seismic velocity of 2 500 m/s.

Large earthquakes generate large strains. The long wavelengths would typically shake dams as a unit, simultaneously throughout (Oriard 2002). With blast vibrations, the wavelengths are significantly shorter, and the various parts of the embankment are unlikely to be in phase. Additionally, the damage potential increases with the duration of the event.

Appropriate limits for blast-induced liquefaction and vibrations at earth dams and embankments have been discussed in numerous publications, including Charlie et al. (1987, 1992, 2001), Oriard (2002), Al-Qasimi et al. (2005) and Pfeifer (2010). According to Pfeifer (2010), the amount of damage from blasting correlates best to the PPV, while PGA is more appropriate when evaluating damage from earthquakes.

Al-Qasimi et al. (2005) found little or no blast-induced residual pore pressure increase (PPR less than 0.1) occurred at a PPV less than 10 mm/s. For a blast using millisecond delays (i.e. as is the case for typical open pit blasts), cyclic liquefaction was produced for a PPV exceeding 130 mm/s in a level deposit containing saturated tailings (Al-Qasimi et al. 2005). Charlie et al. (1987, 1992) suggested the following criteria for blasting near dams (Table 4), based on liquefaction potential and susceptibility to pore pressure increases.

Table 4: General Guidelines to Vibration Damage Thresholds for Blasting Near Dams (i.e., Tailings Embankments)

Dam Construction	PPV Limit (mm/s)
Dams constructed of or having foundation materials consisting of loose sand or silts that are sensitive to vibration.	25
Dams having medium dense sand or silts within the dam or foundation materials.	50
Dams having materials insensitive to vibrations in the dam or foundation materials and adequate static Factor of Safety (FoS).	100

Note: From Charlie et al. (1987, 1992).

The information presented in Table 4 can be used as general guidelines for assessing the potential for blast vibration induced liquefaction to embankment structures. For structures where no laboratory data or field tests exist to the susceptibility to vibrations, the threshold should be set at a maximum of 50 mm/s.

Only a general description is available for the Victoria Dam (Section 2.1). Thus, while the structure would seem to be fairly resistant to blast vibrations, the actual construction and current conditions are not well known. Additionally, the critical nature of the dam with respect to the provincial energy supply suggests that a PPV limit of 50 mm/s would be considered appropriate.

The proposed design of the TMF (Section 2.2) suggest an embankment that is not susceptible to liquefaction. A PPV limit of 100 mm/s would seem appropriate. However, since the proposed TMF has not been constructed, and alterations between the design and the construction could occur, a PPV limit of 50 mm/s would be considered appropriate. This may be reconsidered once the embankment has been constructed.

4.2 Blast Vibration Model

The rate at which ground vibrations attenuate from a blast site is dependent on a number of variables. The variables include the blast parameters (delay timing, type of explosive, etc.), topography of the site, as well as the characteristics of the in situ material (bedrock and/or soil materials). Two of the most important variables that affect the PPV induced by a blast are the distance from the source (seismic waves attenuate with distance) and the maximum explosive charge weight per delay period. The most common method of normalizing these two factors is by means of plotting the scaled distance (distance divided by the square root of the charge weight per delay) against the PPV.

The PPV (mm/s) is given by the following equation:

$$PPV = K(SD)^e$$

where K and e are site constants and the Scaled Distance (SD) is defined as:

$$SD = \left(\frac{D}{\sqrt{W}}\right)$$

where D is the distance (m) between the blast and receptor; and,

W is the maximum weight of explosive (kg) detonated per delay period.

Numerous studies have been carried out over the years and have yielded predictive formulas for various types of blasting operations. Examples are cited in Singh et al. (1993), Scott (1996), ISEE (2011) and Oriard (2002). In the absence of site-specific data, estimates of the site constants may be obtained from these studies and the limited information concerning the site. Because of the level of uncertainty associated with such estimates, the site constants may be more conservative than site-specific constants derived from an attenuation analysis of the data from monitored blasts at the site. Site-specific predictive models typically involve monitoring a number of site blasts at specific locations. The use of literature derived constants should only be used until actual data for the site and the type of blasting are obtained.

Based on the initial information provided by Marathon regarding the proposed blast parameters at the Marathon and Leprechaun sites, the proposed attenuation model for Valentine open pit blasts is shown in the equation below. In the absence of site-specific data, the model is applicable when blasting is conducted in an open pit towards a free face in average conditions:

$$PPV = 1140\left(\frac{D}{\sqrt{W}}\right)^{-1.60}$$

The proposed vibration attenuation models for Valentine project open pits are plotted on Figure 2.

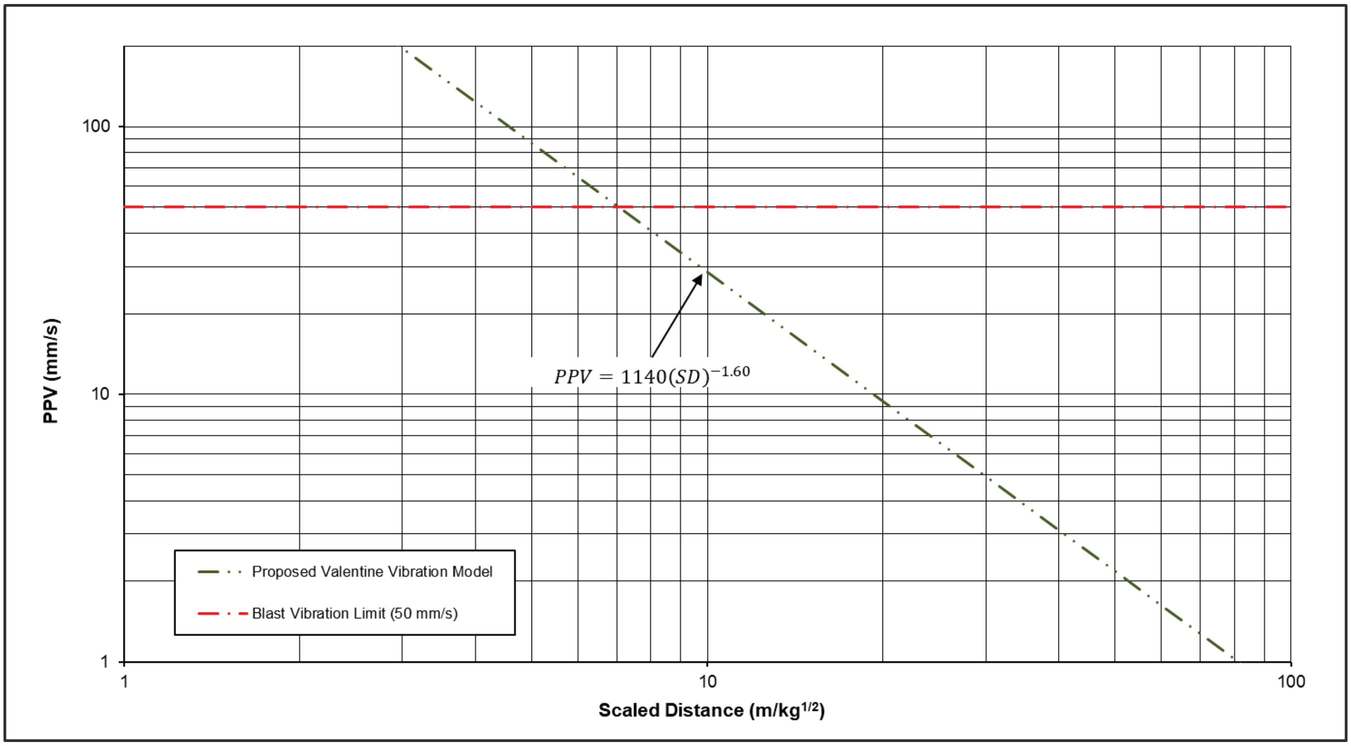


Figure 2: Ground Vibration Attenuation Models for the Valentine Project Open Pits.

As shown in Figure 2, the estimated minimum SD required for the open pit blasting operations at the Marathon and Leprechaun pits to remain within the recommended limit of 50 mm/s is 7.06 m/kg$^{1/2}$. The analysis presented within this report assumes this as a worst-case scenario. That is, the shortest separation distance with the largest explosive charge weight per delay period.

5.0 BLAST IMPACT ASSESSMENT

5.1 Ground Vibration Estimate

Golder conducted a preliminary ground vibration estimate, which is displayed in Figure 3. The estimate shows the shows the vibration amplitudes for a range of separation distances for the proposed Leprechaun and Marathon open pits based on the blast design parameters provided by Marathon. The data is also summarised in Table 5.

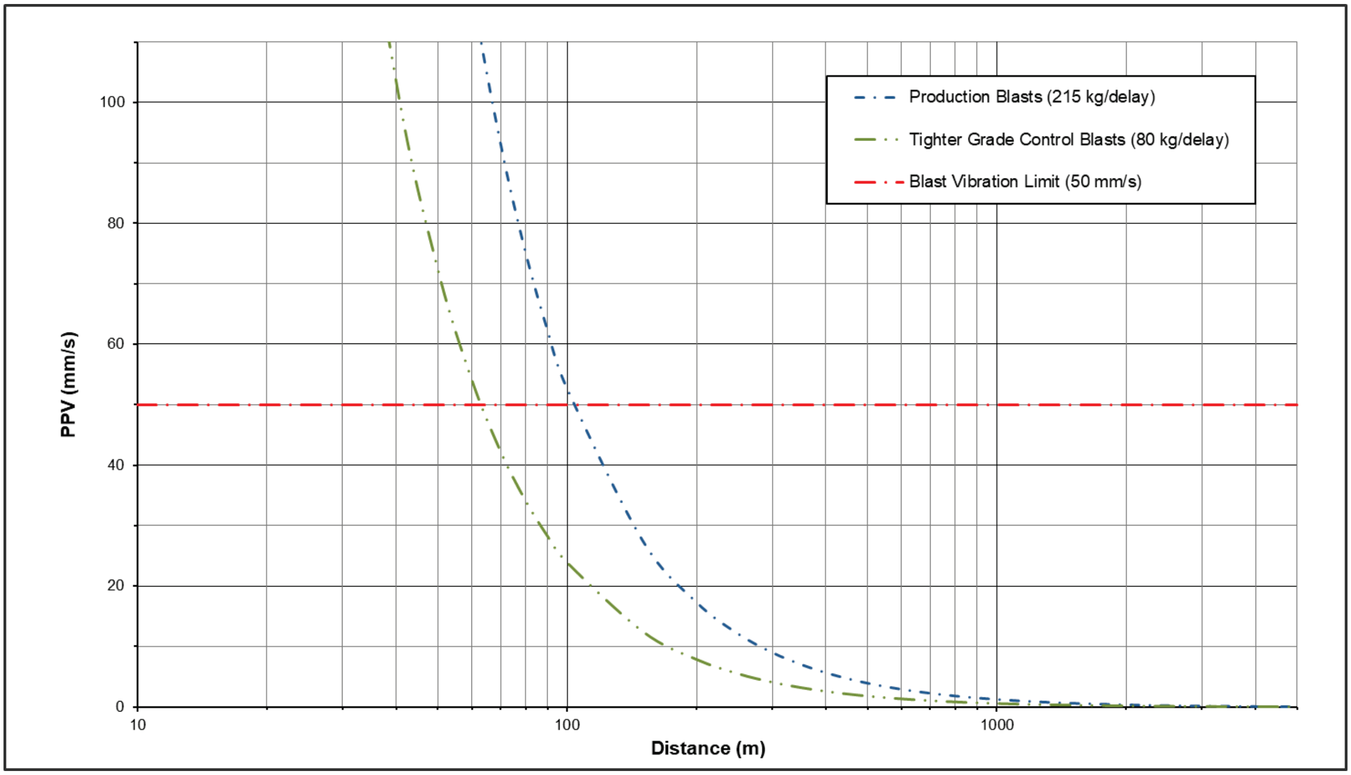


Figure 3: Estimated Peak Particle Velocity (PPV) for a Range of Distances from the Leprechaun and Marathon Open Pits

Table 5: Summary of Estimated Blast Vibration at a Range of Separation Distances for Valentine Blasts

Distance (m)	PPV (mm/s)	
	Production Blasts	Tighter Grade Control Blasts
100	52.8	24.0
200	17.4	7.9
500	4.0	1.8
1,000	1.3	0.60
1,500	0.69	0.31
2,000	0.44	0.20
2,500	0.31	0.14
3,000	0.23	0.10
3,500	0.18	0.08
4,000	0.14	0.07
4,500	0.12	0.06
5,000	0.10	0.05

The analysis indicates that the following minimum separation distances from a proposed Marathon blasts are required to remain within the recommended upper vibration limit of 50 mm/s:

- Production Blasts – 104 m; and
- Tighter Grade Control Blasts – 63 m.

Blasts carried out at a distance greater than 104 m from either of the structures therefore remain compliant with the 50 mm/s suggested limit.

5.2 Blast Impact Summary

Based on the recommended PPV limit for the Victoria Dam and the Valentine TMF, the blast design parameters provided by Marathon, and the proposed ground vibration attenuation model, the estimated PPVs for the proposed Valentine project blasts are shown in Table 6.

Table 6: Estimated Blast Induced Vibrations for the Production Blasts

Blast Source	Receptor	Minimum Distance (m)	PPV Limit (mm/s)	Estimated PPV[(a)] (mm/s)
Leprechaun Pit	Victoria Dam	3,740	50	0.16
	TMF	3,370	50	0.19
Marathon Pit	Victoria Dam	3,790	50	0.16
	TMF	1,100	50	1.14

a) Assuming a maximum explosive weight for Production Blasts of 215 kg.

Although a worst-case scenario has been assumed for the analysis, the predicted blast-induced vibrations are well below the assumed limits at both the Victoria Dam and proposed TMF embankment. With an explosive charge weight of 215 kg/delay (for Valentine blasts) the estimated PPV is 1.14 mm/s at 1,100 m.

Golder notes that the estimated PPV levels are likely to change due to changes in the mine plan, the blast design, as well as with recommended calibration of the vibration attenuation model. Collecting blast monitoring data and calibrating the vibration attenuation model, will provide guidance as to when, if at all, blast designs should be altered to accommodate vibration levels at Victoria Dam or the Valentine TMF.

Due to the inherent variability in site specific conditions, caution must be exercised when assessing the potential damage from blast-induced vibration. Actual vibrations will need to be monitored during the ongoing blasting operations.

6.0 RECOMMENDED MITIGATIVE MEASURES

The ground vibration analysis presented in this report are based on models presented in published literature. Although the models provide initial approximations, they should be calibrated with site-specific data to provide refined estimates. It is suggested that a monitoring program be developed and conducted to calibrate and refine the ground vibration models used in this study.

A PPV trigger point for the embankment should be set at 35 mm/s (70% of the proposed limit). When blast parameters suggest a ground vibration in excess of 35 mm/s at the toe of the embankment / dam or when a PPV of 35 mm/s is recorded during ground vibration monitoring, blast design should be altered to accommodate the vibration limit.

When a change in mining method is planned or there is a potential for significant change(s) in the blast design than those considered in this study, the potential impacts of the change(s) should be reassessed.

Based on Golder's analysis, it is unlikely that mitigative measures will be required to maintain PPV levels below the recommended threshold for potential damage to the TMF embankment or the Victoria Dam due to blasting from the proposed open pit mine. This assessment is based on the proposed TMF design and understanding of the Victoria Dam. The potential blast impacts should be considered prior to implementing any TMF design changes.

7.0 CONCLUSIONS AND RECOMMENDATIONS

In addition to our experience on similar projects and published literature, the following key information provided by Marathon was used to arrive at the findings discussed in this report:

- Blast design parameters for the proposed Leprechaun and Marathon open pits;
- Design drawings and specifications for the TMF; and,
- Location of Victoria Dam, the TMF and proposed Leprechaun and Marathon open pits.

A description of the Victoria Dam construction was provided by Read and Cole (1972).

The following is a summary of the findings of our study and recommendations for further work if necessary:

- Rationale for the use of a PPV-based limit is presented to mitigate blast vibration damage at the TMF and Victoria Dam.
- Analyses indicate that blasts are likely to induce PPV levels that are well below the suggested limit of 50 mm/s for the TMF and Victoria Dam at the respective embankment toes. The maximum estimated PPV levels for the proposed mine blasts are as follows:
  - TMF – 1.14 mm/s at a minimum separation distance of 1,100 m from the Marathon Pit; and,
  - Victoria Dam – 0.16 mm/s at a minimum separation distance of 3,740 m from the Leprechaun Pit.
- The ground vibration model implemented in this report is based on models presented in published literature and our experience on similar projects. The models should be calibrated with data from recordings made at the toe of the constructed TMF and the Victoria Dam.
- While a PPV of 50 mm/s is considered an appropriate limit for the toe of the embankment of the TMF and Victoria Dam, a trigger point of 35 mm/s (70% of the recommended threshold) should be considered as the ground vibration level at which the potential blast impacts are to be reassessed.
- Blast monitoring will provide guidance as to when, if at all, blast designs should be altered to accommodate vibration limits at TMF or the Victoria Dam.
- The potential blast impacts should be reassessed prior to implementing any significant changes to the following:
  - mine design;
  - blast design;
  - TMF location; or,
  - TMF embankment design.

- Pore pressure, settlement and lateral movement monitoring of the TMF embankment should be considered alongside the ground vibration monitoring data to provide a near real-time estimate of potential blast impact.

8.0 CLOSURE

We trust the above meets your present requirements. If you have any questions or comments, please contact the undersigned.

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https://golderassociates.sharepoint.com/sites/117078/project files/6 deliverables/5. blast impact study/rev0_sept2020/19130660-r-rev0 marathon valentine project blast impact 16sep_20.docx

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