APPENDIX 4-E
MITCHELL PIT LANDSLIDE GENERATED WAVE MODELLING

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Project No.: 0638-013-33

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Dear Mr. Smolik,

Re: Mitchell Pit – Landslide Generated Wave Modeling

At the request of Seabridge Gold Inc. (Seabridge), BGC Engineering Inc. (BGC) has completed a study to estimate the potential magnitudes of waves generated by failures from the slopes of the Mitchell Pit into the Mitchell Pit Lake post mine closure. BGC has developed seven potential failure scenarios based on our previous work on the design of the open pit slopes (BGC, 2010) and a review of the interactions between the Mitchell Block Cave and the open pit slopes (BGC, 2012a). Waves generated by each of the failures have been estimated through a combination of empirical and numerical methods. The likelihood of generating each of the modeled waves after the mine has been closed has been estimated. The results of this work are provided for use by Seabridge and their consultants as input into the closure water management plans for the KSM Project.

This study demonstrates that:

1. Slope failures of 20 M m^3 from the North or South walls or 6 M m^3 from the East Wall of the Mitchell Pit could generate waves large enough to overtop the closure dam. However, it is significantly more likely that these failures would occur during operations of the block cave and prior to the pit lake filling and therefore not be available to create waves once the pit lake has formed.
2. Inter-ramp scale slope failures of approximately 1.1 M m^3 are equally likely to occur before or after the pit lake has formed from a range of locations around the Mitchell Pit. The waves generated by these types of failures are not adequate to overtop the closure dam.

The likelihood that a landslide in to the Mitchell Pit Lake generates a wave that overtops the currently designed closure dam is “extremely unlikely”. If by the end of the actual mine operations the overall slope failures have not occurred, the owner can re-evaluate the likelihood of the slope failures occurring or modify the plan for the pit lake to avoid the potential for large landslide generated waves post mine closure.

1.0 INTRODUCTION

1.1. Study Background

As part of the proposed KSM Project, the Mitchell Zone will be mined by conventional open pit and block cave methods. The open pit will be mined from year -2 to year 23, resulting in ultimate slope heights of approximately 1,200 m. The eastern edge of the open pit will intersect the left lateral flank of the existing Snowfield Landslide (Drawing 1). The pit will also intercept the surface traces of the Mitchell Thrust Fault (MTF) and Sulphurets Thrust Fault (STF). After completion of open pit mining, the block cave will be initiated in year 26; production from the underground is projected to continue until year 55. During block caving, the toes of the open pit slopes will be removed as a crater forms in the bottom of the pit in response to block caving; reducing the elevation of the final floor of the excavation by approximately 180 m.

After closure, the combined pit-cave excavation will fill with water to form a pit lake with an elevation of 810 metres above sea level (masl); the lake level will be managed by a dam with a crest elevation at 870 masl and a spillway at 820 masl. The pit lake is predicted to fill over approximately 5 years (BGC, 2012c). The lake will be maintained in perpetuity as part of the final mine closure plan. Water flowing out from the lake reports to the water treatment pond, located near the confluence of the Mitchell and Sulphurets Valleys. Water is treated prior to release to the environment.

1.2. Scope of Work

During the KSM Risk and Fatal Affects review meetings (September 26 and 27, 2012), it was noted that a large failure or landslide from the pit slopes located above the pit lake after mine closure could generate a wave with potential to overtop the closure dam located at the western rim of the Mitchell Pit. Water overtopping this dam could damage the dam; reducing its effectiveness in managing the lake level or resulting in a pulse of water reporting further downstream to the water treatment pond.

Seabridge requested that BGC:

1. Review the range of possible slope failures that could result in waves being generated in the pit lake.
2. Estimate the magnitudes of waves generated by the failures using published empirical relationships and numerical modeling.
3. Estimate the likelihood of occurrence for each of the analyzed landslide-wave scenarios post mine closure.

BGC understands that the results of the current work will be used by Seabridge and Klohn Crippen Berger Ltd. (KCBL) to design the closure dam and closure water management plan for the KSM Project.

2.0 POSSIBLE FAILURES FROM THE SLOPES OF THE MITCHELL PIT

2.1. Overview

Slope stability analyses completed to date (BGC, 2012a) suggest that some slopes of the Mitchell Pit will become unstable due to the development of the block cave. Seven possible slope instabilities with the potential to occur as rapid landslides are identified in Table 1 and described below. Three of the “failure scenarios” originate from the North Wall, three from the South Wall, and one in the East Wall. A range of failure volumes and initiation locations has been considered in developing these scenarios to be used in the wave generation modeling. The initiation locations of scenarios A, B, E, and F were selected to allow a sensitivity analysis of source elevations to be completed. The details of each potential failure are discussed below. The locations and extents of each potential landslide are provided by Drawing 1. The probability of occurrence of each event is discussed in Section 4.0.

2.2. Failure Scenario A

Scenario A considers an inter-ramp scale rock avalanche from the North Wall, involving the failure of a 150 m high slope resulting in a failure volume of approximately 1.1 M m^3 of material originating at an elevation of 1,100 masl. The slope height of the failure is limited by the presence of the “geotechnical berms” included in the pit slope design (BGC, 2010). The factor of safety (FOS) against this scenario during open pit mining is approximate 1.2; the FOS is estimated to reduce to 1.1 (BGC, 2012a) by the completion of the block cave. An example of a similar sized failure from an existing open pit is provided in Figure 1.

2.3. Failure Scenario B

Scenario B considers a rock avalanche of the same scale as Scenario A, initiating from an elevation of 1,400 masl. The section of pit slope involved in this scenario is located farther from the limits of the block cave and is thus expected to be less disturbed by caving. A FOS of 1.2 is estimated for this potential failure during mining of the open pit; the FOS is not estimated to change due to the development of the block cave, based on modeling work completed by BGC (2012a).

2.4. Failure Scenario C

Scenario C considers a collapse of the majority of the North Wall above the elevation of the pit lake (Drawing 1) or “overall” slope failure. This scenario assumes a failure volume of approximately 20 M m^3. The estimated FOS is 1.0 for this slope during the development and by the completion of the block cave (BGC, 2012a). The initiation elevation represents the centre of mass of the assumed failure mass. An example of a similar failure which occurred from the slope of the Palabora open pit above the operating block cave is provided in Figure 1.

2.5. Failure Scenario D

An inter-ramp scale rock avalanche from the portion of the East Wall which intersects the Snowfield Landslide is considered in Scenario D (Drawing 1). A failure volume of approximately 6 M m^3 has been estimated for this scenario, based on the height and width if pit slope area intersecting the disturbed rock mass of the Snowfield Landslide. The estimate FOS is 1.0 (BGC, 2012a) for this section of slope, after block caving has been initiated. An example of a similar sized failure from an existing open pit is provided in Figure 1.

2.6. Failure Scenario E

Scenario E considers an inter-ramp scale rock avalanche composed of 1.1 M m^3 of material and originating in the South Wall at an elevation of 1,100 masl (Drawing 1). Based on work completed by BGC (2012a), the estimated FOS for this section of slope by the end of block caving is 1.1. This scenario is similar to Scenario A.

2.7. Failure Scenario F

Scenario F considers an inter-ramp scale rock avalanche of similar size to Scenario E, but originating from a higher elevation of 1,400 masl in the South Wall (Drawing 1). A FOS of 1.2 is estimated for this potential failure during mining of the open pit; the FOS is not estimated to change due to the development of the block cave, based on modeling work completed by BGC (2012a).

2.8. Failure Scenario G

Scenario G considers a collapse of the majority of the South Wall above the elevation of the pit lake (Drawing 1). This scenario assumes a failure volume of approximately 20 M m^3. The estimated FOS is 1.0 for this slope during the development and by the completion of the block cave (BGC, 2012a). This scenario is similar to Scenario C.

3.0 LANDSLIDE GENERATED WAVE MAGNITUDES

3.1. Overview

Wave development in a reservoir due to landslides can be divided into three stages: (1) slide impact with wave generation; (2) wave propagation with wave transformation and (3) impact and run-up of the impulse wave with resulting load transfer to the dam and, in some cases, overtopping of the dam. To model the landslide scenarios described in Section 2.0, a hybrid wave modeling approach was used. An empirical spreadsheet model provided by Heller et al. (2009) was used for the wave generation stage. However, given the complex topography around the closure dam, empirical equations (Heller et al. 2009) are of limited use in calculating wave propagation and run-up. Therefore, an integrated hydrodynamic modeling package, TELEMAC-2D (2010), was used for the wave propagation and run-up modeling.

3.2. Wave Generation Modeling

3.2.1. Model Description

The wave generation stage was analyzed using the set of empirical equations presented by Heller et al. (2009), which are based on statistical analysis of 434 laboratory wave channel and basin tests carried out by Fritz (2002), Zweifel (2004) and Heller (2007). This compilation of work represents the most comprehensive empirical study of its kind.

With this model, the maximum wave height at the slide impact zone, H_M, is calculated by:

$$H_M = (5/9)P^{4/5}h \tag{1}$$

Where *h* is the still water depth at the slide impact zone; *P*, the impulse product parameter, is defined as:

$$P = FS^{1/2}M^{1/4}\{cos[(6/7)\alpha]\}^{1/2} \text{ for } 0.17 \leq P \leq 8.13 \tag{2}$$

Where *F* is the slide Froude number; *S* is the relative slide thickness, a ratio of slide thickness to still water depth; *M* is the relative slide mass, a ratio of the impact slide mass to the mass of displaced water, and also a parameter related to impact velocity; and *α* is the slide impact angle.

The wave period, T_M, can be given by:

$$T_M = 9P^{1/2}(h/g)^{1/2} \tag{3}$$

Where *g* is gravitational acceleration (9.81m/s^2).

The wave length, L_M, is defined as:

$$L_M = T_M c \tag{4}$$

Where *c* is the wave celerity, as determined by the still water depth and wave height.

3.2.2. Assumptions and Input Parameters

The inputs to Heller et al.'s (2009) model include slide volume, slide dimensions; slide impact velocity; slide impact angle; slide material properties (i.e. bulk slide density and bulk slide porosity); and the still water depth at the slide impact zone. The estimation of these parameters is described below. The selected parameter values are summarized in Table 2.

Slide Geometries

Many uncertainties are involved in estimating the geometries of potential landslides. A slide volume versus area relation based on an inventory of 529 landslides worldwide, complied by Guzzetti et al. (2008), was used to estimate the most-likely landslide dimensions:

$$V = 0.0844A^{1.4324} \tag{5}$$

Where V (m^3) is the slide volume and A (m^2) is the surface area. Following the industry standard approach of assuming a 1:1 slide width to slide length ratio, the average thickness, width, and length of each potential landslide at the impact location in the lake is presented in Section 2.0 can be calculated using Eq.(5) (Table 2).

Slide Impact Velocity

Slide impact velocity has a large influence on the impulse wave height at the landslide impact zone. It can be estimated using the energy equation (Korner, 1976):

$$V_s = \sqrt{2g\Delta Z_{sc}(1 - tan\delta cot\alpha)} \tag{6}$$

Where V_s is the slide impact velocity, ΔZ_{sc} is the drop height of the centre of gravity of the slide, α is the slide impact angle, and δ is the dynamic bed friction angle.

The following relationship for rock falls and rock avalanches was used to estimate δ (after Li, 1983):

$$\log_{10}\left(\frac{\Delta Z_{sc}}{L}\right) = -0.153 \log_{10} V + 0.664 \tag{7}$$

Where *L* is the maximum horizontal travel distance and *V* is the rock slide volume. $\frac{\Delta Z_{sc}}{L}$ defines the fahrböschung (Heim, 1932), which approximates an equivalent coefficient of friction (Hsu, 1975).

Rock slide initiation elevations were chosen based on the slope profile at each potential source. Based on the designed closure pit lake DEM data, the vertical distance between the initial centre of mass and the pit lake water level was calculated for each scenario. The fahrböschung for each scenario based on Eq. (7) is also presented in Table 2. Assuming a slide impact angle of 45º at the slide impact zone, the impact velocity for each scenario was calculated using Eq. (6), as summarized in Table 2.

Slide Material Properties

The bulk slide density (1,800 kg/m^3) and bulk slide porosity (35%) have been estimated based on published values for other natural landslides.

Still Water Depth

A still water depth of 400 m is assumed for all wave generation models, based on the elevation of the pit lake and the elevation extraction level of the block cave which represents the bottom of the pit lake.

3.2.3. Estimated Wave Characteristics

The estimated initial wave characteristics are summarized in Table 3. For the scenarios with same initiation elevation but different volumes, for example, scenarios A, C, D, E and F, the impact velocities vary from 50 to 61 m/s. For the scenarios with same landslide volume, but different initiation elevation, for example, scenarios A and B or scenarios E and F, the impact velocities vary from 50 to 72 m/s. It shows that the slide impact velocities are more sensitive to the initiation elevations than to the total volumes. These wave characteristics were then imported to TELEMAC-2D as boundary conditions for the wave propagation and run-up modelling, as described below.

3.3. Wave Propagation and Run-Up Modeling

3.3.1. Model Description

The TELEMAC Computational Fluid Dynamics (CFD) is an integrated near-shore and river system modeling software suite initially developed by Electricite de France in 1987. It has been extensively modified and upgraded over the last 20 years. (www.opentelemac.com).

One of the main codes within the TELEMAC suite, TELEMAC-2D, is widely used for the analysis of free surface flows and has been applied previously to the simulation of tsunamis and landslide-generated waves (Horsburgh et al. 2008; Hayir et al. 2008). It solves the depth-integrated shallow water (Saint-Venant) equations to simulate free-surface flows or waves in two dimensions of horizontal space. TELEMAC-2D uses the finite-element or finite-volume method and a computation mesh of triangular elements. At each point of the mesh, the program calculates the depth of water and the two velocity components. TELEMAC-2D also offers an open ended environment and a set of FORTRAN sub-routines that all for customization of the boundary conditions.

The program Blue Kenue, developed by National resources Canada (NRCC 2010), was used for pre- and post-processing of the TELEMAC-2D input and results.

3.3.2. Input Data and Data Pre-Processing

Inputs to a TELEMAC-2D model include topography and bathymetry inside the modeling domain, boundary conditions that provide the inflow hydrograph or initial wave conditions, and the simulation control conditions.

Mesh Generation and Bathymetric Data

The extent of the modeling domain covers the east side of the pit lake and the downstream side of the closure dam, as shown on Drawing A-1 to A-7 for each scenario respectively.

The Blue Kenue software was used to generate a triangular mesh inside the modeling domain. The mesh densities vary from 5 m to 20 m in the modeling domain. For estimating the wave run-up height in the dam area more accurately, the mesh density was set to the finest, approximately 5 m. The mesh density was set to approximately 20 m throughout the rest of the domain.

The topographic and bathymetric data inside the modeling domain were combined with the designed closure pit lake surface, the designed dam and spillway geometry and BC TRIM data. Note that a simplified spillway model, limited to an area from 421415 - 421640 E and 6265790 - 6265920 N was used as no detailed digital model is currently available. The program ArcGIS was used to merge these data together and generate a Digital Elevation

Model (DEM). ArcGIS was then used to extract the bathymetry bottom elevation at each node in the mesh.

Boundary Conditions

Two phases of boundary conditions were set for each run. Phase 1 was used to introduce the initial landslide-generated wave to the model domain. The total wave inflow volume was set to match the volume of displaced landslide material. The boundary at the impact zone for each scenario was set as liquid, allowing the wave to enter at the impact zone. Phase 1 completed when the volume of the inflow matched the total volume of the landslide. The boundary at the impact zone was then set as a vertical wall to simulate the post-landslide condition and prevent water from leaving the model domain.

Initial Conditions

In Phase 1, the initial water level was set to 810 masl. For Phase 2, the results file from Phase 1 was input as the initial conditions for the wave propagation and run-up modeling.

Simulation Duration

Given the wave propagation and run-up process, the simulation durations were set to 5 minutes for scenarios A, B, E and F, and 10 minutes for scenarios C, D and G.

3.4. Modeling Results

The outputs from the TELEMAC-2D models include the time series of water depth, velocity, discharge, highest water elevation, and highest velocity. The wave run-up heights at the closure dam for the seven scenarios are summarized in Table 3. The inundation area boundaries for the seven scenarios are shown on Drawings A-1 to A-7 in Appendix A.

As shown in Table 3, the wave run-up heights are more sensitive to the landslide volumes than to the impact velocities, as the wave run-up heights are almost identical for scenarios A, B, E and F. Larger landslides result in higher the wave run-up heights at the closure dam. The wave run-up height reflects the overall raise in the level of the pit lake due to the displacement of water as well as the impact pulse of the landslide into the lake.

The model results suggest that the closure dam would be overtopped for scenarios C and G, with slide volumes of approximately 20 M m^3. The overtopping water volumes for scenarios C and G were also calculated based on the output time series of flow rates along the dam crest, as shown in Table 3. The flow hydrographs along the dam crest for Scenarios C and G are shown in Figures 2 and 3, respectively. These hydrographs indicate that, even with the presence of a spillway, the dam could still potentially be overtopped during a large landslide-generated wave event. The potential large landslide from the North Wall (Scenario C) could generate waves that run up higher at the dam crest than those from the South Wall (Scenario G); however, given the precision of the analysis these run up estimates could be considered to be equivalent.

4.0 LIKELIHOOD OF OCCURRENCE OF THE MODELED WAVES

The likelihood of generating the modeled waves is dependent on:

1. The likelihood of the landslide of the required size occurring.
2. The presence of the pit lake.

Of the seven landslide scenarios considered, some are events that may only occur one time. The basic annual probability of each landslide scenario has been estimated; then the combined annual probability of those events that may only occur once has been estimated for the time period when the pit lake is present. The likelihood of occurrence for a given wave can then be estimated.

4.1. Basic Annual Probability for all Failure Scenarios

Silva et al (2009) provide an empirical relationship between estimated FOS for engineered slopes and the annual probability of failure based on data from 75 civil and mining projects; several open pit case histories are included (Figure 4). BGC has used this relationship in conjunction with the estimated FOS for each of the seven failure scenarios to estimate their basic annual probability of failure (Table 4) due to the development of the block cave. Those scenarios with the lowest estimated FOS have the highest basic annual probability of failure.

4.2. Combined Annual Probability for Scenarios C, D, and G

Failure scenarios C, D, and G represent failure events that can occur one time only. Once these large slope failures have happened, future failure events from the margins of these zones would be similar to the inter-ramp scale failures of scenarios A, B, E, and F. Therefore, the combined annual probability of scenarios C, D, and G must be estimated taking into account the potential that these failures have already occurred during cave mining and prior to the pit lake forming i.e. prior to Year 60 of the KSM Project.

Following the approach of Lee and Clark (2002), the combined annual probabilities of failure for scenarios C, D, and G before Year 60 are estimated by multiplying the basic annual probabilities by the probabilities that the failures have not already occurred:

$$P_{(\text{Year 60})} = P_{(\text{Basic})} \times P_{(\text{not occurred by year 60})}$$

Assuming the pit slopes approach the minimum FOS by the midpoint of cave mining or approximately Year 40, the probability that the failure has not occurred by Year 60 can be estimated from:

$$P_{(\text{not occurred by year 60})} = (1 - P_{(\text{Basic})})^{N}$$

Where N = 20 or the number of years between the pit slopes reaching the minimum FOS condition and completion of filling of the pit lake.

The combined annual probabilities of failure for scenarios C, D, and G at Year 60 are provided in Table 4 with their basic annual probabilities for comparison. It is significantly more likely that each of these failures will occur during the development of the block cave and before the pit lake has formed.

4.3. Likelihood of Generating the Modeled Waves

The seven failure scenarios and resulting waves can be divided into two groups, with respect to likelihood of occurrence:

1. Failures of approximately 1.1 M m^3 (Scenarios A, B, E, and F) resulting in waves which run-up to 823 masl on the face of the closure dam. These waves are considered to be "likely" to occur after closure of the mine, based on the estimated probability ranges of the slope failures (annual probability ~ 0.10 to 0.25).
2. Failures of approximately 6 M m^3 to 20 M m^3 (Scenarios C, D, and G) resulting in waves which will overtop the closure dam or run-up to near the crest. These waves are considered to be "extremely unlikely" to occur after the lake is filled, based on the estimated probability ranges for the slope failures (annual probability ~ 1×10^{-6}).

Once the pit lake has formed, the inter-ramp scale failures and resulting waves are more likely to occur than the waves from the overall slope failures from the North or South walls.

5.0 SUMMARY

BGC has analyzed potential landslide generate waves due to failure of the slope of the Mitchell Pit post mine closure. Seven failure scenarios were developed reflecting a range of possible landslide volumes and initiation locations. An empirical wave generation model was combined with a numerical wave propagation model to estimate the wave heights resulting from the landslide scenarios. Waves generated by inter-ramp scale failures are estimated to not have run-up heights that overtop the closure dam. Waves generated by larger "overall" slope failures are estimated to have maximum run-up heights that could overtop the crest of the closure dam.

The likelihood of generating a given wave is dependent on the likelihood of a landslide occurring once the pit lake has filled. The inter-ramp slope failures are equally likely to occur before or after the pit lake has formed. The overall slope failures are most likely to occur prior to the pit lake filling and therefore not be available to create waves once the pit lake has formed. The results of the current work suggest that the likelihood of a landslide in to the Mitchell Pit lake generating wave that overtops the currently designed closure dam is "extremely unlikely". If by the end of the actual mine operations the overall slope failures have not occurred, the owner can re-evaluate the likelihood of the slope failures occurring or modify the plan for the pit lake to avoid the potential for large landslide generated waves post mine closure.

6.0 CLOSURE

BGC Engineering Inc. (BGC) prepared this document for the account of Seabridge Gold Inc. The material in it reflects the judgment of BGC staff in light of the information available to BGC at the time of document preparation. Any use which a third party makes of this document or any reliance on decisions to be based on it is the responsibility of such third parties. BGC accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this document.

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Yours sincerely,

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Att: Table 1 – 4; Figure 1 – 4; Appendix A; Drawing 1

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TABLES

Table 1. Failure Scenarios

Scenario	Location[1]	Landslide Type	Initiation Elevation (masl)	Volume (M m^3)
A	North Wall	Inter-ramp scale rock avalanche	1100	1.13
B	North Wall	Inter-ramp scale rock avalanche	1400	1.13
C	North Wall	Overall scale slope collapse	1100	20.00
D	East Wall (Snowfield Landslide)	Inter-ramp scale rock avalanche	1100	6.00
E	South Wall	Inter-ramp scale rock avalanche	1100	1.13
F	South Wall	Inter-ramp scale rock avalanche	1400	1.13
G	South Wall	Overall scale slope collapse	1100	20.00

NOTES:

1. Scenario locations are outlined on Drawing 1.

Table 2. Wave Model Input Parameters

Scenario	Volume (m3)	Initiation Elevation (masl)	Width[1] (m)	Length[1] (m)	Thickness[1] (m)	Slide Impact Angle[2] (°)	Fahrböschung[3] (°)	Impact Velocity[4] (m/s)
A	1.13E+06	1100	307	307	12	45	28.7	50
B	1.13E+06	1400	307	307	12	45	28.7	72
C	2.00E+07	1100	838	838	28	45	19.4	61
D	6.00E+06	1100	551	551	20	45	23.0	57
E	1.13E+06	1100	307	307	12	45	28.7	50
F	1.13E+06	1400	307	307	12	45	28.7	72
G	2.00E+07	1100	838	838	28	45	19.4	61

NOTES:

1. Dimensions at impact area; calculated using the empirical relationships of Guzzetti et al., (2008). Based on scenarios in Table 1.
2. Assumed values.
3. Calculated from the scenario volume according to Corominas (1996); used to estimate dynamic bed friction angle which is related to the slide impact velocity.
4. Calculated based on the energy equation presented by Korner (1976).

Table 3. Wave Modeling Results

Scenario	Initial Wave Characteristics at Landslide Impact Zone[3]				Consequence	
	Height (m)	Amplitude (m)	Period (s)	Length (m)	Max Wave Run-Up Elevation at the Closure Dam (masl)	Closure Dam Overtopped
A	21	17	24	512	823	No
B	28	22	26	585	823	No
C	51	41	30	791	877	**Yes**
D	36	29	27	659	868	**Possible**
E	21	17	24	512	823	No
F	28	22	26	585	823	No
G	51	41	30	791	876	**Yes**

NOTES:

1. Dam crest elevation assumed to be 870 masl.
2. Initial lake water level assumed to be 810 masl.
3. Wave characteristics at the impact zone were estimated using Heller et al.'s (2009) model.
4. A simplified spillway model, limited to an area from 421415 - 421640 E and 6265790 - 6265920 N was used as no detailed digital model is currently available.

Table 4. Annual Probability of the Landslide - Wave Scenarios

Scenario	**Landslide Volume ($M\ m^3$)**	**Slope Failure FOS**	**Basic Annual Probability**	**Annual Probability at Year 60[1]**	**Wave Run-Up Elevation at the Closure Dam (masl)**
A	1.13	1.1	0.25	0.25	823
B	1.13	1.2	0.10	0.10	823
C	20.00	1.0	0.50	9.5E-07	**877**
D	6.00	1.0	0.50	9.5E-07	**868**
E	1.13	1.1	0.25	0.25	823
F	1.13	1.2	0.10	0.10	823
G	20.00	1.0	0.50	9.5E-07	**876**

NOTES:

1. Accounting for the possibility that the overall slope failures may have already occurred by Year 60.

FIGURES

Similar to Scenarios A, B, E, and F

Similar to Scenario D

Similar to Scenarios C and G

BGC ENGINEERING INC. AN APPLIED EARTH SCIENCES COMPANY	REPORT TITLE: MITCHELL PIT – LANDSLIDE GENERATED WAVE MODELING
	FIGURE TITLE: SLOPE FAILURE EXAMPLES
CLIENT: SEABRIDGE GOLD INC.	PROJECT NO.: 0638-013-33
	FIGURE NO.: 1

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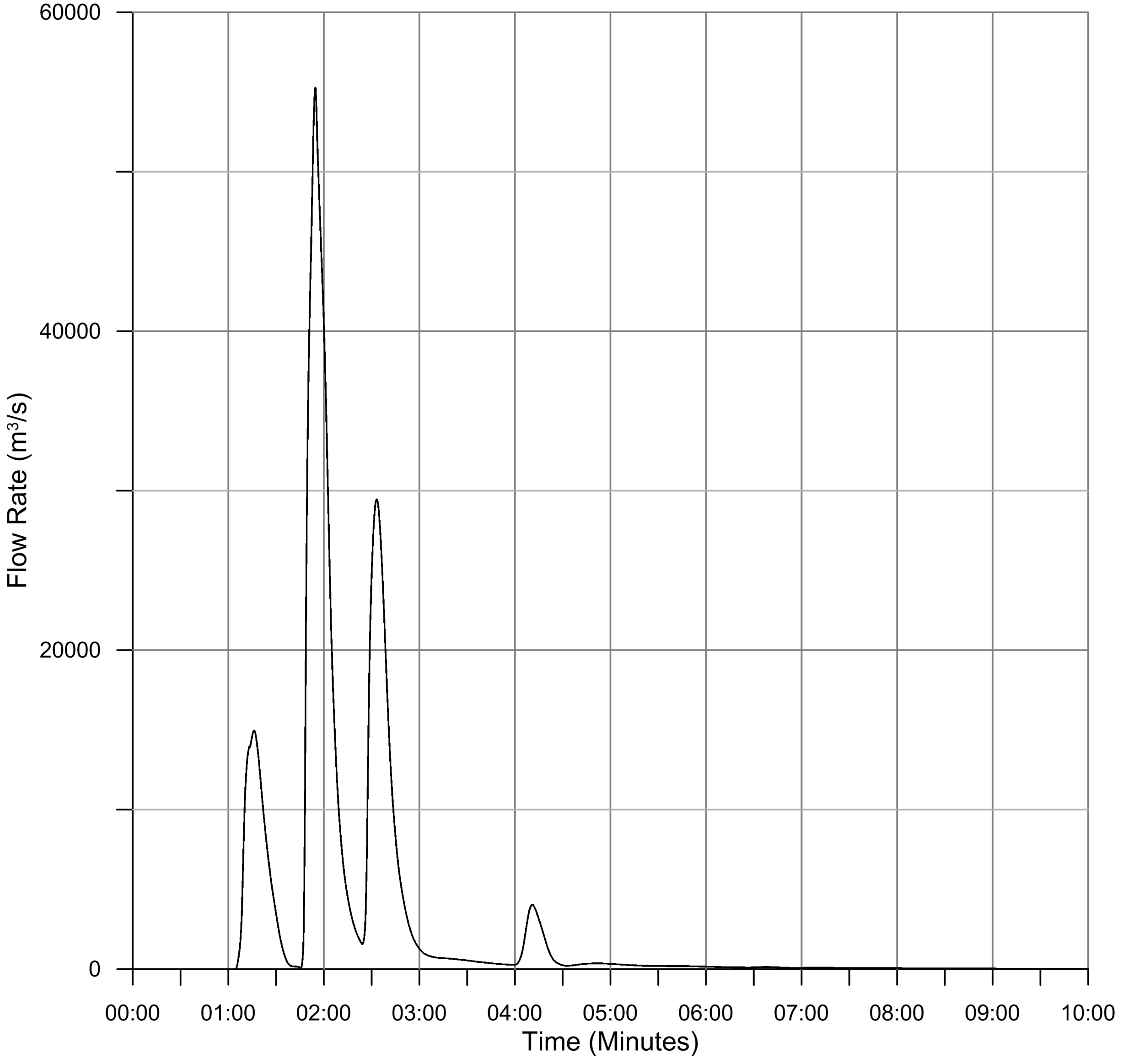

NOTES:
1.

BGC ENGINEERING INC.
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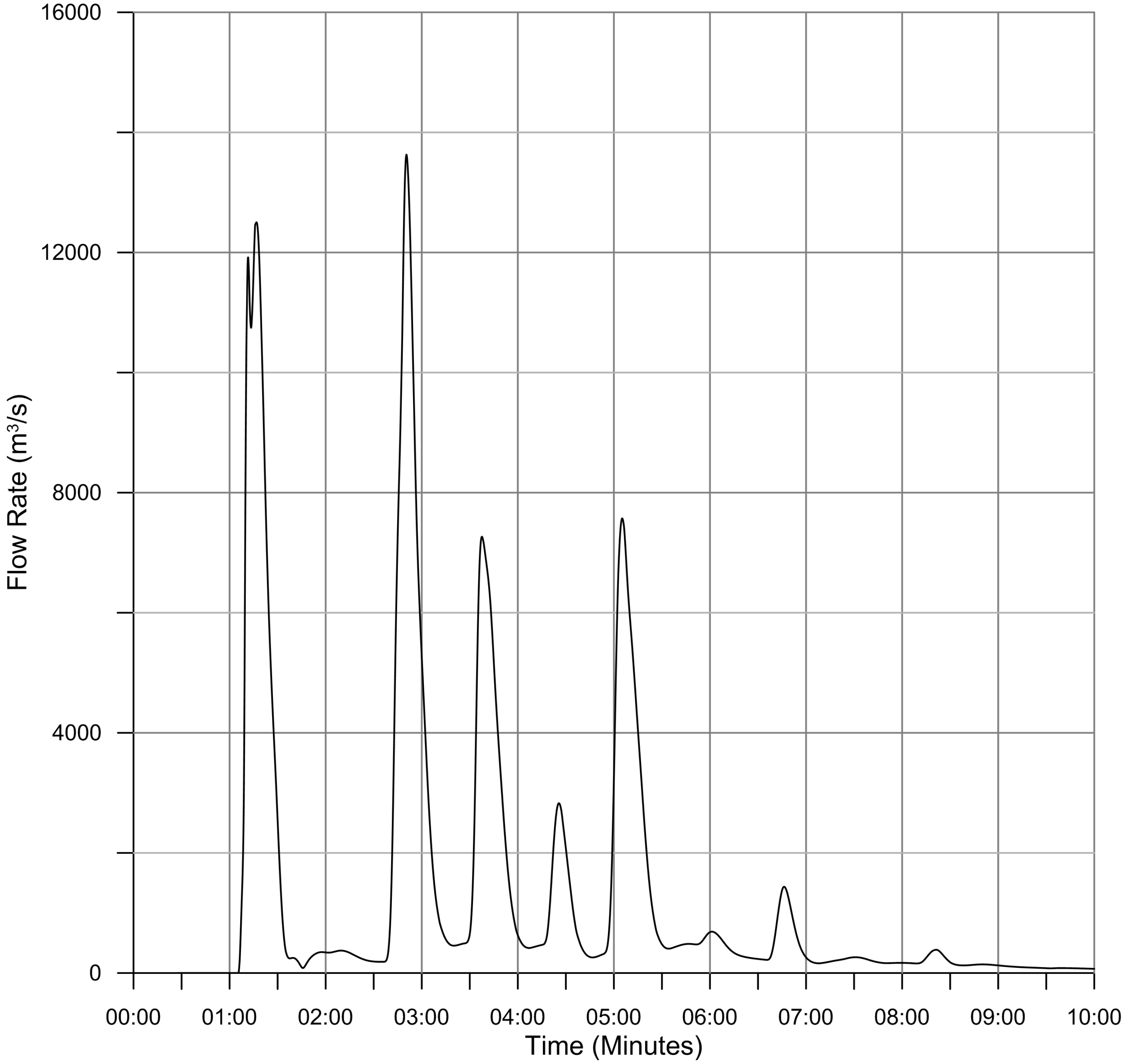
REPORT TITLE:	MITCHELL PIT – LANDSLIDE GENERATED WAVE MODELING
FIGURE TITLE:	SCENARIO C FLOW RATE THROUGH THE SPILLWAY AND OVER THE DAM CREST

CLIENT:	PROJECT No.:	FIGURE No.:
SEABRIDGE GOLD INC.	0638-013-33	2

N:\BGC\PROJECTS\0638 SEABRIDGE\013 KSM PFS UPDATE AND EA SUPPORT\33. WAVE ANALYSIS\99 LETTER REPORT\FIGURES\

DECEMBER 24, 2012



NOTES:

1.

BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

REPORT TITLE:	MITCHELL PIT – LANDSLIDE GENERATED WAVE MODELING
FIGURE TITLE:	SCENARIO G FLOW RATE THROUGH THE SPILLWAY AND OVER THE DAM CREST
CLIENT:	SEABRIDGE GOLD INC.
PROJECT No.:	0638-013-33
FIGURE No.:	3

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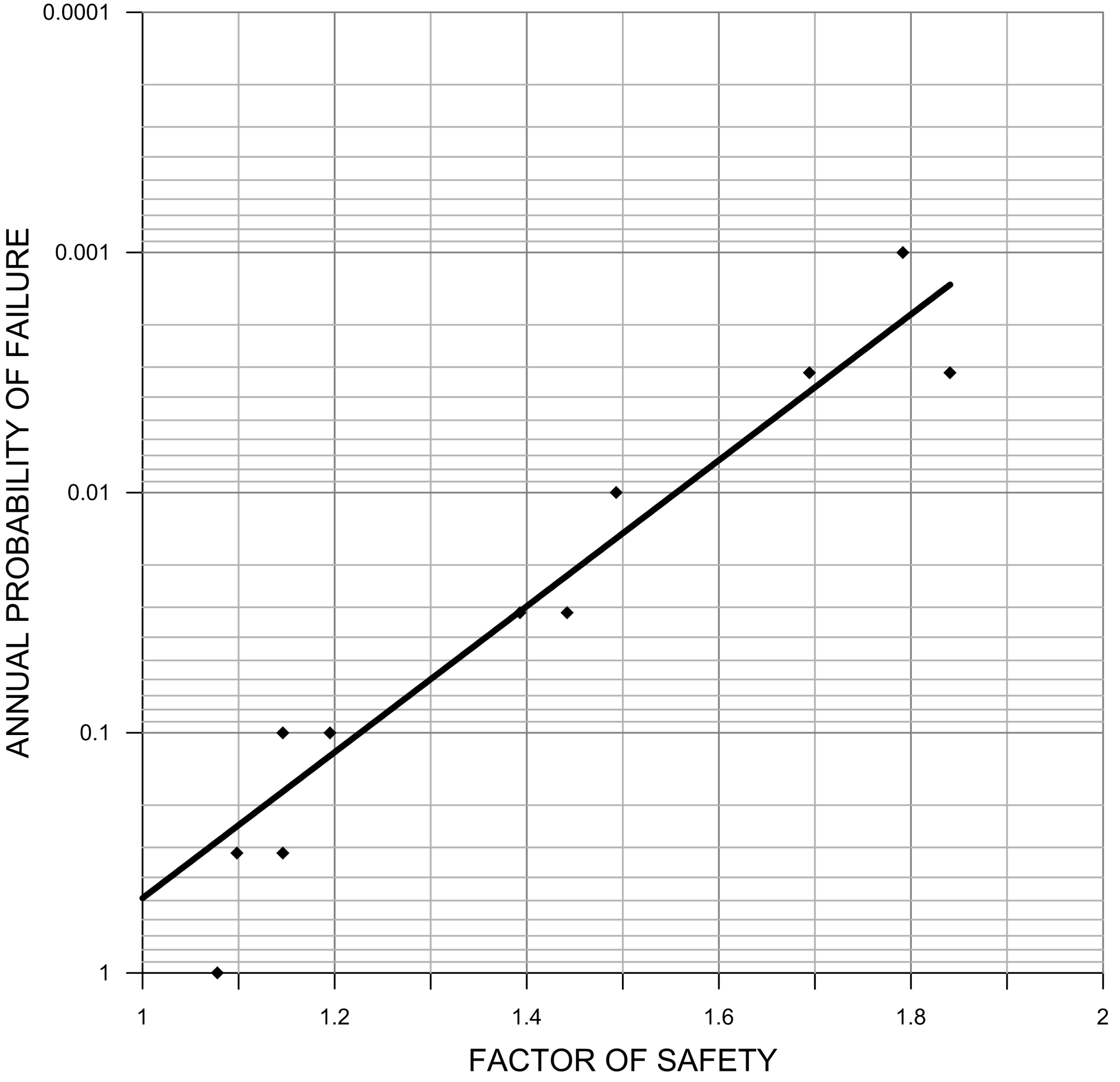

NOTES:

1. AFTER SILVA ET AL (2009).
2. DATA FOR CATEGORY III PROJECTS SHOWN.

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REPORT TITLE:
MITCHELL PIT – LANDSLIDE GENERATED WAVE MODELING

FIGURE TITLE:
ANNUAL PROBABILITY OF FAILURE VERSUS FACTOR OF SAFETY

CLIENT:
SEABRIDGE GOLD INC.

PROJECT No.:
0638-013-33

FIGURE No.:
4

N:\BGC\PROJECTS\0638 SEABRIDGE\013 KSM PFS UPDATE AND EA SUPPORT\33. WAVE ANALYSIS\99 LETTER REPORT\FIGURES\

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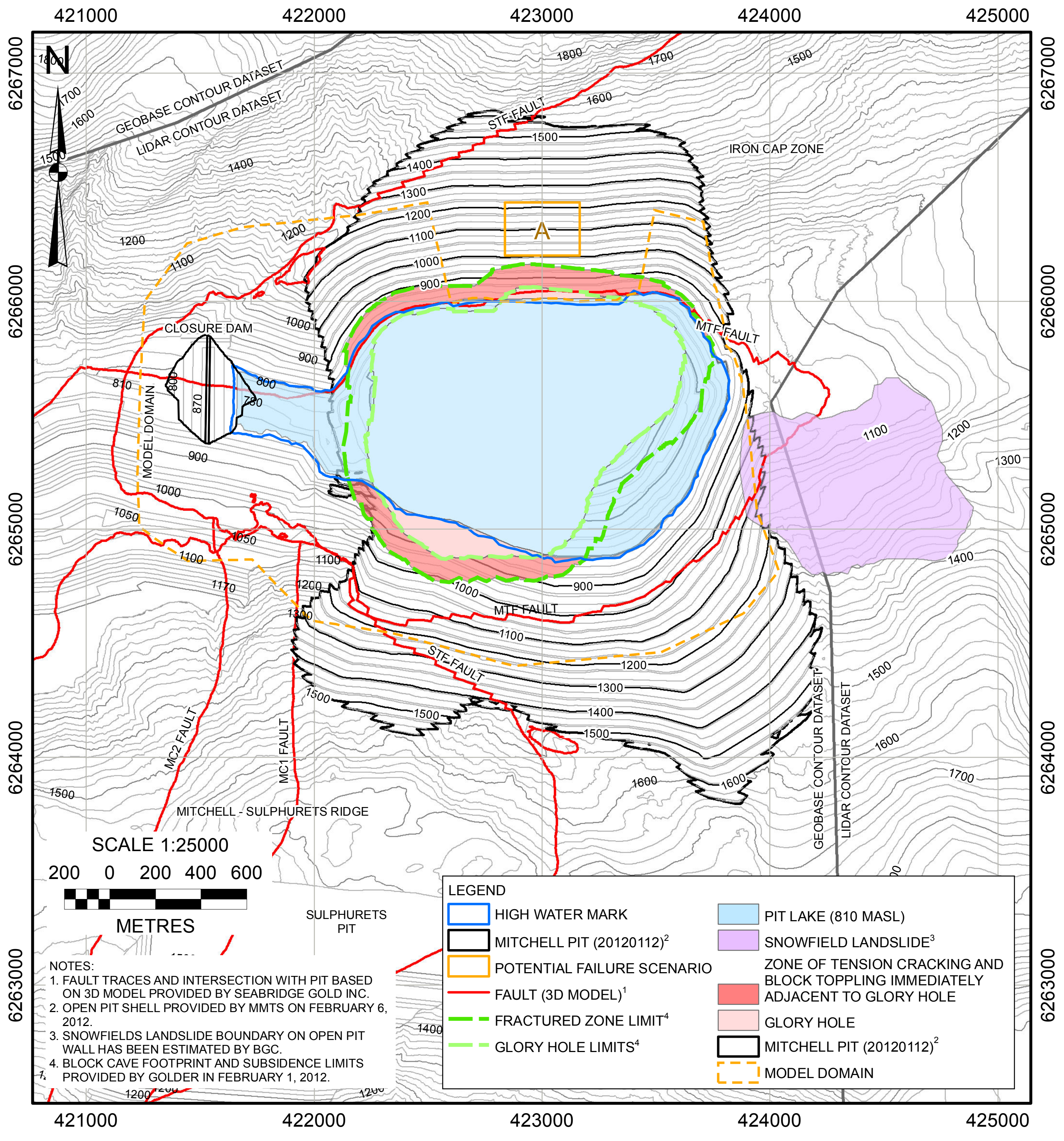
APPENDIX A



LEGEND

- 🟦 HIGH WATER MARK
- ☐ MITCHELL PIT (20120112)[2]
- 🟧 POTENTIAL FAILURE SCENARIO
- 🟥 FAULT (3D MODEL)[1]
- 🟩 FRACTURED ZONE LIMIT[4]
- 🟩 GLORY HOLE LIMITS[4]
- 🟦 PIT LAKE (810 MASL)
- 🟪 SNOWFIELD LANDSLIDE[3]
- 🟥 ZONE OF TENSION CRACKING AND BLOCK TOPPLING IMMEDIATELY ADJACENT TO GLORY HOLE
- 🟥 GLORY HOLE
- ☐ MITCHELL PIT (20120112)[2]
- 🟧 MODEL DOMAIN

NOTES:

1. FAULT TRACES AND INTERSECTION WITH PIT BASED ON 3D MODEL PROVIDED BY SEABRIDGE GOLD INC.
2. OPEN PIT SHELL PROVIDED BY MMTS ON FEBRUARY 6, 2012.
3. SNOWFIELDS LANDSLIDE BOUNDARY ON OPEN PIT WALL HAS BEEN ESTIMATED BY BGC.
4. BLOCK CAVE FOOTPRINT AND SUBSIDENCE LIMITS PROVIDED BY GOLDER IN FEBRUARY 1, 2012.

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BGC ENGINEERING INC.
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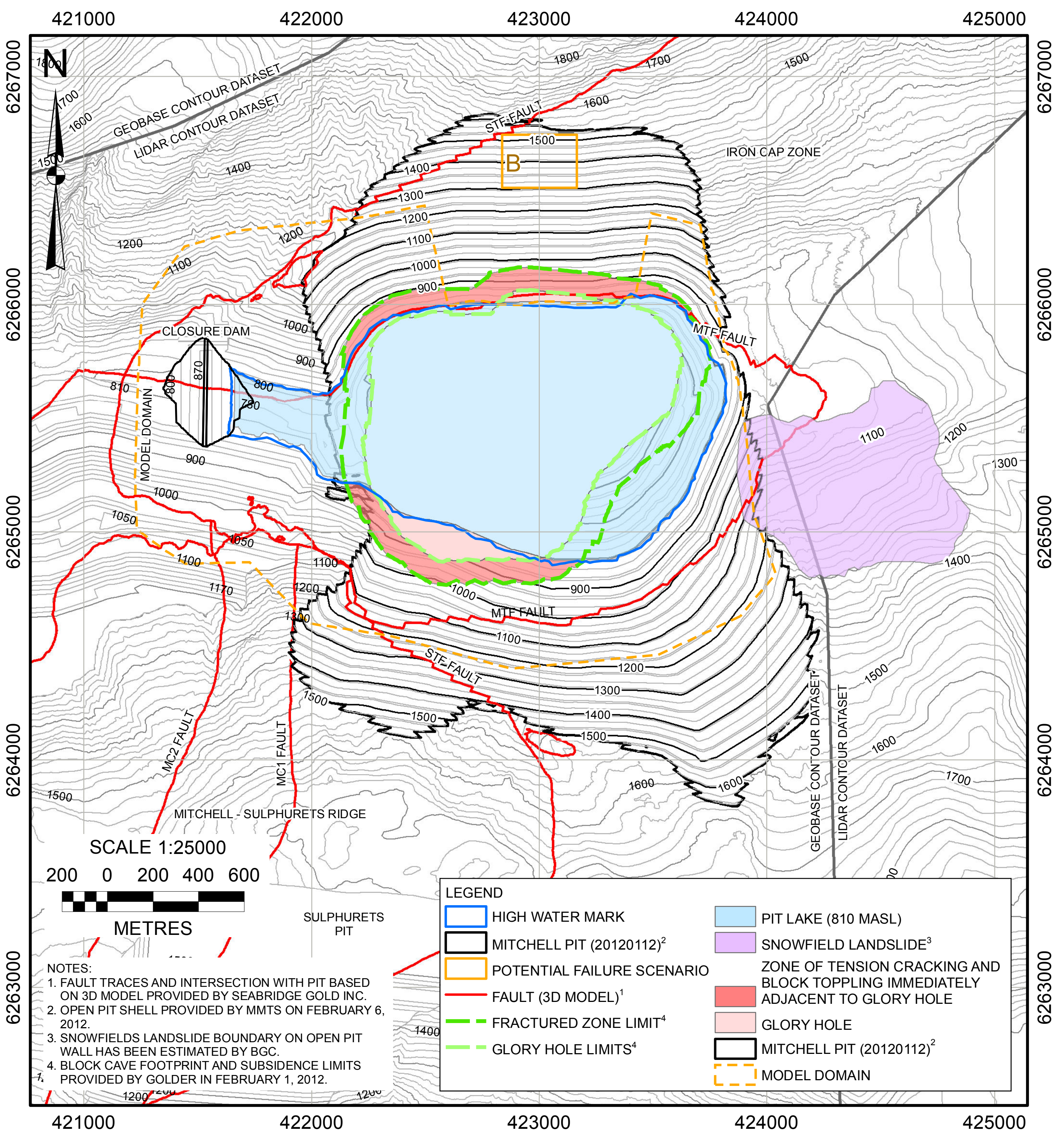
PROJECT
MITCHELL PIT - LANDSLIDE GENERATED WAVE MODELING

TITLE
POST CLOSURE SLOPE FAILURE
SCENARIO A

CLIENT
SEABRIDGE GOLD INC.

PROJECT No.	DWG No.:	REV.:
0638013-33	A-1	

DWG TO BE READ WITH BGC REPORT TITLED "MITCHELL PIT - LANDSLIDE GENERATED WAVE MODELING" DATED DECEMBER 2012



NOTES:
1. FAULT TRACES AND INTERSECTION WITH PIT BASED ON 3D MODEL PROVIDED BY SEABRIDGE GOLD INC.
2. OPEN PIT SHELL PROVIDED BY MMTS ON FEBRUARY 6, 2012.
3. SNOWFIELDS LANDSLIDE BOUNDARY ON OPEN PIT WALL HAS BEEN ESTIMATED BY BGC.
4. BLOCK CAVE FOOTPRINT AND SUBSIDENCE LIMITS PROVIDED BY GOLDER IN FEBRUARY 1, 2012.

SCALE:	1:25,000	DESIGNED:	SL
DATE:	DEC 2012	CHECKED:	JD
DRAWN:	LL	APPROVED:	DK

BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

PROJECT
MITCHELL PIT - LANDSLIDE GENERATED WAVE MODELING

TITLE
POST CLOSURE SLOPE FAILURE
SCENARIO B

CLIENT
SEABRIDGE GOLD INC.

PROJECT No.	DWG No.:	REV.:
0638013-33	A-2	

DWG TO BE READ WITH BGC REPORT TITLED "MITCHELL PIT - LANDSLIDE GENERATED WAVE MODELING" DATED DECEMBER 2012

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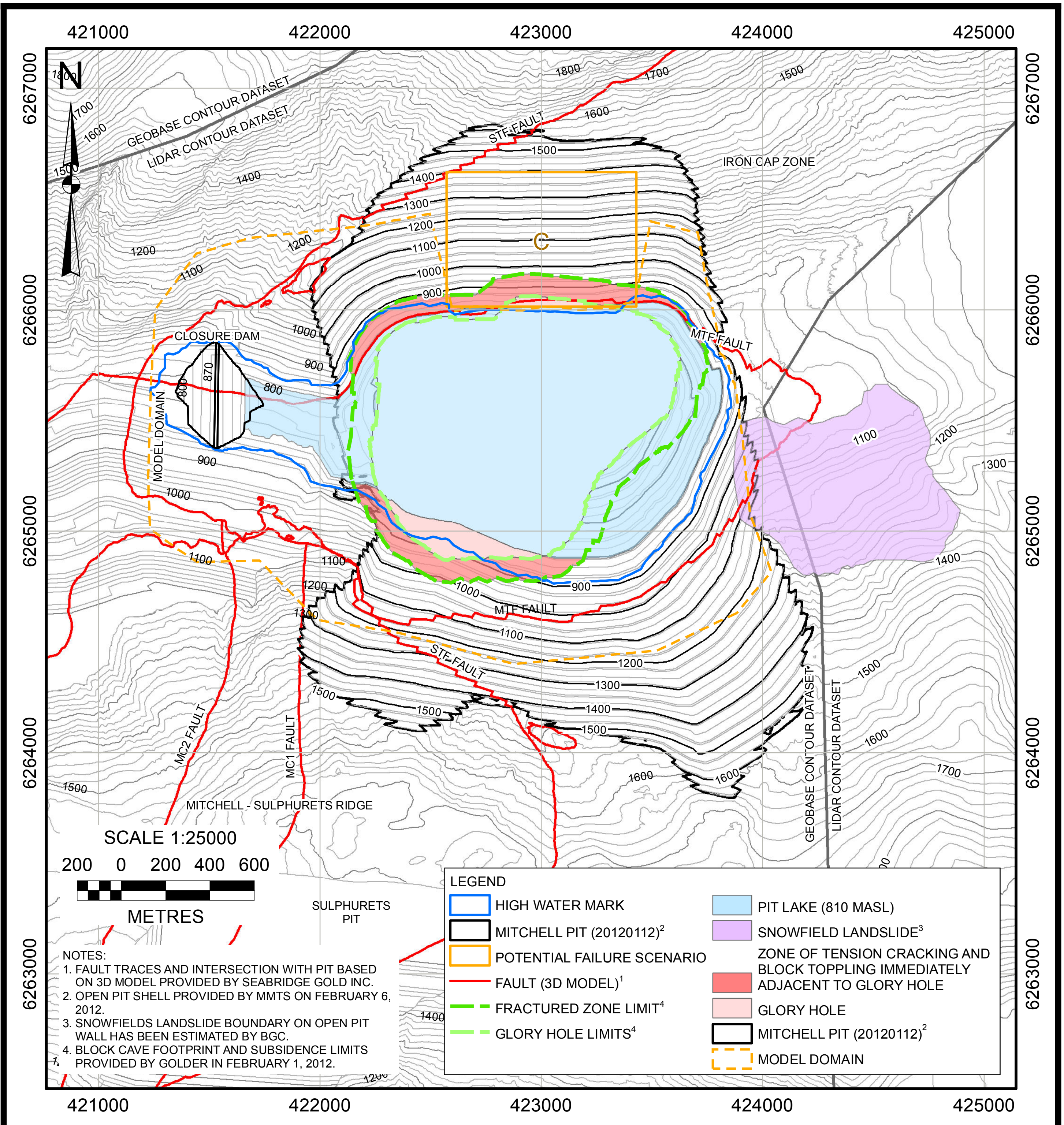

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NOTES:
1. FAULT TRACES AND INTERSECTION WITH PIT BASED ON 3D MODEL PROVIDED BY SEABRIDGE GOLD INC.
2. OPEN PIT SHELL PROVIDED BY MMTS ON FEBRUARY 6, 2012.
3. SNOWFIELDS LANDSLIDE BOUNDARY ON OPEN PIT WALL HAS BEEN ESTIMATED BY BGC.
4. BLOCK CAVE FOOTPRINT AND SUBSIDENCE LIMITS PROVIDED BY GOLDER IN FEBRUARY 1, 2012.

LEGEND

HIGH WATER MARK	PIT LAKE (810 MASL)
MITCHELL PIT (20120112)[2]	SNOWFIELD LANDSLIDE[3]
POTENTIAL FAILURE SCENARIO	ZONE OF TENSION CRACKING AND BLOCK TOPPLING IMMEDIATELY ADJACENT TO GLORY HOLE
FAULT (3D MODEL)[1]	GLORY HOLE
FRACTURED ZONE LIMIT[4]	MITCHELL PIT (20120112)[2]
GLORY HOLE LIMITS[4]	MODEL DOMAIN

NAD 1983 UTM Zone 9N

SCALE:	1:25,000	DESIGNED:	SL
DATE:	DEC 2012	CHECKED:	JD
DRAWN:	LL	APPROVED:	DK

BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

PROJECT
MITCHELL PIT - LANDSLIDE GENERATED WAVE MODELING

TITLE
POST CLOSURE SLOPE FAILURE
SCENARIO C

CLIENT
SEABRIDGE GOLD INC.

PROJECT No.	DWG No.:	REV.:
0638013-33	A-3	

DWG TO BE READ WITH BGC REPORT TITLED "MITCHELL PIT - LANDSLIDE GENERATED WAVE MODELING" DATED DECEMBER 2012

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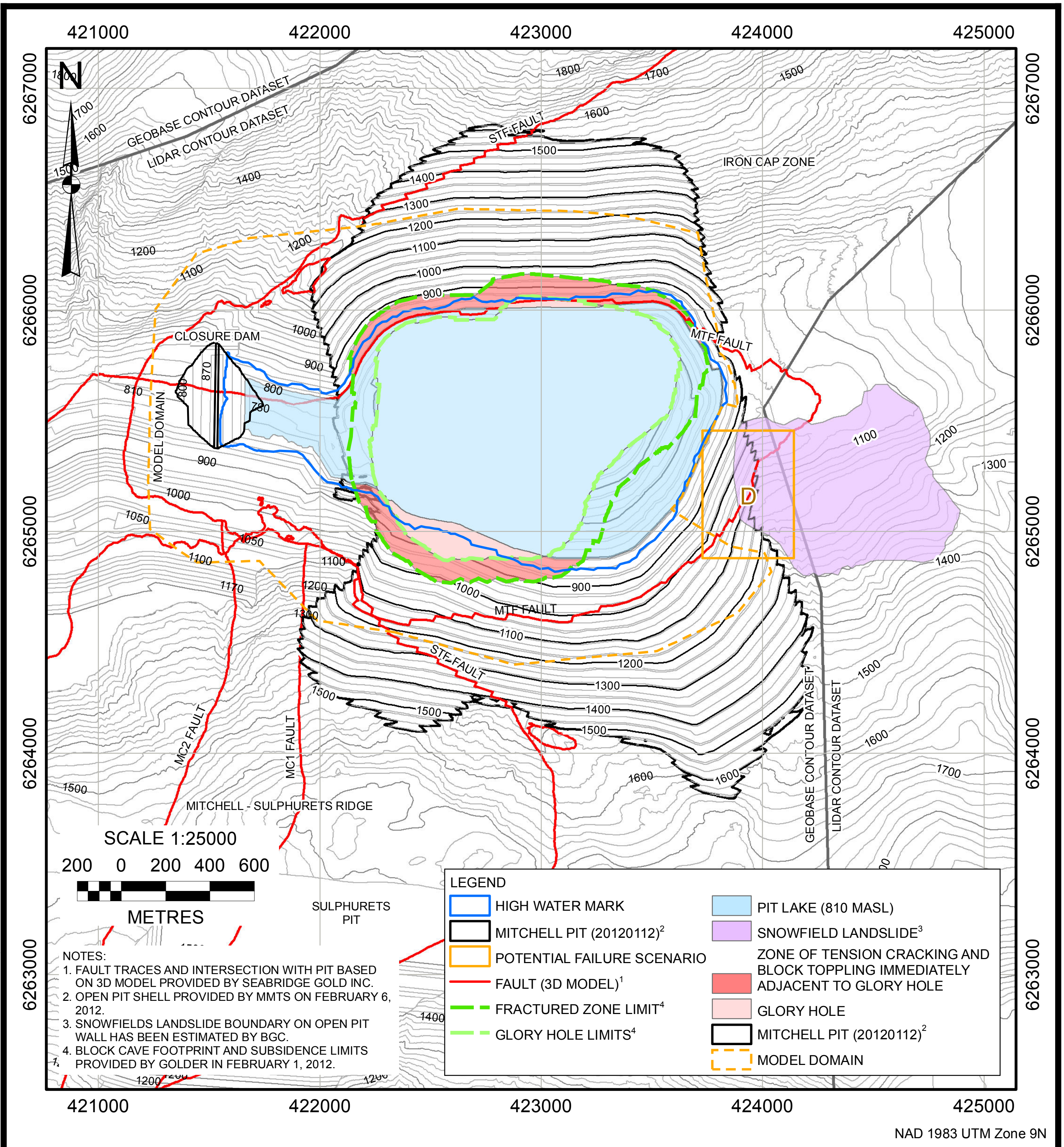

NOTES:
1. FAULT TRACES AND INTERSECTION WITH PIT BASED ON 3D MODEL PROVIDED BY SEABRIDGE GOLD INC.
2. OPEN PIT SHELL PROVIDED BY MMTS ON FEBRUARY 6, 2012.
3. SNOWFIELDS LANDSLIDE BOUNDARY ON OPEN PIT WALL HAS BEEN ESTIMATED BY BGC.
4. BLOCK CAVE FOOTPRINT AND SUBSIDENCE LIMITS PROVIDED BY GOLDER IN FEBRUARY 1, 2012.

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BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

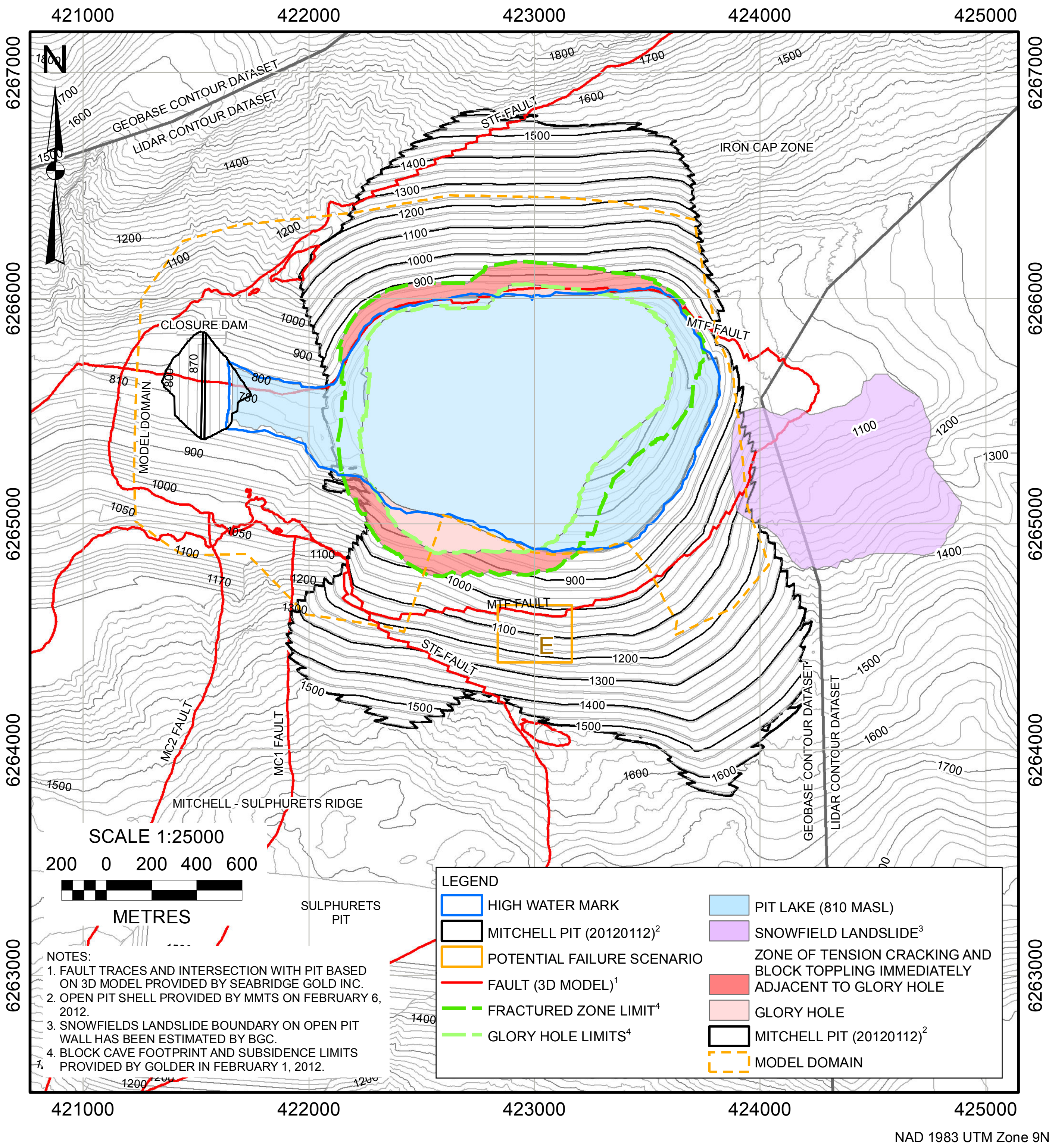
PROJECT
MITCHELL PIT - LANDSLIDE GENERATED WAVE MODELING

TITLE
POST CLOSURE SLOPE FAILURE
SCENARIO D

CLIENT
SEABRIDGE GOLD INC.

PROJECT No.	DWG No.:	REV.:
0638013-33	A-4	

DWG TO BE READ WITH BGC REPORT TITLED "MITCHELL PIT - LANDSLIDE GENERATED WAVE MODELING" DATED DECEMBER 2012



NOTES:
1. FAULT TRACES AND INTERSECTION WITH PIT BASED ON 3D MODEL PROVIDED BY SEABRIDGE GOLD INC.
2. OPEN PIT SHELL PROVIDED BY MMTS ON FEBRUARY 6, 2012.
3. SNOWFIELDS LANDSLIDE BOUNDARY ON OPEN PIT WALL HAS BEEN ESTIMATED BY BGC.
4. BLOCK CAVE FOOTPRINT AND SUBSIDENCE LIMITS PROVIDED BY GOLDER IN FEBRUARY 1, 2012.

LEGEND

▭	HIGH WATER MARK	▭	PIT LAKE (810 MASL)
▭	MITCHELL PIT (20120112)[2]	▭	SNOWFIELD LANDSLIDE[3]
▭	POTENTIAL FAILURE SCENARIO	🟥	ZONE OF TENSION CRACKING AND BLOCK TOPPLING IMMEDIATELY ADJACENT TO GLORY HOLE
—	FAULT (3D MODEL)[1]	▭	GLORY HOLE
- -	FRACTURED ZONE LIMIT[4]	▭	MITCHELL PIT (20120112)[2]
- -	GLORY HOLE LIMITS[4]	▭	MODEL DOMAIN

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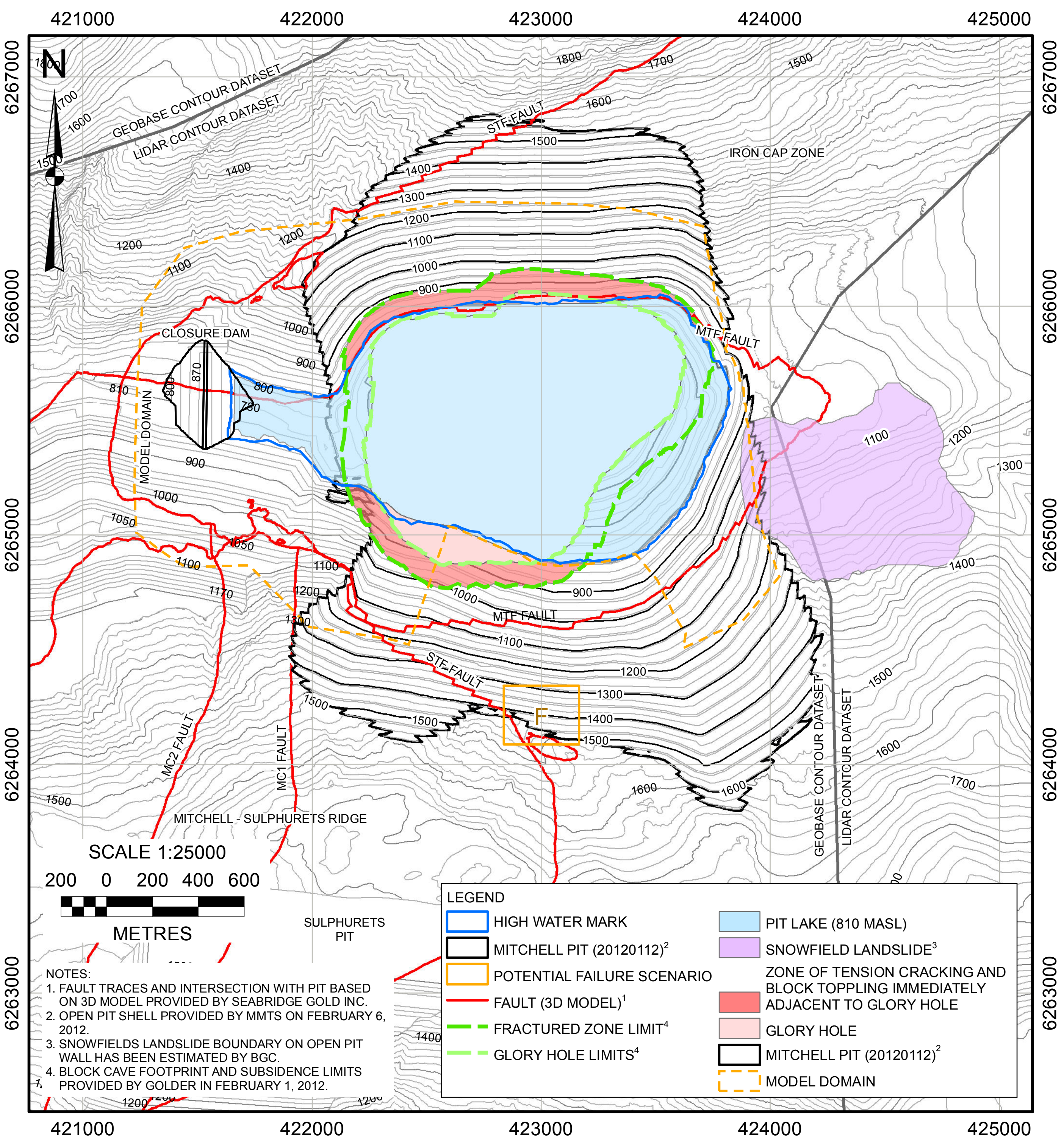
PROJECT
MITCHELL PIT - LANDSLIDE GENERATED WAVE MODELING

TITLE
POST CLOSURE SLOPE FAILURE
SCENARIO E

CLIENT
SEABRIDGE GOLD INC.

PROJECT No.	DWG No.:	REV.:
0638013-33	A-5	

DWG TO BE READ WITH BGC REPORT TITLED "MITCHELL PIT - LANDSLIDE GENERATED WAVE MODELING" DATED DECEMBER 2012



NOTES:
1. FAULT TRACES AND INTERSECTION WITH PIT BASED ON 3D MODEL PROVIDED BY SEABRIDGE GOLD INC.
2. OPEN PIT SHELL PROVIDED BY MMTS ON FEBRUARY 6, 2012.
3. SNOWFIELDS LANDSLIDE BOUNDARY ON OPEN PIT WALL HAS BEEN ESTIMATED BY BGC.
4. BLOCK CAVE FOOTPRINT AND SUBSIDENCE LIMITS PROVIDED BY GOLDER IN FEBRUARY 1, 2012.

LEGEND

▭	HIGH WATER MARK	🟦	PIT LAKE (810 MASL)
▭	MITCHELL PIT (20120112)[2]	🟪	SNOWFIELD LANDSLIDE[3]
▭	POTENTIAL FAILURE SCENARIO	🟥	ZONE OF TENSION CRACKING AND BLOCK TOPPLING IMMEDIATELY ADJACENT TO GLORY HOLE
—	FAULT (3D MODEL)[1]	▨	GLORY HOLE
- -	FRACTURED ZONE LIMIT[4]	▭	MITCHELL PIT (20120112)[2]
- -	GLORY HOLE LIMITS[4]	⬚	MODEL DOMAIN

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SCALE:	1:25,000	DESIGNED:	SL
DATE:	DEC 2012	CHECKED:	JD
DRAWN:	LL	APPROVED:	DK

BGC ENGINEERING INC.
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PROJECT
MITCHELL PIT - LANDSLIDE GENERATED WAVE MODELING

TITLE
POST CLOSURE SLOPE FAILURE
SCENARIO F

CLIENT
SEABRIDGE GOLD INC.

PROJECT No.	DWG No.:	REV.:
0638013-33	A-6	

DWG TO BE READ WITH BGC REPORT TITLED "MITCHELL PIT - LANDSLIDE GENERATED WAVE MODELING" DATED DECEMBER 2012

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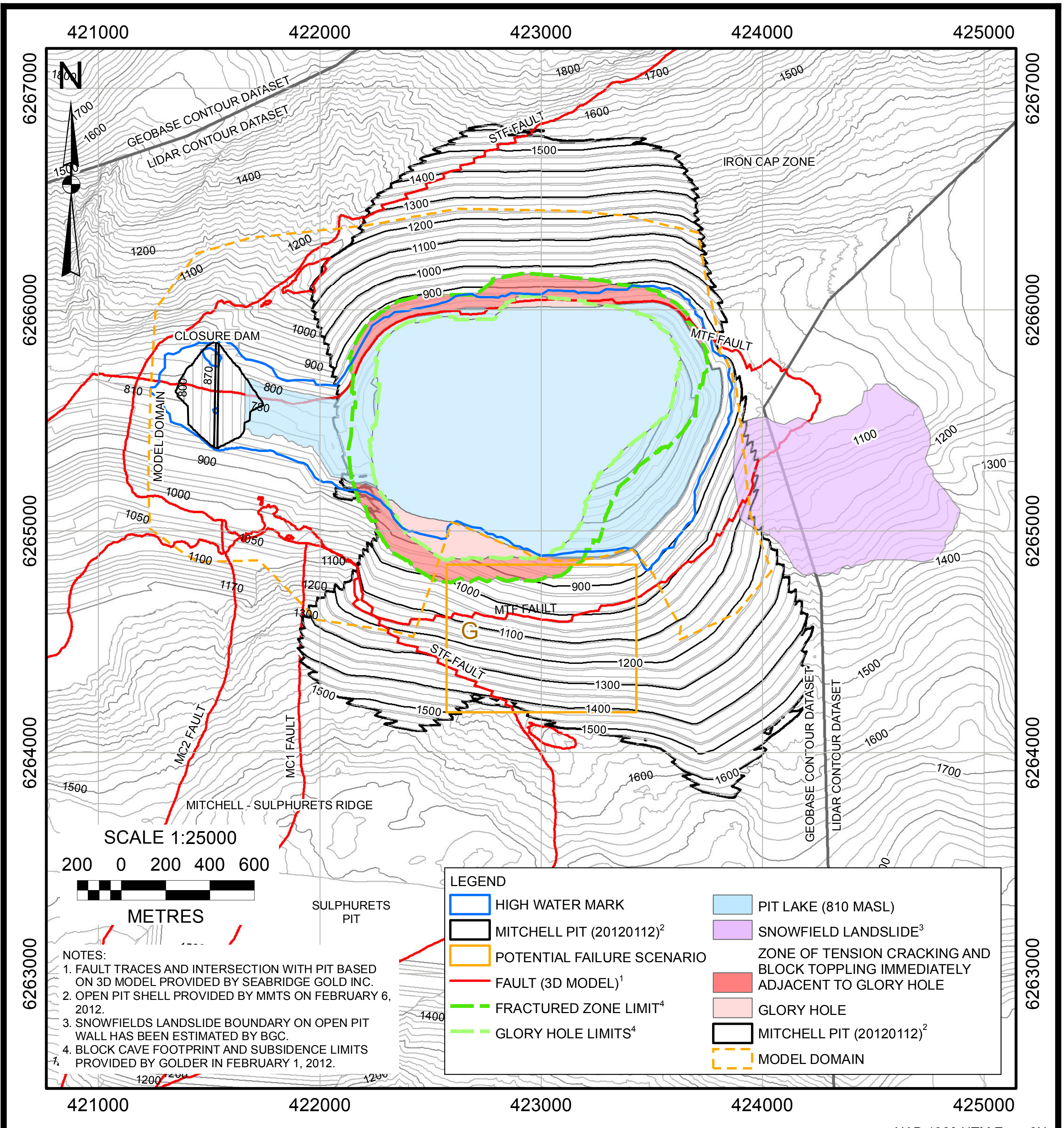

LEGEND

- 🟦 HIGH WATER MARK
- ▭ MITCHELL PIT (20120112)[2]
- 🟧 POTENTIAL FAILURE SCENARIO
- — FAULT (3D MODEL)[1]
- - - FRACTURED ZONE LIMIT[4]
- - - GLORY HOLE LIMITS[4]
- 🟦 PIT LAKE (810 MASL)
- 🟪 SNOWFIELD LANDSLIDE[3]
- 🟥 ZONE OF TENSION CRACKING AND BLOCK TOPPLING IMMEDIATELY ADJACENT TO GLORY HOLE
- ▭ GLORY HOLE
- ▭ MITCHELL PIT (20120112)[2]
- ⬚ MODEL DOMAIN

NOTES:

1. FAULT TRACES AND INTERSECTION WITH PIT BASED ON 3D MODEL PROVIDED BY SEABRIDGE GOLD INC.
2. OPEN PIT SHELL PROVIDED BY MMTS ON FEBRUARY 6, 2012.
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4. BLOCK CAVE FOOTPRINT AND SUBSIDENCE LIMITS PROVIDED BY GOLDER IN FEBRUARY 1, 2012.

SCALE:	1:25,000	DESIGNED:	SL
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BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

PROJECT
MITCHELL PIT - LANDSLIDE GENERATED WAVE MODELING

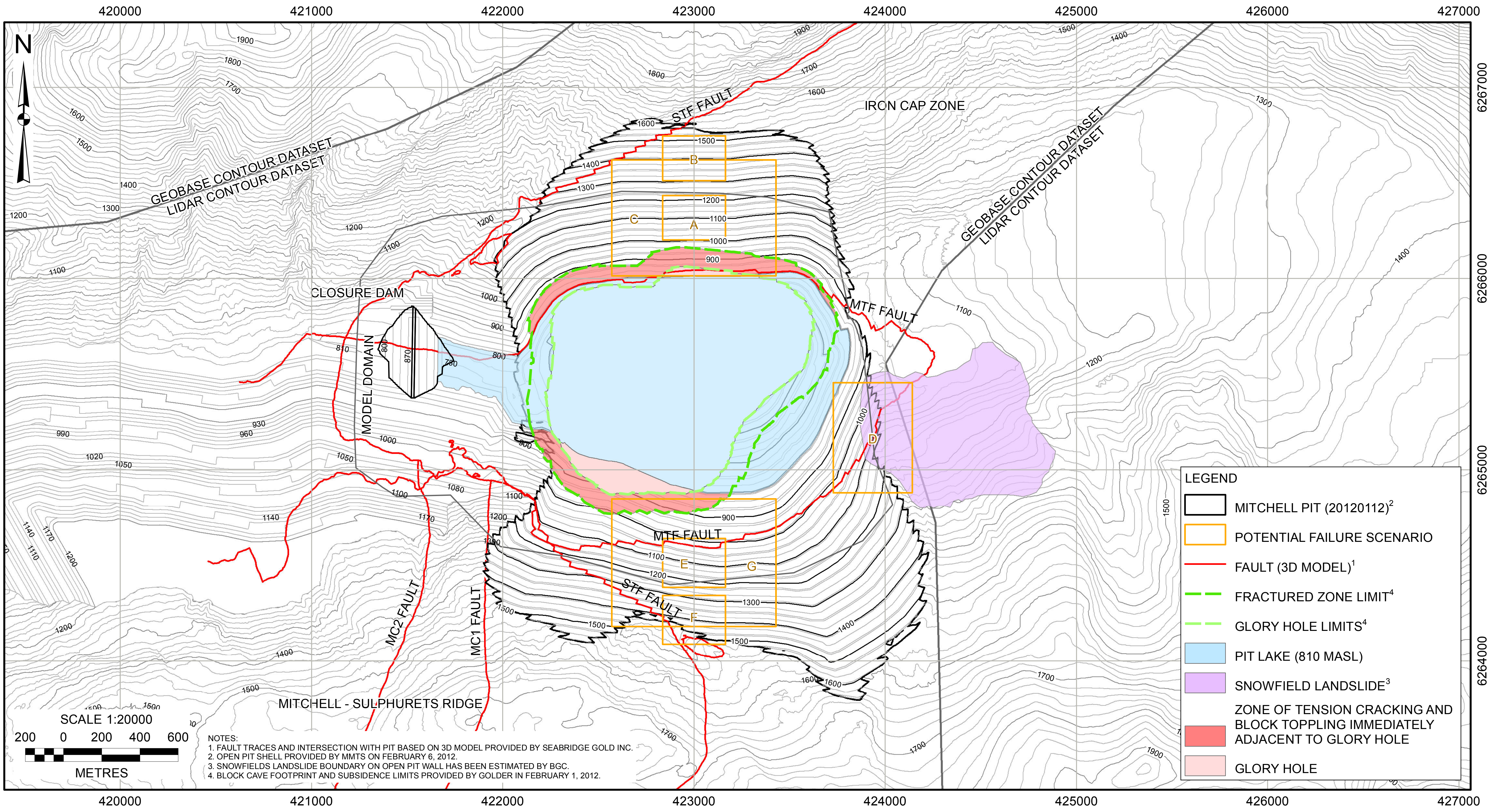
TITLE
POST CLOSURE SLOPE FAILURE
SCENARIO G

CLIENT
SEABRIDGE GOLD INC.

PROJECT No.	DWG No.:	REV.:
0638013-33	A-7	

DWG TO BE READ WITH BGC REPORT TITLED "MITCHELL PIT - LANDSLIDE GENERATED WAVE MODELING" DATED DECEMBER 2012

DRAWINGS



LEGEND

- MITCHELL PIT (20120112)[2]
- POTENTIAL FAILURE SCENARIO
- FAULT (3D MODEL)[1]
- FRACTURED ZONE LIMIT[4]
- GLORY HOLE LIMITS[4]
- PIT LAKE (810 MASL)
- SNOWFIELD LANDSLIDE[3]
- ZONE OF TENSION CRACKING AND BLOCK TOPPLING IMMEDIATELY ADJACENT TO GLORY HOLE
- GLORY HOLE

NOTES:
1. FAULT TRACES AND INTERSECTION WITH PIT BASED ON 3D MODEL PROVIDED BY SEABRIDGE GOLD INC.
2. OPEN PIT SHELL PROVIDED BY MMTS ON FEBRUARY 6, 2012.
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4. BLOCK CAVE FOOTPRINT AND SUBSIDENCE LIMITS PROVIDED BY GOLDER IN FEBRUARY 1, 2012.

NAD 1983 UTM Zone 9N

REV.	DATE	REVISION NOTES	DRAWN	CHECK	APPR.

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DATE: DEC 2012
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DESIGNED: SL
CHECKED: JD
APPROVED: DK

PROFESSIONAL SEAL:

BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

CLIENT: SEABRIDGE GOLD INC.

PROJECT: MITCHELL PIT - LANDSLIDE GENERATED WAVE MODELING

TITLE: POST CLOSURE SLOPE FAILURE SCENARIOS

PROJECT No.: 0638013-33
DWG No.: 01
REV.:

DWG TO BE READ WITH BGC REPORT TITLED "MITCHELL PIT - LANDSLIDE GENERATED WAVE MODELING" DATED DECEMBER 2012

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