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Detailed Engineering of the East Diversion Channel

Design Report of East Diversion Channel

Agnico Eagle Mines Limited

Mining & Metallurgy

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1.0 INTRODUCTION

1.1 Context

Agnico Eagle Mines Limited, Meadowbank Division ("Agnico Eagle") is developing the Whale Tail Pit, a satellite gold deposit on the Whale Tail property, as a continuation of current mine operations and milling at the Meadowbank Mine. The Amaruq property is a 408 km² site located on Inuit Owned Land, approximately 150 km north of the Hamlet of Baker Lake and approximately 50 km northwest of the Meadowbank Mine in the Kivalliq region of Nunavut. The property, whose location is shown on Figure 1-1 was acquired by Agnico Eagle in April 2013.

Figure 1-1: Meadowbank and Whale Tail site locations

The Meadowbank Mine is an approved mining operation and Agnico Eagle will extend the life of the mine by constructing and operating the Whale Tail Pit. The location of the East Diversion Channel discussed in the sections to follow is shown on Figure 1-2. Currently, water flows naturally from the Lake A53 to the Whale Tail Lake. As part of the Amaruq project, a Whale Tail Dike will be built in Whale Tail Lake, separating the lake into the north and south lake. The North Whale Tail Lake will be dewatered to allow for the construction of the open pit and the future Whale Tail Attenuation Pond. The discharge from Lake A53 will be diverted to the South Whale Tail Lake via a new diversion channel called the East Diversion Channel.

The channel is designed to divert non-contact water from Lake A53 to the South Whale Tail Lake, thus minimizing contact water reporting to the Whale Tail Attenuation Pond and allowing clean water to flow to the neighboring water bodies.

The East Channel will be built in 2019. Therefore, during the 2019 freshet, diversion of the non-contact water will be done by pumping, as presented in Appendix B.

The objective of this report is to present the detailed design of the East Diversion Channel.

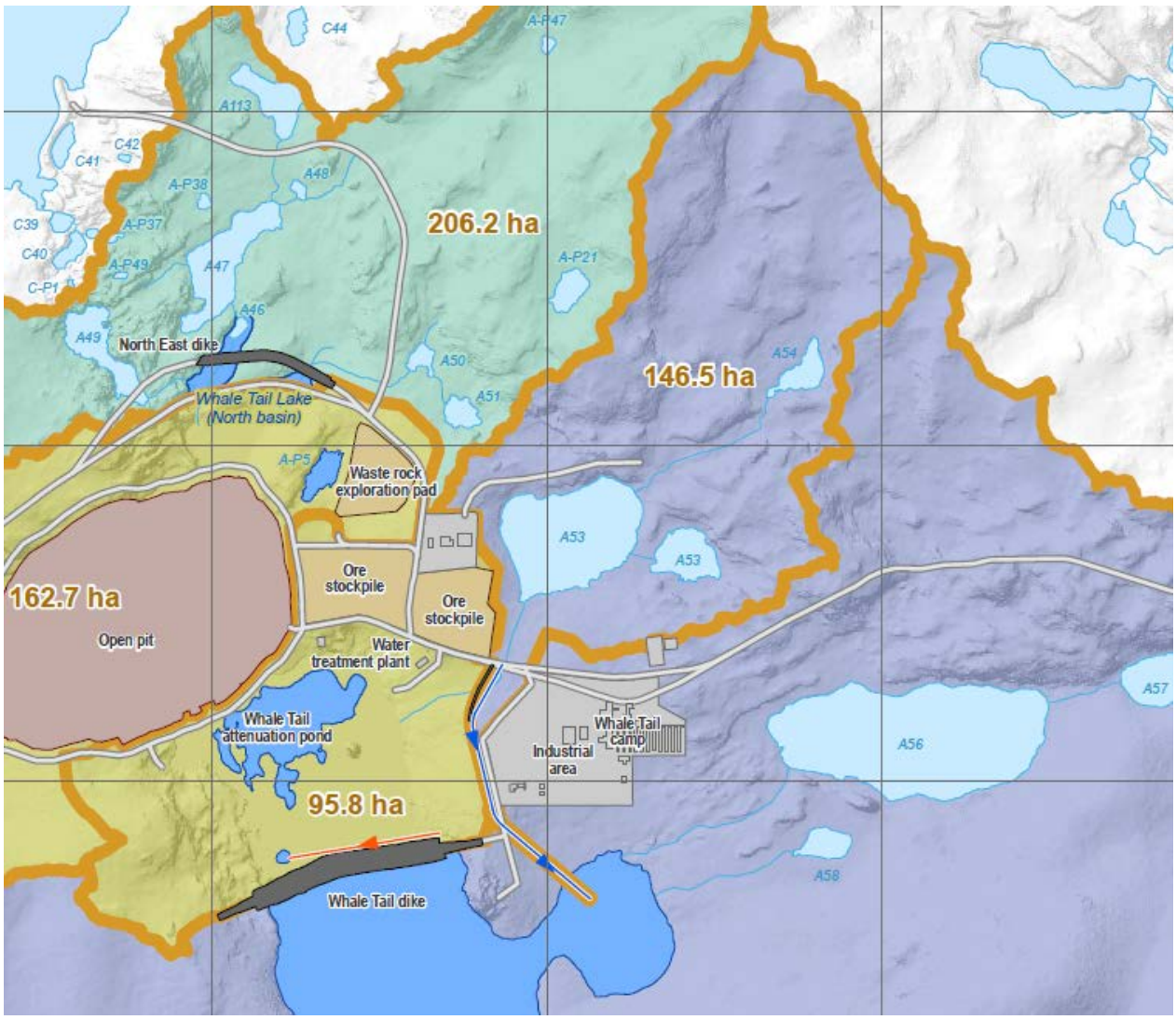

Figure 1-2: East Diversion Channel Location

1.2 Organization of the Report

This report presents the available geotechnical information, the design criteria, the hydrological and geotechnical design related to the East Diversion Channel.

2.0 Guidelines and standards

The discharge criterion of the channel was estimated using the rationale method as recommended by the Ministry of Transportation of Quebec (MTQ, 2014) for watersheds of 25 km^2 or less.

3.0 Available Geotechnical Information

Drawing no. 651298-9000-4GDD-0001 shows the locations of investigation boreholes carried out in the vicinity of East Diversion Channel. The majority of boreholes are destructive boreholes with Tamrock drill rig (Series L and WTA) allowing an estimation of bedrock elevation. The nearest geotechnical boreholes were done for the purpose of the Whale Tail dike design (Serie AMQ18).

The overburden consists of glacial till composed of mostly gravel, sand and some silt. The presence of cobbles was also noted.

The embankment of pad “Q” is in place on top of the overburden on about 400 m of the channel’s alignment. The embankment is constituted of rockfill material of various thicknesses between 500 and 1500 mm.

The depth of the bedrock varies between 3.5 m and 8 m with the thickest overburden occurring towards the South Whale Tail lake. The bedrock is a greywake. The depth of the bedrock towards the A55 Lake is unknown.

4.0 Design Basis and Criteria

4.1 Design Basis

The following elements were considered during the design of the Diversion Channel:

- The upper part of the channel will be formed partially by a combination of cut and embankments, which will also act as cofferdams to prevent the incoming water from Lake A53 to flow in its natural path to North Whale Tail Lake ;
- The upper part of the channel with the embankments will be lined with a bituminous geomembrane to serve as cofferdams ;
- The design flood for the channel has been selected to be a 1:100 year event so as to limit the treatment of clean water overflowing into the Whale Tail Attenuation Pond (SNC-Lavalin 2018a).
- The channel will be routed to Lake A55, a tributary of South Whale Tail Lake, in order to reduce the length of the channel, and avoid the passage of the channel via esker #7. During operation,

Lake A55 and South Whale Tail Lake will be at the same elevation. Water from South Whale Tail Lake will then be rerouted towards Mammoth Lake via the South Whale Tail Diversion channel.

5.0 Hydrology

5.1 Available Data

The baseline hydrology for the Amaruq mine site was assessed in SNC-Lavalin 2018b (Report No. 651298-2600-4HER-0001).

The following table presents the IDF[1] depths generated by Environment Canada for the Baker Lake A meteorological station, based on data measured between 1987 and 2006. These curves were used for the determination of peak flow for the design of East Diversion Channel.

Table 5-1 : Baker Lake A IDF Curves (1987-2006)

Duration	Return Period [year]						
	2 years	5 years	10 years	20 years	25 years	50 years	100 years
	Annual Rainfall Depth [mm]						
5 min	2	3	3	4	4	5	5
10 min	2	3	4	5	5	5	6
15 min	3	4	4	5	5	6	6
30 min	4	6	6	7	8	9	9
1 h	6	9	10	12	12	14	15
2 h	9	13	16	19	20	22	25
6 h	17	23	27	31	32	36	39
12 h	22	32	39	45	48	54	60
24 h	27	40	48	57	59	67	75

5.2 Hydraulic Design

Runoff from Lake A53 watershed (see Figure 1-2) are planned to be diverted into Lake A55 with a diversion ditch. This ditch will be crossing two access roads with culverts. The most upstream set of

[1] IDF = Intensity, duration and frequency

culverts was already designed and is excluded from the present analyses. Drawing 170824AMABA.dwg provided by AEM provides a survey of the existing culverts. This data was used for design. Detailed design of the culverts to provide as part of the construction of the East Channel, as long as those upstream of the East Channel, is presented in Appendix C.

5.3 Peak Discharge

Peak discharge is computed using the rational method, as recommended in MTQ (2014) for watersheds of 25 km^2 or less. This method consists of determining the rainfall depth, for the desired return period and duration, and to transform the rainfall depth into rainfall intensity. The duration must be equal to the time of concentration for the watershed upstream of the ditch inlet. The peak discharge is then computed using the following formula:

$$Q = \frac{CIA}{360}$$

With:

Q: discharge [m^3/s].

C: peak discharge runoff coefficient [-].

I: average rainfall intensity based on the watershed time of concentration [mm/h]

A: watershed area [ha].

A runoff coefficient of 1.0 is adopted for return periods of 100-years and over. The time of concentration is estimated using the Bransby Williams formula.

5.4 Ditch design

The following ditch characteristics were adopted:

- A minimum freeboard of 0.3 m (good practice).
- A minimum slope of 0.3 % (constructability confirmed by Agnico Eagle).
- A trapezoidal shape with side slopes of 2H:1V (adequate for the existing ground).
- Variable bottom width (to optimize the ditch size).

The diversion ditch is designed for a 100-year return period flood (SNC-Lavalin, 2018c). The ditch dimensions were obtained from a hydraulic simulation made with the HEC-RAS model (HEC, 2018).

5.5 Results

A 100-yr flood peak discharge of 2.3 m^3/s was obtained with the rational method, considering a runoff coefficient of 1, a watershed of 146.5 ha, and the location and size of Lake A53. Two corrugated pipes,

projecting from fill, with a 1200 mm diameter were selected. Detailed design of the culverts is presented in Appendix C.

Table 5-2 presents a summary of the adopted culvert characteristics. The ditch and culverts locations are provided on Drawing 651298-9000-4GDD-0001.

Table 5-2 : Culvert Characteristics

		Upstream Culvert	Downstream Culvert
Culvert station [1]	**[m]**	521	281
Drainage area	**[ha]**	148.2	148.3
Design flood return period	**[year]**	100	100
Runoff coefficient	**[-]**	1.0	1.0
Peak discharge	**[m³/s]**	2.3	2.3
Culvert type		Corrugated	Corrugated
Culvert inlet type		Projecting from fill	Projecting from fill
Number of conduits	**[-]**	2	2
Diameter	**[mm]**	1 200	1 200

[1] Middle of culvert station is given from downstream to upstream (unlike Drawing 651298-9000-4GDD-0001 where stationing is given from upstream to downstream).

Two 1 200 mm diameter conduits were adopted instead of multiple small ones, as they do not require large local ditch widening, and larger conduits are easier to clean.

The water profile along the East Channel was computed with HEC-RAS. A minimum slope of 0.3 % was applied starting from the outlet of the existing culverts up to a point, located downstream from the new culverts, where topography allowed for a steeper slope towards Lake A55. The upstream part of the East Channel, downstream the existing culverts, is located in an existing plain (Figure 5-2). This area is relatively wide and flat, requiring a wide section of channel (20 m) with embankments. Once the East Channel reaches the left bank of that plain, a narrower channel of 1 m can be used, up to the new culvert location, where a widening to 3.6 m is required (note that the channel dimensions stated in this report are on top of the required riprap layer). Downstream the new culvert, a 1 m channel can be used as well, with a widening to 4 m at the channel inlet into Lake A55.

Figure 5-3 presents the water profile obtained with HEC-RAS, and Table 5-3 presents characteristics of the channel at key locations where a width or slope change occurs.

Table 5-3 : East Channel Key Locations Characteristics

Ditch Station[(1)] [m]	Channel Bottom [m]	Bottom Width [m]	Water Depth [m]	Bank Elevation [m]	Embankment Computed El. [m]	Available Freeboard [m]
790	160.96	20	0.80	161.99	162.06	0.30
780	160.93	20	0.83	161.51	162.06	0.30
730	160.78	1	0.90	161.40	161.98	0.30
701	160.70	1	0.91	161.27	161.91	0.30
651	160.55	1	0.96	161.43	161.81	0.30
601	160.40	1	1.04	161.73	161.74	0.29
551	160.25	1	1.14	162.00		0.61
548	160.24	1	1.15	162.00		0.61
543	160.22	3	1.18	162.00		0.60
499	160.09	3	0.91	162.00		1.00
494	160.08	1	0.88	162.00		1.04
451	159.95	1	0.91	162.00		1.14
401	159.80	1	0.96	162.01		1.25
351	159.65	1	1.03	162.01		1.33
308	159.52	1	1.12	162.01		1.37
303	159.50	3	1.15	162.01		1.36
259	159.37	3	0.57	161.16		1.22
254	159.36	1	0.49	161.16		1.31
220	158.59	1	0.40	160.02		1.03
201	158.16	1	0.49	159.16		0.51
128	156.50	1	0.52	157.53		0.51
101	155.90	1	0.62	157.18		0.66
51	155.31	1	0.65	156.32		0.36
0	155.00	4	0.71	156.00		0.29

[(1)] Ditch station is given from downstream to upstream (unlike Drawing 651298-9000-4GDD-0001 where stationing is given from upstream to downstream).

On Table 5-3, available freeboard is larger than desired minimum freeboard, from river station 308 to 220, due to topography and the adopted minimum channel slope. Flow velocity is less than 1.0 m/s in the ditch section with a 0.3 % slope (ditch station 790 m to 303 m), and a riprap caliber of 50-100 mm is recommended to avoid suspended solids. In the ditch section downstream from the new culverts, between ditch stations 101 m and 254 m, the slope is approximately 2.3 % with flow velocities up to 3.2 m/s requiring a riprap caliber of 300-400 mm. Between ditch station 101 m and Lake A55 a riprap caliber of 50-100 mm should be used.

Figure 5-1: Existing Flood Plain Upstream Planned East Channel (Picture Taken in July 2016)

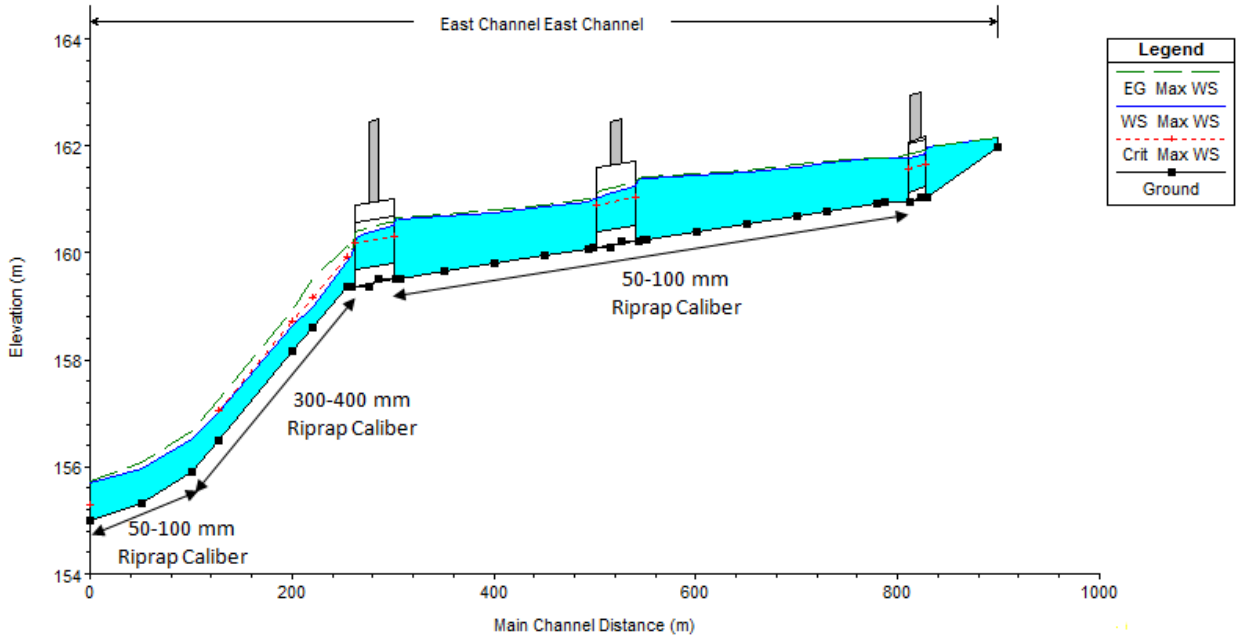

Figure 5-2: East Channel Computed Water Profile

On Figure 5-3 ditch station is given from downstream to upstream (unlike Drawing 651298-9000-4GDD-0001 where stationing is given from upstream to downstream).

6.0 Material

The East Diversion Channel will start from the culverts located under road No. 01 where it will connect with the natural stream coming from Lake A-53. At the outlet of the existing culverts, the channel will be constructed so as to fit with the existing outlet channel, which is 20 m wide, and will then taper to the 1-m design lower downstream

The first 200 m of the channel will be formed with embankments. The embankments will be lined with a bituminous geomembrane. The top of the embankment will be set at elevation 162.0 m

As mentioned in the previous section, riprap (NPAG material) will be required in the channel to avoid erosion and thus limit TSS. The riprap will consist in crushed aggregates with a diameter of 50 – 100 mm and a diameter 300 – 400 mm in the steeper slope at the end of the channel. If the clean 50 – 100 material is too difficult to produce, 0 – 200 mm could be used as riprap due to low flow velocity, but despite the low flow velocity, the presence of fine particles would raise the risk to generate suspended solid in case of flood event. If this option is retained, it is recommended to use a minimum of two (2) row of silt barrier in the channel.

This clean rockfill will not be placed directly over overburden (till). A transition layer consisting of coarse crushed aggregate will be necessary between the bottom of the excavation and the riprap protection layer to minimize the loss of fine material through the riprap. This transition layer will serve as a levelling material after the blasting, following proper protocol, of the channel. However, most of the leveling could be done using the blasted material if the work is done in summer and the material is a well graded glacial till with fines content not exceeding 5%.

The transition material is selected to be filter-compatible with the riprap and the underlying overburden assumed to be glacial till. Verification with the riprap filter sizing criterion[2] and retention criterion[3] was done considering 50 – 100 mm riprap and 300 – 400 mm riprap and overburden with average D_{85} of 50 mm and D_{15} between 0.05 and 2 mm (Based on AMQ18-1693 and AMQ18-1700 sieve analyses). This verification confirmed the selection of crushed coarse filter as transition material (same crushed coarse filter material as the one used for the construction of Whale Tail dike). The esker material cannot be used as a transition material because it is too fine compared to the riprap and retention criteria is not respected.

The transition material will also be used as a base layer for the bituminous geomembrane in the embankment section. Bituminous geomembrane can be laid on crushed material as long as it is smaller than 200 mm (GeoEdmonton 2008).

The next Figure shows the gradation of the proposed materials.

[2] Province of British Colombia, Ministry of Environment, Lands and Parks (2000), Riprap Design and Construction Guide, ISBN 0-7726-4284-4

[3] Canadian Foundation Engineering Manual, 2013 Edition

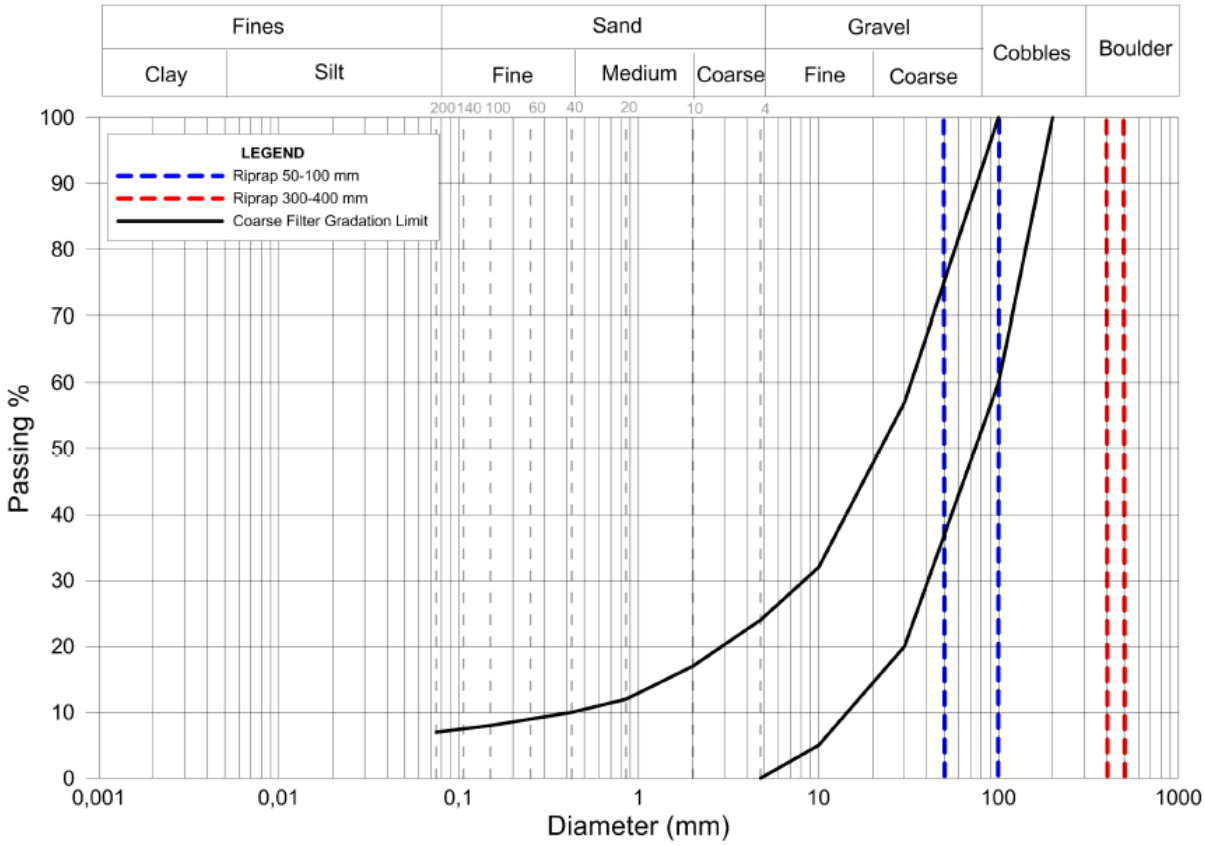

Figure 6-1 : Proposed Gradation

7.0 Construction

7.1 Timing

As the East Diversion Channel passes through the construction pad of the Whale Tail dike (pad Q), its construction will have to be planned after the completion of the works at the Whale Tail Dike.

The construction of the channel is planned after the freshet period of 2019, in September, as required by the water balance. Construction is expected to last 3 months and the infrastructure would be commissioned at the next freshet period. Until the infrastructure construction is completed AEM will use an adaptive water management strategy to control water from Lake A53 watershed. The objectives of this adaptive strategy are:

- Prevent fish migration from Lake A53 toward Whale Tail North Basin during the dewatering operations;
- Maintain a dry East Channel construction area.

The adaptive water management strategy is presented in Appendix B.

7.2 Field Information

Borehole information shows that the bedrock could be encountered during excavation between 0+400 and 0+500 m.

8.0 Quantities

The quantities of materials required for the construction of the East Diversion Channel are presented in the next table. These quantities are extracted from the 3D model developed as part of the design.

A contingency of 20% on fill and excavation materials except coarse filter and 40% on BGM, provided by Agnico Eagle was added to the calculated quantities to cover for loss of materials, repairs, overlaps for the bituminous geomembrane, bentonite loss due to wind, fill cross-contamination, etc. A contingency of 40% was added on coarse filter has this material will also be used as levelling material following blasting and excavation of the channel.

Table 8-1: Quantity Estimation for the Construction of East Diversion Channel

Item	Unit	Estimated Quantity	Contingency	Quantity Including Contingency
Excavation - blasting	m^3	13 000	20%	15 600
Coarse filter (material No. 2)	m^3	3300	40%	4 620
Rockfill (material No. 3)	m^3	620	20%	780
Rip Rap 50 – 100 mm (material No. 4A)	m^3	2300	20%	2760
Rip Rap 300 – 400 mm (material No. 4B)	m^3	1000	20%	1200
Bituminous geomembrane	m^2	2450	40%	3430

9.0 Closure

At the end of Whale Tail Pit project, all channel and ditches will be backfilled so as to promote natural drainage. The restoration will be done in compliance with the closure plan.

10.0 Conclusion

The East Diversion Channel will be used to divert non-contact water from A-53 Lake to lake A55 and South Whale Tail Lake. The upper part of the channel will be sealed in order to block natural drainage going to North Whale Tail Lake. The channel will have a 1 meter width on most of its length and will be protected with riprap.

11.0 Personnel

This report has been prepared by Marie-Hélène Paquette except for Chapter 5 which was prepared by Patrick Scholz. The report was revised by Yohan Jalbert.

We trust that this report is to your satisfaction. Should you have any question, please do not hesitate on contacting us.

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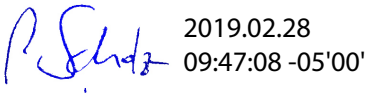

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12.0 References

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Appendix A

Drawing

Appendix B

Technical note: Interim Water Management of Lake A53 – Pumping Option

Appendix C

Design Report for Culverts (Roads #1 & 13)

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