Stormwater Management and Drainage System Design

August 22, 2011	A	Internal Review	R. Zhou			
DATE	REV.	STATUS	PREPARED BY	CHECKED BY	APPROVED BY	APPROVED BY
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Table of Contents

Appendix

1. Introduction

The Mary River Project is a proposed iron ore mine and associated facilities located in northern Baffin Island, in the Qikiqtani Region of Nunavut. The Project involves the construction, operation, closure, and reclamation of a 18 million tonne-per-annum open pit mine that will operate for 21 years. The high-grade iron ore to be mined is suitable for international shipment after only crushing and screening with no chemical processing facilities. A railway system will transport an additional 18 Mt/a of ore from the mine area to an all-season deep-water port and ship loading facility at Steensby Port where to ore will be loaded into ore carriers for overseas shipment through Foxe Basin.

The Project consists of the construction, operation, closure, and reclamation of an open pit mine and associated infrastructures for extraction, transportation and shipment of iron ore from two newly constructed ports at Milne inlet and Steensby inlet. After crushing and screening, iron ore will be transported from the Mine Site to the Ports for shipment.

The development requires to manage stormwater runoff and flow by a well designed stormwater management system to reduce impacts of the development on the environment.

This design memo describes the stormwater water management and drainage system for the Mine Site, the Milne Port and the Steensby inlet.

2. Design Criteria and General Design Considerations

2.1 Objectives

The objectives of the design for the stormwater management and drainage are to provide: i) a safe and efficient stormwater drainage scheme that will minimize disruptions to the mine and operations (including construction) during wet weather periods, while minimizing the potential for negative impacts to the environment in the event of an uncontrolled release of stormwater runoff, and ii) intercept and divert clean stormwater from undisturbed areas, iii) provide peak flow reduction to mitigate the flooding problem of the downstream areas.

2.2 Design Criteria

2.2.1 Surface Drainage

The general criteria for the stormwater management system is described below. Where applicable the criteria described correspond to that described in the Civil Design Criteria.

- All interior site grading and roads will be designed to provide continuous overland flow without erosion to a drainage ditch system.
- Provision must be made to ensure that there is a safe flow path for events up to the one in 10-year event, such that the runoff will not flood key mining areas, cause significant erosion, pick up excessive contaminants or cause other significant problems.

2.2.2 *External Surface Drainage*

Additional criteria for drainage of the external area are as follows:

- Run-off from undisturbed areas surrounding the mine site should be collected in clean-water perimeter ditches and diverted around and / or through the site perimeter.
- To the extent possible, these perimeter ditches will be designed to discharge at locations that best retain the characteristics of the existing (i.e., pre-development) natural drainage patterns.
- Clean water diversion ditches shall be designed to convey the 100-year flood event.

2.2.3 *Stormwater and Sediment Ponds*

Stormwater management ponds are designed to:

- Safely pass the Inflow design flood meeting CDA dam safety guidelines
- Reduce flooding in the downstream area
- Remove sediment concentration to meet the 15 mg/L discharge standard
- Stable under the design earthquake conditions
- Stable under worst load conditions as required by the CDA dam safety guidelines

2.3 Dam Safety Assessment

The stormwater and sediment management ponds need embankment structure to create the required storages. These embankment structures meet the definition of dams (2 meter of height and retains more than 30,000 m^3 of water) and hence must follow the dam safety guidelines of Canada Dam Association (2007). A dam classification is needed to determine many of the design parameters (such as the inflow design flood (IDF), and the design earthquake (DE)). The detailed dam safety assessment will be discussed in Appendix A.

3. Stormwater / Sediment Management and Drainage Systems

3.1 Mine Site

The general layout of the mine site development is presented in drawing H337696-4210-10-014-0001. The mine site stormwater management system includes dirty flow collecting ditches, clean water diversion ditches, stormwater / sediment ponds. There are two main areas where stormwater management systems are required. One area is the treatment of stormwater and sediments surrounding the waste rock stockpile north of the main pit. The following sections discuss the two area's specific features.

3.1.1 Waste Dump Stockpile Area

Figure 3-1 shows the ditches and stormwater ponds for the treatment of the storm water runoff from the waste dump stockpile area. From Figure 3-1, the waste dump stockpile is surrounded by runoff collecting ditches. The ditches have four segments:

- Segment one (Northeast portion) collects runoff from the waste dump stockpile and carries flow in east then south direction down to Stormwater Pond no. 2.
- Segment two (Southeast portion) receives runoff from the waste dump stockpile and flows mainly in east direction and discharges into Pond no. 2.
- Segment three (Northwest portion) collects stormwater and discharges in west then south direction and releases the water into Pond no. 1.
- Segment four (South West portion) collects flows from the waste dump area and flows mainly in west direction and then discharges flow into Pond no. 1.
- Between Pond no. 1 and the waste dump stockpile area, there is a large area where no development is planned and there will be no disturbance to the runoff generated from the area. The water is therefore clean. The flow from this area will, however, flow down in the south direction and will be discharged into Pond no. 1. This will lead to unnecessary treatment of clean water by Pond no. 1 reducing the sediment removal efficiency or increasing the pond storage requirement. In order to avoid to treat the clean water generated by the undisturbed watershed, a clean water diversion ditch is proposed to collect the clean water generated from the natural area and divert the flow to downstream of Pond no. 1. The location of the clean water diversion ditch is shown in Figure 3-1.

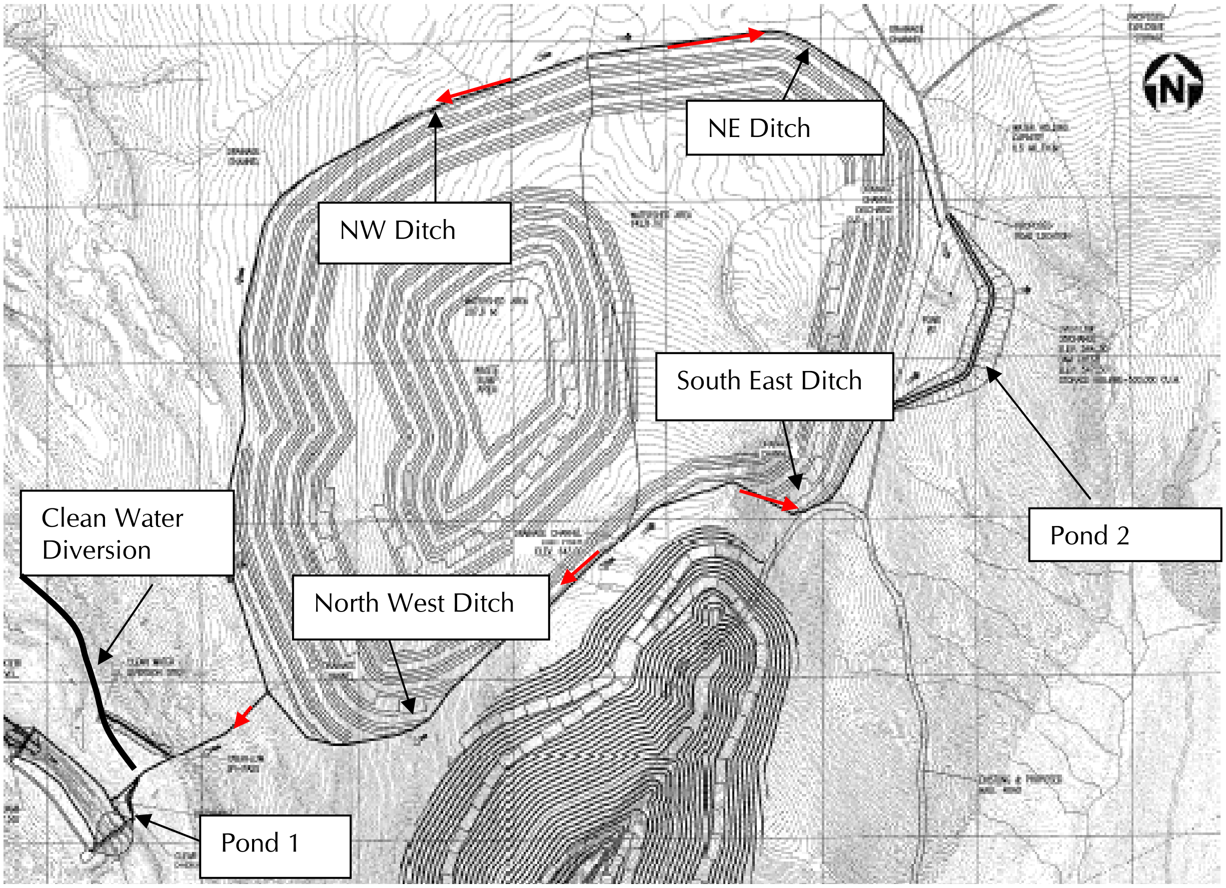


Figure 3-1: Stormwater Management System Layout - Waste Dump Stockpile Area

Two stormwater ponds are proposed to treat the stormwater for sediment removal.

- Pond no. 1 is located on the south west area downstream of the waste dump stockpile. This pond has two cells. Three dams will be required to form the pond cells. Pond no. 1 releases flow into the existing downstream stream.
- Pond no. 2 is located on the East of the waste dump stockpile. The pond treats the stormwater for sediment removal and then discharges to the existing downstream stream near the dam.

It shall be noted that the construction of the ditch and stormwater pond system for the waste rock stockpile area can be undertaken in phases corresponding to the waste rock dump development plan. Pond no. 1 and the runoff ditches to the pond shall be constructed before the waste rock dumping start. However, Pond no. 2 may not be needed until year 15 according to the current waste rock stockpile development plan. The basic criteria to determine if the construction shall be done is that the treatment system shall be in place when waste rock dumping begins in the affected drainage area.

The sizing of the required components (ditches and ponds) will be discussed in the following sections.

3.1.2 *Ore Stockpile Platform Area*

3.1.2.1 *Clean Water Diversion Ditch*

The ore stockpile area is presented in drawing H337697-4210-10-042-0003. The infrastructures in this area are still in the process of modifications. But the general layout of the drainage system shall not change much from what is described in the following sections. Some changes will be expected in the final design phase.

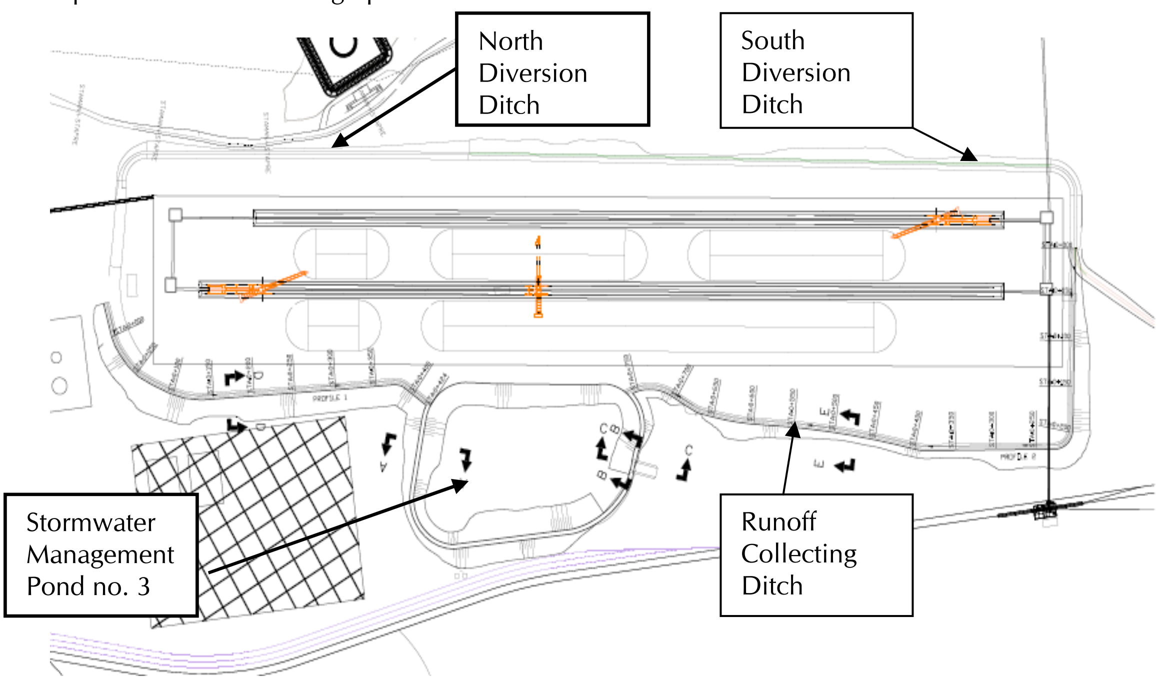


Figure 3-2: The Ore Stockpile Area (Note: Infrastructures in this area is still in the process of modifications and hence the ditch system may need minor modifications. But the general layout would remain unchanged.)

In this region, the area north of the ore stockpile platform will be undisturbed and hence the runoff generated from the area will be clean water. The elevation of the area is higher than the ore stockpile platform. The natural flow will flow into the ore stockpile working area and causes disturbance. For the purpose of avoiding problems, a clean water diversion ditch is designed to divert the flow. This ditch has two segments as shown in drawing H337697-4210-10-042-0003. The north west portion flows in northwest direction and the North East portion flows in Southeast direction and will be discharged into the existing stream.

3.1.2.2 *Drainage Ditch*

The drainage ditch are designed to collect runoff from the ore stockpile platform and carry flow into SWM Pond no. 3 for treatment.

3.1.2.3 *Pond No. 3*

Pond no. 3 is designed to collect the dirty water generated from the ore stockpile area for treatment. After treatment the flow will be discharged into the downstream existing stream.

3.2 Steensby Inlet

3.2.1 *Ore Stockpile Platform on the Island*

The Steensby Inlet (drawing H-337697-4510-10-014-0001) has two main areas where stormwater and sediment treatment are required. One area is the ore stockpile platform in the island. The infrastructures of the ore stockpile platform are still in the process of planning and changes will be made. The basic concept shows in Figure 3-3 is for the stormwater management system of the ore stockpile platform area.

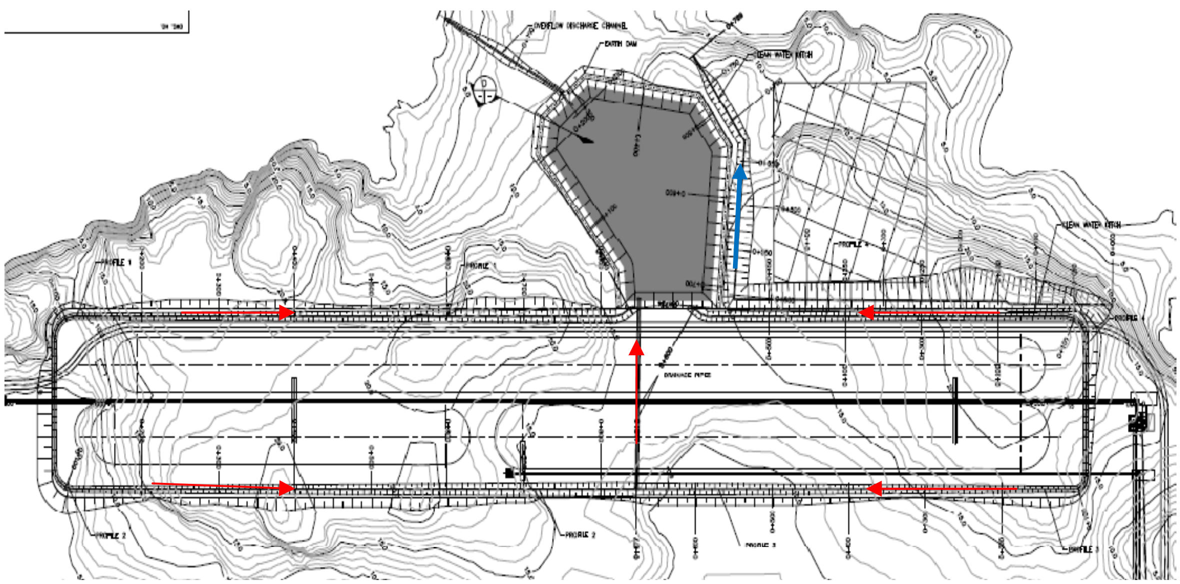


Figure 3-3: Ore Stockpile Platform Stormwater Management System

From Figure 3-3, the surrounding ditch collects the runoff generated by the ore stockpile platform area and put water into the stormwater management pond northwest of the platform. After treatment, the flow is released to the ocean via the downstream channel. The flow collected by the ditch south of the platform will be discharged into a pipe. The pipe will be connected to the stormwater pond. The flow directions shown in Figure 3-3 indicate the flow collection plan.

There is a small area north west of the ore stockpile platform where flow generated will be clean water and therefore a clean water diversion ditch will be used to collect and divert the flow around the SWM pond.

The stormwater management pond is designed to treat the stormwater and sediment. The sizing of the ditches and the ponds will be discussed in the following sections.

3.2.2 *The Stormwater Management System for the Laydown and Storage Area*

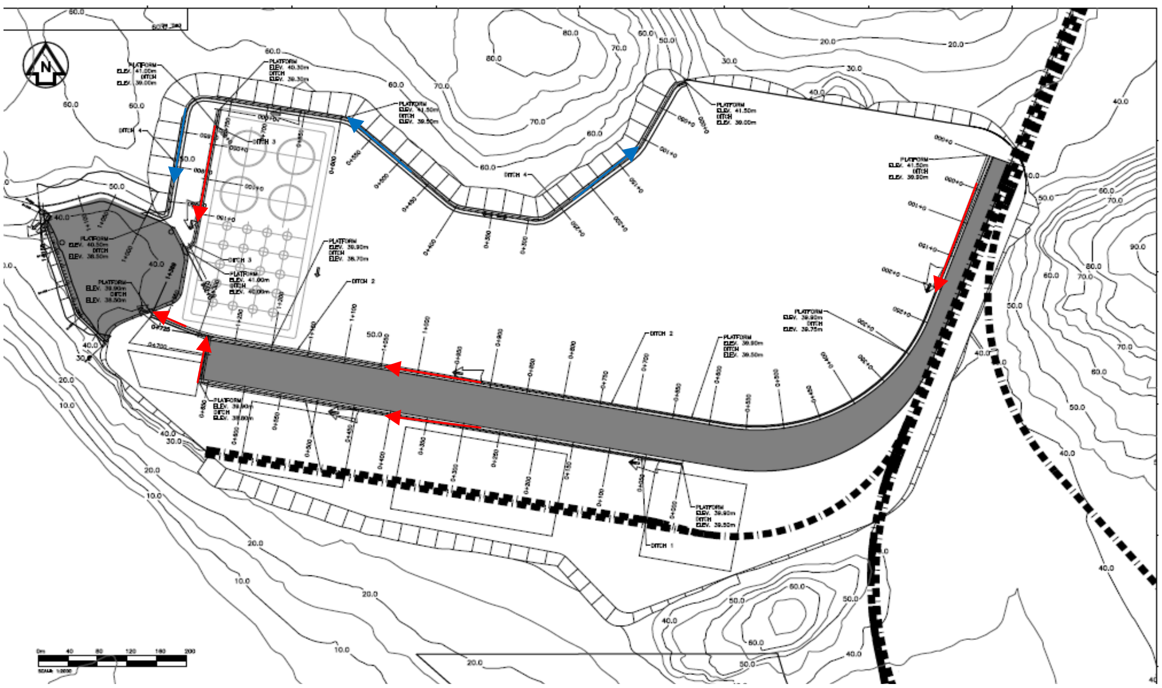


Figure 3-4: Stormwater Management and Drainage Network

This area has three components in the drainage and stormwater management system. The three components include:

- Clean water diversion ditch (Figure 3-4). The clean water diversion ditch has two segments. The East portion flows in Northeast direction and discharges into a small lake north of the area. The second segment flow mainly in West direction bypassing the stormwater management pond and directly discharges to the ocean.
- The drainage ditch collecting flow from the affected area to the pond for treatment (Figure 3-4)
- The stormwater management pond West of the area. After treatment, the water is released to the ocean.

3.3 Milne Inlet

The Milne inlet does not have permanent structures. The drainage work required is to collect the runoff and discharge to the nearest streams or water courses. The area to be served is small and hence the size of the ditches is small. The area is shown in Figure 3-5.

In this area, there are small streams. Land near natural streams will be graded to drain to the natural stream and hence no ditches are required.

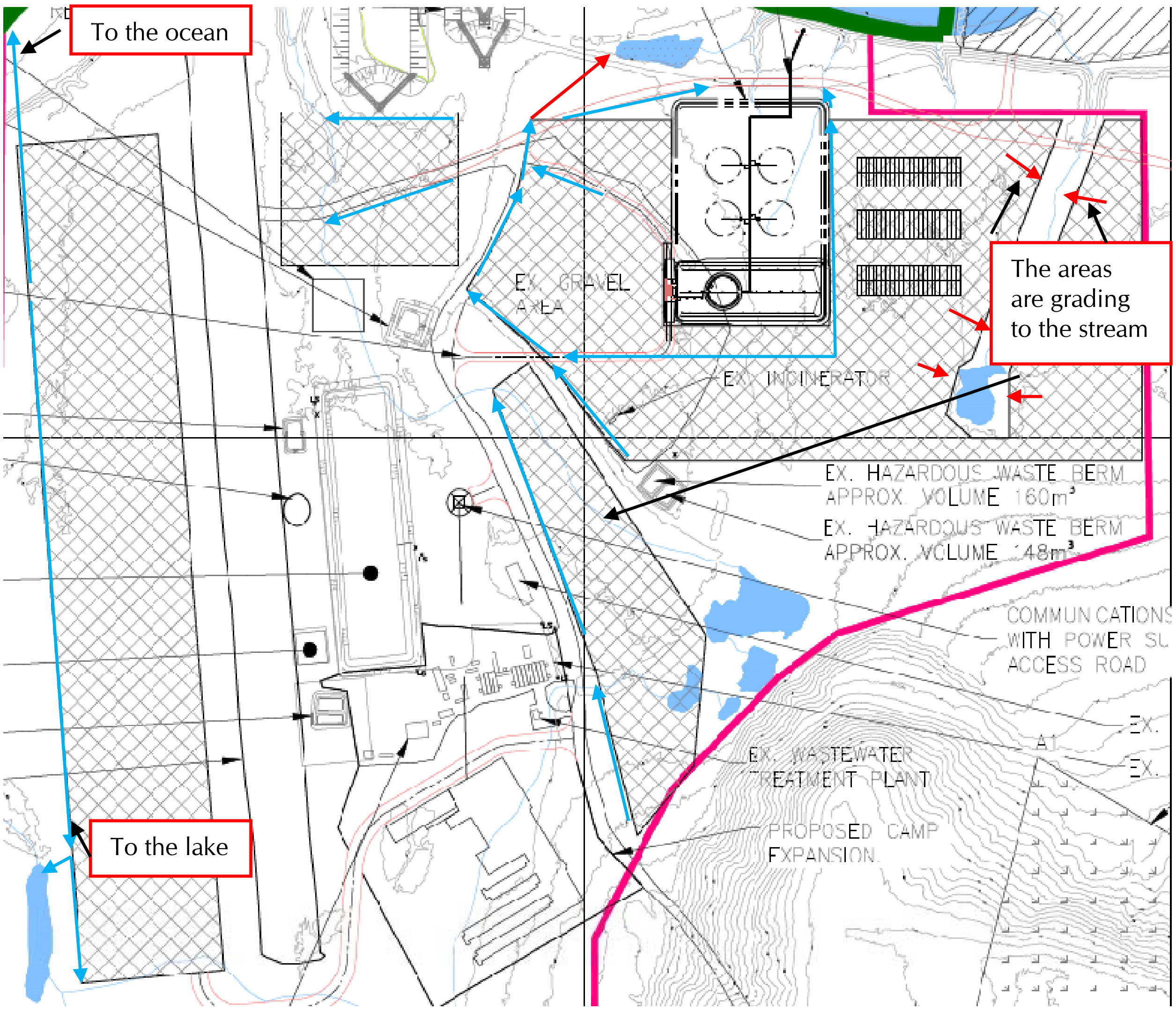


Figure 3-5: Milne Inlet Drainage Plan

4. Stormwater Pond Design

4.1 Stormwater Ponds

4.1.1 Minesite

In the Minesite, three stormwater / sediment ponds are proposed. These SWM ponds are designed to reduce peak flows, to store runoff generated in the area and to reduce sediment (TSS) concentration.

4.1.1.1 Pond No. 1

Figure 4-1 shows the configuration of Pond no. 1. Pond no. 1 collects runoff from the waste rock dump for treatment. Pond no. 1 is formed by three dams. The Block dam has a crest elevation of 355 m. This dam does not allow any flow over the embankment. The only purpose is to block the flow. This dam has a SIGNIFICANT hazard classification and hence the inflow design flood is the 1:200 year flood (Appendix A).

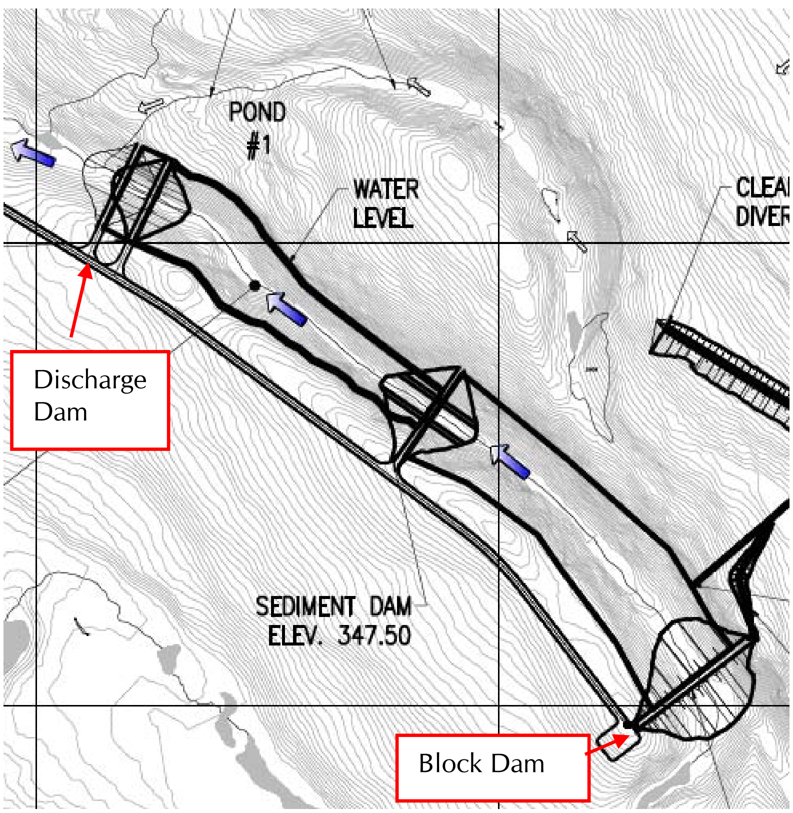


Figure 4-1: Minesite Pond no. 1 Configuration

The dam in the middle of Pond no. 1 is used for separate the pond into two cells. This dam has a crest elevation of 347.5 m. An overflow section in the middle of the dam will allow flows to cell 2. The overflow elevation is set at 344.5 m The bottom width of the overflow weir is 10 m. The side slope of the weir is 2 (H):1 (V). The dam has a SIGNIFICANT hazard classification and the IDF is the 1:200 year flood (Appendix A).

The downstream dam has a crest elevation of 329 m. The dam has an overflow weir at elevation 326 m. The bottom width of the overflow weir is 10 m. the side slope of the overflow section is 2 (H):1 (V). This dam is classified having SIGNIFICANT hazard rating and the IDF is the 1:200 year flood (Appendix A). The total storage capacity of Pond no. 1 is approximately 0.7 million m^3.

4.1.1.2 Pond No. 2

Pond no. 2 collects runoff from the waste rock dump (east part) for sediment removal. The dam has a crest elevation of 547.5 m with an overflow weir at elevation 544.5 m. The dam height is approximately 27 m. The total volume of the pond is about 0.5 million m^3. A spillway is designed to safely pass the IDF. The spillway bottom width is 10 m. The location of the spillway is on the northeast shoulder away from the dam body. The purpose is to avoid overflow on the dam. Due to the fact that this dam is used as access road, the spillway side slope is designed to be 10 (H):1 (V) for allowing transportation. This dam has been classified as SIGNIFICANT hazard rating and the IDF is the 1:200 year flood.

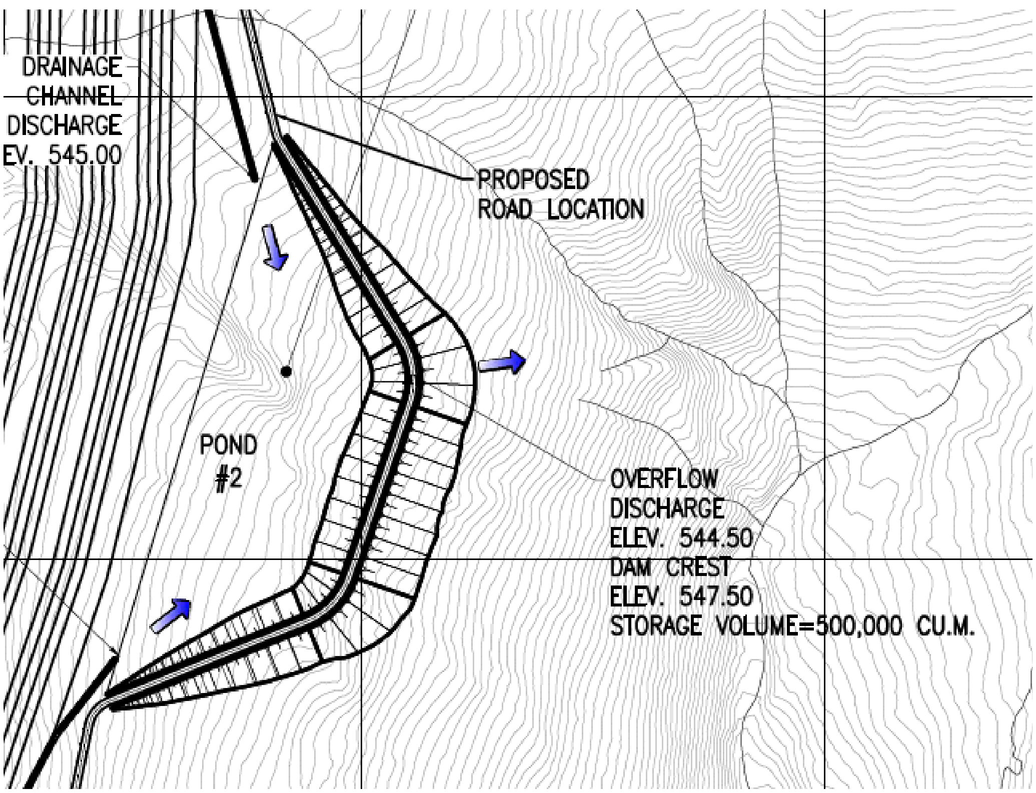


Figure 4-2: Minesite Pond no. 2 Configuration

4.1.1.3 Pond No. 3

The location of Pond no. 3 is shown in Figure 3-2. The dam to form Pond no. 3 has a crest elevation of 204.5 m and an overflow weir at an invert elevation of 203.5 m. The overflow weir bottom width is 10 m with 2 (H):1 (V) side slopes. The storage is 0.15 million m^3 approximately. The surface area of the pond is about 3.6 ha. The dam has a SIGNIFICANT hazard classification and hence the IDF is the 1:200 year flood.

4.1.2 Steensby Inlet

The Steensby Inlet has two SWM ponds. Pond no. 1 is located on the island to treat the stormwater generated by the ore stockpile platform (Figure 3-3). The dam has a crest elevation of 13.0 m. An overflow weir has a bottom width of 10 m at invert elevation of 10.5 m. The dam has a SIGNIFICANT hazard rating and the IDF is the 1:200 year flood (Appendix A).

The SWM Pond no. 2 on the land is shown in Figure 3-4. The crest elevation of the dam is 40 m. The overflow weir invert elevation is 38 m. The width of the weir is 10 m. the side slope of the weir is 2 (H):1 (V). The dam has a storage about 80,000 m^3. The hazard potential of this dam is SIGNIFICANT and hence the IDF is the 1:200 year flood event.

4.2 Peak Flow Estimation

The design of the drainage ditches requires the estimation of the peak flows for the design event. Flow estimation will be based on the following equations developed by Knight Piésold Consulting for drainage greater than or equal to 0.5 km^2:

$$Q_2 = 1.1\ A^{0.79}$$

$$Q_5 = 1.7\ A^{0.77}$$

$$Q_{10} = 2.0\ A^{0.76}$$

$$Q_{25} = 2.6\ A^{0.75}$$

$$Q_{100} = 3.5\ A^{0.73}$$

Where Q = peak flow instantaneous flow in m^3/s

A = drainage area in km^2 ($0.5\ km^2 \leq A \leq 1000\ km^2$)

When the drainage area is smaller than 0.5 km^2, the above equations can not be used. In this case, the rational formulae will be applied for the estimation of peak design flows. The form of the equation is:

$$Q = 0.28\ CIA$$

Where, Q = peak instantaneous flow in m^3/s

A = drainage area in km^2

C = runoff coefficient = 0.9

I = rainfall intensity corresponding to the time of concentration.

The time of concentration is calculated as: $T_c = 0.13\left(\frac{L}{\sqrt{S}}\right)^{0.77}$ where T_c = time of concentration (hour), L = the main channel length (km) and S = the channel slope (m/m).

The rainfall intensity-duration-frequency (IDF) curves of design storms have been analyzed by Knight Piésold Consulting and the IDF curves are summarized in Table 4-1.

Table 4-1: Design Storm Intensity-Duration-Frequency (IDF) Curves (mm/hr)

Duration	2 yrs	5 yrs	10 yrs	15 yrs	20 yrs	25 yrs	50 yrs	100 yrs	200 yrs
5 min	9.5	12.0	14.0	15.1	15.9	16.5	18.3	20.1	22.0
10 min	7.2	9.0	10.5	11.3	11.9	12.4	13.7	15.1	16.5
15 min	6.0	7.5	8.7	9.4	9.9	10.3	11.4	12.6	13.7
30 min	5.0	6.3	7.3	7.9	8.3	8.6	9.5	10.5	11.4
1 hr	4.0	5.2	6.1	6.6	7.0	7.3	8.1	9.0	9.9
2 hr	3.0	3.9	4.6	5.0	5.2	5.5	6.1	6.8	7.4
6 hr	2.0	2.7	3.3	3.6	3.9	4.0	4.6	5.1	5.7
12 hr	1.3	1.8	2.2	2.4	2.6	2.7	3.1	3.4	3.8
24 hr	1.0	1.4	1.7	1.9	2.0	2.1	2.4	2.7	3.0

The determination of the peak flows for each of the ditches will be discussed in Section 5.

4.3 Flood Routing in Stormwater Management Ponds

To design the spillways for stormwater ponds, the equations described in Section 4.1 will not be sufficient since the storage routing effects can not be evaluated by the simple peak flow estimation equations. The storages in the ponds play important role in the determination of water levels and peak outflows from the spillway. In this case, a flood routing model will be used to fully assess the impact of the storages and the required spillway dimensions to safely pass the design floods for each pond.

The US EPA SWMM model is used for the flood routing assessment. The EPA Storm Water Management Model (SWMM) is a dynamic rainfall-runoff simulation model used for single event or long-term (continuous) simulation of runoff quantity and quality from primarily urban areas. The runoff component of SWMM operates on a collection of sub-catchment areas that receive precipitation and generate runoff and pollutant loads. The routing portion of SWMM transports this runoff through a system of pipes, channels, storage / treatment devices, pumps, and regulators. SWMM tracks the quantity and quality of runoff generated within each sub-catchment, and the flow rate, flow depth, and quality of water in each pipe and channel during a simulation period comprised of multiple time steps.

A SWMM model was established for each SWM pond in the Minesite and Steensby Inlet areas. The SWMM model was used to:

- Determine the spillway dimensions required to pass the inflow design flood (IDF)
- Evaluate the water quality performance of the ponds in TSS removal (Section 4.4).

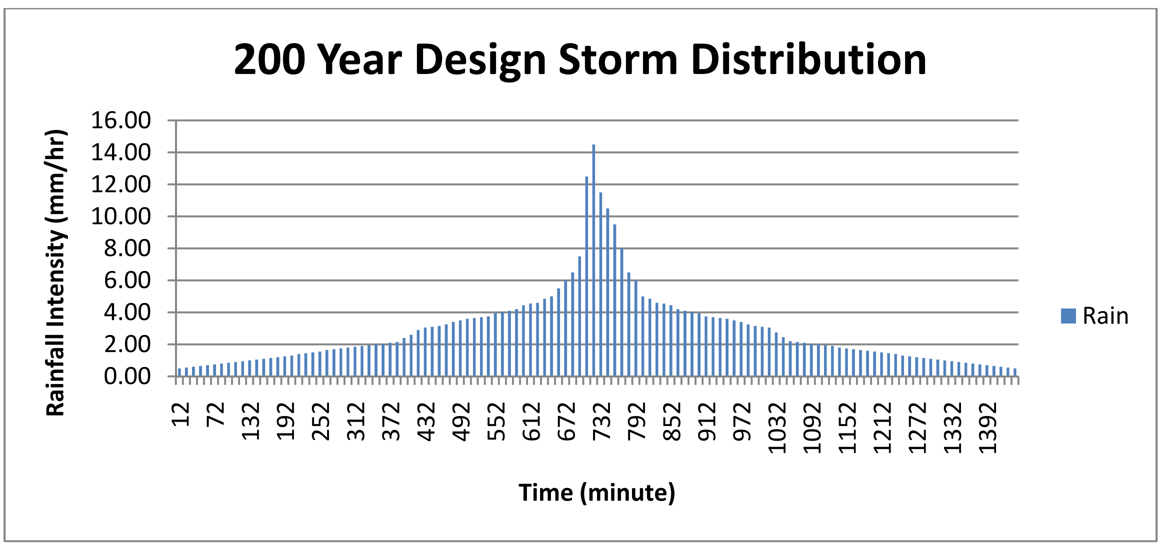
To simulation the flood routing processes in the SWM ponds during IDF, the return period of the inflow design flood shall be determined. This IDF is associated with the dam classification based on CDA dam safety guidelines. This dam classification for each dam will be discussed in Section 6 (Dam Design Section). The following section describes the design storms used in the SWMM model.

4.3.1 Design Storm

Design storm has three components:

- Design frequency (return period)
- Storm volume (mm) and duration (hours)
- Temporal distribution

Figure 4-3: 200 Year Design Storm Distribution



The dam safety assessment results shown that the required IDF for all of the SWM pond embankment structure is the 1:200 year flood event. For the site, Knight Piésold Consulting determined that the 1:200 year design storm has 71 mm in 24 hour period.

The temporal distribution of the storm was developed based on the 'balanced storm' method The 24 hours 'balanced storm' temporal distribution of the 200 year storm is presented in

Figure 4-3. The total storm volume of this event is 71 mm. Figure 4-3 shows in the intensity (mm/hr) for each rainfall block. The time interval is 12 minutes.

4.3.2 Model Parameters

The input to the model includes:

1. drainage areas of the sub-watershed
2. Surface roughness coefficient
3. Infiltration parameters
4. Sediment erosion parameters
5. Precipitation input
6. SWM pond configurations

The model will produce peak flows and the flood hydrographs for each of the sub-watershed and will be able to calculate the combined flows at confluence of sub-watersheds.

Table 4-2 summarizes the sub-watershed areas and the other basic parameters used in the model for Mine site.

Table 4-2: Mine Site SWMM model parameters

	Watershed Area (ha)	Percent of imperious %	Maximum Infiltration rate (mm/hr)
Pond no. 1	207.8	99	3
Pond no. 2	142.8	99	3
Pond no. 3	26.2	99	3

Note: 99% of imperious area is used for frozen ground conditions during spring runoff period which results in almost all precipitation to become runoff.

Table 4-3: Steensby Inlet SWMM Model Parameters

	Watershed Area (ha)	Percent of imperious %	Maximum Infiltration rate (mm/hr)
Pond no. 1	23.3	99	3
Pond no. 2	61	99	3

4.3.3 Spillway Rating Curves

Spillway rating curves are calculated using standard weir equation:

$$Q = CBH^{1.5}$$

Where Q = discharge (m^3/s)

C = weir coefficient = 1.70 (used)

B = Spillway bottom width (m)

H = head of water (m)

4.3.4 Results

The SWMM model is used to simulate the flood routing process in the stormwater ponds for the inflow design flood. The peak water levels in each of the pond are obtained and summarized in Table 4-4. for the mine site and in Table 4-5 for the Steensby Inlet site.

Table 4-4: Peak flows and water levels in the ponds (Minesite)

	Peak Inflow (m^3/s)	Peak Outflow (m^3/s)	Peak water level (m)	Crest Elevation (m)	Freeboard (m)
Pond no. 1	6.09	4.65	326.35	329	2.65
Pond no. 2	4.31	2.66	544.7	547.5	2.80
Pond no. 3	0.84	0.73	203.55	204.5	0.95

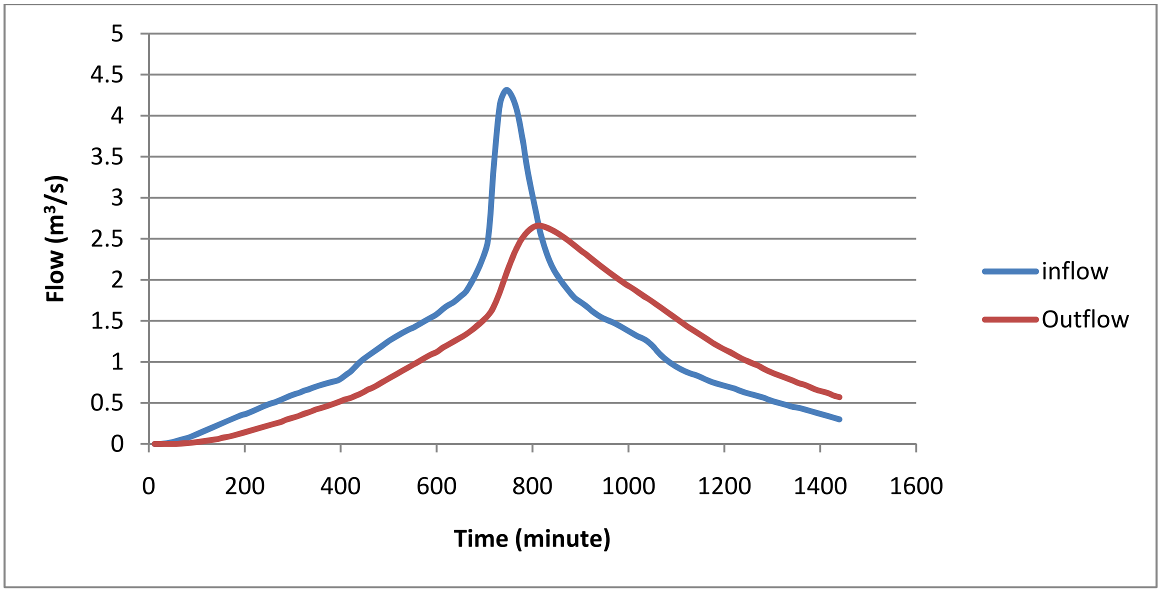
Table 4-5: Peak Flows and Water Levels in the ponds (Steensby Inlet)

	Peak Inflow (m^3/s)	Peak Outflow (m^3/s)	Peak water level (m)	Crest Elevation (m)	Freeboard (m)
Pond no. 1	0.89	0.76	10.64	13	2.36
Pond no. 2	1.63	1.41	38.21	40	1.79

From Table 4-4 and Table 4-5, it is known that the spillway capacities are sufficient to safely pass the IDF. The freeboards meet the CDA dam safety requirement. The stormwater ponds also reduced the peak flows 66-85% depending on the storage characteristics of the ponds.

Figure 4-4 presents one example of the flood reduction function for Minesite Pond no. 2 IDF case. From the figure, it is evident that a significant peak flow reduction is achieved (2.66/4.31 =61.7%).

Figure 4-4: Inflow and outflow hydrographs, Mine Site Pond no. 2



In stormwater management, preventing peak flows from being higher than pre-development conditions is normally required. For this development, the flooding occurs normally on frozen ground and hence the pre- and post- development flood magnitudes does not change significant and therefore the stormwater pond will improve the flood conditions of the site (than the pre-developed conditions). This is one benefit of the ponds.

4.4 Determination of Water Quality Capture Volume

4.4.1 WQCV Calculations

The water quality capture volume(WQCV) is an important design feature for stormwater quality control. The main pollutant to be controlled in the stormwater ponds is the sediment or total suspended solids (TSS) from the watershed. The target TSS concentration is 15 mg/L for all of the final discharge points. Many factors affect the TSS concentration including: A) amount of rainfall and runoff in the watershed, B) the sediment characteristics and the erosion potential, C) the pond storage and surface area, D) the outlet feature which determine the detention time, E) the TSS grain size distribution, and F) the size of the watershed and land use conditions, etc.

For the purpose of the stormwater pond design, the amount of rainfall and the detention time are the two key parameters that affect the performance of a stormwater pond. Current practice is to detent a 24 hours storm in the pond for 40 hours (Grizzard, 1986, Roesner, 1989) which will provide good TSS removal efficiency while the pond storage is still in manageable size. Longer detention time will lead to higher removal efficiency but requires too large pond storage. Therefore, the detention time targeted for the water quality capture volume design is 40 hours.

The WQCV is the amount of storm to be treated in the detention storage. This amount varies from place to place. Typical values is to capture 25 mm storm (Ontario Ministry of Environment, 2003). For the Baffinland area, the 24 hours 25 mm storm is equivalent to a 1:2 year design storm approximately (Knight Piésold Consulting, 2010). This storm volume is used to estimate the WQCV storage requirement.

Table 4-6 summarizes the WQCV for the ponds in the Mine Site and Table 4-7 presents the values for the ponds in Steensby Inlet area.

Table 4-6: Pond WQCV Requirement (Mine Site)

	Drainage area ha	Design Storm mm	WQCV M^3	Pond Surface ha	Depth between Core and Spillway Invert m
Pond no. 1	207.8	25	51950	6.71	0.77
Pond no. 2	142.8	25	35700	10.9	0.33
Pond no. 3	26.2	25	6558	3.6	0.2

Table 4-7: Pond WQCV Requirement (Steensby Inlet)

	Drainage area ha	Design Storm mm	WQCV M^3	Pond Surface ha	Depth between Core and Spillway Invert m
Pond no. 1	23.3	25	5835	2.6	0.22
Pond no. 2	61.0	25	15250	2.85	0.54

To make the required WQCV storage available, there is a need to maintain the water level lower than the spillway invert elevation so that the storm runoff will be stored in the pond and then slowly releases to downstream water course. The slowly release mechanism will be provided using porous rock fill weir at the entrance of spillway. The basic concept is illustrated in Figure 4.5 .

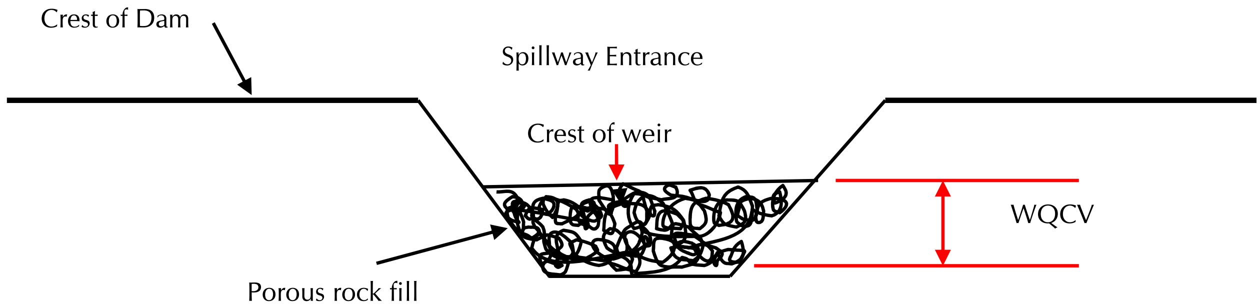


Figure 4.5 WQCV Concept Illustration

This slow flow release configuration are designed to work with dams where spillway can be constructed on natural ground. These dams include: Mine Site Pond no. 2 and no. 3 dams, the stormwater Pond no. 2 in Steensby Port of the laydown and storage area.

For dams for which the spillway cannot be located on natural ground (due to constrain of space), part of the embankment will have to be used as spillway. In this case, the modified dam cross section option two will be used at the spillway location. This dam section allow small amount of seepage flow on the porous rock fill area which acts as the slow flow release mechanism. This design will maintain the safety of the dam while provides the required slow flow release rate at the same time.

When rainfall occur, as long as the rainfall is smaller than or equal to 25 mm, all of the runoff will be stored in the WQCV zone (between normal water level and the invert of the pond spillway). The porous zone of the rock fill section will allow the runoff captured slowly drains down to the normal water level. If the storm is 25 mm, then the time required for the water level to return to normal water level is 40 hours.

When the storm is higher than 25 mm, the WQCV will not be large enough to hold all of the runoff volume and spills will occur. The flow will directly run through the pond over the spillway and being discharged to the downstream river. In this case, the water quality standard may not be met (because there is no sufficient detention time to remove the TSS).

Based on the above discussions, it is evident that the provision of a porous zone above the spillway invert to allow the pond to drain slowly is a key design feature for water quality since without this discharge capacity the normal water level will be at the invert of the spillway and all runoff will be discharged directly to the downstream river. The TSS concentration may be too high.

For each pond, the depth between the porous weir and the invert elevation of the spillway is 1 m. (which is higher than the required values shown in Table 4-6 and Table 4-7, to provide higher TSS removal efficiencies).

4.4.2 SWMM Evaluation of the Pond Storage

A SWMM model was used to evaluate the performance of the WQCV in each pond. The input storm was the 1:2 year 24-hour design storm (25 mm of total rainfall volume). The most difficult parameter for this evaluation is the input TSS concentration since this value changes with many factors, such as the rainfall intensity and duration, the land surface conditions, the operation of the mining activities, etc. US EPA (1983) reported that typical stormwater TSS concentration is in the range of 180 - 548 mg/L depending on the land use. Therefore, a 300 mg/L and 550 mg/L was used in the model to simulate the performance of the SWM ponds. The value of 300 mg/L represents average concentration conditions and 550 mg/L represents the high concentration conditions. It is also noted that mining operation may result in much higher TSS load than Urban area. For this reason, the input TSS concentration five times higher than 550 mg/L (2750 mg/L) was also evaluated.

The equation for the evaluation of the TSS removal is based on the following treatment function of TSS in the SWM pond (SWMM Application Annual, 2009):

$$C_{t+\Delta t} = C^* + (C - C^*)e^{-(\frac{k}{d})\Delta t}$$

Where C = concentration of TSS (mg/L)

C* =TSS concentration cannot be settled by gravity (mg/L) due to small grain size

K = model parameter related to detention time and pond representative depth

d = water depth in the pond

In this equation, it is known that the TSS concentration cannot settle in the pond by gravity is an important parameter. This is a site specific parameter depending on the sediment size distribution. This information, however, can only be available after the mining operation starts. Therefore, it is assumed that this value is less than 15 mg/L since if it is higher than 15 mg/L, no matter how big the sediment pond would be, the targeting TSS concentration will not be met.

Table 4-8 and Table 4-9 summarize the simulation results for the Mine Site and Steensby Inlet respectively.

Table 4-8: SWM Pond Outflow TSS Concentration (Minesite)

	Input TSS = 300 mg/L		**Input TSS = 550 mg/L**		**Input TSS = 2750 mg/L**	
	Peak mg/L	**Mean mg/L**	**Peak mg/L**	**Mean Mg/L**	**Peak Mg/L**	**Mean Mg/L**
Pond no. 1	11.5	8.7	11.7	8.5	13.6	8.6
Pond no. 2	14.6	10.3	19.0	10.7	54	14.4
Pond no. 3	12.5	10.1	14.6	10.4	33.4	12.5

Table 4-9: SWM Pond Outflow TSS Concentration (Steensby Inlet)

	Input TSS = 300 mg/L		**Input TSS = 550 mg/L**		**Input TSS = 2750 mg/L**	
	Peak Mg/L	**Mean Mg/L**	**Peak Mg/L**	**Mean Mg/L**	**Peak Mg/L**	**Mean Mg/L**
Pond no. 1	13.3	10.4	16.2	10.8	41.2	14.4
Pond no. 2	16.7	10.8	22.5	11.5	73.5	17.4

From Table 4-8 and Table 4-9, it is know that when the 25 mm storm runoff is stored for 40 hours, the mean TSS concentrations of the outflows from the ponds will be less than 15 mg/L. The peak concentration could be higher but these high concentrations will last only for a hour or so. The basic requirement of concentration less than 15 mg/L is met. It is very difficult to reduce the peak concentration since this will need extremely large pond and longer detention time.

It shall be noted that the 25 mm storm has a return period of two years. This means that, on average, all storms less than the 2-year event will be controlled to have TSS concentration less than 15 mg/L.

Figure 4.6 shows the TSS concentration variation during the 2-year storm event in Mine Site.

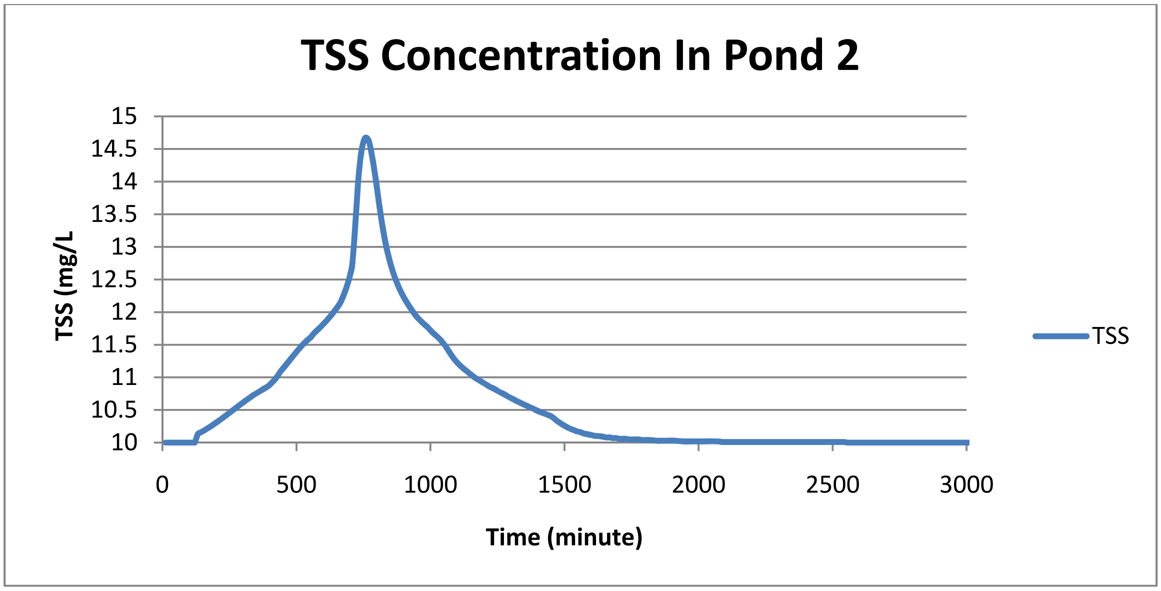


Figure 4.6: Pond TSS Removal Performance Example (Input TSS = 300 mg/L)

Pond no. 2 as an example of the TSS removal performance. This figure presents the out flow TSS concentration.

When the input TSS concentration is as high as 2750 mg/L, the mean outflow TSS concentrations in most SWM ponds will still meet the requirement. The Pond no. 2 in Steensby Inlet will have higher mean TSS exceeding the 15 mg/L target.

It is concluded that the provided WQCV will meet the TSS concentration target for each of the ponds if the input concentrations are less than 2750 mg/L and the TSS cannot settle by gravity is below 15 mg/L. However, it is known that there are many factors affecting the TSS concentration of the site, uncertainties still exist. It is hence recommended that a monitoring system shall be established to measure the TSS concentration in runoff at various locations and if it is found that the TSS concentration exceeds the limit, additional treatment may be needed.

From Table 4-8, it is also interesting to note that the two cells arrangement in Minesite Pond no. 1 will improve the TSS removal performance due to additional detention time by the two cells configuration.

5. Sizing of the Drainage Ditches

5.1 Mine Site Ditches

5.1.1 Waste Rock Stockpile

The drainage area for the waste rock stockpile was divided into four sub-areas. The four sub-areas were called NE, NW, SE, and SW and correspond with the channel alignments. The NW and SW channels combine to form an Outlet channel that leads to a sediment pond. The runoff was calculated using the equations given in Section 9 reference no. 1 as each sub-area was greater than 0.5 km^2. The 10-year design storm was used for these channels. The runoff from each sub-area was calculated at the downstream end. Intermediate discharges along the proposed channel were calculated by prorating the discharge over the channel length.

The minimum channel bottom width listed in the Design Criteria is 1 m. This width was sufficient for all the channels except the Outlet channel at the waste rock stockpile. A 3 m channel bottom was used for its entire length.

The channel slopes ranged from 0.3 percent to 69 percent. The Outlet channel at the waste rock stockpile had the steepest slopes with a minimum slope of 14 percent and a maximum of 69 percent.

Reinforced concrete pipe (n = 0.013) was used for the closed drainage system in the Platform site. A minimum cover of 0.6 m was used over the top of the pipe. The minimum slope considered in the design was a slope that could achieve a pipe flow velocity of 1 m/s.

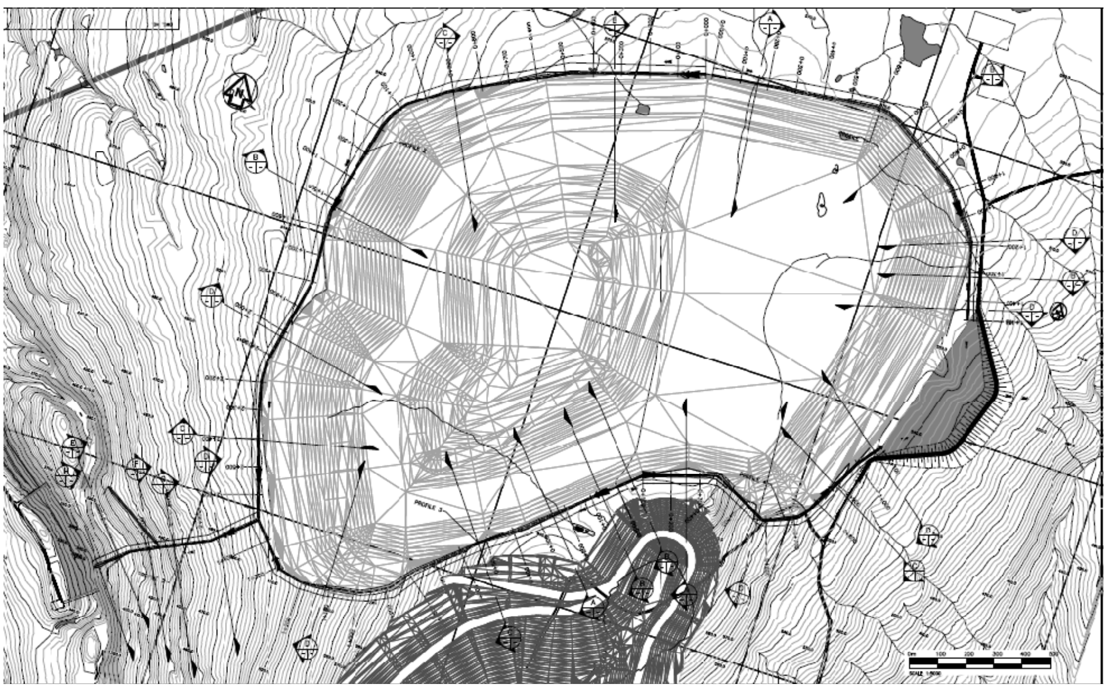


Figure 5-1: The Waste Rock Dump Ditches

Table 5-1: Ditch Size and Riprap Requirements (Waste Rock Stockpile Area)

Channel	Beginning Station (m)	End Station (m)	Channel Type	Discharge (cms)	Bottom Width (m)	d_{50} (mm)	d_{100} (mm)	Riprap thickness (mm)
Profile 1	0	120	A	0.1	1			
Profile 1	120	320	A	0.1	1			
Profile 1	320	370	B	0.4	1	80	100	100
Profile 1	370	655	B	0.5	1	80	100	100
Profile 1	655	890	B	0.8	1	80	100	100
Profile 1	890	1140	B	1.1	1	80	100	100
Profile 1	1140	1245	D	1.4	1	300	380	375
Profile 1	1245	1390	B	1.5	1	80	100	100
Profile 1	1390	1470	D	1.7	1	300	380	375
Profile 2	0	645	B	0.3	1	80	100	100
Profile 2	645	1160	C	0.6	1	160	200	200
Profile 2	1160	1885	B	1.1	1	80	100	100
Profile 2	1885	2160	D	1.8	1	300	380	375
Profile 2	2160	2470	C	2.0	1	160	200	200
Profile 2	2470	2680	C	2.3	1	160	200	200
Profile 2	2680	2795	D	3.2	3	300	380	375
Profile 2	2795	2960	D	3.2	3	300	380	375
Profile 2	2960	3035	G	3.2	3	650	820	813
Profile 2	3035	3110	F	3.2	3	540	680	675
Profile 2	3110	3130	F	3.2	3	540	680	675
Profile 2	3130	3255	E	3.2	3	480	600	600
Profile 2	3255	3290	H	3.2	3	SD	SmartDitch	
Profile 3	0	145	B	0.1	1	80	100	100
Profile 3	145	350	A	0.1	1			
Profile 3	350	565	C	0.3	1	160	200	200
Profile 3	565	705	C	0.5	1	160	200	200
Profile 3	705	910	D	0.6	1	300	380	375
Profile 3	910	1110	D	0.8	1	300	380	375
Profile 3	1110	1210	D	0.9	1	300	380	375
Profile 3	1210	1405	D	1.0	1	300	380	375
Profile 4	0	120	B	0.1	1	80	100	100
Profile 4	120	390	A	0.1	1			
Profile 4	390	500	D	0.4	1	300	380	375
Profile 4	500	560	D	0.5	1	300	380	375

Channel	Beginning Station (m)	End Station (m)	Channel Type	Discharge (cms)	Bottom Width (m)	d_{50} (mm)	d_{100} (mm)	Riprap thickness (mm)
Profile 4	560	615	D	0.6	1	300	380	375
Profile 4	615	740	D	0.7	1	300	380	375
Profile 4	740	1040	C	0.8	1	160	200	200
Profile 4	1040	1120	D	1.1	1	300	380	375
Clean Water	0	270	D	1.0	1	300	380	375

Figure 5-1 shows the ditches surrounding the waste rock dump area. The slope of the ditch in some area is steep and hence the riprap protection may be needed. Table 5-1 summarizes the ditch size and riprap requirement along the profiles. In Table 5-1, eight types of ditches are listed. Type A, B, C, D, E, F, G and H ditches have bottom width varying from 1 m to 3 m.

5.1.2 *Ore Stockpile Platform*

The offsite drainage area is about 0.2 km^2. The runoff is essentially undisturbed and is considered clean water. The design storm is the 100-year event. The runoff will be channelled into an North and South channel. (See Figure 3-3) The outlet for these channels will be the existing drainage ways.

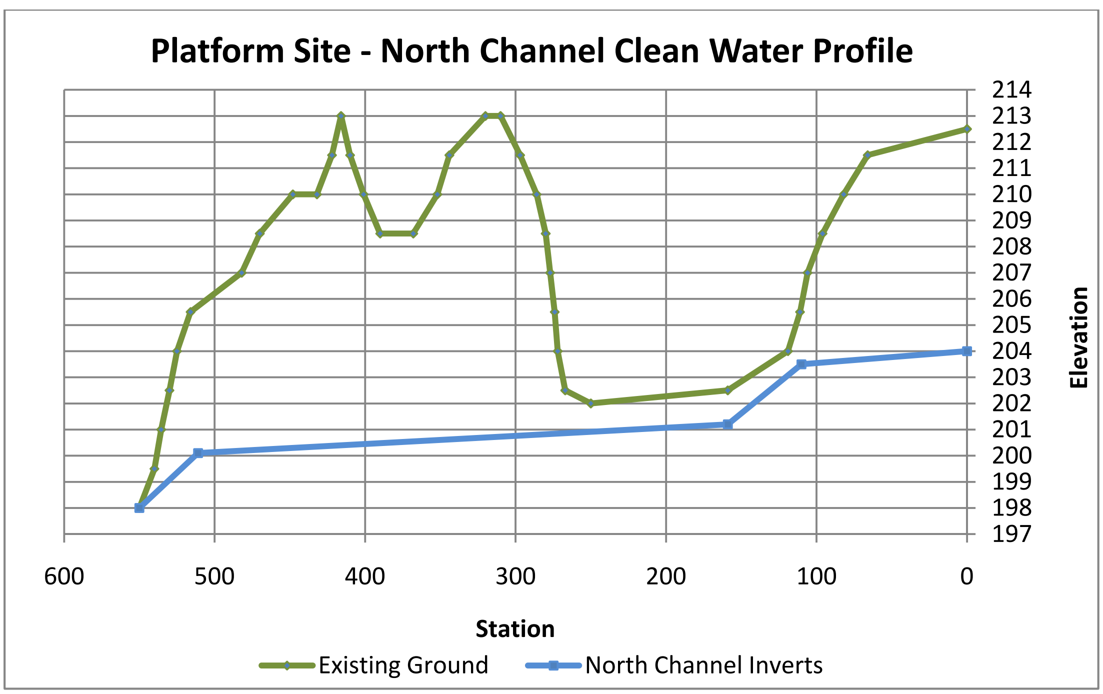


Figure 5-2: North Diversion Ditch (Ore Stockpile Platform)

The channel profiles are shown in Figure 5-2 and Figure 5-3. The channels range in slope from 0.3 to 14.2 percent. The discharges and D_{50} riprap for each section of the channel are shown in Table 5-2. The riprap for these channels were designed using Section 9, references no. 5 and no. 6.

The interior of the Platform site will receive runoff from the stockpiles and will contain sediment. The design storm for the Platform site is the 10-year event. The drainage area for the Platform site is 0.23 km^2. A channel network within the site was considered but it would interrupt access throughout the site. A closed drainage system is proposed for the site. The pipe network would comprise about 1.7 km of mainly 0.3 to 0.6 m pipe and 15 catch basins. The Platform site was divided in 15 sub-areas for the analysis.

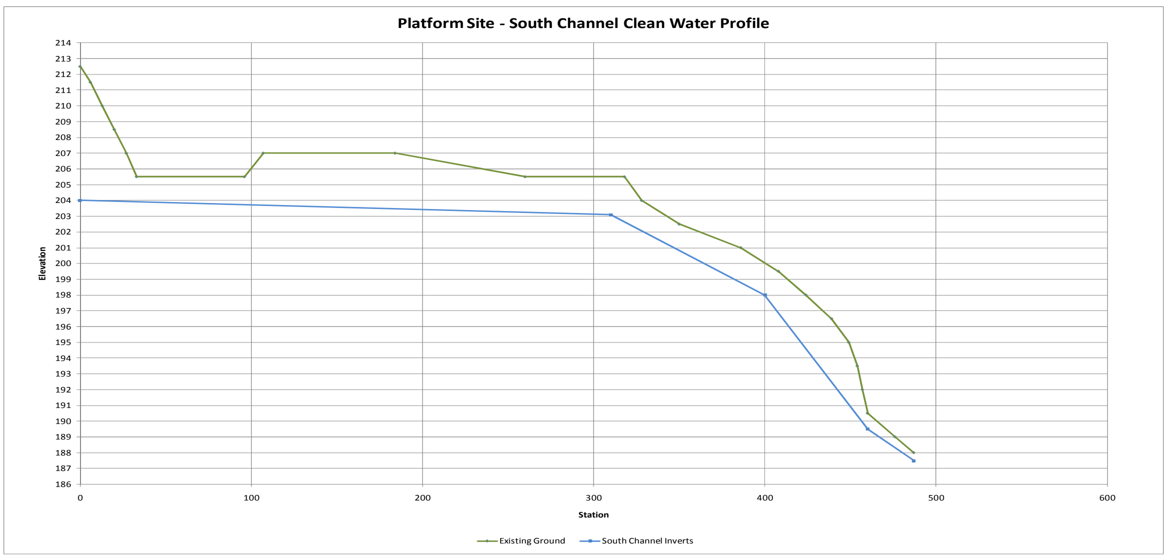


Figure 5-3: South Diversion Ditch (Ore Stockpile Platform)

Table 5-2: Ditch Size and Riprap Requirements (Clean Water Diversion Ditch)

Platform Clean Water Channels								
Channel	**Beginning Station (m)**	**End Station (m)**	**Channel Type**	**Discharge (cms)**	**Bottom Width (m)**	**d_{50} (mm)**	**d_{100} (mm)**	**Riprap thickness (mm)**
North	0	110	A	0.1	1			
North	110	159	B	0.1	1	80	100	100
North	159	511	A	0.45	1			
North	511	550	C	0.45	1	160	200	200
South	0	310	A	0.14	1			
South	310	400	C	0.14	1	160	200	200

Platform Clean Water Channels								
Channel	Beginning Station (m)	End Station (m)	Channel Type	Discharge (cms)	Bottom Width (m)	d_{50} (mm)	d_{100} (mm)	Riprap thickness (mm)
South	400	460	D	0.14	1	300	380	375
South	460	487	C	0.14	1	160	200	200

5.2 Steensby Inlet

5.2.1 Ditch Surrounding Ore Stockpile Platform (Island)

The ditch collect flow generated from the ore stockpile platform and sends the runoff to the SWM pond for treatment. The total area is small and hence the minimum ditch with 1 m bottom width and 2:1 side slope will have sufficient flow capacity to carry the design flow 0.32 m^3/s. The channel slope is 0.003 to 0.005.

5.2.2 Ditch to the SWM Pond no. 2 (Land)

The ditch collect flow generated from the permanent laydown and storage area , and sends the runoff to the SWM pond for treatment. The total area is 61 ha. The ditch with 1 m bottom width and 2:1 side slope will have sufficient flow capacity to carry the design flow 1.56 m^3/s. The channel slope is 0.003 to 0.005.

5.2.3 Clean Water Diversion Ditch

A clean water diversion ditch is required to allow the runoff from undisturbed area to bypass the system and to reduce the treatment requirement. The ditch flows in two directions. The west part flows western direction and bypass the SWM pond. The East ditch flows eastern direction and discharge to a existing water course North of the area. This ditch has a 1 m bottom width and 2 (H):1 (V) side slope with 0.005 channel slopes. The ditch has sufficient flow capacity to carry flows from the watershed.

5.3 Milne Inlet

There are no permanent structures in Milne Inlet. The operations in this area will be short term activities. During operation, there is a need for drainage to avoid disturbance to works. For this reason, the drainage is aimed at drain stormwater into nearby streams without treatment (i.e. no stormwater ponds are required).

Drawing H337697-4510-10-014-0003 shows the overall drainage network for Milne Inlet site. In the area, if there is a stream nearby (about 150 - 200 m), no ditches are planned. The land shall be graded to naturally drains to the existing stream. Where the distance to existing stream is longer than 150 - 200 m, ditches are designed to collect the runoff and the ditches are then connected to the nearest existing stream.

The areas are small and the ditch having 1 m bottom width with 2 (H):1 (H) will be able to drain the stormwater generated from the areas.

6. Dams

The SWM ponds in the Mine Site and Steensby Inlet need embankment structures to create the storage required for stormwater treatment. This section describes the dam design aspect. First a dam safety assessment is performed to obtain the ICC rating of each dam structure and then important issues for the dam design are discussed.

6.1 Dam Safety Assessment

Due to the fact that the embankment structures for stormwater management meets the CDA definition of dams, according to the 2007 CDA guidelines, a dam safety assessment (DSA) was performed to evaluate the incremental consequence category (ICC) classification. This assessment is necessary since many of the design parameters must be consistent with the CDA dam safety requirements. If a dam is designed and constructed but it does not meet the dam safety requirements, it will have to do costly modification to meet these requirements at later stage. The design criteria are different for each ICC rating. The details of the dam safety assessment can be found in Appendix A. Here only the main conclusions are listed.

An ICC rating is based on assessment of incremental impacts of dam failure on loss of life (LOL), social and economical losses and environmental impacts. If a dam imposes hazard to the downstream area, the hazard is evaluated and rated based on the CDA guidelines.

Table 6-1: Summary Of Dam ICC Ratings (Mine Site)

		Dam Height (m)	LOL	Social & Economic Loss	Environmental Damages	Overall
Pond no. 1	Block Dam	25	Low	Low	Significant	Significant
	Sediment Dam	25	Low	Low	Significant	Significant
	Discharge Dam	25	Low	Low	Significant	Significant
Pond no. 2 Dam		27	Low	Low	Significant	Significant
Pond no. 3 Dam		12	Low	Low	Significant	Significant

Table 6-2: Summary Dam ICC Ratings (Steensby Inlet)

	Dam Height (m)	LOL	Social & Economic Loss	Environmental Damages	Overall
Pond no. 1 Dam	8	Low	Low	Significant	Significant
Pond no. 2 Dam	6	Low	Low	Significant	Significant

Based on CDA guidelines, the inflow design flood (IDF) and design earthquake (DE) for each structure are tabulated in Table 6-3 and Table 6-4.

Table 6-3: IDF and Design Earthquake Requirements (Mine Site)

		ICC	IDF	DE
Pond no.1	Block Dam	Significant	1:200	1:1000
	Sediment Dam	Significant	1:200	1:1000
	Discharge Dam	Significant	1:200	1:1000
Pond no.2 Dam		Significant	1:200	1:1000
Pond no.3 Dam		Significant	1:200	1:1000

Table 6-4: S IDF and Design Earthquake Requirements (Steensby Inlet)

	ICC	IDF	DE
Pond no. 1 Dam	Significant	1:200	1:1000
Pond no. 2 Dam	Significant	1:200	1:1000

6.2 Dam Section Design

6.2.1 *Stability*

Dam design is based on CDA guidelines for IDF, DE and stability. Table 6-5 summarizes the safety factors used for the Mary River Project dam design. Four load cases are checked. Table 6-5 summarizes the required Factor of Safety (FS) for the dam design based on CAD guideline corresponding to:

- steady state seepage corresponding to the normal water level (NWL)
- steady-state seepage at NWL in conjunction with earthquake loading. *Note:* The peak ground acceleration (PGA) for the site is 0.122 g based on data from the Canadian Geologic Society (CGS) corresponding to a 1:1000-yr return period.
- upstream slope stability subject to rapid drawdown
- slope stability of the dam slopes at the end-of-construction before impounding water.

Table 6-5: Summary of the Required Factor of Safety for Baffinland Dam Design Based on CAD Guideline

Load Combinations	Required Minimum FS	Type of Analysis
Steady Seepage corresponding to the NWL	1.5	Static analysis
Steady Seepage at NWL plus Earthquake Loads	1.0	Pseudo-static analysis
Upstream slope stability under rapid drawdown	1.2	Static analysis
Dam slope stability Just end of construction	1.3	Static analysis

6.2.2 *Thermal Conditions for Design*

The design basis thermal conditions are:

- The MAGT profiles Baffinland Mary river is assumed to -10ºC.
- The reservoir-bottom mean water temperature is assumed to be 4ºC.
- The annual air temperatures shall be assumed to vary sinusoidally as follows:
  a) max average air temperature is 7ºC in July
  b) min average air temperature is -25ºC in February.
- The natural active layer thickness is assumed to be 2 m(Wahl and Gharapetian, 2009).
- It is assumed that the foundation of the reservoir will thaw to the depth of 8 m in 50 years in the conceptual design stage.

6.2.3 *Additional Specific Requirement*

In addition to maintaining storm water retention requirements, the SWM ponds are required to have sufficient retention time to facilitate sedimentation of sediment within the reservoir (Section 4.4.1). A small amount seepage is required to help maintain the water level in control. The required seepage is assumed to be in the order of 10 L/s for the entire dam. This can be maintained by designing the dam to allow for controlled seepage to meet the flow requirements.

The anticipated type of service of the embankment is retain water continuously.

6.3 Dam Section

Figure 6-1 presents a typical dam section for Minesite SWM Pond no. 2 dam. The dam has the following features:

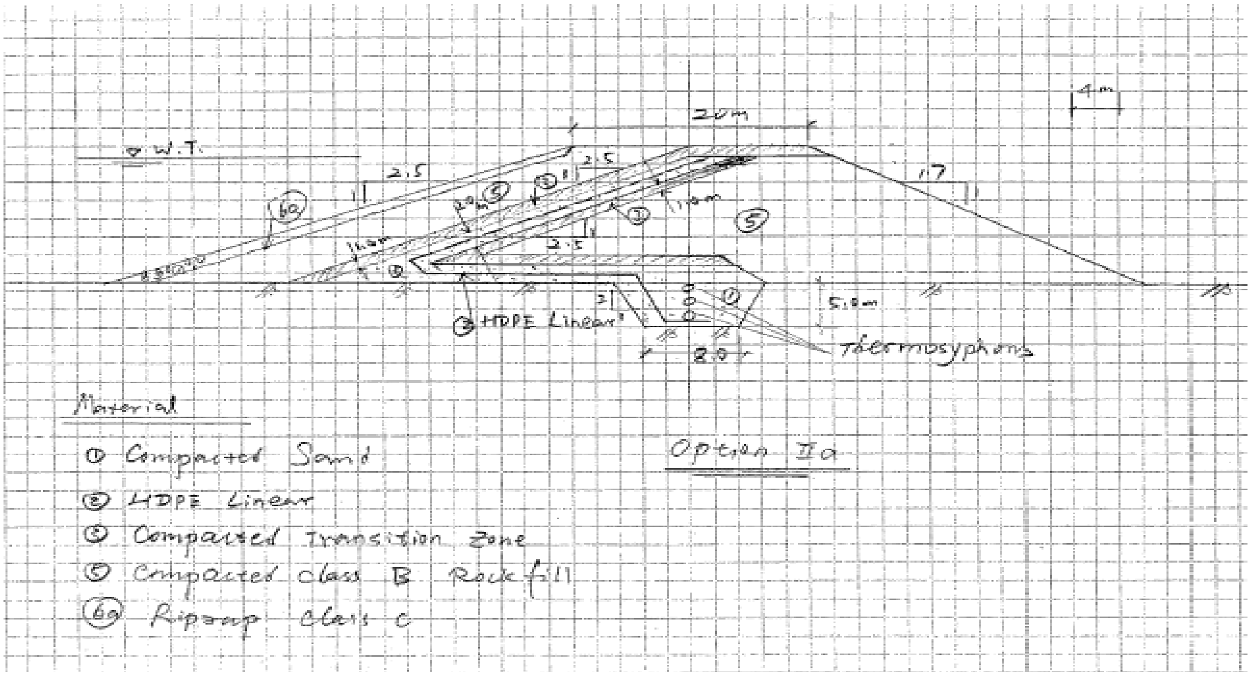


Figure 6-1: Typical Dam Cross Section

The dam consists of a rock fill dam with an HDPE liner as the primary seepage barrier. The main materials in this dam option consist of:

- Zone 1 – Bedding Material (Sand 0 – 13 mm or crusher fines)
- Zone 2 - Transient Zone
- Zone 3 – Compacted Rockfill
- Zone 5 - Riprap-Class C

This dam section has been considered to permit a small amount of seepage through the upper part of the dam to control the reservoir during normal operating condition. An additional liner is proposed to allow controlled seepage of water through the embankment without permitting it to enter the frozen key trench.

The estimated dam geometry consists of a 20 m wide crest (transportation requirement) for this dam, 2.5 H:1 V U/S slope gradient, 1.7 H:1 V D/S slope gradient, a frozen key trench extending 5 m below ground surface and thermal siphons to maintain the thermal regime of the key trench. The crest of this dam is used for access road and hence the crest width is design to be 20 m. For other dams, the crest width is set to be 5 m.

All of the dams use the same configuration with different crest elevation, spillway invert elevation and impermeable core elevation. These are summarized in Table 6-6 and Table 6-7.

Table 6-6: Dam Design Features (Minesite)

		Crest			Slope (H:V)		Spillway			Height m
		Elevation m	Width m	Length m	Up-stream	Down-stream	Width m	Side slope	Invert m	
Pond no. 1	Block Dam	355.0	5	150	2.5:1	1.7:1	-	-	-	25
	Sediment Dam	347.5	5	150	2.5:1	1.7:1	10	2:1	344.5	25
	Discharge Dam	329.0	5	150	2.5:1	1.7:1	10	2:1	326.0	25
Pond no. 2 Dam		547.5	20	800	2.5:1	1.7:1	10	2:1	544.5	27
Pond no. 3 Dam		204.5	5	400	2.5:1	1.7:1	10	2:1	203.5	12

Table 6-7: Dam Design Features (Steensby Inlet)

	Crest			Slope (H:V)		Spillway			Height m
	Elevation m	Width m	Length m	Up-stream	Down-stream	Width m	Side slope	Invert m	
Pond no. 1 Dam	13.0	5	600	2.5:1	1.7:1	10	2:1	10.5	8
Pond no. 2 Dam	40.0	5	500	2.5:1	1.7:1	10	2:1	38.0	6

7. Material Take Off Estimates

The material take off estimations are undertaken for the ditches and the dams. These MTO estimations reflects the current design conditions. Some of the design may be modified and hence new MTO estimations will have to be undertaken when changes are made.

7.1 Ditches

A. Mine Site Waste Rock Dump ditches:

- Excavation volume: 81,972 m^3
  - Riprap volume and filter: 21,274 m^3
  - Fill material volume: not expected
  - Geo textile: 62,597 m^2

B. Minesite Ore Stockpile Clean Diversion Water Ditch:

- Excavation volume: 2,400 m^3
  - Riprap volume: not expected
  - Fill material volume: not expected

C. Minesite Ore Stockpile Drainage Ditch

- Excavation Volume: not expected since the drainage ditch is on the edge of the platform and the ditch is located on the filled materials.
  - Riprap volume: not expected
  - Fill material Volume: 183,545 m^3

D. Steensby Island Drainage Ditch

- Excavation Volume: 38,300 m^3
  - Fill material Volume: 729,760 m^3

E. Steensby Clean Water Diversion Ditch

- Excavation Volume: 103,700 m^3
  - Fill material Volume: not expected

F. Steensby Drainage Ditch on the storage area

  - Excavation volume: 1,154,000 m^3
  - Fill material Volume: not expected

G. Milne Inlet Drainage Ditch

  - Excavation volume: 9,000 m^3
  - Fill volume: not expected

7.2 Dams

- Minesite Pond no. 1 Block Dam: 125,000 m^3
- Minesite Pond no. 1 Sediment Dam: 110,000 m^3
- Minesite Pond no. 1 Discharge Dam: 90,000 m^3
- Minesite Pond no. 2 Dam: 551,500 m^3
- Minesite Pond no. 3 Dam:
  - Fill materials: 152,837 m^3
  - Excavation at spillway: 855 m^3
- Steensby Inlet Pond no. 1 Dam: 285,000 m^3
- Steensby Inlet Pond no. 2 Dam: 11,300 m^3

8. Remaining Works

The current design deals with the overall stormwater management and drainage system for the Minesite, Steensby Inlet and Milne Inlet. The major structures were designed. There are still details to be completed in the next phase of the design. The detailed design includes:

- Hydraulic design of spillway structures, energy dissipater (if required) and erosion control measures. At this stage, the spillway dimensions were determined to make sure that the dams can pass the inflow design flood.
- The dam sections were designed to be stable under different load conditions. The section is not intended to have overflow on the dam body since the dam is embankment structure and overflow on the dam body shall be avoided. However, it is known that Pond no. 1 in Minesite and Pond no. 2 in Steensby may have to allow overflow on the dam body due to various constrains. For these dams, special design will be required to allow overtopping.
- Culverts at several locations where the ditches cross road and / or other structures. At these locations, culverts are needed.
- It has to be realized that the design is a dynamic process. Some of the design features may need to be adjusted to work with the requirements of other professionals. A few iterations between different requirements may be needed to make the entire system work. Therefore, some additional works are required to make the adjustments in the next phase of the design.

9. References

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Appendix A:

Dam Safety Assessment Memo

Project Memo

May 18, 2011

TO: John Binns
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Dam Safety Assessment

1 Introduction

The Mary River Project is a proposed iron ore mine and associated facilities ocated in northern Baffin Island, in the Qikiqtani Region of Nunavut. The Project involves the construction, operation, closure, and reclamation of a 21 million tonne-per-annum open pit mine that will operate for 21 years. The high-grade iron ore to be mined is suitable for international shipment after only crushing and screening with no chemical processing facilities. Three million tonne-per-annum of iron ore will be transported via an upgraded existing road to Milne Inlet where it will be stockpiled for shipment during the open water season. A railway system will transport an additional 18 Mt/a of ore from the mine area to an all-season deep-water port and ship loading facility at Steensby Port where to ore will be loaded into ore carriers for overseas shipment through Foxe Basin.

In the drainage system for stormwater management at the Milne Port, the Steensby Port and the mine site, dykes will be constructed for establishing stormwater management ponds. Based on the definition of Canadian Dam Association's Dam Safety Guidelines (CDA, 2007), a water retaining structure with storage over 30,000 m^3 and height exceeding 2.5 meters is defined as a dam and hence must meet the dam safety requirements. The dam safety requirements consistent of many aspects including risk management system, meeting the design standards and having proper operation, maintenance and surveillance procedures (OMS). And if the dam is classified as HIGH incremental hazard potential (IHP), a proper emergency preparedness and response plan (EPRP) is required.

Due to the fact that the embankment structures for stormwater management meets the CDA definition of dams, according to the 2007 CDA guidelines, a dam safety assessment (DSA) was performed to evaluate the incremental consequence category (ICC) classification. This assessment is necessary since many of the design parameters must be consistent with the CDA dam safety requirements. If a dam is designed and constructed but it does not meet the dam safety requirements, it will have to do costly modification to meet these requirements at later stage. The design criteria are different for each ICC rating. Therefore, a ICC classification must be assessed before any actual work starts.

This dam safety assessment (DSA) is not a full scaled DSA and hence it only addresses the main issues to allow the selection of proper inflow design flood and design earthquake. Many other aspects required by the CDA guidelines will have to be addressed later (for example, if a dam is classified as HIGH ICC structure, EPRP document must be prepared. If required, the EPRP will be done in later stage).

2 CDA Dam Classification and IDF Requirements

Dam classification forms the basis of dam design criteria. Every dam must first be classified based on consequences or risk of dam failure. The CDA dam classification system is presented in Table 2.1. In the table, a classification of consequences is based on three aspects: incremental loss for loss of life (LOL), Environmental and cultural values (EC), and infrastructure and economics (IE). Based on the degree of damages, each dam will be assigned a incremental consequence category (ICC). The inflow design flood (IDF) will be determined according to the ICC classification.

Table 2.1 Inflow Design Flood Requirement (CDA, 2007)

Table 2-1: Dam Classification

Dam class	Population at risk [note 1]	Incremental losses		
		Loss of life [note 2]	Environmental and cultural values	Infrastructure and economics
Low	None	0	Minimal short-term loss No long-term loss	Low economic losses; area contains limited infrastructure or services
Significant	Temporary only	Unspecified	No significant loss or deterioration of fish or wildlife habitat Loss of marginal habitat only Restoration or compensation in kind highly possible	Losses to recreational facilities, seasonal workplaces, and infrequently used transportation routes
High	Permanent	10 or fewer	Significant loss or deterioration of *important* fish or wildlife habitat Restoration or compensation in kind highly possible	High economic losses affecting infrastructure, public transportation, and commercial facilities
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 compensation in kind impossible	Extreme losses affecting critical infrastructure or services (e.g., hospital, major industrial complex, major storage facilities for dangerous substances)

Note 1. Definitions for population at risk:

None—There is no identifiable population at risk, so there is no possibility of loss of life other than through unforeseeable misadventure.

Temporary—People are only temporarily in the dam-breach inundation zone (e.g., seasonal cottage use, passing through on transportation routes, participating in recreational activities).

Permanent—The population at risk is ordinarily located in the dam-breach inundation zone (e.g., as permanent residents); three consequence classes (high, very high, extreme) are proposed to allow for more detailed estimates of potential loss of life (to assist in decision-making if the appropriate analysis is carried out).

Note 2. Implications for loss of life:

Unspecified—The appropriate level of safety required at a dam where people are temporarily at risk depends on the number of people, the exposure time, the nature of their activity, and other conditions. A higher class could be appropriate, depending on the requirements. However, the design flood requirement, for example, might not be higher if the temporary population is not likely to be present during the flood season.

Table 2.2 The IDF requirement corresponding to each of the ICC classification

Consequence Class	IDF
Low	1/100-year
Significant	Between 1/100 and 1/1000-year (Note 1)
High	1/3 between 1/1000-year and PMF (Note 2)
Very High	2/3 between 1/1000-year and PMF Note 2)
Extreme	PMF

Note 1. Selected on basis of incremental flood analysis, exposure and consequence of failure.
Note 2. Extrapolation of flood statistics beyond 1/1000-year flood (10^{-3} AEP) is generally discouraged. The PMF has no asssociated AEP. The flood defined as "1/3 between 1/1000-year and PMF" or "2/3 between 1/1000 year and PMF" has no defined AEP.

According to the CDA 2007 Dam Safety Guidelines, each dam has to be evaluated separately. This memo describes the results of the assessment for each structure in the mine site, the Milne port and Steensby Port. At this stage, there is no dam safety guidelines in Nunavut and hence the assessment will use the CDA guidelines as the basis of the evaluation.

3 ICC Classification

3.1 Minesite Stormwater Pond No. 1 Discharge Dam

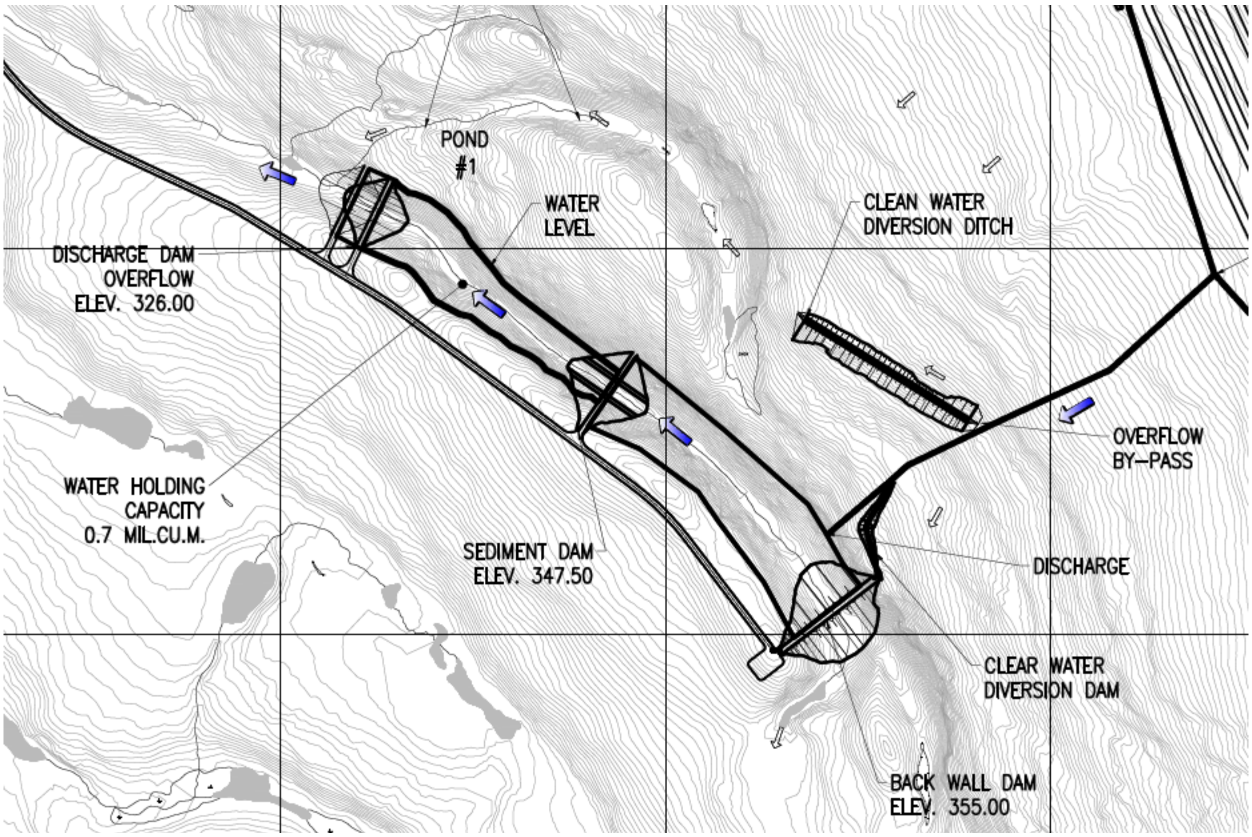

Figure 3-1 Dam Locations of Pond No. 1

This dam is the downstream most structure to retain stormwater in Pond no. 1. The dam is shown on Figure 3-1 has an overflow weir at elevation 326 m. Te length of the dam at the crest is about 150 m. The height of the dam is about 25 m. The dam retains 0.7 million m^3 of water at the normal water level. If the dam fails, the released water will be discharged to the downstream area and eventually be stored in Camp Lake.

There is an access road which may have some erosion damages. In the downstream area, there is no permanent residents and hence no loss of life (LOL) will be resulted. The sediment in the pond will be released to the downstream area and may reach Camp Lake. The sediment will settle in Camp Lake leading to some environmental damages to the lake water quality. The water in Camp lake is used for water supply and hence this high concentration of sediment may have some impacts to the water quality According to this description, the dam will have zero (0) LOL. There will be no third party economic losses. Therefore, this dam is classified as LOW incremental consequence category (ICC) for LOL and

Economics. With respect to the environmental losses, the ICC is classified as SIGNIFICANT due to the impacts to water quality in the downstream area.

The overall ICC category is then SIGNIFICANT.

Based on the CDA guidelines, the inflow design flood shall be between 1:100 year and the 1:1,000 year flood. Due to the relatively low impacts to the downstream area from LOL and economic aspects, and is significant for environmental impact, a 1:200 year design flood is appropriate.

For earthquake, the design level will be the 1:1,000 event based on the CDA guidelines.

3.2 Minesite Stormwater Pond No. 1 Sediment Dam

This dam is located upstream of the discharge dam (Figure 3-1) and downstream of the back wall dam. This dam is acting as sediment barrier for the stormwater pond. The dam is approximately 25 m high and crest length is about 150 m. The crest elevation is at 347.50 m. If the dam fails, the water will be retained in the downstream pond between the discharge dam and the sediment dam. Then if the discharge dam fail because of the failure of the sediment dam, the ICC is SIGNIFICANT. Therefore, the sediment dam will have the same ICC classification as the discharge dam. The design flood shall therefore be the 1:200 year event. The design earthquake will be the 1:1,000 year event.

3.3 Minesite Stormwater Pond No. 1 Back Wall Dam

The back wall dam is located on the upstream end of the stormwater Pond no. 1 to form the upstream cell of the pond. The dam is 25 m high and about 150 m long at the crest. If the dam fails, there will be no LOL and no third party economical damages. The environmental impact would be significant because the released water contains high concentration of sediment from the waste rock stockpile. The overall ICC category assigned to this dam is SIGNIFICANT.

The inflow design flood for this dam shall be the 1:200 year flood and the design earthquake is the 1:1,000 year event.

3.4 Minesite Stormwater Pond No. 2 Dam

Figure 3-2 shows the location of the Pond no. 2 dam. This dam is approximately 15 m high and 800 m long at the crest. The volume of water stored is in the order of 500,000 m^3. The dam crest is an access road. The dam discharges to the Mary River.

If the dam fails, the outflow will enter Mary River and be discharged to the downstream water course. There will be no LOL since there are no residents in the downstream area. The economical damage will be the road operation which is a short term and internal damages. There is no third party damages. Therefore the ICC for LOL and economical damages are LOW.

For environmental damages, there will be high concentration of sediment released to the Mary River and this will lead to water quality problem. But the impact shall be short term water quality problem. The ICC classification for this dam is therefore SIGNIFICANT.

Based on this classification, the inflow design flood shall be the 1:200 year flood and the design earthquake will be the 1:1,000 event.

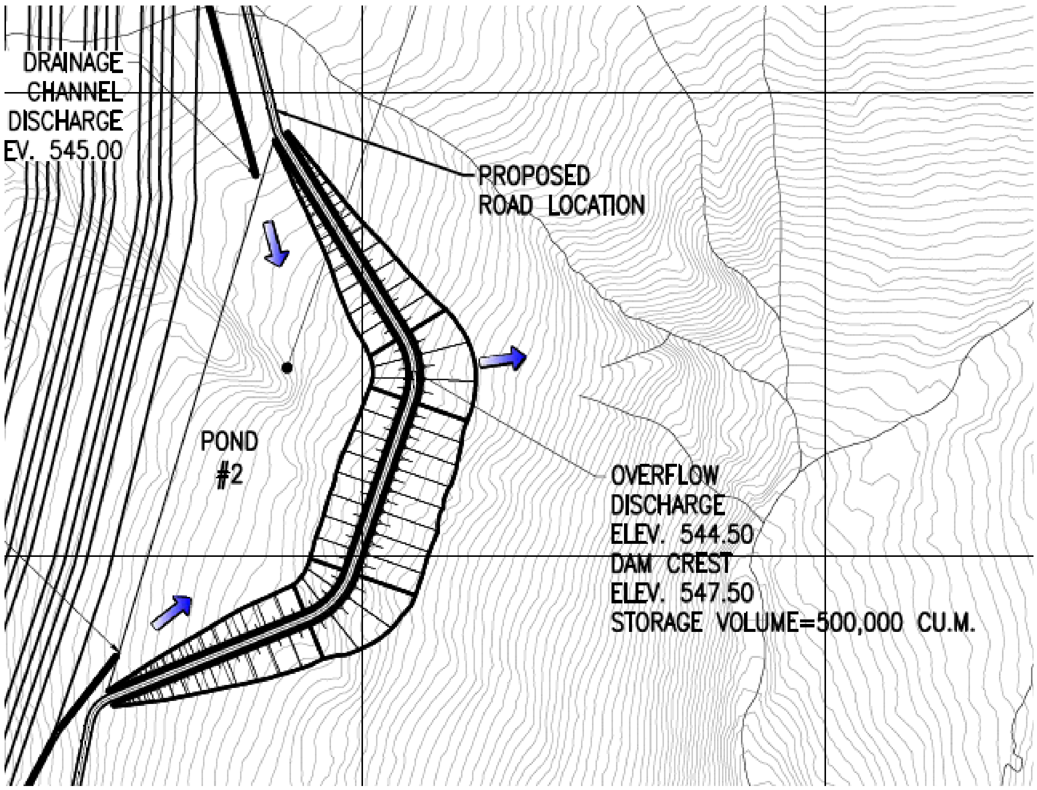

Figure 3-2 Minesite Pond No. 2 Dam

3.5 Minesite Stormwater Pond No. 3 Dam

This dam is located downstream of ROM Stockpile to form the stormwater management pond. The dam is shown on Figure 3-3.

The dam crest elevation is 264.30 m. The dam is 9.3 m high and about 150 m long. The storage is 35,000 m^3.

The failure of this dam will lead to no LOL and third party economical damages and hence the ICC for LOL and Economic damages are LOW. The failure of the dam will lead to high concentration of sediment be released to Mary River which will have short term water quality impacts to the river. The ICC assigned to the dam for Environmental aspect is SIGNIFICANT. And the overall ICC classification is SIGNIFICANT.

The inflow design flood shall therefore be the 1:200 year flood and the design earthquake is the 1:1,000 year event.

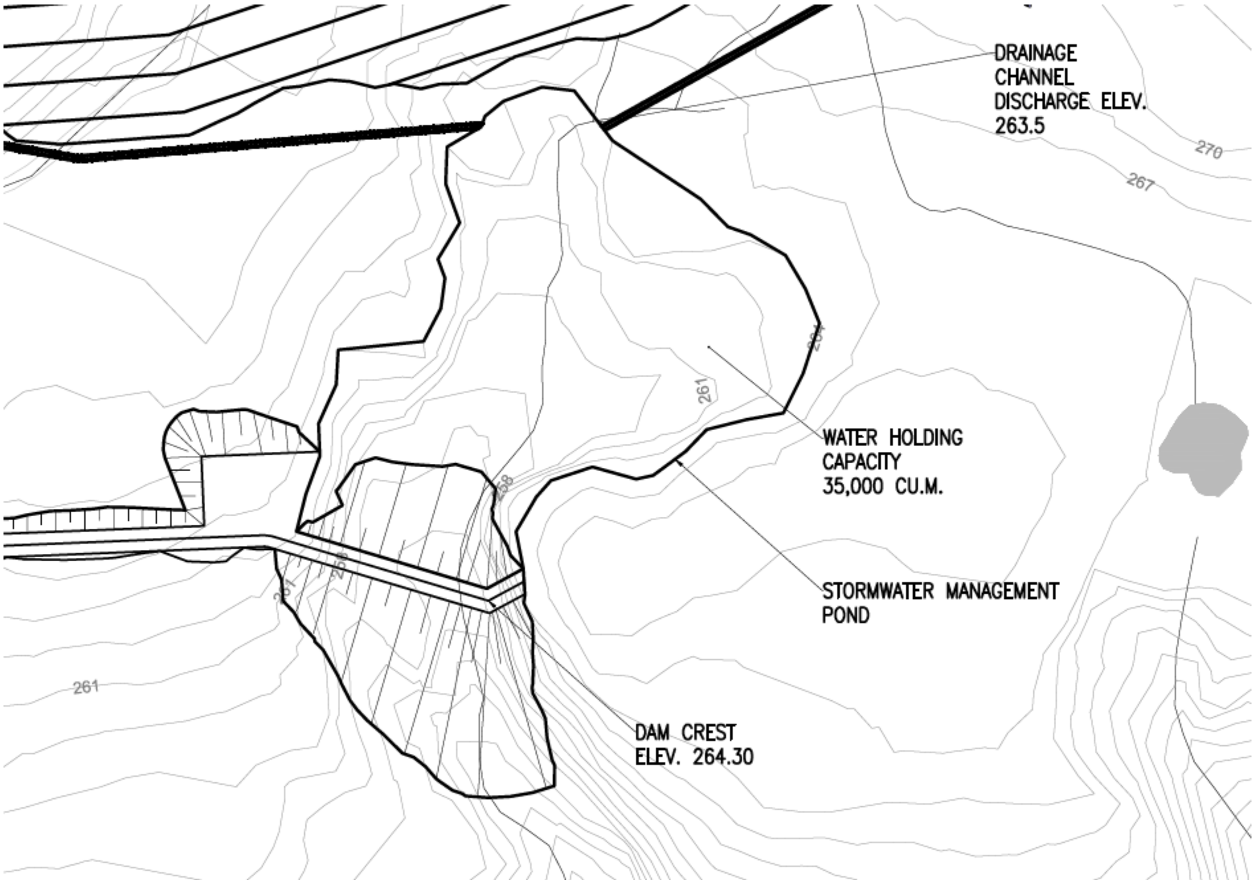

Figure 3-3 Stormwater Management Pond No. 3 Dam

3.6 Minesite Stormwater Pond No. 4 Dam

This dam is located just upstream of the waste water clarification pond. The dam is about 12 m high and more than 400 m long. The storage capacity of the pond is 150,000 m^3. If the dam fails, there will be no LOL and third party economical damages. Therefore the ICC for LOL and economical losses are LOW. The released water will lead to water quality problem in Sheardown Lake. The ICC classification for environmental impact is SIGNIFICANT. The overall ICC for this dam is then SIGNIFICANT.

The inflow design flood shall be the 1:200 year flood and the design earthquake level is the 1:1,000 year event.

The dam is shown on Figure 3-4.

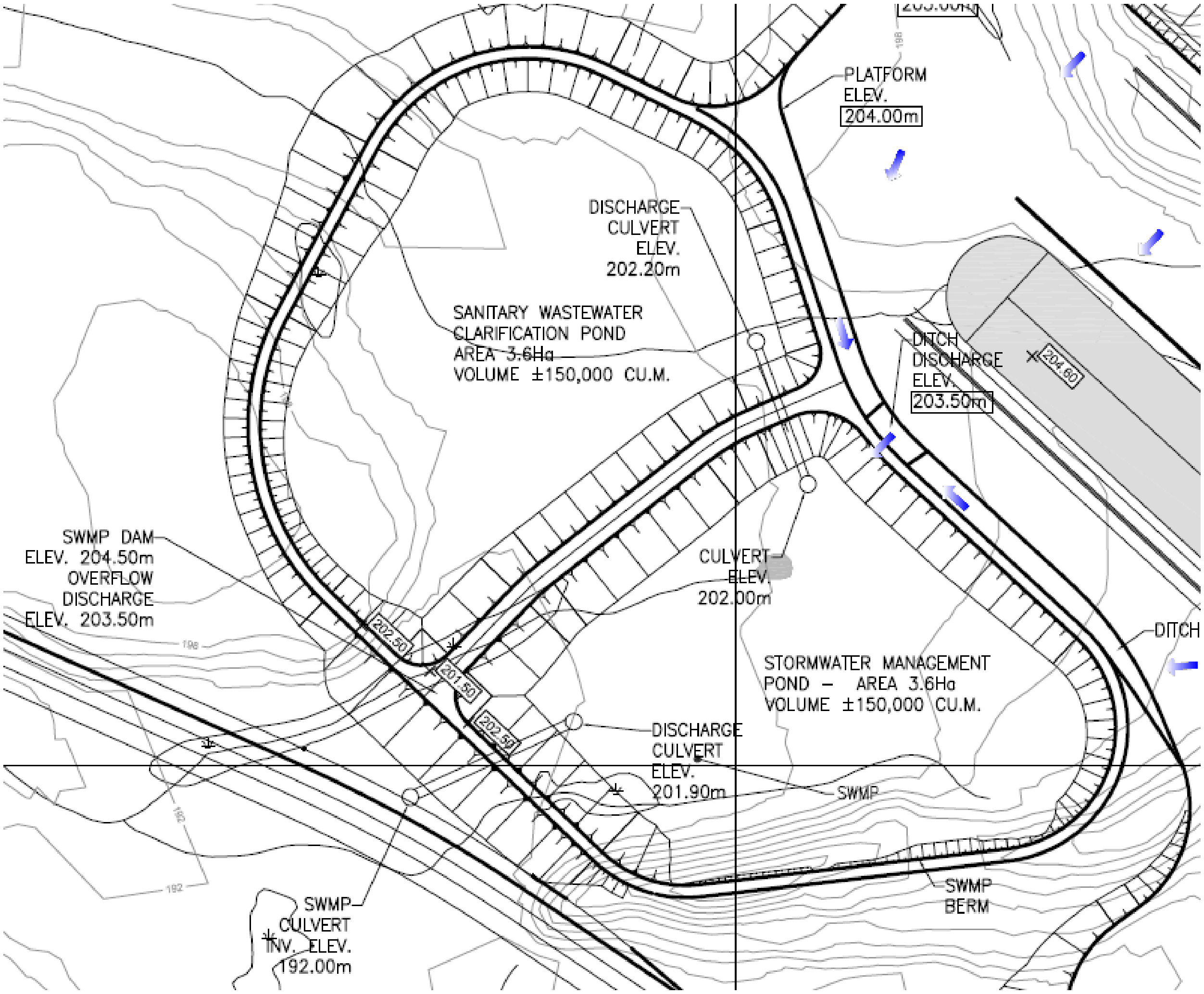

Figure 3-4 Stormwater Management Pond No. 4 Dam

3.7 Milne Port Stormwater Pond No. 10 Dam

This dam is shown on Figure 3-5. This dam is located on the west side of the proposed ore stockpiles in the port operating area. The pond collecting runoff from the stockpile and then the runoff will be pumped to Pond no. 9. The storage capacity of the pond is 40,000 m^3, the dam height is about 6 m. and the crest length is about 250 m.

If the dam fails, the storage will be discharged to Phillips Creek. The downstream 1,200 m runway will be flooded. There will be no LOL and no third party economic losses. The ICC for LOL and economical losses are LOW. The released sediment will lead to environmental damages to the downstream Phillips Creek. The environmental loss is classified as SIGNIFICANT. The overall ICC is SIGNIFICANT.

The IDF for this dam shall be the 1:200 year flood and the design earthquake is the 1:1,000 year event.

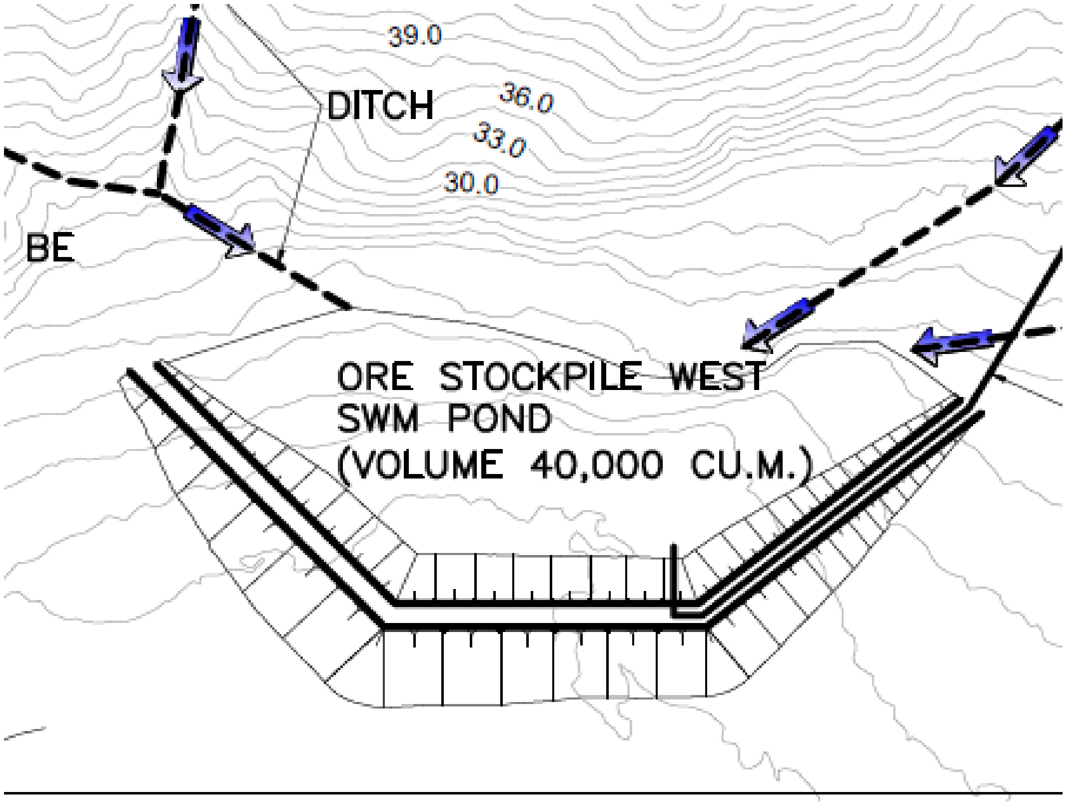

Figure 3-5 Pond No. 1 Dam (Milne Port)

3.8 Milne Port Stormwater Pond No. 9 Dam

This dam is the ore stockpile east pond within the platform. The dam crest is 52 m and the depth of the dam is about 6 m. The total storage of pond has is 200,000 m^3. There will be no LOL and third party economical damages if the dam fails since the pond is located just upstream of the ocean and hence the failure of the dam will lead flows be discharged into the ocean. Therefore, the ICC for LOL and economical damages are LOW. The released water contains high concentration of sediment which will lead to some environmental damages to the downstream water body. The ICC for environmental damages is SIGNIFICANT.

To properly design the dam, a 1:200 year flood shall be used for inflow design flood and the design earthquake is the 1:1,000 year event.

Figure 3-6 shows the general layout of the proposed stormwater management pond.

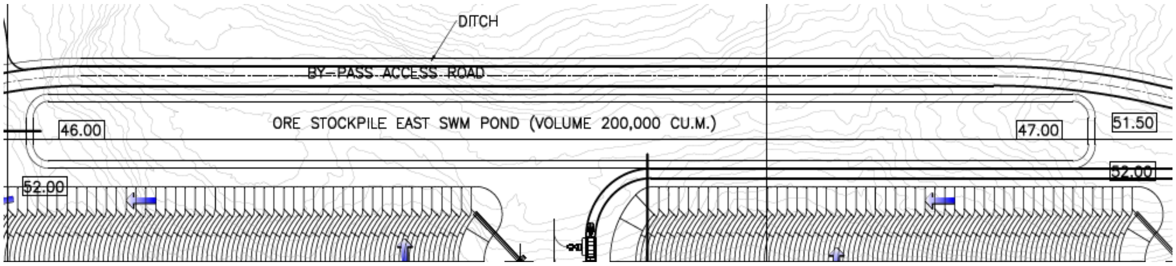

Figure 3-6 SWM Pond no. 9, Milne Port

3.9 Steensby Port, Ore Stockpiles Stormwater Management Pond Dam

This dam is shown on Figure 3-7. The dam is about 8 m high and 600 m long. The pond has a storage capacity of 125,000 m^3. There will be no LOL and third party economical damages if the dam fails since the pond is located just upstream of the ocean and hence the failure of the dam will lead flows be discharged into the ocean. Therefore, the ICC for LOL and economical damages are LOW. The released water contains high concentration of sediment which will lead to some environmental damages to the downstream water body. The ICC for environmental damages is SIGNIFICANT.

To properly design the dam, a 1:200 year flood shall be used for inflow design flood and the design earthquake is the 1:1,000 year event.

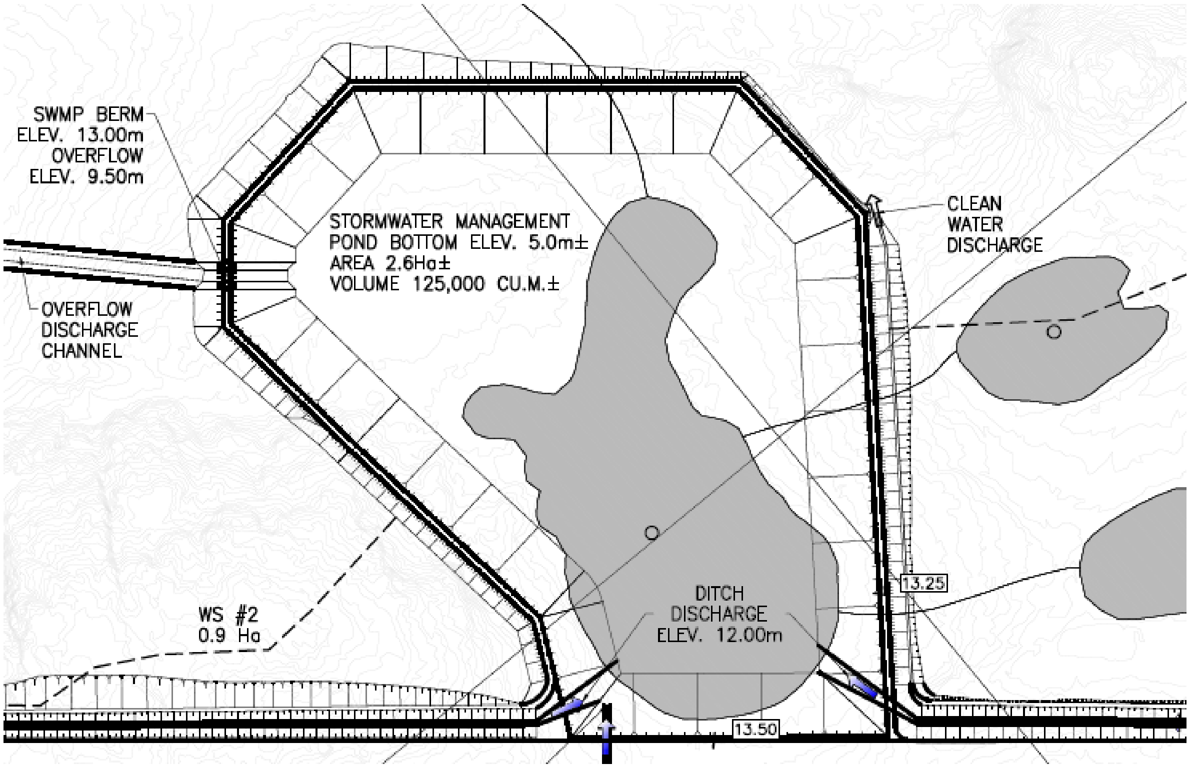

Figure 3-7 Steensby Port Ore Stockpile Stormwater Management Pond

3.10 Steensby Port, Platform Stormwater Management Pond Dam

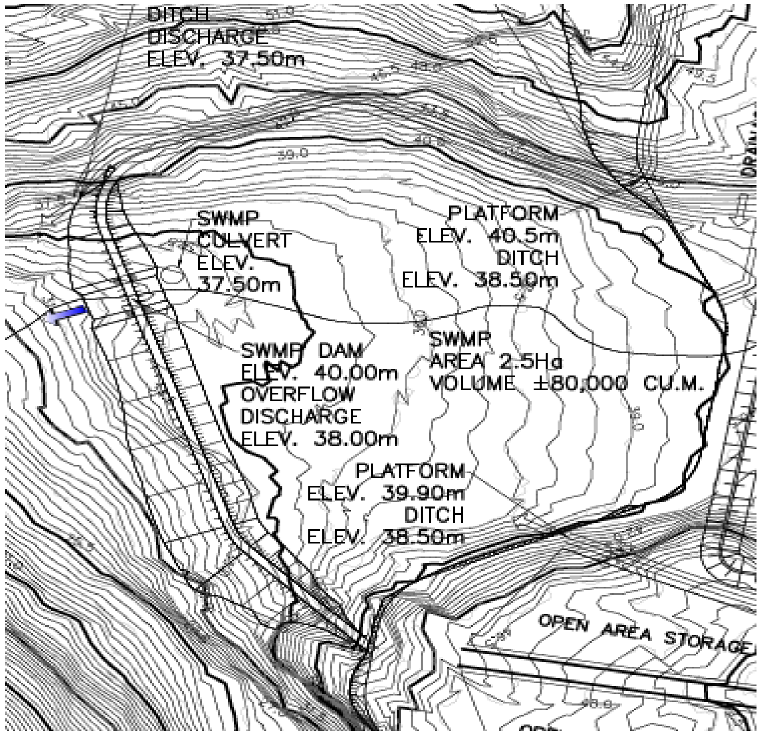

Figure 3-8 Platform Stormwater Management Pond Dam

This dam is located at the west side of the platform for collecting stormwater from the platform area. The dam height is about 4 m and the length of the crest is about 500 m. The total storage is about 80,000 m^3.

If the dam fails, there will be no LOL and third party economical damages. The ICC for LOL and economical losses are LOW. for environmental damages, there will be short term water quality problem to the ocean. The ICC for environment perspective is therefore SIGNIFICANT. The overall ICC is SIGNIFICANT.

Therefore, the inflow design flood for this dam shall be the 1:200 year flood and the design earthquake is the 1:1.000 year event.

4 Freeboard Requirement

For preventing overtopping of the crest during significant wind event, a minimum of 0.9 m freeboard is required during the passage of the inflow design flood (USBR, 1987).

5 Conclusions

It is concluded based on this assessment that:

1. The stormwater management dams have a SIGNIFICANT ICC classification based mainly on environmental damages to the water quality. The LOL and economical damages are LOW. Due to this ICC rating, the inflow design floods and design earthquake are determined.
2. The inflow design flood corresponding to the SIGNIFICANT ICC rating shall be the 1:200 year flood. The IDF will be used for designing the spillways for each of the dams.
3. The design earthquake level will be the 1:1,000 year event. The design earthquake will be used for determining the embankment stability during dynamic conditions.

6 References:

1. Baffinland Iron Mines Corporation, 2010, Mary River Project, Environmental Impact Statement
2. CDA, 2007, Dam Safety Guidelines, Canadian Dam Association
3. USBR, 1987, Design of Small Dams, A Water Resource Technical Publication, US Bureau of Reclamation