Hydromet Plant Residue Storage Options

for the

Commercial Nickel Processing Plant

at

Long Harbour

Newfoundland and Labrador

April 2008

Executive Summary

VALE Inco Newfoundland and Labrador Limited (Vale Inco NL) is proposing to design, construct, operate and eventually decommission a Commercial Nickel Processing Plant in a safe, healthy and environmentally sound manner which will benefit all the stakeholders in accordance with the terms of the *Voisey's Bay Development Agreement*[1]. The proposed hydrometallurgical process generates residue that requires long-term storage in a containment area that meets the required technical, environmental, socio-economic and economic criteria for acceptable operation, decommissioning and closure.

This report describes the residue properties and reviews the alternatives and the decision-making processes used to select the optimum disposal method and location for the long-term storage of the Hydromet Plant residue. The chemical and physical characteristics of the residue, the behaviour in the environment, the methods considered for long-term storage, the closure strategy, the potential site locations for storage, the site selection criteria and evaluation process, the site selected and the reasons for the selection are also described.

This evaluation of the residue storage options is based on a project life of 15 years. Should opportunities for an extended operating life arise in the future, subsequent planning for this would be subject to all applicable approval processes at that time.

Two separate residue types result from the processing of concentrate in the Hydromet Plant. One of the residues contains elemental sulphur with significant acid-generating potential which may mobilize trace metal ions contained in the residue after disposal. The second residue is a gypsum residue which contains iron removed during the processing of the nickel concentrate; this residue has good neutralization potential. The disposal methods considered were either above-ground (sub-aerial) or under water (sub-aqueous). The residue transport method, as either a slurry or as a paste, was investigated together with the implications for storage of these products.

Following the completion of extensive test work, studies and modeling, the selected disposal method was to transport the combined sulphur and gypsum residues as a slurry for sub-aqueous disposal in a natural water body.

Twelve sites were identified as potential sub-aqueous storage sites for the combined residue: seven land based sites and five natural water bodies. These sites were identified based on their storage capacity, topography, watershed, pipeline routing and proximity to the plant site. The option of direct disposal into Long Harbour was not considered since the deposition of residues in an uncontrolled and uncontained environment is prohibited by Canadian law.

The twelve candidate sites were assessed using a Multiple Accounts Analysis methodology.[2] The candidate sites were ranked using criteria grouped into four master categories: environmental, technical, socio-economic and economic. As well a sensitivity analysis comparing different weighting for the master categories was conducted. The results of the Multiple Accounts Analysis and the sensitivity analysis resulted in Sandy Pond being ranked as the most suitable storage site. As a result of this comprehensive assessment, Sandy Pond was selected as the proposed site for long-term sub-aqueous storage of the combined residue from the Hydromet Plant.

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1.0 Introduction

Vale Inco NL is proposing to construct, operate and eventually decommission a Commercial Nickel Processing Plant (the Hydromet Plant) at Long Harbour.

There are two residue types generated at the proposed Hydromet Plant: neutralized leach residue (NLR) and neutralized iron-gypsum residue (FGR). Neutralized combined residue (NCR) is the product of the combination of NLR and FGR.

The plant would process approximately 269,000 tonnes/year of concentrate to produce 50,000 tonnes/year of refined nickel metal and associated cobalt and copper products. This annual production rate would generate 386,000 tonnes of neutralized combined residue (NCR) which would be made up of 241,000 tonnes of neutralized leach residue (NLR) and 145,000 tonnes of neutralized iron-gypsum residue (FGR).

Over the planned 15 year operating life of the facility, a total of 5.8 million tonnes of residue would be generated requiring approximately 6.5 million m^3 of permanent storage volume.

This report addresses the residue properties and the options and decision-making processes used to select the optimum methods and locations for the long-term storage of the residues generated by the hydrometallurgical process.

The residue storage area must have sufficient capacity to safely store the residues over the operating life of the plant and must be amenable to secure storage and rehabilitation during the decommissioning, closure and post closure phases. Adequate contingency capacity should be provided in the original design and consideration should also be given to the potential extension in project life which would require a significant additional storage capacity.

2.0 Methodology for Evaluating Residue Storage Alternatives and Site Selection

The following description summarises the steps that were followed to select the most appropriate residue storage site.

Step 1 Determine the physical and chemical properties of the two primary individual residues and the combined residue. Investigate how they are generated, their quantities, and geotechnical and geochemical characteristics. It is important to understand the short and long-term behaviour of the individual and combined residues under sub-aerial (above ground) and sub-aqueous (under water cover) conditions. A comprehensive program was developed and implemented to evaluate this behaviour.

Step 2 Evaluate the possibility of removing sulphur from the neutralized leach residue to reduce its acid-generating properties which would potentially allow disposal as a non acid-generating material.

Step 3 Identify and thoroughly evaluate the residue disposal options for the individual and combined residues.

Step 4 Select the preferred residue storage concept.

Step 5 Identify candidate residue storage sites.

Step 6 Select a list of candidate sites based on minimum criteria requirements.

Step 7 Define the master groupings and criteria for ranking the potential storage sites using a Multiple Accounts Analysis methodology.

Step 8 Rank the candidate storage sites.

Step 9 Perform a sensitivity analysis on the master groupings.

Step 10 Select the best storage site.

3.0 Process Description and Chemical Composition

3.1 Process Description

The hydrometallurgical process uses pressure oxidative leaching to separate metals within concentrate. Subsequent purification steps lead to the generation of purified nickel, copper and cobalt streams, from which the metals are recovered by electro-winning. Iron and sulphur are removed as a residue during leaching. A gypsum residue is also generated during one of the impurity removal steps. The complete process is indicated in block flowsheet format in Figure 3.1.

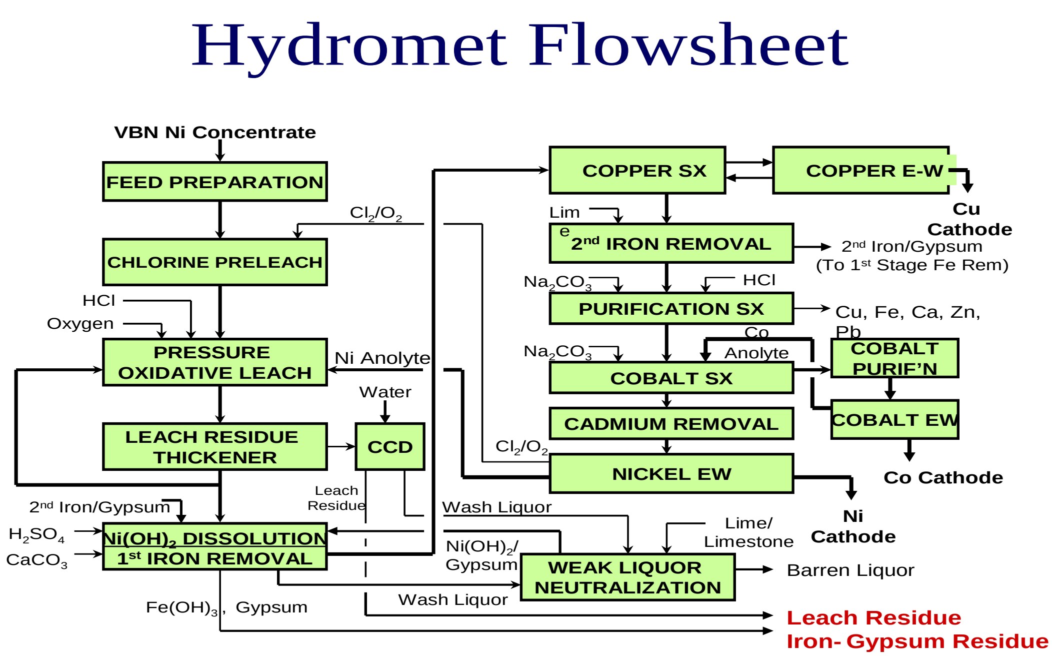

Figure 3.1 Hydromet Flowsheet

As shown in the flow sheet there are two main waste products generated:

Neutralized Leach Residue (NLR) - The pressure oxidation leaching step in the process produces a residue which, after settling, is washed in a series of thickeners to reduce the soluble nickel in the entrained solution and is collected as thickened underflow (about 40% solids) from the last thickener. The washed and thickened leach residue slurry is then neutralized by addition of lime to approximately 10.5 pH.

Neutralized Iron-Gypsum Residue (FGR) - A second residue is produced in an iron precipitation stage where nickel hydroxide, recycled from a downstream weak liquor neutralization step, is dissolved and most of the iron in the solution is precipitated by neutralization with limestone, lime and air. The precipitated iron hydroxide and gypsum (calcium sulphate) are separated by thickening followed by two stages of washing and filtration. The washed solids are neutralized with lime to approximately 10 pH.

3.2 Residue Chemical Composition

The neutralized leach residue (NLR) consists of predominantly hematite (iron oxide) and elemental sulphur. This residue also contains minor amounts of unreacted iron-nickel sulphide (pentlandite) and iron-copper sulphide (chalcopyrite), precipitated nickel and copper hydroxides and partially hydrated ferric oxide. Extensive electron microprobe and X-Ray diffraction studies carried out by CANMET[3] indicate that the elemental sulphur is present in the form of spheroids (~10 μm) mixed with tiny particles of iron oxide (~1 μm) and minor amounts of partially hydrated ferric oxide, some of the sulphur occupies the hollow cores of iron oxide shells.

The iron-gypsum residue (FGR) consists of gypsum with a small amount of ferric hydroxide, electron microscope images show that it is made up of very fine, short, orthorhombic crystals.

The neutralised combined residue (NCR) is a combination of the above two residues.

Table 3.1 Composition of Hydromet Residues

Chemical Composition	Residue Type		
	NLR	FGR	NCR
Iron Oxide (wt %)	62.7	0	37.9
Iron Hydroxide (wt %)	0	5	3.6
Gypsum (wt%)	11.4	94	41.2
Elemental Sulphur (wt%)	25	0	16.6
Nickel (wt%)	0.4-0.6	0.1	0.3-0.5
Copper (wt%)	0.4-0.6	0.04	0.3-0.5

Note: Totals do not add up to 100% due to other very minor substances present in the residues (aluminum and silicon oxides, calcium carbonate).

A complete description of the geotechnical and geochemical properties of the different residue types is included in Appendix A. This provides a summary of the results from an extensive test program developed to characterize and quantify the long-term behaviour of the residues under alternative disposal conditions.

3.3 Investigation into Sulphur Removal from the Residue

The potential for elemental sulphur oxidation was evaluated for both sub-aerial and sub-aqueous storage of the residues in specially designed lysimeter test tanks. These tests are in their fourth year of operation and acidification and metal mobilization has been confirmed in both the NLR and NCR. The observed rates of metal mobilization, however, in the sub-aqueous tests are extremely low in comparison to the rates observed in the sub-aerial tests.

One method of reducing the acid-generating potential of the residue would be to remove the sulphur from the residue prior to storage. This possibility was evaluated based on an existing flotation technology method applied to the separation of elemental sulphur from zinc pressure leaching plant residues, as is currently practiced in the mining industry.

A test program was developed and implemented at the Vale Inco Technical Services Laboratory to investigate the potential process options. The results of this test work indicated the following:

- The test process failed to produce a non acid-generating product;
- An intermediate product is formed which contains 70 % of the initial elemental sulphur, this product is difficult to dispose of and has no commercial value;
- Two waste streams are generated from the original single residue stream, both of which retain significant acid generating potential, thus compounding the initial disposal problem.

Based on the results of the laboratory work and a review of the commercial operations it was concluded that separation of elemental sulphur from the Hydromet residue is technically infeasible and would therefore not be considered further.

For a detailed description of the sulphur removal test program and a summary of results refer to Appendix A.

4.0 Sub-aerial versus Sub-aqueous Disposal and Storage

4.1 Description of Residue Disposal and Options

Two main alternatives for residue disposal were considered: sub-aerial (no water cover) and sub-aqueous (with a water cover).

4.1.1 Sub-aerial Residue Disposal and Storage

Sub-aerial residue disposal can be achieved by pumping the residue either as a slurry or as a thickened slurry (paste) to a suitable containment area. The main advantage of sub-aerial deposition is that it reduces fish habitat losses and it does not require the establishment of a water cover. In a dry climate, sub-aerial disposal in the form of a paste allows for maximum water conservation. In locations where underground or open pit mining occurs close to the processing plant, a paste could be produced and disposed as a backfill material underground. Deposition of the residue as a paste reduces the footprint of the storage site and the size of engineered dams. Disposal as a paste eliminates segregation of fines during deposition, resulting in a more uniform deposit with improved consolidation characteristics.

There are several disadvantages and/or challenges associated with sub-aerial disposal. Since suitable dry land based areas are usually located on topographical highs, extensive dam construction for tailings slurries will be required and suitable bedrock must be found to build safe dams. Residue contained by dams presents a considerable environmental risk to downstream watersheds upon dam failure. Since the Hydromet residue may generate acid, groundwater contamination is a potential concern, therefore a synthetic liner must be considered.

In addition, surface cracking and acidification with associated metal remobilization will remain a concern during operation and post closure for sub-aerial sites, whether the residue is deposited as a slurry or as paste. A major disadvantage of sub-aerial residue disposal as a paste is the high energy costs associated with pumping the slurry to the disposal site.

Mitigation measures for sub-aerial disposal include the provision of a water treatment plant for excess contaminated water and the installation of engineered dry covers after closure of a disposal site. Dry covers that prevent/minimize water infiltration and oxygen flux can take the form of multiple soil layers and/or geosynthetics (e.g. HDPE geomembrane). While dry covers minimize oxygen-water infiltration, they cannot be guaranteed for long-term post closure mitigation. Dry covers are susceptible to degradation by natural causes (freeze/thaw), long term residue consolidation, vegetation growth and rodent activity. In a wet climate, groundwater monitoring, return water treatment and dam maintenance will therefore be required in perpetuity.

Desirable residue properties for sub-aerial storage include: rapid settling when deposited as a slurry, good filtration properties if deposited as a filter cake, non acid-generating, high strength for traffic-ability, low susceptibility to dusting and minimum need for long term monitoring after closure.

Test results indicate that both the neutralized leach (NLR) and combined residue (NCR) exhibit properties which lack the desirable features for sub-aerial storage. Both have very poor filterability (therefore the residues cannot be stored by dry stacking), are slow settling if deposited as a slurry (thus requiring a large settling area) and become increasingly more acid-generating in sub-aerial cycles of wet and dry conditions. The NLR and NCR can be deposited as a paste, but due to the narrow range of pumpable % solids (60 to 63) the paste plant would need to be located near or at the storage site. This would require pumping of the residue as a slurry to the paste plant with the excess water being pumped back to the Hydromet plant. Although the size of the storage site can be reduced when the residue is produced as paste, the surface of the residue will still be subject to the same risk of acidification as with slurry stacking. The NLR and NCR residues are also susceptible to significant dusting upon drying due to the micron size iron-oxide particles in the residue. Dusting has been observed at the Demonstration Plant in Argentia.

Elemental sulphur generated from other industrial de-sulphurization operations is commonly poured into large blocks and stored in sub-aerial piles. This technique minimizes the surface area exposed to air and water. Nevertheless, acid production from the sulphur blocks is still a concern and management problem. Research is currently ongoing in Canada to investigate potential alternative underground storage methods to handle this material.

In contrast to sulphur blocks, the elemental sulphur in the Hydromet residue is present as micron sized particles. The surface area per unit weight of sulphur in the NCR and NLR residues is extremely high, which contributes to the high acid generating potential. Acid generation is limited only by access of oxygen from the air, water infiltration and seasonal temperature variations, therefore NLR and NCR residues are not suitable for sub-aerial storage.

The iron-gypsum residue (FGR) (unlike the NLR and NCR), is suitable for sub-aerial storage. The residue filters well, settles rapidly, is non acid-generating and shows the required strength for traffic-ability. Dusting is only a problem if dried residue is disturbed by traffic and this is relatively easily overcome by irrigating traffic areas. Both dry and wet stacking could apply for this residue. Because of the climate wet stacking would be the preferred storage option for the FGR.

4.1.2 Sub-aqueous Residue Disposal and Storage

The disposal of residue under a water cover represents the most reliable technology for containment of acid-generating residue because it limits access of oxygen to the residue. Sub-aqueous disposal can be achieved by pumping the residue in the form of a slurry either to a natural water body (pond), or an artificial containment area in which a water cover can be established and maintained. To be effective a water cover must be sufficiently thick to prevent re-suspension of solids due to pond wave action and seasonal turnover. An accepted engineering standard is to use a minimum water cover of 1m.

Residue deposition in a natural water body has the additional advantage of minimizing the need for dam construction and the risks associated with dam failure and residue spillage into downstream watersheds.

The use of engineered or man-made sites for sub-aqueous residue deposition presents many challenges, most notably the establishment and maintenance of a water cover during and after closure. Engineered land based sub-aqueous sites may also require lining as well as extensive dam construction thus increasing risk of long-term groundwater contamination. Dam failure could potentially result in total release of the residue into the downstream watersheds.

Mitigation measures include the provision of a water treatment plant for excess water from the site during operation and for a limited period after closure, and the placement of a sand cover after closure to form a physical barrier which further reduces the access of oxygen to the residue.

The low hydraulic conductivities of the NCR and NLR (estimated to reach ~ 10^{-6} cm/sec at closure based on the geotechnical studies) are positive features for the placement of these residues in sub-aqueous mode. This is because the low hydraulic conductivity limits potential seepage into the groundwater and also limits the physical transport of oxygen into the residues. Because of the very high acid-generating potential of the NCR and NLR and their favourable low hydraulic conductivities, these residues are best stored under a water cover.

The FGR is primarily composed of calcium sulphate. Sub-aqueous storage of this residue would result in complete dissolution of the residue as the water flows through the storage pond and eventually makes its way into Long Harbour. FGR is unsuitable for sub-aqueous storage.

4.2 Separate versus Combined Residue Disposal and Storage

The results of the storage option evaluation are summarized in Table 4.1. The geochemical studies have shown that both the neutralized leach residue (NLR) and the neutralized combined residue (NCR) contain elemental sulphur which cannot be effectively removed from the residues in order for them to behave as non acid-producing residues. Based on the results of sub-aerial and sub-aqueous testing of these residues, sub-aqueous storage of the NLR and NCR residues is the only viable option. The iron-gypsum residue (FGR), when stored separately from NLR, was shown to require sub-aerial storage to prevent it from complete dissolution and discharge to the natural environment.

Table 4.1 Summary of Disposal Option Evaluation

Residue	Sub-aqueous	Sub-aerial (stacking)	Sub-aerial (paste)
NLR	Slow acidification, forms a self-sealing, low permeability residue that slows seepage of contaminants into groundwater, separate storage of NLR and FGR would require two storage sites	Rapid acidification, would require effluent treatment system in perpetuity, not a viable option.	Rapid acidification, would require effluent treatment system in perpetuity, not a viable option.
FGR	Dissolves completely under water cover, not a viable option	Can be successfully stacked, separate storage of FGR from NLR would require two storage sites.	Can be stored as paste. Separate storage of FGR would require two storage sites.
NCR	Behaves similarly to NLR, slow acidification under water cover, forms a self-sealing, low permeability residue that slows seepage of contaminants into groundwater, combined residue occupies less volume than sum of individual residues, closure simpler with less long-term environmental management required, only one storage site.	Rapid acidification, would require treatment system in perpetuity, not a viable option.	Rapid acidification, would require treatment system in perpetuity, not a viable option.

Two options for the storage of the Hydromet Plant residues remain for consideration:

1. Sub-aqueous storage of the combined residues (NCR).
2. Sub-aqueous storage of the neutralized leach residue (NLR) coupled with the sub-aerial storage of the iron-gypsum residue (FGR).

The second option of providing two separate residue storage sites for the individual process residues was rejected for the following reasons:

- The project footprint would be increased and the environmental, technical, economic and socio-economic impacts associated with residue storage would be almost doubled due to the parallel systems: two sets of access roads and slurry pipelines, two separate storage areas, larger overall footprint and more affected habitat. Closure for the two storage sites would be more onerous.

- The volume of the neutralized leach residue represents about 62% of the volume of the combined residues. Therefore it is estimated that the capital and operating cost of the NLR only sub-aqueous site would be lower than the combined residue NCR sub-aqueous site, however the cost reduction would not off-set the increase due to FGR storage.

- The sub-aerial disposal of the iron-gypsum residue (FGR) would require an estimated 15 ha of suitable land area in addition to the approximately 70 ha required for sub-aqueous storage of the NLR. The capital and operating cost of sub-aerial storage of the FGR would be additional to the sub-aqueous storage of the NLR.

It is therefore concluded that the environmental and technical risks and the cost associated with managing two residue storage sites are substantially greater than those associated with a single residue storage site and consequently the sub-aqueous storage of the neutralized combined residue in a single facility is the recommended containment method.

5.0 Storage Concepts and Comparison of Artificial and Natural Sites

5.1 Introduction

There are several alternative disposal concepts which may be applicable for the residue generated at the Hydromet Plant[17].

5.2 Storage Concepts

5.2.1 Storage in a Natural Pond or Water Body

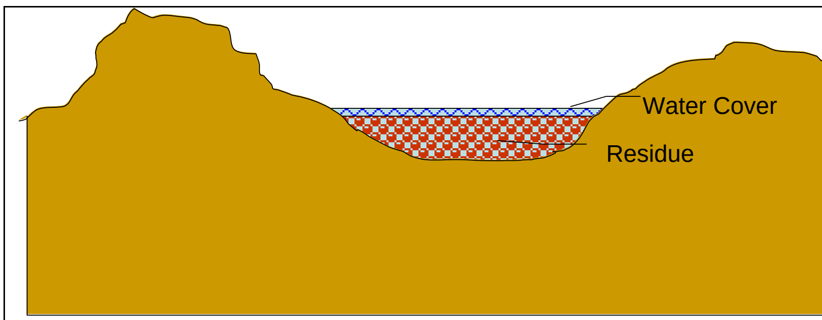

Figure 5.1: Storage in a Natural Pond

The slurried residue would be discharged via a pipeline to a naturally occurring pond close to the plant site. The pond water levels would not be significantly changed (Figure 5.1). The top elevation of the residue would be set to prevent wave action from eroding the residue into the water column. Selection of the top elevation of the residue also needs to consider pond level fluctuations with respect to seasonal and long term meteorological variations (e.g., extensive wet or drought years).

In the medium term sediment generated in the pond drainage area from surface water run-off will form an oxygen consuming layer over the residue (refer to section 5.3.2).

Local groundwater gradients would typically be into the pond along the majority of the perimeter (assuming groundwater naturally discharges into the pond) and would remain relatively unchanged.

This concept requires the least engineering input since no significant structures (i.e., dams) would be required, consequently it also represents the lowest performance risk alternative.

The following are current industrial examples of this type of disposal method:

- Duck Pond Mine – Central, Newfoundland
- Moose Lake – Sudbury, Ontario

5.2.2 Storage in an Artificial Reservoir Created in a Natural Depression or Valley

An artificial reservoir can be formed to contain the residue (Figure 5.2). Such sites are typically located in natural depressions or valleys and would be selected to achieve the following:

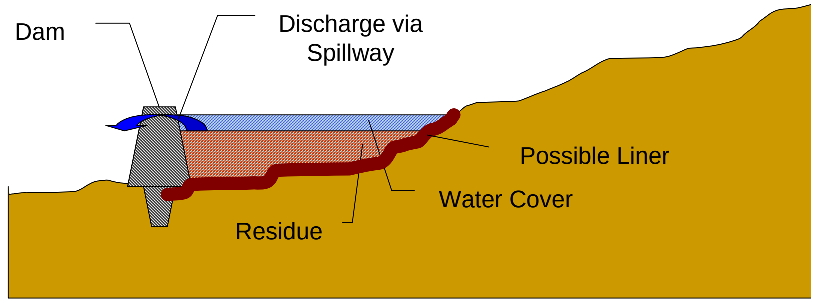

Figure 5.2: Storage in an Artificial Reservoir

- Minimize the volume of dam fill required.
- Maximize use of existing topography.
- Provide adequate watershed to maintain the water cover during potential low precipitation or extended dry periods.

A liner may or may not be required depending on the application. A liner is provided to limit seepage losses, to maintain the water cover or to reduce the rate of contaminant migration to the groundwater. In this application, with high acid generating potential residue, a liner is required for the land based sites to prevent potential groundwater contamination.

Examples of storage of acid mine drainage (AMD) mine wastes in artificial reservoirs include:

- Heath Steel Mine - New Brunswick
- Victoria Junction Tailings Pond - Nova Scotia

The following are examples where liners have been used in Canada in artificial reservoirs:

- Golden Giant Mine (Ontario) – HDPE lined tailings dam provided to maintain a water cover until a natural oxygen consuming cover becomes established.
- North Cell at Heath Steele Mine (New Brunswick) – a till liner was extended upstream of the dam to limit seepage.

5.2.3 Storage in a Natural Pond Augmented by a Dam Structure

An option which is often considered where a natural pond does not have sufficient storage capacity is a natural pond site with associated dam or dams which are designed to increase the storage capacity of the original pond. This residue disposal option does not clearly fit into the category of a natural pond or an artificial reservoir, but is a hybrid of the two. The dams are required if the total volume of the residue to be stored could not be contained under the existing pond water level therefore dams are provided to raise the original water level of the pond.

With respect to the evaluation items discussed earlier, such a hybrid option would fit in between the two categories. For example, outward groundwater gradients are expected, but would not be as high as for an artificial reservoir. Similarly in the event of a geotechnical failure some residue may be released, but this would be a smaller volume than the equivalent artificial reservoir.

5.2.4 Storage in an Artificial Reservoir Created Completely by Dam Construction

If a suitable valley is not found then the entire perimeter structure could be formed by a dam. Essentially the residue would be contained by a ring dike as shown in Figure 5.3. In this case it would be necessary to have very low seepage through the dike and the bottom of the facility so that the water cover is maintained, often requiring a composite synthetic liner. Examples of this type of facility include

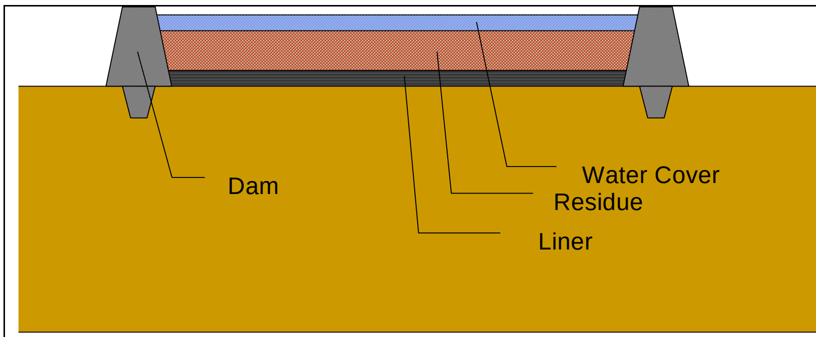

Figure 5.3: Storage in an Artificial Reservoir – Ring Dike

- The Lisheen tailings management facility in Ireland where AMD tailings are sub-aqueously disposed in a pond with a composite liner (linear low density polyethylene (LLDPE) underlain by a geosynthetic clay liner (GCL). This facility is located on an area of flat bog (wetland) which forms an additional natural liner beneath the artificial liner.

- The proposed Victor Diamond Mine near Attawapiskat in Ontario has also selected a ring dike structure for containment of fine processed kimberlite. This facility will not be lined since the kimberlite tailings is non acid-generating. Again this site is located on a large featureless, flat area of muskeg (wetland).

This type of approach would only be considered where there is a large area of flat land available and the natural level topography does not allow the use of existing depressions or valleys. Since the dam must be formed around the complete structure it requires a considerable volume of rockfill. Typically this rockfill would be obtained from waste rock generated from the excavation of a mine and is often complemented during operation by the use of tailings material from the process plant. The Hydromet Plant does not generate a waste product suitable for dam wall construction. Since the topographical features of the surrounding terrain of the Hydromet Plant are very different from the above examples, and to the contrary are conducive to the use of natural features to reduce the volumes of dam fill required (which reduces cost and environmental footprint), a ring dam construction is rejected for the Hydromet Plant residue storage.

5.2.5 Storage in an Artificial Excavated Pit

The option of storing the residue in an artificial excavated pit would not normally be considered at a green field site; however, it has been investigated here in some detail. An excavated pit is not a conventional choice for the following reasons:

- Normally the local topography allows use of a natural depression or valley to act as a retaining structure. Typically at the Hydromet site this valley would contain some standing water or aquatic habitat. Effectively this is a natural - ready made pit.

- The amount of residue generated over the 15 year plant life is large, requiring a volume of 6.5 million m^3. This translates into a 15 m deep pit. Following removal of overburden the site must be drilled and blasted to remove the rock which would then be loaded and trucked to another site for storage. This is effectively a major quarrying operation the cost of which is extremely high. Storage of the excavated material represents a considerable environmental impact. It should be noted that a portion of the material could be used for site development but the requirement is low.

- An understanding of the water retaining capacity of the pit would require an initial geotechnical investigation, involving the drilling of a number of boreholes; again cost would be a consideration here.

- The potential for acid generation from the residue means that there is a requirement to ensure that the pit is effectively sealed; engineering solutions such as localised shotcrete or grouting in combination with the installation of a composite liner may be required. These measures may prove technically challenging.

- There would be definite operational concerns with safety aspects in relocating the effluent pipe distribution system at the bottom of a 15 m pit. This would be required periodically to ensure sub-aqueous disposal of the residue.

Excavated pits have been used to store tailings from mining operations; however these pits are normally mined out open pits previously excavated as a part of the mining operation. It is also possible that an excavated pit could be considered if there were a requirement for rockfill to develop major roads or infrastructure, such a requirement may be considered for a remote mining site which is being developed in a northern climate in an area of extensive permafrost for example, which has limited civil foundation bearing capacity. The Hydromet site consists of glacial till and outcropping bedrock which fortunately requires a small amount of rockfill and aggregate to develop.

In conclusion an excavated pit, although technically feasible requires a significant amount of engineering effort. As a general statement the larger the engineering effort required the greater the environmental impact and the associated cost.

5.3 Comparison of Natural Pond and Artificial Reservoir Concepts

The evaluation of the merits of a natural pond versus an artificial reservoir is discussed in this section with respect to technical aspects including normal operation, potential failures and long term care and maintenance. The economic issues are not considered at this stage of the evaluation.

5.3.1 Normal Operation

Maintaining Water Cover

Given the potentially short time of exposure required for the residue to generate net acidity, it is imperative that the water cover be maintained without interruption.

For the design of a facility this requires the definition of a return event with respect to a drought year and selecting the appropriate timing, calculating/estimating seepage losses, evaporative losses, etc. For a natural pond, there is a natural record of the pond levels being maintained closer to a geologic time scale. While the calculations for an artificial reservoir can be done with a high level of confidence, it does nonetheless represent some risk with respect to the long term performance.

Therefore from this perspective a natural pond is preferred because it has a lower risk of losing the water cover in the long term.

Groundwater Contamination

Most natural ponds in the region are in groundwater discharge zones, in other words groundwater flows into the pond. Figure 5.4 provides a simple schematic representation of groundwater flows. In contrast groundwater at an artificial reservoir is most likely to flow out of the facility as shown in Figure 5.5. This is likely to result in a higher rate of contaminant release from an artificial reservoir as opposed to a pond, all other factors being equal.

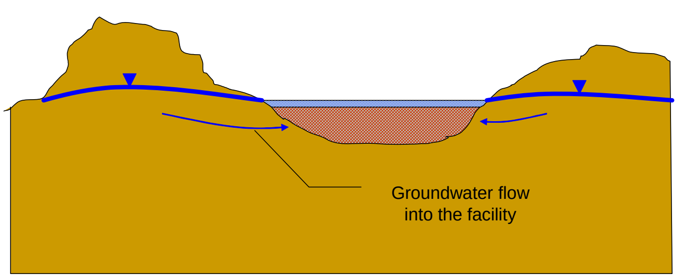

Figure 5.4: Typical Groundwater Regime for a Natural Pond

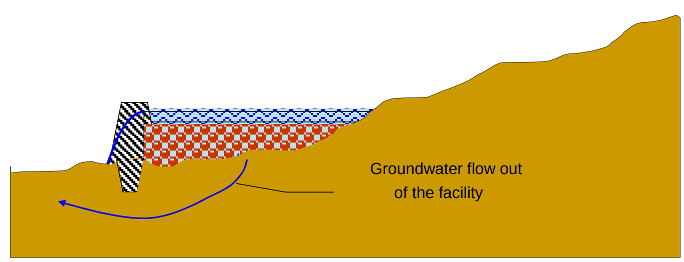

Figure 5.5: Typical Groundwater Regime for an Artificial Reservoir

While the addition of composite synthetic liners to the design of an artificial reservoir can reduce the rate of contaminant migration this represents an increase in the level of engineering and hence performance risk versus natural hydraulic containment. The main concern with a liner is that it would deteriorate over extended time periods and there would be no practical way to replace it.

Therefore the natural pond would be preferred due to the existence of a silt/clay/organic layer which naturally forms at the bottom of the pond and which acts to reduce the flux to the groundwater. A natural pond therefore has a lower rate of contaminant release to the environment along groundwater pathways and as a result is preferred over the artificial reservoir.

5.3.2 Development of an Oxygen Consuming Cover

Forested or heavily vegetated watersheds reporting to the natural pond or to the artificial reservoir will contribute organic debris (e.g., sediment, leaves, bark, twigs, etc.) by means of surface water run-off. This debris will settle on the top of the residue. Over decades the organic debris will build up and form an oxygen consuming cover. While the water cover itself is the primary oxygen barrier, it still contains dissolved oxygen which, under some conditions, may cause undesirable contamination of groundwater. In any case, such an oxygen consuming layer becomes an additional safety factor with respect to the long term performance of the facility.

The development of a natural oxygen consuming layer would be much slower and less effective in the case of a ring dyke reservoir construction.

5.3.3 Potential Failures

Geotechnical Failure

In practical terms, there are no credible failure mechanisms for a natural pond except if a dam structure is involved.

For the scenario shown in Figure 5.2, a large amount of the residue could be released in case of a dam failure. Given the potentially short time for the residue to start to oxidize, it is likely that a significant impact to the downstream receiving waters would occur should the dam structure fail over the medium term time frame. The extent of clean-up and remediation required in this case would be high.

While the risk of dam failure can be managed with good design, construction, operation, surveillance and maintenance, it is never zero.

Therefore the natural pond is preferred with respect to geotechnical failure because there are no credible failure mechanisms.

Liner Material Failure

Some US states require tailings impoundments to be lined with geomembranes, GCLs, etc. However, it should be noted that facilities relying on synthetic materials such as geomembranes are subject to service life limitations. For example accelerated aging tests on HDPE suggest a service life on the order of 200 years depending on physical stress, chemical and solar exposure. Performance beyond this time frame is difficult to quantify. While the bentonite in a GCL is a natural material, there may be service life concerns related to the geosynthetics above and below the bentonite.

It can not be proven that geomembranes and geosynthetics will not eventually fail. Even natural materials such as bentonite may change properties over extended time periods. While primarily a concern with synthetic or processed materials, other natural construction materials such as rockfill may also weather resulting in clogging of granular filters by physical breakdown and chemical precipitation over time. Construction materials can be selected and tested to minimize the chance of a failure happening, however the risk is still lower with decreasing amounts of engineering.

The nature of the residues is such that failure at any time in the medium term could have significant environmental implications. For this reason a natural pond with no reliance on engineered features in the long term would be preferred.

5.3.4 Long Term Care and Maintenance

Any containment facility reliant on a dam will require regular inspections and maintenance in perpetuity. For example, the spillways will need to be inspected to be kept clear of debris and trees will need to be periodically removed from the dams. While there may be few if any ‘moving parts’ such as water treatment facilities or pumping facilities, a dam structure will never be a true walk away facility.

Storage in a natural pond however is as close to a ‘walk away’ closure condition as possible. It is unlikely that any maintenance would ever be required. It is however expected that for all closure scenarios monitoring of the receiving environment will be undertaken.

In general, ‘walk away’ closure conditions are considered to be the most desirable, since they involve the lowest failure risk and require the least amount of monitoring and maintenance following closure.

5.4 Conclusion

From the perspective of managing, containing and preventing the generation of acid drainage from the residue, sub-aqueous storage below the water level of a natural pond is the preferred concept. This is consistent with long standing views of the management of acid generating wastes in the mining industry. It should be noted that a number of storage facilities in the mining industry which were originally designed and constructed as sub-aerial disposal sites, have over time developed acid drainage problems. These sites have now been converted, or are being converted, to sub-aqueous storage facilities as a proven method to resolve the acid drainage problems.

6.0 Sub-Aqueous Storage Site Selection

Having determined that sub-aqueous disposal is the best storage alternative for the residue produced by the Hydromet plant, Vale Inco NL conducted an exhaustive examination of potential deposition sites within the area of the proposed plant. The key criteria used to identify candidate sites included: proximity to the proposed plant site, ability to contain 6.5 million cubic metres of residue generated over the planned 15 year operating life, ability to provide and maintain a water cover over the residue in perpetuity, and ability to minimize seepage into the groundwater.

The search area for suitable sites was restricted to land to the south and southwest of the proposed plant site and, with one exception, to the west of the highway Route 101. For reasons of security, visibility and public safety, it is preferable to avoid, where possible, pipeline and highway crossings.

Twelve candidate sites were chosen for evaluation within 14 km of the proposed plant site. Note that there were no substantial differences in the quality of potential additional candidate sites beyond the 14 km radius, and such remote sites would only result in a larger environmental footprint with more communities and watersheds affected.

Within the search area, there were no completely dry land sites large enough to satisfy residue storage requirements and therefore selected land based candidate sites always contained some quantity of aquatic life. However, one dry land area close to the plant was identified as a location to construct an excavated pit. With the exception of the excavated pit, it was determined that all candidate land based and natural water bodies require some form of engineered structure to meet residue storage capacity requirements and to develop a secure containment facility.

6.1 Site Selection Evaluation Process

The following procedure was used to select the preferred site for sub-aqueous residue storage:

- **Identification of candidate sites:** Twelve candidate sites were identified as potentially having the necessary characteristics to contain the Hydromet residue;
- **Selection of the preferred site:** The selected candidate sites were ranked according to master groupings and criteria. The site with the highest ranking based on the accessed criteria was selected;
- **Sensitivity analysis:** Different weightings were assigned to the master groupings of site selection criteria to determine the effect of bias on the rankings.

6.2 Identification and Description of Candidate Sites

Figure 6.1 shows the location of the twelve candidate sites, designated as sites RS-1 to RS-12, for the sub-aqueous storage of 6.5 million m^3 of neutralized combined residue over 15 years of operation. Sites RS-2, 4, 5, 6, 7, 8 and 12 qualify as land based storage sites as they do not incorporate named ponds. With the exception of RS-12, these sites do however, contain minor water bodies which are considered as fish habitat. Complete dry land sites large enough to satisfy the residue storage requirements could not be found, however a potential dry land site could be created by excavating a large volume of material and levelling a sloping area close to the plant (RS-12). Sites RS-1, 3, 9, 10 and 11 qualify as natural water body sites as they contain named ponds. Table 6.1 identifies the type and location of the twelve candidate sites.

Table 6.1 Site Identification and Location

Site	Type	Location
RS-1	Pond	Sandy Pond situated north east of the plant.
RS-2	Land Based	Situated east of the plant in the east tributary of the Rattling Brook Big Pond watershed.
RS-3	Pond	Rattling Brook Lakes situated south of the plant
RS-4	Land Based	Situated south east of the plant in the south tributary of the Rattling Brook Big Pond watershed.
RS-5	Land Based	Situated south west of the plant in the Ship Harbour watershed.
RS-6	Land Based	Situated south west of the plant in the Ship Harbour hillside watershed.
RS-7	Land Based	Situated south west of the plant in the Little Rattling brook watershed
RS-8	Land Based	Situated south of the plant in the Rattling Brook watershed.
RS-9	Pond	Ship Harbour Big Pond situated south east of the plant.
RS-10	Pond	Railway Lakes situated south of the plant.
RS-11	Pond	Rocky Pond situated south west of the plant.
RS-12	Land Based	Excavated pit situated west of the plant.

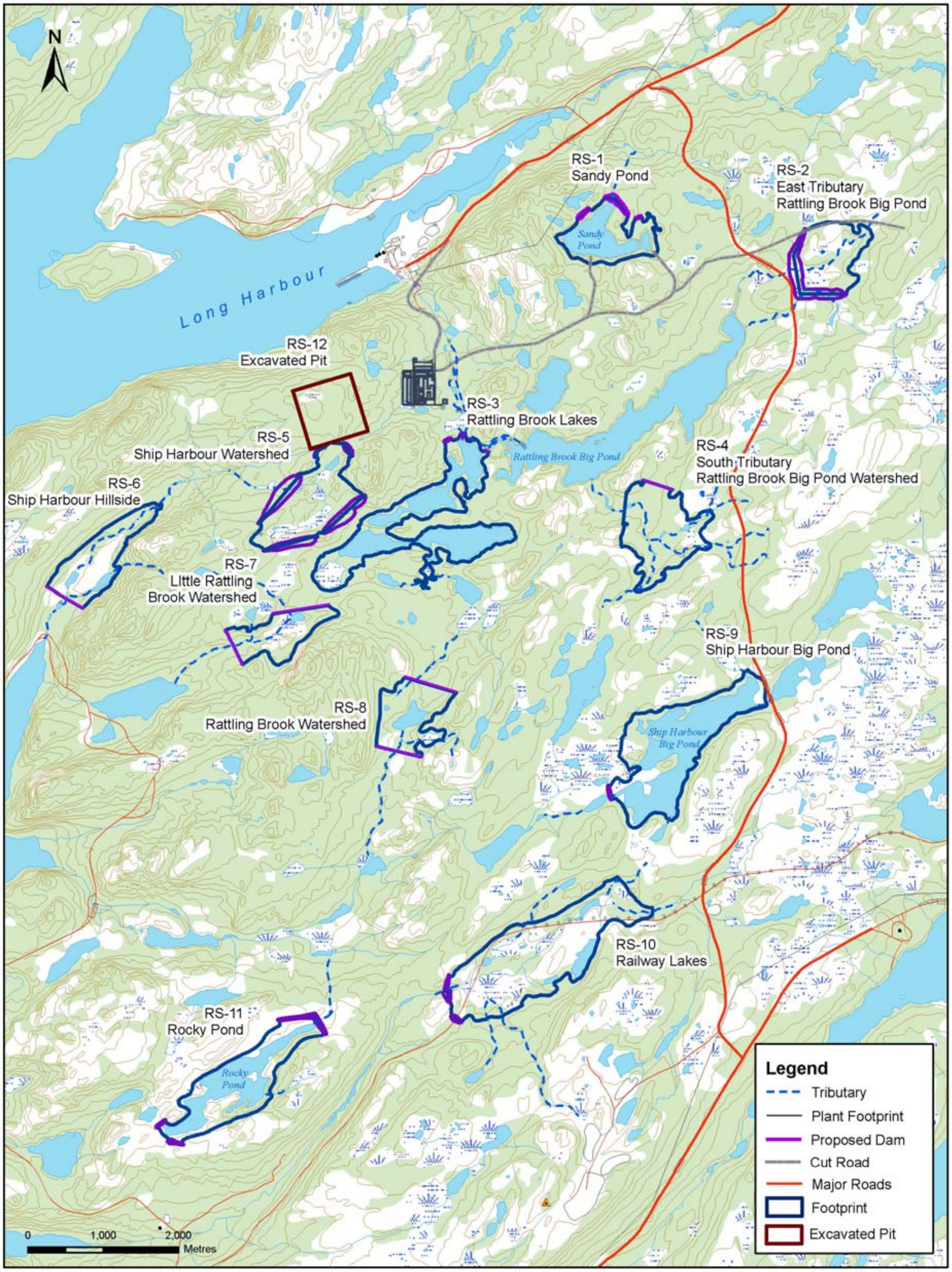

Figure 6.1 Locations of Twelve Candidate Residue Storage Sites

6.2.1 RS-1 Sandy Pond

This pond is located 4 km east of the proposed plant site upper tier at an elevation of 126 m, approximately 19 m in elevation above the proposed plant site. It has a watershed area of approximately 4.7 km^2 and a pond surface area of 38 hectares. The pond is located at the top of a watershed and one small stream diversion would be needed within the watershed.

Based on bathymetry, it has a natural capacity to hold 2.9 million cubic metres of residue. To hold 6.5 million cubic metres of residue, three dams totalling 250,000 cubic metres would be required. The closure water level would be at 139 metres and the flooded surface would be approximately 74 ha. The site has good potential for expansion; a moderate raise in dam height of 8 m would allow the storage capacity to double.

6.2.2 RS-2 East Tributary-Rattling Brook Big Pond

This land-based site is located 5.5 km from the proposed plant site and to the east of Rattling Brook Big Pond adjacent to Highway 101. It is located high in the watershed, with a total watershed area of approximately 33 km^2, with extensive stream and pond habitat downstream. In order to provide adequate storage capacity for the residue at this site, a very large dam (over 1.5 km long, 29 m high and requiring approximately 1.9 million cubic metres of material) would have to be constructed. The surface area of the flooded surface would be 74 ha. The site lacks bedrock and is underlain by till material. The site is located on a geological fault and has poor groundwater inflow/counterpressure. A synthetic liner would be required and any leaks would result in seepage into groundwater. There are concerns over the ability to maintain an adequate water cover. The potential for expansion is low as massive additional dam works would be required.

6.2.3 RS-3 Rattling Brook Lakes

There are four ponds in this location which is 1 km south of the proposed plant site upper tier. The site is approximately 2 to 5 metres lower in elevation (102 m to 105 m) than the proposed plant site. It is situated relatively low in the watershed and has a large watershed area of approximately 33 km^2.

No bathymetry is available for the four ponds in this area which range in depths from 3 to 7 m. Three small dams totalling 16,000 cubic metres would be required for 6.5 million cubic metres of residue storage. Dams would be founded on till material with grout cut-off cores. The closure water level would be at about 107 m; the flooded surface area would be 165 hectares. Five streams would need to be diverted within the watershed and, in addition to the 110 hectares of current surface water, would result in a large quantity of aquatic habitat affected. The potential for expansion is good.

6.2.4 RS-4 South Tributary- Rattling Brook Big Pond Watershed Location

This land based site is located 3.6 km south of the proposed plant site on the edges of the Rattling Brook watershed and immediately south of Rattling Brook Big Pond. The site is approximately 300 m from Highway 101. It contains five small water bodies with a surface area of 1.6 ha. Two large dams and one small dam would be required with a total volume of about 1.27 million cubic meters of material, a maximum height of 32.5 m and a length of 1.02 km. Dams would be founded on bedrock and anchored with a grout curtain cut-off core. An area of 102 hectares would require flooding for establishment of a suitable water cover. The site is located at the height of the land in a watershed of approximately 33 km^2 in size. Due to its location high in the watershed, there are concerns over the ability to maintain an adequate water cover. Due to the height of the dam a large portion of the storage contents could be released in the event of a dam failure and directed towards Rattling Brook Big Pond. There is also a concern that potential seepage from the storage area would impact Rattling Brook Big Pond, the potable water source for the plant. The potential for expansion is low to moderate due to the extensive dam works that would be required.

6.2.5 RS-5 Ship Harbour Watershed Location

This land based site is situated in the upper levels of the Ship Harbour watershed, about 2.5 km south-west from the plant site. The total watershed size is about 8.5 km^2, however only 130 ha of watershed is up-gradient of the site. Due to its location high in the watershed, there are concerns over the ability to maintain an adequate water cover. Four dams totalling 2.67 km in length and 30 m height with a volume of 2.5 million cubic metres would be needed to contain the residue and allow for establishment of a 100 ha water cover. Any expansion of the site would require additional dams, therefore any additional residue storage capacity is an issue. The site is covered with vegetation and would require extensive water diversion works. The site also contains six small water bodies with a total surface area of about 7 ha. The site drains towards the community of Ship Harbour.

6.2.6 RS-6 Ship Harbour Hillside

This land based site is located in a broad valley that slopes gently towards and is the closest to the community of Ship Harbour. The location is at about 5.9 km to the west of the proposed plant site. The site is located low in the watershed. The total watershed size is about 8.5 km^2, with over 90% of the watershed up-gradient, therefore extensive water diversion works would be required. A dam of 26.5 m height and 560 m length totalling 785,000 cubic metres of material would be required to generate the required 74 hectares of flooded area for the residue. Because of deep overburden (up to 30 m in places), pond lining would likely be required to allow sub-aqueous placement because water would drain rapidly into the overburden without a liner. The site is affected by a geological fault and seepage control would be difficult due to topography and expected hydrogeological regime. The site is covered with vegetation and trees which require removal. The site contains two small water bodies with a total surface area of about 4.5

ha. The site drains towards the community of Ship Harbour. There is a low potential for expansion due to poor ground conditions.

6.2.7 RS-7 Little Rattling Brook Watershed Location

This land based site is situated in the Little Rattling Brook watershed, but also adjacent to the Rattling Brook watershed, about 4.5 km to the south west of the proposed plant site. The watershed area is 6.5 km^2, with the site located high in the watershed (about 250 ha of watershed area up-gradient). Due to its location high in the watershed, there are concerns over the ability to maintain an adequate water cover. Two large dams totalling 1.3 km in length and 36 m high with a volume of 1.8 million cubic metres of material would be required to provide sufficient capacity to store the residue. The dams would be founded on bedrock and keyed into the rock foundation. The size of the flooded area would be 57 ha. The area would require lining to prevent seepage into groundwater, and installation of the liner would be difficult due to the steepness of the terrain. A small water body 1.7 ha in size is present and water diversion work would be needed to re-direct the upstream drainage from the site. There is a low to moderate potential for expansion due to the very extensive dams that would be required.

6.2.8 RS-8 Rattling Brook Watershed Location

This land based site is located approximately 5.6 km to the south of the proposed plant site plant at the top of two watersheds, mostly placed into the Ship Harbour Brook watershed, but also partly into the Rattling Brook watershed. The total watershed area is about 35 km^2. Two large dams totalling 1.35 km and 28 m high with a volume of 1.25 million cubic metres would be required to provide sufficient capacity to contain the residue. Dams would be partially founded on bedrock and anchored into the rock. The site would require lining to prevent seepage into groundwater, and installation of the liner would be difficult due to the steepness of the terrain. The size of the flooded area would be 69 ha. Extensive water diversion work would be required. The site contains four water bodies with a total surface area of about 11.4 ha. There is moderate potential for expansion, however the amount of material required for additional damming is extensive.

6.2.9 RS-9 Ship Harbour Big Pond

This site is located 7.5 km southeast of the proposed plant site and is situated at approximately 44 metres higher in elevation (151 m) than the proposed plant site. It has a watershed area of approximately 35 km^2, with about 760 ha up-gradient of the site. The discharge flows in a westerly direction for more than 5 km until it eventually discharges into Ship Harbour. No bathymetry is available for the pond; thus, it has been assumed that a capacity to hold 5.9 million cubic metres of residue exists. One small dam of about 200 m in length and 4.25 m in height, with a volume of 11,000 cubic metres would be required and the water level would be approximately 156 metres. The current pond surface area of 116 ha would increase to about 173 ha. The site has a medium to high potential for groundwater seepage since the additional flooded area is mostly glacial till. Five streams would need to be diverted within the watershed. The potential for expansion is considered good.

This is the only one of the twelve site alternatives that is not solely Crown Land. There are as many as 5 registered cabins and 8 additional cabin lots along the shoreline, as well as camping areas along the secondary highway (Route 101) which crosses the watershed. Flooding of cabins and the highway could potentially happen in preparing this site as a residue storage area.

6.2.10 RS-10 Railway Lakes

Railway Lakes consists of seven ponds and four smaller water bodies which are located 11 km south of the proposed plant site upper tier and are approximately 13 metres higher in elevation (120 m average) than the proposed plant site. The watershed area is approximately 29 km^2, with the site located high in the watershed with approximately 3.8 km of stream below it. No bathymetry is available for the ponds in this area which are very shallow with little natural storage capacity. Two dams with a length of 540 m, a height of 17m and a volume of 39,000 cubic metres would be required for 6.5 million cubic metres of storage. Water level would be about 132 metres and the surface area flooded would be approximately 215 hectares compared to an existing surface water area of 25 ha. Five streams would need to be diverted within the watershed.

Although this site is not considered a land based site, it would have the largest area of terrestrial habitat affected of all the twelve sites. There is a good potential for expansion.

6.2.11 RS-11 Rocky Pond

This pond is located 14 km southwest of the proposed plant site upper tier and is situated at approximately 27 metres higher in elevation (134 m) than the proposed plant site. Its watershed area is about 35 km^2, with a small watershed area of approximately 87 hectares located up-gradient of the pond. It has nearly 4 km of stream below it. The current pond surface area is 62 ha.

Based on bathymetry, it would currently have the capacity to hold 3.7 million cubic metres of residue. To hold 6.5 million cubic metres, three dams with a length of 1.12 m, a height of 8.8 m and a volume of 150,300 cubic metres would be required and water level would be about 142 metres. The surface area flooded would be approximately 124 hectares. One stream would need to be diverted within the watershed.

This site is the furthest distant from the commercial plant. There is good potential for expansion.

6.2.12 RS-12 Excavated Pit

Since a site was not available without any water bodies that could potentially be fish habitat, a land based site approximately 2 km from the plant site was selected as a location for an excavated pit. The natural topography of the area would be disturbed by cutting and major excavation in a relatively steep area that slopes towards the plant site. The site is located at the height of a watershed of approximately 33 km^2 in area, and drains towards Rattling Brook. The aerial extent of the excavated pit would be about 76 ha, with an additional 100 ha required to dispose of about 23 million cubic metres of excavated material. In order to contain 6.5 million cubic metres of residue, the pit would need to be 15 m deep. The potential for expansion would be low.

There would be no requirement for a dam as the walls of the pit would act as a containment dam. Given the large size of the excavation and disturbance to groundwater and runoff, there is a potential for groundwater seepage issues. Depending on the geotechnical characteristics of the rock walls, there could be a requirement for a liner or a sprayed-on cover of cementitous material such as shotcrete or grout.

Given the location at the height of the watershed with very low interception of flows, there are concerns about the ability to achieve and maintain a water cover. Initial water cover would be via a water pumping system. This pumping system would need to be maintained throughout the operational life to ensure an adequate water cover. Upon closure, ongoing maintenance of the pumping system would be required, or alternatively the pit could be pumped dry and the residue backfilled with excavated material from the construction.

7.0 Ranking Criteria

7.1 Introduction

A team of Vale Inco personnel and external consultants developed selection criteria used to rank the twelve candidate residue storage sites. Criteria were grouped into four master categories: environmental, technical and operational, economic and socio-economic. Within each master category a number of criteria were identified to ensure that the full breadth and depth of each category was evaluated for every candidate site (see Table 7.1). Sections 7.1 to 7.4 provide more details of the criteria used in the site evaluation. A description of each site in relation to all criteria is contained in Appendix B.

7.2 Environmental Criteria

7.2.1 Distance from Plant Site

The longer the distance, the greater the project footprint and the more habitat potentially affected. A longer residue pipeline has a higher potential for a spill, with attendant needs for additional and larger emergency spill collection pond requirements.

7.2.2 Dam Failure Potential – Geotechnical and Seismic

This criterion is related to the size of the structure, the extent of the upstream watershed and the location of any known geological faults which would undermine residue and dam stability. The entire area is not seismically active and has one of the lowest ratings in the National Building Code. Dam reliability is considered for the extreme long term (in perpetuity).

7.2.3 Dam Failure Consequences

The proportion of residue contents released upon dam failure is related to the extent of constructed dams, the height of the dams and the natural basin containment below the dam foundation elevation. The effects of residue spillage will depend on the size of the downstream watershed, the direction of the down gradients and the nature of the habitat. For the excavated pit (RS-12), which has no dam, this criterion applies to potential slope stability issues with the walls of the pit.

7.2.4 ARD – Metal Leaching Potential

If the residue was allowed to oxidize, acid generation and metal leaching would occur. The larger the area for flux, the greater the potential for acid leaching. The ability to maintain a water cover is paramount.

Table 7.1 Ranking Criteria

Environmental Criteria	Technical & Operational Criteria	Economic Criteria	Socio-economic Criteria
• Distance from Plant Site (km) • Dam Failure Potential – Geotechnical and Seismic • Dam Failure Consequences • ARD – Metal Mobilization and Leaching Potential • Freeze Drying/Dusting Potential • Topographical Aspects • Hydrology • Hydrogeology • Surface Area (ha) and Maximum Depth of Affected Lacustrine (Pond) Habitat • Surface Area (ha) of Affected Terrestrial Habitat • Surface Area (ha) of Affected Riverine Habitat • Total Watershed Area (km2) • Downstream Habitat Loss • Geotechnical Site Footprint (ha) • Water Quality • Atmospheric • Climate Change • Post Closure – Rehabilitation and Land Use • Fish Habitat Compensation Effort • Fish Habitat Monitoring • Additional Habitat Monitoring • Atlantic Salmon • Brook Trout • Arctic Char • Eels • Other (Rainbow Smelt, Stickleback) • Avifauna • Moose • Other Wildlife	• Distance from Plant Site (km) • Dam Design Details: • Number, Length, Height, Volume, Ratio • Surface Area of Residue Storage Site at Final Water Level for Closure • Dam, Access Road and Quarry – Total Footprint • Potential for Increase in Residue Containment Capacity • Flexibility with regard to Operational and Environmental Changes • Construction Risk • Operational Risk • Closure Risks/Uncertainties • Post Closure – Rehabilitation & Land Use	• Capital Cost • Operating Cost • Closure Cost • Post Closure Cost • Environmental Compensation & Monitoring Cost • Total Capital and Operating Cost	• Landowner • Historic Resources • Employment Opportunities • Perceived Community Response • Visual Impact • Resource Use and Recreation • Angling

7.2.5 Freeze Drying/Dusting Potential

If the residue becomes exposed, it becomes susceptible to degradation by natural causes, such as freeze-drying and in combination with high wind can result in dust generation and contamination problems. Maintenance of a permanent water cover alleviates this concern.

7.2.6 Topographical Issues

Good relief allows for the use of natural land features thereby making containment easier and requiring less dam construction. The topography in the area is such that there are numerous ponds and streams, rendering it difficult to find a residue disposal site that completly avoids a waterbody. The undulating topography is a factor in building roads and pipelines to the residue disposal site, and the number of stream crossings and stream diversions required. Soil characteristics and depth of till varies considerably over the area.

7.2.7 Hydrology

The position in the watershed determines how much upstream diversion may be required and the natural inflow available for maintaining a water cover or the requirement for a pumping system to maintain water inflow to provide the necessary water cover over the residue. The relative effect on local streams is also considered.

7.2.8 Hydrogeology

Groundwater flow into the site is desirable as it offers counter pressure against water infiltrating into the groundwater and ultimately releasing to the environment. Natural water bodies are likely to have groundwater inflow, whereas land-based sites are most likely to have groundwater flowing out. This is likely to result in a higher rate of contaminant release from a land-based site as opposed to a natural water body, all other factors being equal. Synthetic liners can be installed in some cases to control seepage into groundwater. Hydraulic conductivity is an important consideration; sites underlain by low hydraulic conductivity bedrock are preferred to those underlain by till material.

7.2.9 Surface Area and Maximum Depth of Affected Lacustrine (Pond) Habitat

The greater the area and depth of affected ponds, the greater the potential for effects on fish and fish habitat.

7.2.10 Surface Area of Affected Terrestrial Site

The larger the size of terrestrial area affected, the greater the potential for disturbance to vegetation, avifauna, moose, fox, hare and other terrestrial mammals.

7.2.11 Surface Area of Affected Riverine Habitat

Affected riverine habitat includes any diverted streams upstream of the residue storage site, as well as streams downstream of the site which would have altered flows.

7.2.12 Total Watershed Area

The size of the affected watershed indicates the potential environmental impact.

7.2.13 Downstream Habitat Loss

This is the area affected by site water retention and altered flow. It includes both stream habitat as well as standing waterbody/steadies.

7.2.14 Geographical Site Footprint

The total surface area of the residue storage facility, includes dams, roadways and pipeline routes, quarries, and disposal areas. A smaller footprint is also favourable in terms of closure and post closure site management.

7.2.15 Water Quality

Background water quality is similar in all area water bodies. There is the potential to re-use water in the process, and the better the water quality the less treatment will be required. Water quality is based on the ratio of watershed to residue disposal area. A higher ratio will result in better water quality during operation.

7.2.16 Atmospheric

Wind is a key consideration. Increased wave action under high wind conditions results in higher suspended solids levels which in turn affects oxidation rates. The prevailing winds in the area are predominantly from the southwest direction. Local topography dictates a secondary direction from the northeast. The combined fetch for the predominant winds was estimated for each site.

7.2.17 Climate Change

In the long term, the impact of climate change on temperature and precipitation amounts in the area is predicted to be significant. The predicted increase in temperature over the next century is small. Modelling of precipitation change indicates a degree of variation which is difficult to incorporate into the current project design. To ensure that the residue storage pond could withstand any extreme floods, dam design is based on a strongly conservative assumption of a 1:100 wet-year annual runoff followed by a 1:100 year spring runoff.

7.2.18 Post Closure – Rehabilitation and Land Use

Ideally the residue disposal sites would be able to return to their previous land use following closure. This is not possible for land-based sites, since there is a need to permanently maintain a water cover. All sites containing natural water bodies will require some degree of enlargement, therefore terrestrial habitat will be permanently converted to a water body. The lesser the amount of habitat alteration, the more desirable the option.

7.2.19 Fish Habitat Compensation Effort

The greater the area and quality of fish habitat present, the more habitat compensation is required to satisfy DFO's policy of no net loss of productive aquatic habitat.

7.2.20 Fish Habitat Monitoring Effort

In order to verify that the fish habitat compensation program is successful at meeting its objectives, monitoring will be conducted for an estimated period of ten years.

7.2.21 Additional Habitat Monitoring

Downstream habitat that is not included in compensation may require additional habitat monitoring to confirm that there are no unanticipated harmful effects.

7.2.22 Atlantic Salmon

Atlantic salmon is a prized sport fish species. Landlocked Atlantic salmon are known to be present in several area ponds and may be present in others. There is also a possibility that anadromous salmon are present in low abundance in some area waters.

7.2.23 Brook Trout

Brook trout is a commonly found species in area ponds and streams and "trouting" is a popular recreational activity.

7.2.24 Arctic Char

Arctic char has been located in Rattling Brook Big Pond and could be present in other ponds and streams in that drainage system. It would also be a valued sport fish species.
Eels

7.2.25 Other Fish Species

Eels, rainbow trout and stickleback are known or likely to be present in many area streams and ponds. American eels are a Species of Concern under the federal *Species at Risk Act* (SARA). The other two species are forage fish.

7.2.26 Avifauna

The area provides habitat for a number of avifauna species, e.g., raptors, songbirds and waterfowl. In general, lower elevation ponds can be expected to support higher numbers of waterfowl and fish-eating raptors than higher elevation sites. This is due to the presence of more emergent and submergent aquatic vegetation at the lower elevation sites, compared to mostly sphagnum moss in the more acidic higher elevation ponds.

Higher elevation sites with more wind exposure and leaching of nutrients have less dense forest cover and therefore lower densities and species richness of upland birds would be expected there in comparison to lower elevation sites.

7.2.27 Moose

Moose is an important component of the ecosystem and a major big game species. Moose prefer balsam fir stands, riparian shrubs associated with stream channels, and also occasionally use hardwood-mixed wood stands on south-facing slopes. Areas adjacent to expansive wetlands would be favoured during the summer months. Moose tend to avoid barren exposed areas.

7.2.28 Other Wildlife

Red fox, snowshoe hare and red squirrel are likely to be present throughout the area. River otter and mink are likely to be associated with larger bodies of water with inflow channels or medium-sized ponds with numerous interconnecting streams. Beavers are likely widespread, but tend to prefer smaller ponds with directed flow through the system.

7.3 Technical and Operational Criteria

7.3.1 Distance from Plant Site

Distance from the plant affects routing and pipeline length, road alignment, access length and number of stream crossings and low/high points increasing pumping efforts.

7.3.2 Dam Design Details

Considered in this category are the number of dams required to provide the necessary residue storage capacity, the total length of all dams, the constructed height above the existing grade of the tallest dam structure, the total volume of material for construction of dams, and the ratio of dam material volume to residue storage capacity (a measure of storage efficiency). A lower ratio means that dam construction and residue containment is less challenging. For the excavated pit (Site RS-12), this criterion considered stabilization of the rock slopes, and the volume of material excavated.

7.3.3 Surface Area of Residue Storage Site at Final Water Level for Closure

The total footprint of the residue storage area at close of operations is considered. The greater the surface area of residue, the higher the metal leaching potential.

7.3.4 Dam, Access Road and Quarry Total Footprint

Included in this category is the affected area associated with the construction and development of dams, access roads and quarries. The smaller the footprint of the residue disposal site, the easier it will be to manage the deposition of the residue and maintenance of a water cover. Site preparation complexity will be affected by glacial till overburden thickness ranges, especially for the land based sites where boulders will need to be removed. The site should ideally be located in a small as possible watershed to minimize stream diversion requirements but provide enough natural drainage for the residue water cover required.

7.3.5 Potential for Increase in Residue Containment Capacity

In the event that the nickel processing plant life gets extended, increased residue storage capacity would be required. The extent of modifications to achieve a potential doubling of capacity was evaluated. A lower dam volume to residue storage capacity indicates a better potential for storage site capacity expansion.

7.3.6 Flexibility With Regard to Operational and Environmental Changes

Process upsets and changes have the potential to alter the composition of the residue slurry, which in turn may alter the supernatant water quality. The effluent treatment facility is designed to allow for anticipated changes. Extreme drought or flood conditions may impact the residue storage facility in terms of maintenance of water cover or required decant pump flow rates.

7.3.7 Construction Risk

Risks associated with construction include key factors such as ease of access, the extent of up-gradient watershed and diversion requirements, need for synthetic liners, site layout, design assumptions, site data and relative working conditions.

7.3.8 Operational Risk

Risks associated with operation include key factors such as length of access road and pipeline and accessibility for general maintenance as well as in the event of an incident such as a pipeline leak; ability to achieve initial water cover and to maintain it at sufficient depth throughout operation and number of deposition points required.

7.3.9 Closure Risk/Uncertainties

All sites will require long term monitoring and maintenance. The long term stability of water-retaining structures is of concern as is the ability to maintain a water cover over time.

7.3.10 Post Closure – Rehabilitation and Land Use

The ability to return the area to its original use or an acceptable alternative use is covered in this criterion. Since there is a need to maintain permanent water cover, there is no potential for any land-based site to return to terrestrial habitat. Likewise, any land that is flooded to expand a natural water body will not return to terrestrial habitat. Affected water bodies will, over time, return to productive aquatic habitat.

7.4 Socio-Economic Criteria

7.4.1 Historic Resources

Disturbance or destruction of any sites containing historic resources would not be desirable. A Historic Resources Overview Assessment was done and it was determined that the area does not present the classic attributes of a high-expectations archaeological prospect[5].

7.4.2 Employment Opportunities

The larger and more complex the site, the more labour is needed for construction. Operational complexity also adds to workforce requirements. Employment opportunities are also available during decommissioning and post-closure monitoring.

7.4.3 Perceived Community Response

The safest and most environmentally favourable alternative, preferably in an area little used and not visible, was considered to be the most favourable from the perspective of the community. Feedback from attendees at information sessions and meetings was considered.

7.4.4 Visual Impact

Sites are evaluated in terms of whether the dam and/or water surface would be visible from a community, highway or area highly used for recreation (e.g., trails, cabins). The preference is for the site to be not visible.

7.4.5 Resource Use and Recreation

Use of the area for activities such as berry picking, boating, ATV use, cabins, hunting and hiking are considered.

7.4.6 Angling

Since fishing is such an important recreational activity, the extent of loss of angling opportunities associated with each site is considered. The size of the affected waterbodies, ease of access, and the productivity affect the extent of angling traditionally taking place. Some commercial eel fishing takes place in a number of area tributaries.

7.5 Economic Criteria

7.5.1 Capital Cost

Capital costs for construction of the pipeline, access road and dams were considered.

7.5.2 Operating Cost

Operating costs principally include pumping, pipeline, road and dam maintenance, effluent and groundwater monitoring, and decant water treatment.

7.5.3 Closure Cost

Decommissioning costs include additional construction costs (e.g. underwater residue cover placement).

7.5.4 Post-Closure Cost

Post-closure costs include site rehabilitation, water cover and groundwater monitoring. Regular dam inspection and maintenance, seepage collection and continued road and return water pipeline inspection and maintenance were considered.

7.5.5 Environmental Compensation and Monitoring Cost

This includes costs associated with providing replacement habitat for the fish habitat lost as a result of the construction of the residue storage site. It also includes the ongoing monitoring costs for a period of up to 10 years.

7.5.6 Total Capital and Operating Cost

This is simply the sum of the costs for all the items listed in this category. These costs are all detailed in Appendix C.

8.0 Multiple Accounts Analysis

8.1 Introduction

A selection process was used to take key criteria from the initial master list of 54 criteria and these selected criteria were then used to do a relative comparison between the twelve residue disposal site alternatives. A total of 21 criteria were brought forward – 11 environmental, 6 technical/operational, 1 economic, and 3 socio-economic. In an effort to bring forward as many factors as possible, in many instances related criteria were combined, for example "Quantity of Aquatic Habitat Disturbed" is a combination of three environmental criteria (surface area and depth of affected lacustrine (pond) habitat, surface area of affected riverine habitat, and downstream habitat loss). In the Technical/Operational category, "Operational Risk" takes into account dam details (number, length, height, volume of fill, ratio of dam volume to residue storage capacity), flexibility with regard to operational and environmental changes, deposition management, water management, and dam access road length and accessibility. In the economic category, all capital and operating costs were combined into one.

In an attempt to be as balanced as possible, both terrestrial and aquatic habitat had two criteria brought forward – quantity and quality of each. In cases where criteria appeared in two categories, (e.g., distance from plant site which is both an environmental and technical/operational criterion), it was brought forward for evaluation in one category only, in this case environmental. As noted above, however, it still did get considered in the group of items covered by "Operational Risk".

For the 21 criteria, a scoring system was devised to distinguish between the best and the worst case. The best score was a 5, and the worst score was a 0. For example, in considering total watershed area, a site with a smaller affected watershed will have potentially less environmental impact than a site in a large watershed and would therefore score higher.

Appendix D (Scoring Matrix) presents the criteria, identifies those which are a combination of others from the initial master list, and explains the scoring system for each individual criterion.

8.2 Multiple Accounts Analysis Results

Table 8.1 presents the results of the base case multiple accounts analysis. As noted above, the maximum score on each criterion is a 5, so the maximum score in each category is 5 times the number of criteria in that category. For example, the environmental category has 11 criteria, therefore the maximum score for a "perfect" site would be 55; the socio-economic category has 3 criteria, so the maximum score would be 15, and so on.

The total score of each site alternative is summed for each of the four categories and the overall score is provided. The proportionate contribution to the total score is determined by dividing the actual score into the maximum score. For example, a site which scores 25 out of a possible 55 for the environment category has a ratio score for environment of 0.45. The highest ratio score in each category would be the best residue storage site from the perspective of that particular category. In order to give a balanced representation, all four categories (environmental, technical/operational, economic, and socio-economic) were weighted equally in the final ratio ranking. The scores in all four categories are summed, and the one with the highest overall total is considered to be the best site alternative.

The results show that Sandy Pond has the highest total score, thereby ranking first of the twelve alternatives.

8.2.1 Sensitivity Analysis

Further analysis was undertaken to evaluate the relative importance of the four categories in determining the site ranking. The following scenarios were evaluated:

- Ranking of each site according to each separate category on its own (Table 8.2);
- Ranking with environmental criteria excluded (Table 8.3);
- Ranking with technical /operational criteria excluded (Table 8.3);
- Ranking with economic criteria excluded (Table 8.3);
- Ranking with socio-economic criteria excluded (Table 8.3).

Full results of the sensitivity analysis are presented in Appendix E. The results show that Sandy Pond ranks as the best residue storage site in terms of environment and technical/operational criteria, and is second on economic and socio-economic criteria. In all cases when the ranking is done based on excluding one category at a time, Sandy Pond ranks first.

Table 8.1 Ranking for Residue Disposal Alternatives

RANKING FOR RESIDUE DISPOSAL ALTERNATIVES

Options Analysis		Site Number	Site RS-1	Site RS-2	Site RS-3	Site RS-4	Site RS-5	Site RS-6	Site RS-7	Site RS-8	Site RS-9	Site RS-10	Site RS-11	Site RS-12
		Site (Location) Decription	Sandy Pond	East Tributary - Rattling Brook	Rattling Brook Lakes	South Tributary - Rattling Brook	Ship Harbour - Watershed	Ship Harbour - Hillside	Little Rattling Brook - Watershed	Rattling Brook - Watershed	Ship Harbour Big Pond	Railway Lakes	Rocky Pond	Excavated Pit
Category	**Counter**	**Criteria**												
ENVIRONMENTAL	1	Distance from Plant Site	4	3	5	4	5	3	4	3	3	1	1	5
	2	Total Watershed Area	5	2	2	2	5	5	5	2	2	3	2	2
	3	Quantity of Aquatic Habitat Disturbed	3	3	2	3	4	3	3	3	3	2	3	5
	4	Quality of Aquatic Habitat Disturbed	3	5	3	3	0	0	0	0	0	0	0	5
	5	Quantity of Terrestrial Habitat Disturbed	3	1	1	0	0	1	2	2	2	0	1	0
	6	Quality of Terrestrial Habitat Disturbed	3	3	2	3	1	3	4	3	2	2	2	3
	7	Dam Failure Consequences	2	0	2	0	2	4	3	0	0	0	1	2
	8	Compensation Effort and Monitoring	4	3	3	3	3	4	4	3	1	2	2	5
	9	Water Quality	3	2	2	2	2	2	2	2	2	2	1	2
	10	Post Closure Rehabilitation	2	1	3	0	0	1	1	1	3	1	3	0
	11	Dam Reliability	5	3	3	3	3	1	3	3	5	3	4	4
		Environmental Score	**37**	**26**	**28**	**23**	**25**	**27**	**31**	**22**	**23**	**16**	**20**	**33**
TECHNICAL AND OPERATIONAL	1	Dam Design Details	4	2	4	2	1	3	2	3	5	4	4	4
	2	Ratio of Dam Volume to Residue Storage Capacity	5	3	5	4	2	4	3	4	5	5	5	5
	3	Dam, Storage, Quarry and Access Road Footprint	5	3	2	3	3	4	4	4	1	0	2	0
	4	Construction Risk	4	2	3	4	4	2	2	4	3	3	3	4
	5	Operational Risk	4	4	2	3	4	3	4	4	3	2	3	5
	6	Closure Risks/Uncertainty	4	2	4	2	2	2	2	2	4	4	4	3
		Technical and Operational Score	**26**	**16**	**20**	**18**	**16**	**18**	**17**	**21**	**21**	**18**	**21**	**21**
ECO-NOMIC	1	Total Capital and Operating Cost	4	0	5	3	0	1	1	3	4	3	3	0
		Economic Score	**4**	**0**	**5**	**3**	**0**	**1**	**1**	**3**	**4**	**3**	**3**	**0**
SOCIO-ECONOMIC	1	Percieved Community Response	3	2	1	2	1	0	2	4	0	3	2	3
	2	Visual Impact	5	1	5	1	5	0	1	5	1	3	1	5
	3	Resource Use and Recreation	4	4	2	3	4	4	4	4	1	3	3	4
		Socio-Economic Score	**12**	**7**	**8**	**6**	**10**	**4**	**7**	**13**	**2**	**9**	**6**	**12**
		Overall Score	**79**	**49**	**61**	**50**	**51**	**50**	**56**	**59**	**50**	**46**	**50**	**66**

	RS-1	RS-2	RS-3	RS-4	RS-5	RS-6	RS-7	RS-8	RS-9	RS-10	RS-11	RS-12
Maximum Environment Weighting	55											
Maximum Technical and Operational Weighting	30											
Maximum Economic Weighting	5											
Maximum Socio-Economic Weighting	15											
Ranked Environment Score	37	26	28	23	25	27	31	22	23	16	20	33
Ranked Technical and Operational Score	26	16	20	18	16	18	17	21	21	18	21	21
Ranked Economic Score	4	0	5	3	0	1	1	3	4	3	3	0
Ranked Socio-Economic Score	12	7	8	6	10	4	7	13	2	9	6	12
Environment Ratio	0.67	0.47	0.51	0.42	0.45	0.49	0.56	0.40	0.42	0.29	0.36	0.60
Technical and Operational Ratio	0.87	0.53	0.67	0.60	0.53	0.60	0.57	0.70	0.70	0.60	0.70	0.70
Economic Ratio	0.80	0.00	1.00	0.60	0.00	0.20	0.20	0.60	0.80	0.60	0.60	0.00
Socio-Economic Ratio	0.80	0.47	0.53	0.40	0.67	0.27	0.47	0.87	0.13	0.60	0.40	0.80
Ratio Score	**3.14**	**1.47**	**2.71**	**2.02**	**1.65**	**1.56**	**1.80**	**2.57**	**2.05**	**2.09**	**2.06**	**2.10**
Overall Ranking	**1**	**12**	**2**	**8**	**10**	**11**	**9**	**3**	**7**	**5**	**6**	**4**

Table 8.2 Ranking of Sites by Category

Site Alternative		Environment	Technical/Operational	Economic	Socio-economic
RS-1	Sandy Pond	1	1	2	2
RS-2	East Tributary Rattling Brook	6	11	10	7
RS-3	Rattling Brook Lakes	4	6	1	6
RS-4	South Tributary Rattling Brook	7	7	4	9
RS-5	Ship Harbour Watershed	7	11	10	4
RS-6	Ship Harbour Hillside	5	7	8	11
RS-7	Little Rattling Brook Watershed	3	10	8	7
RS-8	Rattling Brook Watershed	9	2	4	1
RS-9	Ship Harbour Big Pond	9	2	2	12
RS-10	Railway Lakes	12	7	4	5
RS-11	Rocky Pond	11	2	4	9
RS-12	Excavated Pit	2	2	10	2

Table 8.3 Ranking Exclusive of each Category Respectively

Site Alternative		Exclusive of Environment	Exclusive of Technical/Operational	Exclusive of Economic	Exclusive of Socio-economic
RS-1	Sandy Pond	1	1	1	1
RS-2	East Tributary Rattling Brook	12	12	8	11
RS-3	Rattling Brook Lakes	2	2	4	2
RS-4	South Tributary Rattling Brook	7	5	10	6
RS-5	Ship Harbour Watershed	10	10	5	12
RS-6	Ship Harbour Hillside	11	11	11	10
RS-7	Little Rattling Brook Watershed	9	9	6	8
RS-8	Rattling Brook Watershed	3	3	3	4
RS-9	Ship Harbour Big Pond	6	8	12	3
RS-10	Railway Lakes	4	4	7	7
RS-11	Rocky Pond	5	7	9	5
RS-12	Excavated Pit	8	6	2	9

9.0 Selection of Sandy Pond

Based on the results of the Multiple Accounts Analysis and the sensitivity analysis described in Section 8.0, Sandy Pond was selected as the site for sub-aqueous storage of the combined residue from the Hydromet Plant. The Sandy Pond site is shown in Figure 9.1. Sandy Pond is located within a bowl shaped valley which discharges through a small stream on the northeast side of the pond. This stream first flows northeast for about 600 m then joins a larger stream flowing west into Long Harbour.

The key positive features of Sandy Pond are: the smallest watershed area and footprint (the site is located at the top of a watershed requiring only one small stream diversion), minimal social impact (the site is not visible from local communities, and is seldom used for recreational activities). It is isolated and difficult to access from existing roads. It is most favourable for closure considerations (sufficient watershed to naturally maintain water cover, relatively low dams, small area of storage of about 74 ha, thick residue deposit with relatively small surface area and relatively low potential environmental impact should the dams fail).

A major issue related to Sandy Pond is with respect to the protection afforded fish and fish habitat under the *Fisheries Act* of Canada. The Department of Fisheries and Oceans (DFO) operates on the "No Net Loss" principle, i.e. any loss of productive fish habitat has to be offset in an acceptable manner such that there is no net loss in capacity. Fish habitat can only be altered or destroyed if authorized by the Minister of Fisheries and Oceans. Such authorization would not be granted under section 35 (2) of the *Fisheries Act* for the deposit of a deleterious substance. Such authorization could be granted through amendments to the *Metal Mining Effluent Regulations*, issued under section 36 (5) of the *Fisheries Act*. Under an amended MMER, the operation would require designation as per Schedule II and approval from the Department of Fisheries and Oceans for compensation for loss of fish habitat.

The loss of fish habitat as a result of site preparation and dam construction at Sandy Pond will be balanced by habitat gains elsewhere. Vale Inco NL will quantify the extent of harmful alteration, disruption or destruction (HADD) of fish habitat and work with DFO to develop an appropriate fish habitat compensation program. This is a stepwise process which includes consideration of possible habitat compensation options, development of a compensation strategy, development of a detailed compensation plan, issuance of a legally binding Compensation Agreement, Authorization of HADD and a monitoring program.

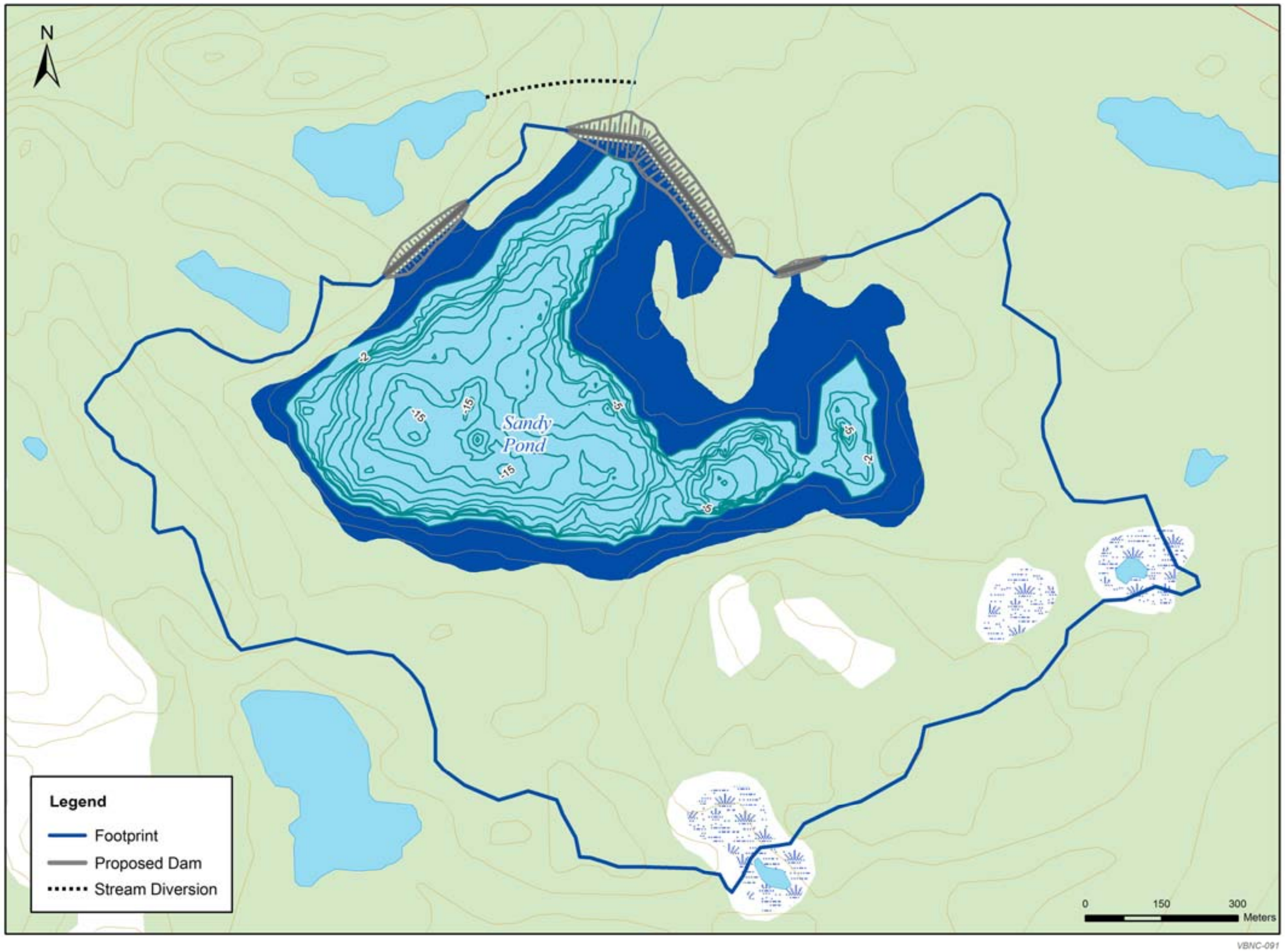

Figure 9.1 Sandy Pond

10.0 References

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2. Evaluation of Tailings Management Alternatives, Hope Bay Doris North Project, Nunavut, Canada. SRK Consulting, August 2006.
3. Characterization of VBNC Leach Residues and Processing Solutions. Part 1. Characterization of Leach Residues. T.T. Chen, J.E. Dutrizac and G. Poirier, CANMET, June 2005.
4. Residue Disposal Concepts and Comparison and Natural Sites. Memo from AMEC Earth & Environmental to VBNC. September 24, 2007.
5. Gerald Penney Associates Limited. Historic Resources Overview Assessment (Stage 1) Long Harbour, Placentia Bay. 2006.

11.0 Glossary

bathymetry - the measurement of the depth of bodies of water.

chalcopyrite - iron/copper sulphide – FeCuS - a sulphide mineral of copper and iron.

FGR **-** neutralized gypsum residue

goethite – partially hydrated ferric oxide – FeO.OH - a red, yellow, or brown mineral, one of the common constituents of rust.

hematite – ferric oxide – Fe_2O_3 - a black or blackish-red to brick-red mineral.

hydrometallurgical - a hydrometallurgical process technology is a process in which metals-bearing minerals or mattes are processed in an aqueous phase for the separation and recovery of the valuable metals in the form of pure metals or as intermediate metal product.

kilopascals (kPa) – a unit of pressure - 101.35 kPa are equivalent to one atmosphere of pressure.

lysimeter – rectangular plexiglass tank – 200 liter capacity - laboratory column for sampling and monitoring the movement of water and chemicals.

mounding - refers to dredged sediments disposed of in the water that build up instead of dispersing with currents and/or tides.

morphology - the characteristics and configuration of rocks and land forms .

NCR **–** neutralized combined residue

NLR **–** neutralized leach residue

pentlandite – iron/nickel sulphide - a mineral (iron and nickel sulphide) that is the chief ore of nickel.

paste – a soft, smooth, thick mixture or material.

rheology – the friction between liquid and solids – the study of how readily a liquid-solids mixture will flow.

viscosity – the thickness or resistance to flow of a liquid.

APPENDIX A

RESIDUE GEOTECHNICAL & GEOCHEMICAL PROPERTIES

Residue Geotechnical & Geochemical Properties

A leach residue and an iron-gypsum residue are generated from the processing of nickel concentrate in the Hydromet Plant (see Figure 1).

The pressure oxidation leaching step in the process produces a residue which, after settling, is washed in a series of thickeners to reduce the soluble nickel in the entrained solution and is collected as thickened underflow (about 40% solids) from the last thickener. The washed and thickened leach residue slurry is then neutralized by addition of lime to adjust the pH to about 10.5.

Hydromet Flowsheet

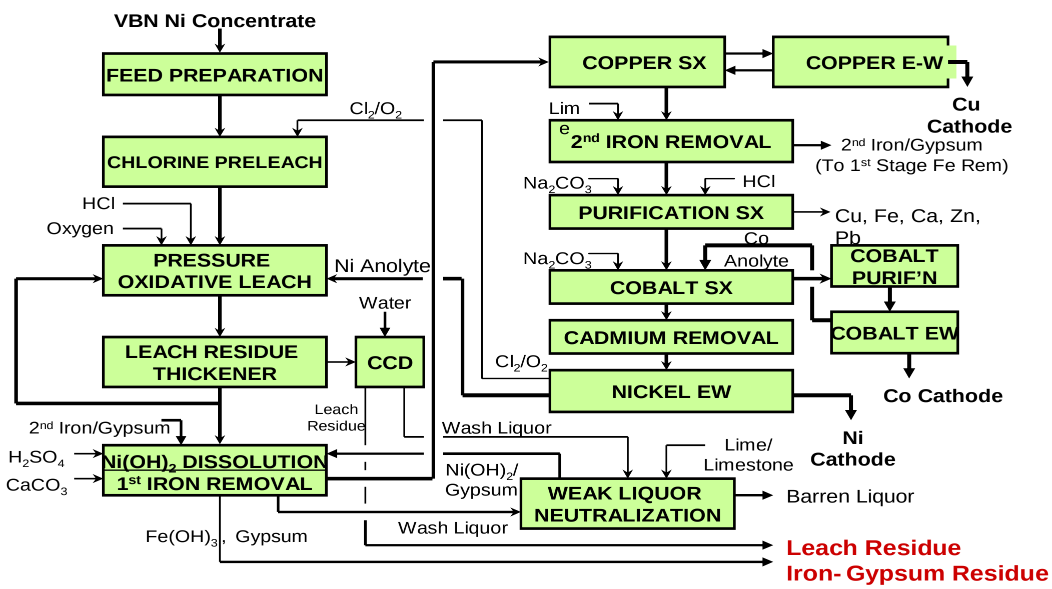

Figure 1 – Hydromet Flowsheet

A second residue is produced in an iron precipitation stage where nickel hydroxide, recycled from a downstream weak liquor neutralization step, is dissolved and most of the iron in the solution is precipitated by neutralization with limestone, lime and air. The precipitated iron hydroxide and gypsum (calcium sulphate) are separated by thickening followed by two stages of washing and filtration. The washed solids are neutralized with lime to a pH of about 10.

Residue Composition

The neutralized leach residue (NLR) consists mostly of hematite (iron oxide, Fe_2O_3) and elemental sulphur (S^0). This residue also contains minor amounts of unreacted iron-nickel sulphide (pentlandite) and iron-copper sulphide (chalcopyrite), precipitated nickel and copper hydroxides and partially hydrated ferric oxide (FeO.OH) (see Table 1). CANMET[2] has concluded from extensive electron microprobe and X-Ray diffraction studies of the leach residue that the elemental sulphur is present in the form of spheroids (~10 μm) mixed with tiny particles of iron oxide (~1 μm) and minor amounts of partially hydrated ferric oxide. Electron microscope photographs of the residue indicate that some of the sulphur occupies the hollow cores of iron oxide (see Figure 2).

The structure of the iron hydroxide-gypsum residue is shown in electron microscope photographs in Figure 3. This residue consists mainly of gypsum with about 5% ferric hydroxide (see Table 1). The neutralized combined residues have the compositions shown in Table 1.

Table 1 - Composition of Hydromet Plant Residues

	HYDROMET		
	NCR	**NLR**	**FGR**
Iron Oxide (wt %)	37.9	62.7	0
Iron Hydroxide (wt %)	3.6	0	5
Gypsum (wt%)	41.2	11.4	94
Elemental Sulphur (wt%)	16.6	25	0
Nickel (wt%)	0.3-0.5	0.4-0.6	0.1
Copper (wt%)	0.3-0.5	0.4-0.6	0.04

Note: Totals do not add up to 100% due to other very minor substances present in the residues (aluminum and silicon oxides, calcium carbonate).

NCR = neutralized combined residue

NLR = neutralized leach residue

FGR = neutralized gypsum residue

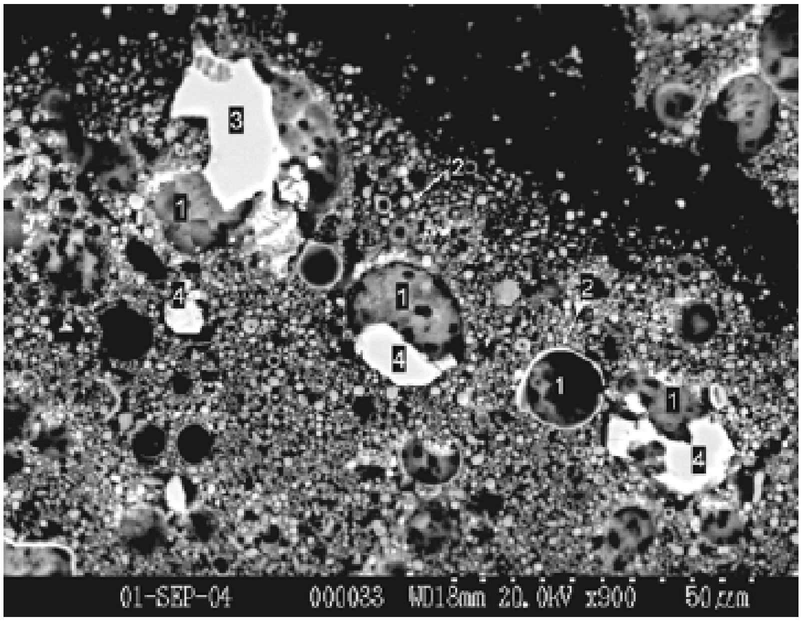

Figure 2 - General morphology of Sample 60min leach residue.

1- sulphur, 2- hematite or goethite, 3- pentlandite, 4- chalcopyrite

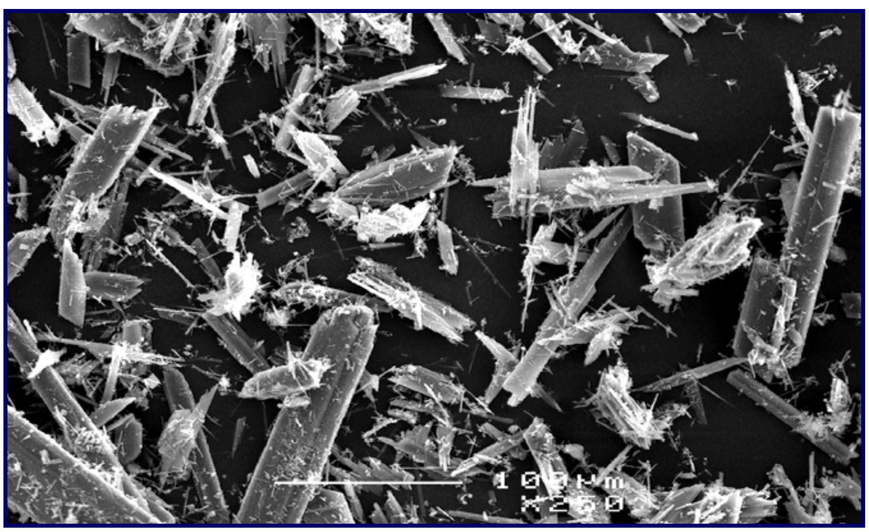

Figure 3 - Ferric Hydroxide-Gypsum Residue

Geotechnical Characterization of Hydromet Plant Residues

Geotechnical studies of residues produced in pilot facilities and in the hydrometallurgical nickel processing demonstration plant currently operating at Argentia, Newfoundland and Labrador were conducted. Knight Piesold[3] completed a laboratory geotechnical testing program on NLR, FGR and NCR including particle sizes, strength, rheological (pumping ability), freeze-thaw, drained and undrained settling, slurry consolidation and hydraulic conductivities, and soil-water characteristics. Ardaman&Associates[4] completed a geotechnical evaluation of FGR produced at the hydrometallurgical nickel processing demonstration plant, and Jacques Whitford[5] measured hydraulic conductivities on NCR produced at the demonstration plant. Golder Paste Technology Ltd[24] investigated the paste properties of the individual and combined residues. The results of the geotechnical tests are summarized in Table 2 and discussed below.

Rheological Characteristics of Hydromet Residues

- There is no significant difference in viscosity for NCR and NLR in the range of 45 to 55% solids;
- The NCR and NLR slurries are considered to be pumpable up to 50% solids;
- The NCR and NLR slurries behave as pastes in the range 60 to 63 % solids;
- Addition of about 3 wt % Portland Cement improves the angle of deposition of the NCR and NLR pastes;
- In the opinion of Kight Piesold the FGR can be pumped as a slurry up to about 47 % solids, and behaves as a paste in the range of 51 to 55 % solids. Golder considers that the FGR would not make a pumpable paste as it thickens too much.

The rheological characterization of the residues shows that the NCR and NLR will behave about the same and can be pumped as slurries up to 50 % solids. Both Knight Piesold and Golder Paste Technology Ltd determined that the NCR and NLR behave as pumpable pastes in the range 60 to 63 %. Knight Piesold considered this to be a very narrow range and suggested that it would be difficult to control. Therefore, it would be prudent to install a paste plant near the residue disposal site. The FGR can also be pumped as a slurry up to 47 % solids. The FGR is probably not suitable for pumping as a paste. Because the FGR is essentially a gypsum residue, and gypsum residues are routinely stored by either wet or dry stacking (as a slurry or a filter cake), it is unlikely that storing of the FGR as a paste would be considered.

Hydromet Residue Geotechnical Characteristics under Sub-aerial Conditions

Neutralized Combined Residue (NCR) and Neutralized Leach Residue (NLR)

- The final air dried densities for NCR and NLR were about the same at 1.33 and 1.39 t/m3 respectively and both would therefore occupy about the same final volume per tonne of residue stored in sub-aerial fashion;

- Both NCR and NLR had the characteristics of low plasticity fine grained-silts; that is, they have little tendency to act as pastes ;
- Freeze-thaw tests showed negligible effect on the dry densities of all residues indicating that the residues would remain stable under summer-winter seasonal variations;
- Both NCR and NLR had high suction pressures, indicative of water retention, meaning that it is difficult to achieve a high solids content without applying very high vacuum suction pressures;
- Both NCR and NLR showed significant strength gain above 55 % solids content at which point the surface may be stable enough to consider driving on it;
- All residues showed high resistance to liquefaction in cyclic shear strength testing indicating good stability under seismic events, i.e. they would be unlikely to liquefy and collapse;
- Both NLR and NCR showed very poor filtration capacity and, therefore, the residues require pumping as slurries to the storage site.

The sub-aerial geotechnical properties of the NCR and NLR residues are very similar. This means that when the FGR is combined with the NLR to form NCR, the physical properties of the FGR are lost and the NCR takes on the physical properties of the NLR. Both the NCR and NLR when pumped to a sub-aerial storage site will settle and consolidate slowly. The settled NCR and NLR residues will tend to retain water, but will show significant strength above about 55 % solids. The air dried surface will have a density in the range 1.33 to 1.39 t/m^3. Results indicate that this dry density will be unaffected by summer-winter seasonal variations. Because of a very poor filtration capacity, the NCR and NLR need to be pumped as slurries. Placement of the residues in the form of a paste would reduce the water content of the residues by about 50 % prior to storage.

Neutralized Iron-Gypsum Residue (FGR)

- The FGR residue is characterized as non-plastic fine grained silt;
- It has a dry density of 1.04 t/m^3;
- Freeze-thaw cycles have no effect on dry densities;
- It has low suction pressure (does not retain water);
- FGR has high resistance to liquefaction in cyclic shear testing indicating good stability under seismic events;
- FGR filters well and, therefore, can be transported as a filter cake, if desired;
- Vertical permeabilities for FGR range from 2.6 x 10-4 cm/sec at low pressures to 4.8 x 10-5 cm/sec at 100 kilopascals (kPa);
- The FGR, containing 95% gypsum, exhibits similar geotechnical properties to gypsum for sub-aerial storage.

Table 2 - Summary of Physical Test Results

Property	Neutralized Iron-Gypsum Residue (FGR)		Neutralized Leach Residue (NLR)	Neutralized Combined Residues (NCR)	
	Ardaman@ Associates	Knight Piesold	Knight Piesold	Jacques-Whitford	Knight Piesold
Average specific gravity	2.34	2.99	3.35		3.03
Plasticity Index (%)	-	Non Plastic	5.4	-	2.9
Particle sizing-Malvern-micron >100 <100 to>50 <50 to>10 <10 to>2	10 35 53 2	10 45 24 31	0 0.5 35 65	0 15 45 40	0 0.1 35 65
Undrained settling time (h)	-	5 to 28	50 to 94	-	67 to 158
Drained settling time (h)	-	5 to 22	50 to 70	-	70 to 142
Air Entry Suction Pressure(kPa)	-	70	500	-	400
Consolidation Void Ratio at 100kPa	1.69	Not Available	1.54	1.92	1.33
Hydraulic Conductivity (cm/sec) 1 kPa 100 kPa	2.6×10^{-4} 4.8×10^{-5}	1.3×10^{-4} 3.4×10^{-8}	3.6×10^{-5} 2.7×10^{-6}	5×10^{-6} 2×10^{-6}	2.8×10^{-6} 4.7×10^{-7}
Cyclic Resistance Ratio (Direct Simple Shear)	-	0.31	0.25	-	0.28
Moisture Content for Undrained Shear Strength of 50 kPa (%)	-	54	39	-	38
Solids Content for 25.0 mm Slump (%)	-	52	61	-	61
Capacity for Filtration	-	Good	Very Poor	-	Very Poor

Hydromet Residue Characteristics under Sub-aqueous Conditions

- Settled undrained dry densities are in the range of 0.9 to1.0 t/m^3 for NCR and NLR at low confining pressure, increasing to a range of 1.0 to 1.1 t/m^3 at a confining pressure of 200kPa. These data are useful for the design of storage areas where the residue is placed on a low permeability surface such as clay;
- Settled drained dry densities are in the range 1.0 to 1.1 t/m^3 for NCR and NLR at low confining pressure, increasing to a range of 1.1 to 1.3 t/m^3 at a confining pressure of 200 kPa. These densities are used to determine the required volume for a sub-aqueous storage site;
- Vertical permeabilities for both NCR and NLR range from 10^{-5} cm/sec at low pressure to $5x10^{-7}$ cm/sec at 200kPa close to the range of permeabilities of clay substrates which are considered to be relatively impermeable;
- FGR would dissolve completely under sub-aqueous conditions and therefore cannot be contained in a sub-aqueous site.

The consolidation and permeability data for the NCR and NLR are very similar and confirm that these residues will behave about the same when placed under water cover . The lower void ratio of the NCR versus the NLR, as measured by Knight Piesold, suggests that the NCR would occupy a lower volume per tonne of residue than the NLR, after consolidation. The low vertical permeabilities of the residues will minimize the seepage rate of interstitial water into the groundwater.

Geochemical Characterization of Hydromet Plant Residues

Determination of the geochemical properties of the neutralized residues from the Hydromet Plant is essential to predict their behaviour in the environment under either sub-aerial or sub-aqueous storage conditions. Of main concern is the potential release of acidity due to elemental sulphur and/or sulphide oxidation reactions resulting in the eventual dissolution of the nickel, copper and iron contained in the residue.

Knight Piesold[6,7] has completed bulk solid and supernatant analyses, residue mineralogy, acid-base accounting, TCLP (toxic characterization leach procedure), SPLP (simulated precipitation leach procedure), modified SPLP (pH 2.5 to 9.0), sequential rinsing (pH 3 to 9), and kinetic humidity cell tests. These studies were carried out on NCR, NLR and FGR and also on the unneutralized leach residue (ULR) to simulate a worst case scenario in which no residual neutralization potential would be present. Because the residues are neutralized with lime before being deposited in storage sites, some inherent neutralization capability is expected as a result of the elevated pH ~10.5. This residual capability can neutralize some of the acid formed when the elemental sulphur in the leach residue oxidizes to form sulphates.

The acid-base accounting properties (ABA) of the residues are of particular significance as these determine whether the residues contain sufficient acid neutralization potential (NP) to overcome the maximum acid producing potential (APP) of the residues. This is expressed as net neutralization potential (NNP = NP - APP) in kg $CaCO_3$ per tonne of residue. The standard ABA procedure calculates the acid-producing potential based on oxidation of the sulphide-sulphur content of the residue which is assumed to be present as pyrite (FeS_2). Each mole of sulphide sulphur is considered to have a potential production of one mole of sulphuric acid, corresponding to an APP of 32.25 kg $CaCO_3$/tonne. However, the NLR and NCR only contain minor amounts of sulphide-sulphur and major amounts of elemental sulphur. Oxidation of the elemental sulphur has also the potential for production of one mole of sulphuric acid per mole of elemental sulphur, according to the reaction:

$$S^0 + 1.5\ O_2 + H_2O = H_2SO_4$$

Therefore Knight Piesold[6] has treated elemental sulphur exactly the same as the sulphide-sulphur for the calculation of the APP of the residues. The acid neutralization potential (NP) of the residues was determined by the modified Sobek method at ambient temperature. In this method the residue is acidified with HCl to a pH of 2 and back titrated with NaOH to pH 8.3. Results obtained by Knight Piesold are shown in Table 3.

Because of uncertainties in the calculation of APP (depending on the accuracy of sulphide and elemental sulphur analyses) and the measurement of NP (can be affected by reaction with carbonates), it is generally accepted that if the NNP is greater than 20 kg$CaCO_3$/tonne the residue is non-acid-generating and with NNP values less than –20 kg$CaCO_3$/tonne, the residue is acid-generating. The NNP values of –788.9 and –783.1 kg$CaCO_3$/tonne for NLR and NCR in Table 3.3 are indicative of a very high net acid producing potential for these residues.

Another indicator used in the mining industry is the neutralization potential ratio, expressed as NPR = NP/APP. If this ratio is less than 1, the residue is considered acid producing and if the ratio is greater than 3, the residue is considered non acid producing. The NPR for the hydromet residue is not only below 1, but negative.

Table 3 - ABA Results for Voisey's Bay Residue Samples (Modified Sobeck Method)

Sample	Total Sulfur (4)	Elemental Sulfur (5)	Sulfate Sulfur (1)	Sulfide Sulfur (2)	Acid Production Potential APP (3) Calculated	Neutralization Potential NP Measured	Net Neutralization Potential NNP = NP-APP Calculated	Neutralization Potential Ratio NPR = NP/APP
	(wt%)				($kgCaCO_3$/tonne)			(g/g)
NLR	28.3	24.8	2.1	0.3	784.4	-4.5	-788.9	-0.006
NCR	26.7	24.6	2.1	0.4	781.3	-1.8	-783.1	-0.002

Notes:

1. Sulphate Sulphur by HCl digestion
2. Sulphide Sulphur by HNO_3 digestion
3. Based on the sum of elemental sulphur and sulphide sulphur in wt% x 31.25
4. Enhanced Leco
5. Carbon disulphide extraction

CANMET[8,10] has been conducting long term sub-aqueous testing on NCR and NLR generated in the ITSL mini pilot plant in Mississauga, Ontario, simulating a series of post closure scenarios (stagnant, followed by circulating and flow through water covers). The tests are conducted in specially designed 200 liter capacity rectangular type fish tanks (referred to as lysimeters) equipped with sampling ports at three levels in the liquid phase and three levels in the solids phase. To date tests with a stagnant water cover and circulating water covers, each operated for about 300 days, have been completed. Tests simulating flow through and groundwater seepage are now underway. Results to date on the flow through tests for NCR and NLR, simulating closure indicate that the concentrations of Fe, Cu and Ni have stabilized and show a trend for decrease after about 250 days.

CANMET[9,10] is also conducting sub-aerial testing using the lysimeter tanks without water cover and simulating bi-weekly rainfall (wet cycle), drainage and dry cycle. The tests are being conducted on NCR, NLR and FGR generated in the ITSL mini pilot plant. The residues were inoculated with sulphur oxidizing bacteria commonly found in sub-aerial sulphide residues to test for acidification. The tests are in the third year of operation and are ongoing. It is noted that the rate of release of Fe, Cu and Ni are steadily increasing even after three years of operation. The current rates of metal mobilization are nearly two orders of magnitude larger than for the sub-aqueous rates.

The investigations to date have shown that, consistent with the mineralogy, both the NLR and NCR are prone to acid generation leading to the release into solution of the nickel, copper and iron contained in the neutralized residues. For sub-aqueous residue storage the rate of acid production is limited by the rate of diffusion of oxygen to the residue surface. As the reactive sulphur depletes from the surface, diffusion rates into the residue surface layers become a limiting factor for the rate of acid production. Consequently the rate of acid generation and resulting nickel, copper and iron mobilization is expected to decrease with time. In contrast, for the sub-aerial residue storage, the reactivity of the residues continues to increase after each wet and dry cycle which would require effluent treatment during operation and after closure in perpetuity.

The FGR, which is not prone to acid generation, showed no acidity or metal release after 30 months under sub-aerial placement. Sub-aqueous storage of FGR was not studied as this residue cannot be effectively contained under a water cover. It would essentially completely dissolve as water flows through the storage pond. This would therefore be no different from discharging the residue directly into ground water and subsequently into Long Harbour. Marine disposal of residue solids is not allowed under Federal regulations.[11]

Investigation into Sulphur Removal

One method of reducing the acid-generating potential of either the NCR or NLR would be to remove the sulphur from the residues before storing them. This possibility was tested based on existing technology applied to the separation of elemental sulphur from zinc pressure leaching plant residues as practiced by Cominco and Hudson Bay Mining and Smelting[12].

The sulphur removal process consists of an initial residue flotation step to separate the bulk of the elemental sulphur from the residue. If successful, the residues will be sufficiently depleted in elemental sulphur to be classed as non-acid producing residues for long-term storage. Based on an extensive review of available guidelines for non-acid-generating residues by Hatch[12], it was concluded that the Net Acid-generating Potential of the residue should be equivalent to neutralization of less than 20 kg $CaCO_3$/tonne. The acid producing potential of a residue is equivalent to 32.25 kg of $CaCO_3$/tonne per wt% sulphur. Therefore 20 kg of $CaCO_3$/tonne corresponds to a maximum elemental sulphur content in the flotation residue of 0.7 wt %. This would require removal of at least 97.5 % of the elemental sulphur from the residue.

In a second step, the separated solids containing elemental sulphur could be further processed to produce a commercial grade sulphur. The sulphur could be recovered from the remaining solids by heating to about 140ºC to melt the sulphur, followed by hot filtration to collect the bulk of the sulphur in the form of a filtrate. The sulphur depleted filter cake could be recycled to the pressure leaching step in the hydrometallurgical process.

The above flotation procedure, followed by melting and filtration of the elemental sulphur product was tested on the NLR. Flotation was optimized at the ITSL[13] Laboratories in Mississauga, Ontario and the hot melt and filtration step was tested by Dynatec[14] on a representative sample of the elemental sulphur flotation concentrate provided by ITSL. The following results were obtained:

- A maximum of 87 % of the elemental sulphur, together with 20 % of the iron oxide, was captured in the flotation concentrate in the optimum flotation test. The remaining NLR residue, about 60 % of the original residue by weight, still contained 6 wt % elemental sulphur, an order of magnitude higher than required to be considered a non-acid-generating residue;

- Testing of the Sulphur Melt and Hot Filtration Process (June 2004) on the optimized elemental sulphur concentrate sample provided by ITSL indicated that only 18 % of the elemental sulphur was removed from the residue after hot filtration, basically leaving a filter cake having a composition of 51.8 % S^0 (about 71 % of the total elemental sulphur in the original leach residue before flotation) and 25.8 % Fe.This filter cake cannot be recycled to the plant as it would compromise the operation of the autoclave and nickel extraction. In addition, export specifications were not met in the sulphur filtrate product due to too high concentrations of arsenic at 0.6g/t, selenium at 12g/t and tellurium at 3g/t). The product specifications require concentrations of arsenic, selenium and tellurium of <0.25g/t, <1g/t and <1g/t, respectively.

Extensive microscopic studies on the autoclave leach residues by CANMET[2] have shown that a large part of the sulphur in the pressure oxidation autoclave leach residue is trapped within iron oxide spherical shells and/or covered by iron oxide particles (see Figure 2). This can explain the poor selectivity for elemental sulphur separation from the leach residue by flotation. The encapsulation of the elemental sulphur into the iron oxide also explains the poor removal of the molten sulphur by hot filtration.

Based on all the work completed and a review of commercial operations and residue disposal options, Vale Inco NL has concluded that separation of elemental sulphur is technically not viable and will not be considered further because: (1) it fails to produce an acceptable non-acid-generating residue, (2) it produces an intermediate filter cake residue with over 70 % of the initial elemental sulphur and (3) it produces a non-commercial sulphur product.

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APPENDIX B

MAJOR CATEGORIES WITH MASTER CRITERIA

Criteria No.	Criteria Description	Definitions/Rationale	Site RS-1 Sandy Pond Natural Pond	Site RS-2 East tributary - Rattling Brook Land based	Site RS-3 Rattling Brook Lakes Natural Pond	Site RS-4 South tributary - Rattling Brook Land based	Site RS-5 Ship Harbour - Watershed Land based	Site RS-6 Ship Harbour - Hillside Land based	Site RS-7 Little Rattling Brook - Watershed Land based	Site RS-8 Rattling Brook - Watershed Land based	Site RS-9 Ship Harbour Big Pond Natural Pond	Site RS-10 Railway Lakes Natural Pond	Site RS-11 Rocky Pond Natural Pond	Site RS-12 Excavated Pit Land based
C1-1	**Distance from Plant Site (km)**	Longer distance - greater footprint, higher potential for spill, more affected habitat. Additional/larger emergency spill collection pond requirements.	4 km	5.5 km	1.0 km	3.6 km	1.25 km	5.9 km	4.5 km	5.6 km	7.5 km	11 km	14 km	2 km
C1-2	**Dam Failure Potential - Geotechnical and Seismic**	Related to size of structure, upstream affected watershed, location of known geological faults. The entire area is not considered seismically active and has one of the lowest ratings in the National Building Code. Dam reliability considered for the extreme long term duration (in perpetuity).	Dam reliability very high for this site as the dams are relatively small and are founded on bedrock, core can be grouted into the bedrock.	Dam reliability at this site is very low as the structure would be founded on till material and there is a geological fault along this valley.	Dams are relatively small and low therefore reliability is moderate, dams founded on till material with grout cut-off cores. The perimeter is convoluted. Has a large surface area of storage.	Dam failure probability at this site would be medium even though it has one of the highest dams of the sites reviewed. The dam would be founded on bedrock and anchored with a grout curtain cut-off core.	Dam reliability at this site is considered to be moderate to low due to size and number of dams required.	Dam reliability at this site would be very low as the valley sides have over 25m of overburden till material on which the dam sides would be founded.	Dam reliability at this site would be moderate even though it has the highest dams of the sites reviewed. The dams would be founded on bedrock and keyed into the rock foundation.	Dam reliability for this site would be moderate to high as the dams would be partially founded on bedrock and anchored into the rock.	Dam reliability at this site would be very high as it has the lowest dam height of the sites reviewed and the smallest volume of material in its construction.	Dam reliability at this site would be high as the dams are relatively small.	Dam reliability at this site would be high as the dams are small and not over 10m high.	Not applicable
C1-3	**Dam Failure Consequences**	Extent of affected watershed, infrastructure and habitat.	Dam failure or seepage would have the potential to affect all freshwater pond and stream habitat downstream of the site to the eventual outflow to Placentia Bay. The total stream habitat downstream of this option is estimated at 2,101m and the total pond/steady habitat is estimated at 0.14ha.	Dam failure or seepage would have the potential to affect all freshwater pond and stream habitat downstream of the site to the eventual outflow to Placentia Bay. The total stream habitat downstream of this option is estimated at 4,703m and the total pond/steady habitat is estimated at 234.53ha.	Dam failure or seepage would have the potential to affect all freshwater pond and stream habitat downstream of the site to the eventual outflow to Placentia Bay. The total stream habitat downstream of this option is estimated at 2,016m and the total pond/steady habitat is estimated at 64.53ha.	Dam failure or seepage would have the potential to affect all freshwater pond and stream habitat downstream of the site to the eventual outflow to Placentia Bay. The total stream habitat downstream of this option is estimated at 2,641m and the total pond/steady habitat is estimated at 1424.41ha.	Dam failure or seepage would have the potential to affect all freshwater pond and stream habitat downstream of the site to the eventual outflow to Placentia Bay. The total stream habitat downstream of this option is estimated at 2,211m and the total pond/steady habitat is estimated at 2.01ha.	Dam failure or seepage would have the potential to affect all freshwater pond and stream habitat downstream of the site to the eventual outflow to Placentia Bay. The total stream habitat downstream of this option is estimated at 460m and the total pond/steady habitat is estimated at 0.62ha.	Dam failure or seepage would have the potential to affect all freshwater pond and stream habitat downstream of the site to the eventual outflow to Placentia Bay. The total stream habitat downstream of this option is estimated at 1,747m and the total pond/steady habitat is estimated at 36.53ha.	Dam failure or seepage would have the potential to affect all freshwater pond and stream habitat downstream of the site to the eventual outflow to Placentia Bay. The total stream habitat downstream of this option is estimated at 4,461m and the total pond/steady habitat is estimated at 33.17ha.	Dam failure or seepage would have the potential to affect all freshwater pond and stream habitat downstream of the site to the eventual outflow to Placentia Bay. The total stream habitat downstream of this option is estimated at 5,254m and the total pond/steady habitat is estimated at 53.92ha.	Dam failure or seepage would have the potential to affect all freshwater pond and stream habitat downstream of the site to the eventual outflow to Placentia Bay. The total stream habitat downstream of this option is estimated at 4,919m and the total pond/steady habitat is estimated at 4.36ha.	Dam failure or seepage would have the potential to affect all freshwater pond and stream habitat downstream of the site to the eventual outflow to Placentia Bay. The total stream habitat downstream of this option is estimated at 3,797m and the total pond/steady habitat is estimated at 23.46ha.	This option requires no dam therefore there is no potential for failure. The total stream habitat downstream of this option (Rattling Brook) is estimated at 2,016m and the total pond/steady habitat is estimated at 23.46ha.
C1-4	**ARD - Metal Mobilization and Leaching Potential**	Potential for acid generation and metal leaching. Larger area for flux greater potential for acid leaching. The ability to retain a water cover - loss of water cover increases the potential for acidification and leaching.	Natural pond with dam, good water inflow, low ARD potential.	Sub-aqueous with dam, minimum water inflow, high ARD potential.	Natural pond with dam, good water inflow, low ARD potential.	Sub-aqueous with dam, some water inflow, moderate ARD potential.	Sub-aqueous with dam, some water inflow, moderate ARD potential.	Sub-aqueous with dam, some water inflow, moderate ARD potential.	Sub-aqueous with dam, some water inflow, moderate ARD potential.	Sub-aqueous with dam, some water inflow, moderate ARD potential.	Natural pond with dam, good water inflow, low ARD potential.	Natural pond with dam, good water inflow, low ARD potential.	Natural pond with dam, good water inflow, low ARD potential.	Sub-aqueous, no dam, low water inflow, high ARD potential
C1-5	**Freeze Drying/Dusting Potential**	Fine particulate size and freeze drying combined with high wind dust generation and containment problems. The ability to retain a water cover - the loss of water cover increases the potential for dust generation.	Natural pond Small area Very low dusting potential	Land based Small area Moderate dusting potential	Natural pond Large area Low dusting potential	Land based Medium area Moderate dusting potential	Land based Medium area Moderate dusting potential	Land based Small area Moderate dusting potential	Land based Small area Moderate dusting potential	Land based Small area Moderate dusting potential	Natural pond Large area Low dusting potential	Land based Large area Moderate to high dusting potential	Natural pond Large area Low dusting potential	Land based Large area Moderate to high dusting potential
C1-6	**Topographical Aspects**	Use of natural land features. Distribution and depth of till in valley - impact on dam design.	Site is at the height of the watershed and is a natural depression in the bedrock.	Located in NE/SW sloping gentle gradient valley, and relatively contained at the down gradient end. High in watershed.	Enclosed in a series of natural depressions with an extensive and convoluted perimeter. Mid to low in watershed.	Located in SE/NW sloping gentle gradient valley, and relatively contained at the down gradient end. High in watershed.	Poorly defined valley NE/SW orientation, moderate perimeter. High in watershed.	Well defined till covered valley, NE/SW sloping gradient, open at down gradient and pronounced relief. Low in watershed.	Located in NE/SW sloping steep gradient valley, and relatively open at the down gradient end. High in watershed.	Located in poorly defined valley, N/S orientation, gentle relief open at end of valley. Site is at located watershed divide (high). Significant outcrop of bedrock at surface.	Large natural depression, relatively large perimeter, low relief. Site intrudes into existing road infrastructure. High in watershed.	Located in poorly defined valley, NE/SW orientation, gentle relief open at end of valley/natural basins. Largest perimeter, inundates existing trailways. Bedrock outcrops. Mid in watershed.	Located in NE/SW orientation well defined natural depression, open at down gradient end. High in watershed.	Natural topography disturbed by cut and major excavation. Located in a relatively steep area which slopes toward the plant site - oriented W/E. No natural containment features. Small perimeter - depression excavated in bedrock. Placement of excavated material will create additional topographic disturbance. High in watershed.

Criteria No.	Criteria Description	Definitions/Rationale	Site RS-1 Sandy Pond Natural Pond	Site RS-2 East tributary - Rattling Brook Land based	Site RS-3 Rattling Brook Lakes Natural Pond	Site RS-4 South tributary - Rattling Brook Land based	Site RS-5 Ship Harbour - Watershed Land based	Site RS-6 Ship Harbour - Hillside Land based	Site RS-7 Little Rattling Brook - Watershed Land based	Site RS-8 Rattling Brook - Watershed Land based	Site RS-9 Ship Harbour Big Pond Natural Pond	Site RS-10 Railway Lakes Natural Pond	Site RS-11 Rocky Pond Natural Pond	Site RS-12 Excavated Pit Land based
C1-7	**Hydrology**	Relative effect on local streams, water diversions, natural inflow potential.	Without diversion of upstream drainage around the proposed site, it is estimated that 48% of the drainage basin will be intercepted. This would correspond to a similar reduction in water flows in the remaining downstream habitat. Habitat directly downstream would likely be dewatered with less effect farther downstream.	Without diversion of upstream drainage around the proposed site, it is estimated that 5.0% of the drainage basin will be intercepted. This would correspond to a similar reduction in water flows in the remaining downstream habitat. Habitat directly downstream as far as Rattling Brook Big Pond would likely be dewatered with less effect farther downstream.	Without diversion of upstream drainage around the proposed site, it is estimated that 82.7% of the drainage basin will be intercepted. This would correspond to a similar reduction in water flows in the remaining downstream habitat. Habitat downstream would likely be dewatered to the extent that it would no longer be suitable fish habitat.	Without diversion of upstream drainage around the proposed site, it is estimated that 19.8% of the drainage basin will be intercepted. This would correspond to a similar reduction in water flows in the remaining downstream habitat. Habitat downstream as far as Rattling Brook Big Pond would likely be dewatered with less effect farther downstream.	Without diversion of upstream drainage around the proposed site, it is estimated that 14.1% of the drainage basin will be intercepted. This would correspond to a similar reduction in water flows in the remaining downstream habitat. Habitat directly downstream would likely be dewatered with less effect farther downstream.	Without diversion of upstream drainage around the proposed site, it is estimated that 91.8% of the drainage basin will be intercepted. This would correspond to a similar reduction in water flows in the remaining downstream habitat. Habitat downstream would likely be dewatered to the extent that it would no longer be suitable fish habitat.	Without diversion of upstream drainage around the proposed site, it is estimated that 35.3% of the drainage basin will be intercepted. This would correspond to a similar reduction in water flows in the remaining downstream habitat. Habitat directly downstream would likely be dewatered with less effect farther downstream.	Without diversion of upstream drainage around the proposed site, it is estimated that 3.3% of the drainage basin will be intercepted. This would correspond to a similar reduction in water flows in the remaining downstream habitat. Habitat directly downstream would likely be dewatered with less effect farther downstream.	Without diversion of upstream drainage around the proposed site, it is estimated that 29.5% of the drainage basin will be intercepted. This would correspond to a similar reduction in water flows in the remaining downstream habitat. Habitat directly downstream would likely be dewatered with less effect farther downstream.	Without diversion of upstream drainage around the proposed site, it is estimated that 54.8% of the drainage basin will be intercepted. This would correspond to a similar reduction in water flows in the remaining downstream habitat. Habitat directly downstream would likely be dewatered with less effect farther downstream.	Without diversion of upstream drainage around the proposed site, it is estimated that 11.8% of the drainage basin will be intercepted. This would correspond to a similar reduction in water flows in the remaining downstream habitat. Habitat directly downstream would likely be dewatered with less effect farther downstream.	Excavation will disturb the groundwater and run-off. Permanent change to hydrology. It is estimated that 1.15 km2 of the drainage basin would be intercepted.
C1-8	**Hydrogeology**	Relative effect on deep groundwater, impact on other water bodies. Ultimate release of ground water to the environment. Ground water volume/flow control and monitoring	There would be minimal ground water effect from this site because of the low hydraulic conductivity of the bedrock underlying the site. Monitoring wells would be installed downstream of the main dam. Ground water flow from this site would eventually be to the sea in Long Harbour.	This site has moderate potential for groundwater effects as a synthetic impermeable liner would be installed under the entire flooded area and any leaks would result in seepage into groundwater. Monitoring wells would be installed downstream of the dam. Groundwater flow would be into Rattling Brook Big Pond.	This site has relatively high potential for seepage into the groundwater as the site would not be lined and it appears that sections of the lakes have overburden material at the base. Seepage from this site would be into the rattling Brook drainage stream and into the sea at Long Harbour	The potential for seepage into the groundwater table from this site is low to medium as the site is underlain with bedrock but would require extensive liners at the dam faces to tie into the bedrock, seepage from this site would be into the Rattling Brook Big Pond.	This site has a medium to high potential for seepage into the ground water. The site is located on glacial till material and would require a synthetic impermeable liner for the flooded area. Any leaks that occur would affect the groundwater. Seepage from this site would be into the Rattling Brook Lakes watershed and eventually on to the sea at both Ship and Long Harbour.	There is a high potential for this site to have seepage into the groundwater. The site is overlain in places with more than 20 meters of glacial till on the side slopes and a synthetic impermeable liner would be required under the flooded area. Seepage from this site would be into the water course draining into Ship Harbour less than a km downstream.	This site has a high potential for seepage into the groundwater, the site has the highest height of dams for the sites reviewed and would require extensive liners to anchor into the abutments at the valley side areas. Installation of a liner would be difficult due to the steepness of the terrain. Seepage from this site would be into Little Rattling Pond that drains to the sea at Ship Harbour.	This site has a high potential for seepage into the ground water. The site has two relatively high dams that would be difficult to tie into the steep side walls of the valley. Installation of a liner would be difficult due to the steepness of the terrain. Seepage from this site would take a long time to migrate to any water bodies because of its location.	This site has a medium to high potential for seepage into the groundwater. The dam is very small but the surrounding terrain is mostly glacial till and there will be no liner installed as this site is a natural water body. Seepage into the groundwater from this site would eventually get into the watershed draining into Ship Harbour.	There is a high potential for seepage from this site into the groundwater as there will be no liner in this site since it is impractical to line a site of over 200 ha and the area is mostly glacial till material with a small number of natural ponds. Seepage from this site would eventually drain into Placentia Sound.	This site has a high potential for seepage into the groundwater as there are extensive glacial till deposits around the site. Seepage from this site would eventually report to the Fox harbour brook and on to the sea at Ship Harbour.	The excavation will disturb the groundwater and run-off, causing a permanent change to the hydrogeology. Seepage will likely be low (depending on rock quality) and will report to the Rattling Brook drainage system and on to Long Harbour.
C1-9	**Surface Area (ha) and Maximum Depth of Affected Lacustrine (Pond) Habitat.**	Size and quality of natural water bodies, capacity.	Sandy Pond is the only pond habitat within the proposed site with a surface area of 37.8ha. Maximum depth has been measured at 16.5m.	A total of three small water bodies/steadies are within the proposed site with a surface area of 0.65ha. Maximum depths have been estimated at less than 1m.	A total of seven water bodies/steadies are within the proposed site (including Sam Howe's Pond) with a total surface area of 102.60ha. Maximum depths have been measured at 12.3m (Sam Howe's).	A total of five water bodies/steadies are within the proposed site with a total surface area of 1.58ha. Maximum depths have been estimated at 1.0m.	A total of six water bodies/steadies are within the proposed site with a total surface area of 7.14ha. Maximum depths have been estimated at 1.0m.	A total of two water bodies/steadies are within the proposed site with a total surface area of 4.56ha. Maximum depths have been estimated at 1.0m.	Only one small water body is located within the proposed site with a total surface area of 1.67ha. Maximum depths have been estimated at 1.0m.	A total of four water bodies/steadies are within the proposed site with a total surface area of 11.35ha. Maximum depths have been estimated at 1.0m.	A total of two water bodies/steadies are within the proposed site (including Ship Harbour Big Pond) with a total surface area of 114.38ha. Maximum depths have been measured at 11.5m.	A total of eleven water bodies/steadies are within the proposed site with a total surface area of 25.16ha. Maximum depths have been estimated at 1.0m.	Only one water body (Rocky Pond) is located within the proposed site with a total surface area of 61.76ha. Maximum depths have been measured at 20.0m.	Terrestrial site
C1-10	**Surface Area (ha) of Affected Terrestrial Habitat.**	Size and quality of terrestrial habitat, capacity.	The total aerial extent of terrestrial habitat within the proposed site is estimated at 35.75ha.	The total aerial extent of terrestrial habitat within the proposed site is estimated at 65.69ha.	The total aerial extent of terrestrial habitat within the proposed site is estimated at 62.11ha.	The total aerial extent of terrestrial habitat within the proposed site is estimated at 100.41ha.	The total aerial extent of terrestrial habitat within the proposed site is estimated at 92.57ha.	The total aerial extent of terrestrial habitat within the proposed site is estimated at 69.09ha.	The total aerial extent of terrestrial habitat within the proposed site is estimated at 55.45ha.	The total aerial extent of terrestrial habitat within the proposed site is estimated at 57.12ha.	The total aerial extent of terrestrial habitat within the proposed site is estimated at 58.65ha.	The total aerial extent of terrestrial habitat within the proposed site is estimated at 187.65ha.	The total aerial extent of terrestrial habitat within the proposed site is estimated at 61.27ha.	The total aerial extent of terrestrial habitat within the proposed site is estimated at 76.6 plus 100 ha for excavated material disposal. Approximately 180 ha in total.
C1-11	**Surface Area (ha) of Affected Riverine Habitat.**	Size and quality of riverine habitat, capacity.	An estimated total of 29m of stream habitat is located within the proposed site.	An estimated total of 1,279m of stream habitat is located within the proposed site.	An estimated total of 619m of stream habitat is located within the proposed site.	An estimated total of 3,089m of stream habitat is located within the proposed site.	An estimated total of 1,439m of stream habitat is located within the proposed site.	An estimated total of 2,166m of stream habitat is located within the proposed site.	An estimated total of 1,156m of stream habitat is located within the proposed site.	An estimated total of 901m of stream habitat is located within the proposed site.	An estimated total of 370m of stream habitat is located within the proposed site.	An estimated total of 4,249m of stream habitat is located within the proposed site.	An estimated total of 162m of stream habitat is located within the proposed site.	Terrestrial site
C1-12	**Total Watershed Area (km2)**	Size of affected watershed indicates potential environmental impact.	4.71 km2	33.33 km2	33.33 km2	33.33 km2	8.46 km2	8.46 km2	6.49 km2	34.65 km2	34.65 km2	29.11 km2	34.65 km2	33.33 km2

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C1-13	**Downstream Habitat Loss.**	Total area affected by site water retention and loss of flow. Including quality downstream terrestrial, riverine and lake habitats.	Downstream habitat that would most likely be dewatered as a result of water retention, diversion and use is estimated as 2,416m of stream and 0.14ha of water body/steady.	Downstream habitat that would most likely be dewatered as a result of water retention, diversion and use is estimated as 2,221m of stream and 0.16ha of water body/steady.	Downstream habitat that would most likely be dewatered as a result of water retention, diversion and use is estimated as 2,720m of stream and 64.53ha of water body/steady.	Downstream habitat that would most likely be dewatered as a result of water retention, diversion and use is estimated as 527m of stream and 0.60ha of water body/steady.	Downstream habitat that would most likely be dewatered as a result of water retention, diversion and use is estimated as 652m of stream and 1.37ha of water body/steady.	Downstream habitat that would most likely be dewatered as a result of water retention, diversion and use is estimated as 446m of stream and 0.62ha of water body/steady.	Downstream habitat that would most likely be dewatered as a result of water retention, diversion and use is estimated as 998m of stream and no water body/steady.	Downstream habitat that would most likely be dewatered as a result of water retention, diversion and use is estimated as 1,713m of stream and no water body/steady.	Downstream habitat that would most likely be dewatered as a result of water retention, diversion and use is estimated as 734m of stream and 3.60ha of water body/steady.	Downstream habitat that would most likely be dewatered as a result of water retention, diversion and use is estimated as 2,847m of stream and 4.36ha of water body/steady.	Downstream habitat that would most likely be dewatered as a result of water retention, diversion and use is estimated as 1,440m of stream and 1.54ha of water body/steady.	Downstream habitat that would most likely be dewatered as a result of water retention, diversion and use is unknown but likely minimal.
C1-14	**Geographical Site Footprint (ha)**	Size and quality impact of disturbed surface site footprint on ecosystem. Including road access development, dams, quarry and disposal areas.	The total surface area of the site is estimated at 92.6 ha.	The total surface area of the site is estimated at 126.1 ha.	The total surface area of the site is estimated at 167.8 ha.	The total surface area of the site is estimated at 139.0 ha.	The total surface area of the site is estimated at 145.0 ha.	The total surface area of the site is estimated at 100.6 ha.	The total surface area of the site is estimated at 107.2 ha.	The total surface area of the site is estimated at 116.5 ha.	The total surface area of the site is estimated at 185.2 ha.	The total surface area of the site is estimated at 239.3 ha.	The total surface area of the site is estimated at 154.4 ha.	The total surface area of the site is estimated at 180 ha (76.6 footprint, 100 excavated spoil disposal).
C1-15	**Water Quality**	Supernatant water quality and treatment - re-use potential for the process. Water quality based on ratio of watershed and residue areas. A higher ratio will result in better water quality during operation.	Small residue area with 2.4 times dilution factor.	Small residue area with 2.2 times dilution factor.	Large residue area with 4.7 times dilution factor.	Medium residue area with 4.8 times dilution factor	Medium residue area with 1.3 times dilution factor	Small residue area with 9 times dilution factor.	Small residue area with 4.4 times dilution factor.	Small residue area with 2.2 times dilution factor.	Large residue area with 4.4 times dilution factor.	Large residue area with 8 times dilution factor.	Medium residue area with 1.6 times dilution factor	Medium residue area with 1 times dilution factor
C1-16	**Atmospheric**	Relative effect of wind. Wave action - suspended solids affects oxidation reaction rate.	The combined fetch for the predominant winds across the site (southwest and northeast) are estimated to be 3.4km.	The combined fetch for the predominant winds across the site (southwest and northeast) are estimated to be 12.2km.	The combined fetch for the predominant winds across the site (southwest and northeast) are estimated to be 14.4m.	The combined fetch for the predominant winds across the site (southwest and northeast) are estimated to be 5.0km.	The combined fetch for the predominant winds across the site (southwest and northeast) are estimated to be 4.8km.	The combined fetch for the predominant winds across the site (southwest and northeast) are estimated to be 7.1km.	The combined fetch for the predominant winds across the site (southwest and northeast) are estimated to be 10.4km.	The combined fetch for the predominant winds across the site (southwest and northeast) are estimated to be 3.7km.	The combined fetch for the predominant winds across the site (southwest and northeast) are estimated to be 15.3km.	The combined fetch for the predominant winds across the site (southwest and northeast) are estimated to be 8.0km.	The combined fetch for the predominant winds across the site (southwest and northeast) are estimated to be 13.3km.	The combined fetch for the predominant winds across the site (southwest and northeast) are estimated to be 3km.
C1-17	**Climate Change**	The impact of climate change on temperature and precipitation levels in the area is predicted to be significant in the long term. The predicted increase in temperature over the next century is small. Modelling of precipitation change indicates a degree of variation which is difficult to incorporate in the current design. Dam design is based on a very conservative double 1:100 maximum annual rain/ spring run-off combination.	Lower dam size, reduced impact of extreme rain event.	Large dam size high risk of impact of extreme rain event.	Smallest dam size, low risk of impact of extreme rain event.	Large dam size high risk of impact of extreme rain event.	Largest dam size highest risk of impact of extreme rain event.	Moderate dam size and height limits impact of extreme rain event.	Large dam size high risk of impact of extreme rain event.	Moderate dam size and height limits impact of extreme rain event.	Smallest dam size, low risk of impact of extreme rain event.	Small dam size, low risk of impact of extreme rain event.	Small dam size, low risk of impact of extreme rain event.	No dam - no risk due to extreme rain event.
C1-18	**Post Closure - Rehabilitation and Land Use.**	Ability to return land to original use or acceptable alternative use. Least change for natural water bodies.	Moderate ability to return to aquatic habitat	No ability to return to terrestrial habitat	Moderate ability to return to aquatic habitat	No ability to return to terrestrial habitat	No ability to return to terrestrial habitat	No ability to return to terrestrial habitat	No ability to return to terrestrial habitat	No ability to return to terrestrial habitat	Moderate ability to return to aquatic habitat	Large permanent terrestrial habitat loss	Moderate ability to return to aquatic habitat	Large permanent terrestrial habitat loss
C1-19	**Fish Habitat Compensation Effort.**	The greater the area and quality of fish habitat the more habitat compensation required.	Compensation would be required for Sandy Pond as well as the outflow stream as Sandy Pond provides the majority of flows until farther downstream. The quality of fish habitat and compensation effort is considered moderate.	Compensation would not likely be required as the small intermittent stream within the proposed site is not considered fish bearing waters. However, the habitat downstream in the tributary could be affected by the reduction is drainage basin area, especially during extreme summer low flows. The quality of fish habitat and compensation effort is considered low.	Compensation would be required for Rattling Brook Lakes (which includes Sam Howe's Pond) as well as the downstream portion of Rattling Brook which would have significantly reduced flows. The amount of downstream compensation would be dependant on the diversion option for Rattling Brook Big Pond. The quality of fish habitat and compensation effort is considered high.	Compensation would be required for the stream habitat within the site as well as stream habitat downstream of the dam. Portions of the stream habitat above the proposed site could be maintained by diverting to a small sub-tributary to the east. The quality of fish habitat is considered high. Compensation effort is considered moderate.	Compensation would be required for any fish bearing water within the site. There is no fish habitat anticipated upstream of the site. The quality of fish habitat and compensation effort is considered low.	Compensation would be required for any fish bearing water within the site as well as any dewatered habitat downstream. The quality of fish habitat and compensation effort is considered low.	Compensation would be required for any fish bearing water within the site as well as any dewatered habitat downstream. The quality of fish habitat and compensation effort is considered low.	Compensation would be required for any fish bearing water within the site as well as any dewatered habitat downstream. There is no fish habitat anticipated upstream of the site. The quality of fish habitat and compensation effort is considered low.	Compensation would be required for Ship Harbour Big Pond as well as a downstream portion of Ship Harbour Brook which would have significantly reduced flows. The amount of downstream compensation would be dependant on the input of other tributaries to the main stem. The quality of fish habitat and compensation effort is considered high.	Compensation would be required for the stream and pond habitat within Railway Lakes as well as a downstream portion of Railway Brook which would have significantly reduced flows. The amount of downstream compensation would be dependant on the input of other tributaries to the main stem. The quality of fish habitat and compensation effort is considered high.	Compensation would be required for Rocky Pond as well as the downstream outflow to the main stem as well as a downstream portion of Ship Harbour Brook which could have reduced flows. The amount of downstream compensation would be dependant on the input of other tributaries to the main stem. The quality of fish habitat and compensation effort is considered high.	Compensation for an excavated pit would not likely be required, however any potential groundwater connection between the site and the nearest fish habitat would need to be established (Rattling Brook). The compensation effort is considered negligible.

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C1-20	**Fish Habitat Monitoring Effort**	Compensation planning and monitoring.	Compensation monitoring associated with this option would be conducted over ten years and is considered moderate.	Compensation monitoring associated with this option would be conducted over ten years and is considered low.	Compensation monitoring associated with this option would be conducted over ten years and is considered high.	Compensation monitoring associated with this option would be conducted over ten years and is considered moderate.	Compensation monitoring associated with this option would be conducted over ten years and is considered low .	Compensation monitoring associated with this option would be conducted over ten years and is considered low.	Compensation monitoring associated with this option would be conducted over ten years and is considered low.	Compensation monitoring associated with this option would be conducted over ten years and is considered low.	Compensation monitoring associated with this option would be conducted over ten years and is considered high.	Compensation monitoring associated with this option would be conducted over ten years and is considered moderate.	Compensation monitoring associated with this option would be conducted over ten years and is considered high.	Compensation monitoring for an excavated pit would not likely be required.
C1-21	**Additional Habitat Monitoring**	Additional habitat monitoring.	Additional monitoring related to the quantity of downstream habitat not included in compensation (i.e. habitat still considered fish habitat) with this option would be considered minimal as most downstream habitat will be compensated.	Additional monitoring related to the quantity of downstream habitat not included in compensation (i.e. habitat still considered fish habitat) with this option would be considered moderate. Rattling Brook Big Pond and all mainstream habitat downstream will require monitoring.	Additional monitoring related to the quantity of downstream habitat not included in compensation (i.e. habitat still considered fish habitat) with this option would be considered minimal as most downstream habitat will be compensated.	Additional monitoring related to the quantity of downstream habitat not included in compensation (i.e. habitat still considered fish habitat) with this option would be considered moderate. Rattling Brook Big Pond and all mainstream habitat downstream will require monitoring.	Additional monitoring related to the quantity of downstream habitat not included in compensation (i.e. habitat still considered fish habitat) with this option would be considered moderate.	Additional monitoring related to the quantity of downstream habitat not included in compensation (i.e. habitat still considered fish habitat) with this option would be considered minimal as most downstream habitat will be compensated.	Additional monitoring related to the quantity of downstream habitat not included in compensation (i.e. habitat still considered fish habitat) with this option would be considered low.	Additional monitoring related to the quantity of downstream habitat not included in compensation (i.e. habitat still considered fish habitat) with this option would be considered moderate.	Additional monitoring related to the quantity of downstream habitat not included in compensation (i.e. habitat still considered fish habitat) with this option would be considerable. Much of Ship Harbour Brook will require ongoing monitoring.	Additional monitoring related to the quantity of downstream habitat not included in compensation (i.e. habitat still considered fish habitat) with this option would be considered moderate.	Additional monitoring related to the quantity of downstream habitat not included in compensation (i.e. habitat still considered fish habitat) with this option would be moderate. Much of Ship Harbour Brook will require ongoing monitoring.	Additional monitoring related to the quantity of downstream habitat not included in compensation (i.e. habitat still considered fish habitat) with this option would be considered minimal. While the site would not be directly linked to fish habitat, monitoring of Rattling Brook would be required for potential groundwater effects.
C1-22	**Atlantic Salmon**		Atlantic salmon are not present (anadromous or landlocked)	Atlantic salmon are not present (anadromous or landlocked)	Atlantic salmon are not present (anadromous or landlocked)	Atlantic salmon are not present (anadromous or landlocked)	Landlocked Atlantic salmon may be present within the ponds but would be anticipated in low abundance due to the intermittent nature of the watershed	Landlocked Atlantic salmon may be present within the ponds but would be anticipated in low abundance due to the intermittent nature of the watershed	Landlocked Atlantic salmon may be present within the ponds but would be anticipated in low abundance due to the intermittent nature of the watershed. A complete barrier at the mouth of Little Rattling Brook eliminates anadromous use.	Landlocked and anadromous Atlantic salmon may be present within the ponds but would be anticipated in low abundance due to the intermittent nature of the watershed in location of residue storage area	Landlocked Atlantic salmon are present within Ship Harbour Big Pond. Abundance of landlocked form is relatively high but anadromous would be low due to a partial obstruction approximately 3.2km upriver from its confluence	Landlocked Atlantic salmon are likely present within Railway Lakes. Abundance of landlocked form is unknown but anticipated to be relatively low due to the small size of ponds. Anadromous salmon would also be anticipated to be low due to several series of rapids and falls downstream of the proposed site	Landlocked Atlantic salmon are present within Rocky Pond. Abundance of landlocked form is relatively high but anadromous abundance would be low due to a partial obstruction approximately 3.2km upriver from its confluence	No fish present in excavated pit.
C1-23	**Brook Trout**		Brook trout are known to be present, although in low abundance	Brook trout are not likely present upstream of highway 101 due to intermittent nature of the stream and barriers to migration	Brook trout are known to be present, abundance is unknown	Brook trout are known to be present, abundance is unknown	Brook trout are likely present within the ponds but would be anticipated in low abundance due to the intermittent nature of the watershed	Brook trout are likely present within the ponds but would be anticipated in low abundance due to the intermittent nature of the watershed	Brook trout are likely present within the ponds but would be anticipated in low abundance due to the intermittent nature of the watershed, particularly the upper portion where the proposed residue storage area is situated	Brook trout are likely present within the ponds but would be anticipated in low abundance due to the intermittent nature of the watershed, particularly the upper portion where the proposed residue storage area is situated	Brook trout are known to be present, abundance is relatively high	Brook trout are likely present within the ponds, abundance is unknown	Brook trout are known to be present, abundance is relatively moderate	No fish present in excavated pit.
C1-24	**Arctic Char**		Not present	Arctic char are not likely present upstream of highway 101 due to intermittent nature of the stream and barriers to migration	Arctic char are in Rattling Brook Big Pond therefore they could be present in this tributary at some time	Arctic char are in Rattling Brook Big Pond therefore they could be present in this tributary at some time	Not likely present due to small watershed/pond sizes and intermittent stream flows in location of residue storage area	Not likely present due to small watershed/pond sizes and intermittent stream flows in location of residue storage area	Not likely present due to small watershed/pond size and intermittent stream flows in location of residue storage area	Not likely present due to small watershed/pond size and intermittent stream flows	Arctic char are not likely present but due to the size of the pond, they may be present in low abundance	Not likely present due to small watershed/pond sizes in location of residue storage area	Arctic char are not likely present but due to the size of the pond, they may be present in low abundance	No fish present in excavated pit.

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C1-25	**Eels**	American eels are a Species of Concern under SARA	Eels present but in low abundance.	Eels not present	Eels not present	Eels not present	Eels most likely present	Eels most likely present	Eels probably not present (complete obstruction)	Eels most likely present	Eels most likely present	Eels most likely present	Eels most likely present	No fish present - excavated pit.
C1-26	**Other (Rainbow Smelt, Stickleback)**		Other species are present (rainbow smelt) in relatively high abundance.	No other species known to be present.	No other species known to be present.	No other species known to be present.	Other species are likely present (stickleback), abundance unknown.	Other species are likely present (stickleback), abundance unknown.	Other species are likely present (stickleback), abundance unknown.	Other species are likely present (stickleback), abundance unknown.	Other species are likely present (stickleback), abundance unknown.	Other species are likely present (stickleback), abundance unknown.	Other species are likely present (stickleback), abundance unknown.	No fish present in excavated Pit.
C1-27	**Avifauna**	Important components of ecosystem e.g. raptors, waterfowl, songbirds.	Low to moderate waterfowl use	Low avifauna use	High waterfowl use	Low avifauna use	High waterfowl use	Moderate avifauna use	Low potential avifauna use	Low potential avifauna use	High waterfowl use	High potential waterfowl use	High waterfowl use	Low to moderate avifauna potential use
C1-28	**Moose**	Important component of ecosystem and big game.	36 ha of terrestrial habitat loss. Moderate suitability	65 ha of terrestrial habitat loss. Low suitability	60 ha of terrestrial habitat loss. Moderate suitability.	100 ha of terrestrial habitat loss. Moderate suitability	95 ha of terrestrial habitat loss. High suitability.	70 ha of terrestrial habitat loss. Low suitability.	55 ha of terrestrial habitat loss. Moderate suitability.	60 ha of terrestrial habitat loss. Moderate suitability.	60 ha of terrestrial habitat loss. Moderate suitability.	185 ha of terrestrial habitat loss. Moderate suitability.	62 ha of terrestrial habitat loss. Low suitability.	180 ha of terrestrial habitat loss. Moderate suitability.
C1-29	**Other Wildlife**	Important components of ecosystem e.g. aquatic furbearers, prey species and small game.	Aquatic furbearers	Small game and prey species	Aquatic furbearers	Small game, prey species and aquatic furbearers.	Small game, prey species and aquatic furbearers.	Small game and prey species	Low suitability	Small game, prey species and aquatic furbearers.	Aquatic furbearers	Small game, prey species and aquatic furbearers.	Aquatic furbearers	Small game and prey species

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C2-1	**Distance from Plant Site (km)**	Longer distance - greater footprint. Pipeline and pumping systems increased size, complexity, schedule and cost. Increased operation and maintenance requirements.	4 km	5.5 km	1.0 km	3.6 km	1.25 km	5.9 km	4.5 km	5.6 km	7.5 km	11 km	14 km	2 km
C2-2	**Dam Design Details:**	Dam size - volume of fill, requirement for borrow pits, grout curtain, base, dam wall LLDPE and GCL lining.												
	Number	Number of dams required for residue storage capacity	3	1	3	3	4	1	2	2	1	2	3	None
	Length	Total length of all dams (m)	922 m	1555 m	237 m	1020 m	2665 m	560 m	1300 m	1350 m	203 m	540 m	1177 m	-
	Height	Height of tallest dam structure (m) above grade.	17 m	29 m	7 m	32.5 m	30 m	26.5 m	36 m	28 m	4.25 m	17 m	8.8 m	15 m (depth)
	Volume	Total volume of material for construction of dams (m3)	250,100 m3	1,871,127 m3	15,974 m3	1,266,996 m3	2,483,238 m3	758,594 m3	1,799,323 m3	1,252.070 m3	11,030 m3	138,857 m3	150,276 m3	23,000,000 m3
	Ratio	Ratio of Dam Volume to residue storage capacity. Measure of storage efficiency.	0.038	0.277	0.002	0.194	0.384	0.117	0.274	0.192	0.002	0.021	0.023	-
C2-3	**Surface Area of Residue Storage Site at Final Water Level for Closure**	Total footprint of residue storage area (ha). Influences metal leaching potential.	74 ha	74 ha	165 ha	102 ha	100 ha	74 ha	57 ha	69 ha	173 ha	214 ha	124 ha	64 ha
C2-4	**Dam, Access Road and Quarry - Total Footprint.**	Related to size and type of structure, distance from the plant site. Constructability. Affected area (ha).	The footprint for the dams, quarry and road would occupy a total area of approximately 92.6 ha	The footprint for the dam, quarry and road would occupy approximately 126.1 ha	The foot print for the dams, quarry and road would occupy approximately 167.7 ha	The foot print for the dams, quarry and road would occupy approximately 139.3 ha	The foot print for the dams, quarry and road would occupy approximately 145 ha	The foot print for the dams, quarry and road would occupy approximately 100.6 ha	The foot print for the dams, quarry and road would occupy approximately 107.2 ha	The foot print for the dams, quarry and road would occupy approximately 116.5 ha	The foot print for the dam, quarry and road would occupy approximately 185.2 ha	The foot print for the dams, quarry and road would occupy approximately 239.3 ha	The foot print for the dams, quarry and road would occupy approximately 154.4ha	The foot print for the excavated pit and road would occupy approx 76.6 ha with an additional 80-100 ha for disposal of the excavated material - total area of approximately 180 ha
C2-5	**Potential for Increase in Residue Containment Capacity.**	Modifications required to increase storage capacity. Potential to double capacity required.	A moderate increase of 8m in dam height allows the storage capacity to be doubled. Good potential.	Low potential for expansion, due to massive size of dam required.	Good potential for expansion.	Moderate to low potential for expansion, due to massive size of dam required.	Moderate potential for expansion, due to massive size of dam required and potential additional dams.	Low potential for expansion due to poor ground conditions.	Moderate to low potential for expansion, due to massive size of dam required.	Moderate potential for expansion, due to massive size of dam required.	Good potential for expansion.	Good potential for expansion	Good potential for expansion	Low potential for expansion.
C2-6	**Flexibility with regard to Operational and Environmental Changes.**	Process upsets and changes have the potential to alter the composition of residue slurry, this may alter the supernatant water quality. The effluent treatment facility is designed to cater for anticipated changes. Extreme flood or drought conditions may impact the residue storage facility in terms of water cover or required decant pump flow rates.	Natural pond therefore watershed is sufficient to maintain water level. Adequate pumping capacity for major storm events.	Site is high in watershed with low interception of flow, potential for low water levels. Adequate pumping capacity for major storm events.	Natural pond therefore watershed is sufficient to maintain water level. Adequate pumping capacity for major storm events.	Site is high in watershed with moderate interception of flow, potential for low water levels. Adequate pumping capacity for major storm events.	Site is high in watershed with moderate interception of flow, potential for low water levels. Adequate pumping capacity for major storm events.	Natural wetland low in watershed therefore flow is sufficient to maintain water level. Adequate pumping capacity for major storm events.	Site is high in watershed with moderate interception of flow, potential for low water levels. Adequate pumping capacity for major storm events.	Site is very high in watershed with very low interception of flow, high potential for low water levels. Adequate pumping capacity for major storm events.	Natural pond moderate interception of flow therefore watershed is sufficient to maintain water level. Adequate pumping capacity for major storm events.	Site is high in watershed with moderate interception of flow, potential for low water levels. Adequate pumping capacity for major storm events.	Natural pond moderate interception of flow therefore watershed is sufficient to maintain water level. Adequate pumping capacity for major storm events.	Site is very high in watershed with very low interception of flow, high potential for low water levels. Adequate pumping capacity for major storm events.
C2-7	**Construction Risk.**	Accessibility, upgrade watershed, design assumption and site data, site layout, working conditions, synthetic liners.	Adequate field data, medium access, minimum upgradient watershed, No base liner.	Some field data, medium access, minimum upgradient watershed, Synthetic/geotextile liner.	Minimal field data, short access, largest upgradient watershed, No base liner.	Minimal field data, short access, moderate upgradient watershed, No base liner.	Minimal field data, short access, low upgradient watershed, Synthetic/geotextile liner.	Some field data, medium access, moderate upgradient watershed, Synthetic/geotextile liner.	No field data, medium access, low upgradient watershed, Synthetic/ geotextile liner.	No field data, medium access, low upgradient watershed, No base liner.	No field data, high access, large upgradient watershed, No base liner.	No field data, high access, very large upgradient watershed, No base liner.	No field data, highest access, medium upgradient watershed, No base liner.	Some field data, short access, low upgradient watershed, No base liner.

Criteria No.	Criteria Description	Definitions/Rationale	Site RS-1 Sandy Pond Natural Pond	Site RS-2 East tributary - Rattling Brook Land based	Site RS-3 Rattling Brook Lakes Natural Pond	Site RS-4 South tributary - Rattling Brook Land based	Site RS-5 Ship Harbour - Watershed Land based	Site RS-6 Ship Harbour - Hillside Land based	Site RS-7 Little Rattling Broo Watershed Land based	Site RS-8 Rattling Brook - Watershed Land based	Site RS-9 Ship Harbour Big Pond Natural Pond	Site RS-10 Railway Lakes Natural Pond	Site RS-11 Rocky Pond Natural Pond	Site RS-12 Excavated Pit Land based
C2-8	**Operational Risk.**	Relocation of deposition points, water management - supply of initial water cover and maintenance of supernatant water levels, dam access road length and accessibility. Standby line/discharge point for residue lines.	Medium length access road, good water management, very good deposition management potential.	Medium length access road, good water management, good deposition management potential.	Short length access road, poor water management, very poor deposition management potential.	Short length access road, fair water management, fair deposition management potential.	Short length access road, good water management, fair deposition management potential.	Medium length access road, fair water management, good deposition management potential.	Medium length access road, very good water management, good deposition management potential.	Medium length access road, very good water management, good deposition management potential.	Long access road length, poor water management, very good deposition management potential.	Long access road length, poor water management, very poor deposition management potential.	Longest access road length, good water management, poor deposition management potential.	Short access road length, good water management, very good deposition management potential.
C2-9	**Closure Risks/Uncertainties.**	Most sites have water retaining structures and will require monitoring and maintenance in the long term.	Concerns over long term dam stability. Long term maintenance and monitoring.	Concerns over long term dam stability and ability to maintain water cover. Long term maintenance and monitoring.	Concerns over long term dam stability. Long term maintenance and monitoring.	Concerns over long term dam stability and ability to maintain water cover. Long term maintenance and monitoring.	Concerns over long term dam stability and ability to maintain water cover. Long term maintenance and monitoring.	Concerns over long term dam stability and ability to maintain water cover. Long term maintenance and monitoring.	Concerns over long term dam stability and ability to maintain water cover. Long term maintenance and monitoring.	Concerns over long term dam stability and ability to maintain water cover. Long term maintenance and monitoring.	Concerns over long term dam stability. Long term maintenance and monitoring.	Concerns over long term dam stability. Long term maintenance and monitoring.	Concerns over long term dam stability. Long term maintenance and monitoring.	Concern over ability to maintain water cover in the long term.
C2-10	**Post Closure - Rehabilitation and Land Use.**	Ability to return land to original use or acceptable alternative use.	Medium term return to original aquatic habitat, extension of pond area. 43.1% terrestrial site.	Predominantly terrestrial habitat (78.9%) is permanently changed to a water body.	Medium term return to original aquatic habitat, extension of pond area. 37.0% terrestrial site.	Predominantly terrestrial habitat (91.3%) is permanently changed to a water body.	Predominantly terrestrial habitat (88.6%) is permanently changed to a water body.	Predominantly terrestrial habitat (75.4%) is permanently changed to a water body.	Predominantly terrestrial habitat (78.5%) is permanently changed to a water body.	Predominantly terrestrial habitat (66.9%) is permanently changed to a water body.	Medium term return to original aquatic habitat, extension of pond area. 30.0% terrestrial site.	Medium term return to original aquatic habitat, large extension of pond area. 76.2% terrestrial site.	Medium term return to original aquatic habitat, extension of pond area. 37.3% terrestrial site.	Predominantly terrestrial habitat (100%) is permanently changed to a water body.

Criteria No.	Criteria Description	Definitions/Rationale	Site RS-1 Sandy Pond	Site RS-2 East tributary - Rattling Brook	Site RS-3 Rattling Brook Lakes	Site RS-4 South tributary - Rattling Brook	Site RS-5 Ship Harbour - Watershed	Site RS-6 Ship Harbour - Hillside	Site RS-7 Little Rattling Bro Watershed	Site RS-8 Rattling Brook - Watershed	Site RS-9 Ship Harbour Big Pond	Site RS-10 Railway Lakes	Site RS-11 Rocky Pond	Site RS-12 Excavated Pit
C3-1	**Capital Cost.**	Primary infrastructure - dams, access roads, pump and pipeline systems etc. and indirect project engineering and construction costs.	$46.5 M	$275.1 M	$12.7 M	$110.0 M	$334.6 M	$201.7 M	$235.6 M	$126.8 M	$41.2 M	$73.0 M	$94.5 M	$478.5 M
C3-2	**Operating Cost.**	Residue deposition operating costs - manpower, electrical, major consumables, ongoing development costs. 15 year project life.	$2.5 M	$2.6 M	$4.6 M	$3.5 M	$3.4 M	$2.7 M	$2.6 M	$2.7 M	$5.2 M	$6.2 M	$4.8 M	$2.1 M
C3-3	**Closure Cost.**	Dam deconstruction, spillway development and maintenance. Effluent treatment (2 years) following completion of process. Closure assessment. Residue O.5 m sand cap on closure.	$7.9 M	$7.6 M	$17.0 M	$10.8 M	$10.9 M	$7.7 M	$6.0 M	$7.1 M	$17.4 M	$21.7 M	$12.9 M	$6.5 M
C3-4	**Post Closure Cost.**	Final spillway cut and dam decommission. Ongoing environmental and dam monitoring for a period of 100 years.	$2.5 M	$2.5 M	$2.5 M	$2.5 M	$2.5 M	$2.5 M	$2.5 M	$2.5 M	$2.5 M	$2.5 M	$2.5 M	$2.5 M
C3-5	**Environmental Compensation & Monitoring Cost.**	Costs related to provision of fish habitat to compensate for loss of a lake or stream as well as monitoring (compensation and downstream habitat)	$3.0 M	$1.8 M	$4.5 M	$3.0 M	$1.8 M	$1.5 M	$1.5 M	$1.8 M	$5.0 M	$3.0 M	$4.5 M	$0.5 M
C3-6	**Total Capital and Operating Cost.**	Sum of all costs related above.	**$62.4 M**	**$289.6 M**	**$41.3 M**	**$129.8 M**	**$353.2 M**	**$216.1 M**	**$248.2 M**	**$140.9 M**	**$71.3 M**	**$106.4 M**	**$119.2 M**	**$490.2 M**

Criteria No.	Criteria Description	Definitions/Rationale	Site RS-1 Sandy Pond	Site RS-2 East tributary - Rattling Brook	Site RS-3 Rattling Brook Lakes	Site RS-4 South tributary - Rattling Brook	Site RS-5 Ship Harbour - Watershed	Site RS-6 Ship Harbour - Hillside	Site RS-7 Little Rattling Brook - Watershed	Site RS-8 Rattling Brook - Watershed	Site RS-9 Ship Harbour Big Pond	Site RS-10 Railway Lakes	Site RS-11 Rocky Pond	Site RS-12 Excavated Pit
C4-1	**Landowner.**	All sites located on crown land	Crown Land	Crown Land	Crown Land	Crown Land	Crown Land	Crown Land	Crown Land	Crown Land	Crown Land and leaseholders.	Crown Land	Crown Land	Crown Land
C4-2	**Historic Resources.**	Presence of historic resources. Historic resources assessment conducted, specific sampling in area of sites RS-1 and RS-12.	None found.	Low probability	Low probability	Low probability	Low probability	Low probability	Low probability	Low probability	Low probability	Low probability	Low probability	None found.
C4-3	**Employment Opportunities.**	Workforce requirements, size and complexity of structure.	Low volume of fill. Moderate dam dimensions. Moderate complexity.	High volume of fill. Large dam dimensions. Most complex.	Low volume of fill. Minimal dam dimensions. Low complexity.	Moderate volume of fill. Moderate dam dimensions. Moderate complexity.	High volume of fill. Large dam dimensions. Most complex.	Low volume of fill. Moderate dam dimensions. Moderate complexity.	High volume of fill. Large dam dimensions. Most complex.	Moderate volume of fill. Moderate dam dimensions. Moderate complexity.	Low volume of fill. Minimal dam dimensions. Low complexity.	Low volume of fill. Moderate dam dimensions. Moderate complexity.	Low volume of fill. Moderate dam dimensions. Moderate complexity.	No dam - No fill. Moderate complexity. High volume of spoil from excavation.
C4-4	**Perceived Community Response.**	Concerns about loss of current use, feedback, environmental concerns. The larger and more well used the area, the less favourable the response.	Moderate concern due to relatively small size and low use due to poor accessibility.	Moderate to high concern.	High concern for loss of large pond in close proximity to Long Harbour.	Moderate concern.	High concern from Ship Harbour residents as the groundwater and run-off would drain towards the community.	Very High concern from Ship Harbour residents as dam would be located above the town and the groundwater and run-off would drain towards the community.	Moderate concern.	Low concern.	Very high concern due to the size of the pond and the high recreational use of the area.	Moderate concern.	Moderate concern.	Moderate concern.
C4-5	**Visual Impact.**	Sites with higher dams which are visible from a community, highway, or recreational use area are of more concern.	No visibility from communities or public roadways during construction or operations	This site is highly visible from route 101 as the main dam is within 100 meters of the roadway and will have a visual impact over the surrounding area.	There is no visual impact from this structure as the dams are low and the area is not visible from surrounding communities or roadways.	The dams for this site are highly visible from Route 101 roadway and the flooded footprint would be within 200 meters of the roadway.	This site is not visible from any community or public roadway in the area.	The dam for this residue storage site would be highly visible from Ship Harbour and surrounding area.	Low visibility for the dam structure but a portion of the flooded area would be visible from the Ship harbour access road.	No visibility from communities or public roadways during construction or operations	Highly visible from Route 101 and a portion of the roadway would require re-alignment around the flooded area.	Very low visibility from public roadway, but visible from a recreational trailway.	Visible in the distance from Ship Harbour road.	No visibility from communities and road.
C4-6	**Resource Use and Recreation.**	Use of the area for activities such as berry picking, hunting, hiking, ATV use, cabins, boating.	Some berry picking, ATV use. No cabins.	Some hunting and berry picking. No cabins.	High ATV use, boating and cabins.	Some hunting, ATV trails, berry picking. No cabins.	Berry picking, hunting, ATV use, unacceptable to Ship Harbour residents. No cabins.	Berry picking, hunting, ATV use. Moderate recreational use, unacceptable to Ship Harbour residents.	Low recreational use area some hunting, berry picking. No cabins.	Low recreational use area some hunting, berry picking. No cabins.	High recreational use area, boating, ATV use, hiking, hunting. The site has an extensive cabin development along its shores which would be negatively affected.	Moderate recreational use, ATV trails, hunting, hiking. One recreational trailway would have to be re-routed.	Moderate recreational use, ATV trails, hunting, berry picking. No cabins.	Low recreational use, berry picking, hunting. No cabins.
C4-7	**Angling.**	Fishing is an important recreational activity in the area. Small scale commercial eel fisheries are established at some sites.	Angling for brook trout is known to occur in Sandy Pond, however access is difficult and therefore effort is minimal. Most angling occurs during the winter season due to easier access. Angling pressure has increased recently due to drill trails in the area.	No angling is known to occur in the upper part of this tributary due to very low water levels and its intermittent flows during the summer.	Angling is known to occur in Rattling Brook Lakes (Sam Howe's Pond) for brook trout. The system has cabins and access via ATV trail is direct to the pond therefore effort is considerable throughout the summer and winter seasons	Angling for brook trout within this tributary is considered minimal due to limited access (via highway 101 or by boat from Rattling Brook Big Pond).	No angling is known to occur in the upper part of this tributary due to its intermittent flows during the summer	No angling is known to occur in the upper part of this tributary due to its intermittent flows during the summer	Angling for brook trout is likely to occur in this area (Little Rattling Pond). However access is difficult and therefore effort is considered minimal. Commercial eel fishery.	No angling is known to occur in the upper part of this tributary due to its remote nature. A commercial American eel fishery is conducted near the mouth of Ship Harbour Brook.	Angling is known to occur in Ship Harbour Big Pond for brook trout and ouananiche. The system has cabins and is beside highway 101 therefore effort is considerable throughout the summer and winter seasons. A commercial American eel fishery is conducted within Ship Harbour Brook.	Angling is likely to occur in this area as it is on the former railway bed. There are also many cabins to the east. Angling effort is considered minimal.	Angling is known to occur in Rocky Pond for brook trout and ouananiche. The system has relatively limited access therefore effort is considered moderate throughout the summer and winter seasons. A commercial American eel fishery is conducted within Ship Harbour Brook.	None

APPENDIX C

ECONOMICS – COST ESTIMATE SUMMARY

ECONOMIC SUMMARY FOR ALL RESIDUE DISPOSAL ALTERNATIVES

Quantity and Unit Cost Table

Cost Area	Site Units	Site RS-1 Sandy Pond	Site RS-2 East Tributary - Rattling Brook	Site RS-3 Rattling Brook Lakes	Site RS-4 South Tributary - Rattling Brook	Site RS-5 Ship Harbour - Watershed	Site RS-6 Ship Harbour - Hillside	Site RS-7 Little Rattling Brook - Watershed	Site RS-8 Rattling Brook - Watershed	Site RS-9 Ship Harbour Big Pond	Site RS-10 Railway Lakes	Site RS-11 Rocky Pond	Site RS-12 Excavated Pond	Unit Cost
Capital Costs														
Dams														
Zone 1 Till, 0 - 150 mm with minimum fines	m3	22,200	191,600	1,700	129,800	254,300	77,700	184,300	128,200	1,200	14,300	15,400		$55.00
Zone 2 Till, 0 - 150 mm	m3	79,100	683,900	5,900	463,100	907,600	277,300	657,600	457,600	4,100	50,800	55,000		$55.00
Zone 3 Till, 0 - 450 mm	m3	108,500	938,100	8,100	635,200	1,245,000	380,400	902,100	627,800	5,600	69,700	75,400		$27.00
Zone 4 Granular, 10 - 50 mm	m3	1,100	9,300	100	6,300	12,400	3,800	9,000	6,300	100	700	800		$66.00
Zone 5 Rip - Rap, 150 - 450 mm	m3	8,400	72,400	700	49,000	96,000	29,400	69,600	48,400	500	5,400	5,900		$96.00
Zone 6 Armour bedding, 0 - 300 mm	m3	6,300	54,000	500	36,600	71,600	21,900	51,900	36,100	400	4,100	4,400		$96.00
Zone 7 Armour stone, 0 - 600 mm	m3	9,000	77,300	700	52,400	102,600	31,400	74,300	51,700	500	5,800	6,300		$96.00
Zone 8 Drainage Material, 5 - 50 mm	m3	14,600	125,700	1,100	85,100	166,800	51,000	120,800	84,100	800	9,400	10,100		$58.00
Dams - Options RS 1, 3, 4, 9, 10 & 11														
Bituminous geomembrane, Coletanche ES3	m2	24,000		8,800	133,100				154,100	5,700	40,100	51,900		$30.00
Grouting holes, 10 m deep	No.	120		79	340				450	68	180	392		$1,785.00
Grouting holes, 5 m deep	No.	133												$1,460.00
Grout Curtain	m2	7,900		2,800	11,800				15,600	2,400	6,300	13,600		$684.50
Concrete, 25MPa	m3	2,300		700	3,000				3,900	600	1,600	3,400		$1,000.00
Stainless steel batten strip, 5 mm	m2	810		237	1,020				1,350	203	540	1,177		$43.77
Stainless steel bolt, 10 mmf	No.	1,620		474	2,040				2,700	406	1,080	2,354		$5.00
Overburden Stripping	m3	41,400	97,000	3,800	63,200	133,300	39,100	86,200	77,300	3,000	15,000	23,900		$19.00
Excavation (to bedrock)	m3	44,100		8,800	37,600				49,700	7,500	19,900	43,400		$18.70
Clearing	m2	30,100	168,700	6,500	109,900	231,700	68,000	149,900	134,400	5,100	26,100	41,500		$1.50
Ponds / Dam Liner - Options RS 2, 5, 6, 7, & 8														
HDPE Liner, 60 mil.	m2		1,530,900			1,957,600	1,404,700	1,201,500						$38.00
Geotextile, Terrafix 270R or equivalent	m2		1,798,100			2,294,200	1,670,300	1,407,300						$10.00
Sand	m3		300,400			378,400	298,500	231,400						$15.00
Washed stone	m3		247,200			311,400	245,700	190,500						$15.00
PVC Pipe, 150 mm	m		167,000			210,400	166,000	128,700						$200.00
Class 'A'	m3		100,200			126,200	99,500	77,200						$10.00
Pit-run gravel	m3		200,300			252,300	199,000	154,300						$8.00
Clearing	m2		667,400			840,800	663,300	514,200						$1.50
Pond - Option RS 12														
Excavation - Rock	m3												20,000,000	$18.70
Excavation - Common	m3												3,000,000	$18.70
Clearing	m2												800,000	$1.50
Access Road														
Excavation	m3	43,100												$18.70
Fill	m3	18,400												$27.00
Road surface granular, 10 - 50 mm	m3	4,900												$62.00
Clearing	m2	55,700												$2.39
Access Road	m		5,600	1,025	2,580	2,050	5,925	4,450	5,600	7,550	10,950	13,800	600	$200.00
Construction Road	m		700		1,200		670			1,650	2,250	3,200		$130.00
Diversion Channel														
Excavation	m3	4,500						6,700			57,300	51,100		$18.70
Concrete, 25MPa	m3	20												$1,000.00
Rip - Rap, 200 mm minus	m3	800						700			5,800	5,200		$96.00
Geotextile, Terrafix 270R or equivalent	m2	2,600												$25.00
Clearing	m2	3,000						5,600			47,800	42,600		$2.39
Emergency Spillway														
Excavation	m3	3,800	8,500	1,400	1,300	8,200	3,200	4,300	4,800	2,900	2,900	2,600	700	$18.70
Concrete, 25MPa	m3	40	89	14	13	86	33	44	50	30	30	27	7	$1,000.00
Rip - Rap, 200 mm minus	m3	600	1,200	200	200	1,200	500	600	700	500	500	400	100	$96.00
Geotextile, Terrafix 270R or equivalent	m2	2,100	4,600	800	700	4,500	1,800	2,300	2,600	1,600	1,600	1,400	400	$7.00
Clearing	m2	2,300	5,200	900	800	5,000	2,000	2,600	2,900	1,800	1,800	1,600	400	$2.39
Pipeline														
Residue - 250 mm NB 3LNA HDPE Lined Steel	m	4,000	5,600	1,025	2,580	2,050	5,925	4,450	5,600	7,550	10,950	13,800	600	$903.80
Spare - 250 mm NB 3LNA HDPE Lined Steel	m	4,000	5,600	1,025	2,580	2,050	5,925	4,450	5,600	7,550	10,950	13,800	600	$903.80
Off spec - 400 mm NB PE100 PN20	m	4,000	5,600	1,025	2,580	2,050	5,925	4,450	5,600	7,550	10,950	13,800	600	$983.18
Decant - 450 mm NB PE100 PN16	m	4,000	5,600	1,025	2,580	2,050	5,925	4,450	5,600	7,550	10,950	13,800	600	$1,129.13
Deposition System	km	2.0	2.0	4.5	2.8	2.7	2.0	1.5	1.9	4.7	5.8	3.4	1.7	$500,000.00
Mobilization and Demobilization	Allow	3	1	3	3	4	1	2	2	1	2	3	0	$100,000.00
Monitoring Equipment	Allow	1.0	7.5	0.1	5.1	9.9	3.0	7.2	5.0	0.0	0.6	0.6	0.0	$100,000.00
Engineering Design	Allow													10.0%
QA/QC Supervision	Months	18	6	14	19	34	11	6	4	3	6	9	8	$48,360.00
Operational Costs (Period up to Final Closure)														
Surveillance Costs	Years	15	15	15	15	15	15	15	15	15	15	15	15	$45,000.00
Annual WQ Monitoring	Years	15	15	15	15	15	15	15	15	15	15	15	15	$35,000.00
Maintenance Costs (Access Roads)	km	4.0	5.6	1.0	2.6	1.3	5.9	4.5	5.6	7.6	11.0	13.8	0.6	$5,000.00
Maintenance Costs (Containment)	Allow	$ 10,000.00	$ 10,000.00	$ 10,000.00	$ 10,000.00	$ 10,000.00	$ 10,000.00	$ 10,000.00	$ 10,000.00	$ 10,000.00	$ 10,000.00	$ 10,000.00	$ 10,000.00	15
Deposition System	Allow	1.0	1.0	4.1	2.5	2.5	1.0	1.1	1.1	4.3	5.3	3.1	0.9	$50,000
Shoreline Stabilization	Allow	$ 100,000.00	$ 100,000.00	$ 100,000.00	$ 100,000.00	$ 100,000.00	$ 100,000.00	$ 100,000.00	$ 100,000.00	$ 100,000.00	$ 100,000.00	$ 100,000.00	$ 100,000.00	1
Final Closure Costs														
Cap (300mm Granular mix)	m3	220,800	222,000	494,700	306,000	300,000	222,000	171,000	207,000	519,600	642,900	372,900	192,000	$30.00
Spillway Re-configuration	Allow	1.0	1.0	2.2	1.4	1.4	1.0	0.8	0.9	2.4	2.9	1.7	0.9	$50,000.00
Mobilization and Demobilization	Allow	3	1	3	3	4	1	2	2	1	2	3	0	$100,000.00
Engineering	Allow													10.0%
QA/QC Supervision	Months	6.0	2.0	4.5	6.2	11.3	3.8	2.0	1.2	1.0	1.9	3.1	2.7	$48,360.00
Post Closure Costs (100 years post operation)														
Surveillance Costs	Years	100	100	100	100	100	100	100	100	100	100	100	100	$10,000.00
Annual WQ Monitoring	Years	100	100	100	100	100	100	100	100	100	100	100	100	$15,000.00
Environmental Compensation and Monitoring														
Environmental Compensation and Monitoring	Allow	$ 3,000,000.00	$ 1,750,000.00	$ 4,500,000.00	$ 3,000,000.00	$ 1,750,000.00	$ 1,500,000.00	$ 1,500,000.00	$ 1,750,000.00	$ 5,000,000.00	$ 3,000,000.00	$ 4,500,000.00	$ 500,000.00	1

ECONOMIC SUMMARY FOR ALL RESIDUE DISPOSAL ALTERNATIVES

Cost Table

Cost Area	Site	Site RS-1 Sandy Pond	Site RS-2 East Tributary - Rattling Brook	Site RS-3 Rattling Brook Lakes	Site RS-4 South Tributary - Rattling Brook	Site RS-5 Ship Harbour - Watershed	Site RS-6 Ship Harbour - Hillside	Site RS-7 Little Rattling Brook - Watershed	Site RS-8 Rattling Brook - Watershed	Site RS-9 Ship Harbour Big Pond	Site RS-10 Railway Lakes	Site RS-11 Rocky Pond	Site RS-12 Excavated Pond
Capital Costs													
Dams													
Zone 1 Till, 0 - 150 mm with minimum fines		$ 1,221,000.00	$ 10,538,000.00	$ 93,500.00	$ 7,139,000.00	$ 13,986,500.00	$ 4,273,500.00	$ 10,136,500.00	$ 7,051,000.00	$ 66,000.00	$ 786,500.00	$ 847,000.00	$ -
Zone 2 Till, 0 - 150 mm		$ 4,350,500.00	$ 37,614,500.00	$ 324,500.00	$ 25,470,500.00	$ 49,918,000.00	$ 15,251,500.00	$ 36,168,000.00	$ 25,168,000.00	$ 225,500.00	$ 2,794,000.00	$ 3,025,000.00	$ -
Zone 3 Till, 0 - 450 mm		$ 2,929,500.00	$ 25,328,700.00	$ 218,700.00	$ 17,150,400.00	$ 33,615,000.00	$ 10,270,800.00	$ 24,356,700.00	$ 16,950,600.00	$ 151,200.00	$ 1,881,900.00	$ 2,035,800.00	$ -
Zone 4 Granular, 10 - 50 mm		$ 72,600.00	$ 613,800.00	$ 6,600.00	$ 415,800.00	$ 818,400.00	$ 250,800.00	$ 594,000.00	$ 415,800.00	$ 6,600.00	$ 46,200.00	$ 52,800.00	$ -
Zone 5 Rip - Rap, 150 - 450 mm		$ 806,400.00	$ 6,950,400.00	$ 67,200.00	$ 4,704,000.00	$ 9,216,000.00	$ 2,822,400.00	$ 6,681,600.00	$ 4,646,400.00	$ 48,000.00	$ 518,400.00	$ 566,400.00	$ -
Zone 6 Armour bedding, 0 - 300 mm		$ 604,800.00	$ 5,184,000.00	$ 48,000.00	$ 3,513,600.00	$ 6,873,600.00	$ 2,102,400.00	$ 4,982,400.00	$ 3,465,600.00	$ 38,400.00	$ 393,600.00	$ 422,400.00	$ -
Zone 7 Armour stone, 0 - 600 mm		$ 864,000.00	$ 7,420,800.00	$ 67,200.00	$ 5,030,400.00	$ 9,849,600.00	$ 3,014,400.00	$ 7,132,800.00	$ 4,963,200.00	$ 48,000.00	$ 556,800.00	$ 604,800.00	$ -
Zone 8 Drainage Material, 5 - 50 mm		$ 846,800.00	$ 7,290,600.00	$ 63,800.00	$ 4,935,800.00	$ 9,674,400.00	$ 2,958,000.00	$ 7,006,400.00	$ 4,877,800.00	$ 46,400.00	$ 545,200.00	$ 585,800.00	$ -
Dams - Options RS 1, 3, 4, 9, 10 & 11													
Bituminous geomembrane, Coletanche ES3		$ 720,000.00	$ -	$ 264,000.00	$ 3,993,000.00	$ -	$ -	$ -	$ 4,623,000.00	$ 171,000.00	$ 1,203,000.00	$ 1,557,000.00	$ -
Grouting holes, 10 m deep		$ 214,200.00	$ -	$ 141,015.00	$ 606,900.00	$ -	$ -	$ -	$ 803,250.00	$ 120,785.00	$ 321,300.00	$ 700,315.00	$ -
Grouting holes, 5 m deep		$ 194,180.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Grout Curtain		$ 5,407,550.00	$ -	$ 1,916,600.00	$ 8,077,100.00	$ -	$ -	$ -	$ 10,678,200.00	$ 1,642,800.00	$ 4,312,350.00	$ 9,309,200.00	$ -
Concrete, 25MPa		$ 2,300,000.00	$ -	$ 700,000.00	$ 3,000,000.00	$ -	$ -	$ -	$ 3,900,000.00	$ 600,000.00	$ 1,600,000.00	$ 3,400,000.00	$ -
Stainless steel batten strip, 5 mm		$ 35,453.70	$ -	$ 10,373.49	$ 44,645.40	$ -	$ -	$ -	$ 59,089.50	$ 8,885.31	$ 23,635.80	$ 51,517.29	$ -
Stainless steel bolt, 10 mmf		$ 8,100.00	$ -	$ 2,370.00	$ 10,200.00	$ -	$ -	$ -	$ 13,500.00	$ 2,030.00	$ 5,400.00	$ 11,770.00	$ -
Overburden Stripping		$ 786,600.00	$ 1,843,000.00	$ 72,200.00	$ 1,200,800.00	$ 2,532,700.00	$ 742,900.00	$ 1,637,800.00	$ 1,468,700.00	$ 57,000.00	$ 285,000.00	$ 454,100.00	$ -
Excavation (to bedrock)		$ 824,670.00	$ -	$ 164,560.00	$ 703,120.00	$ -	$ -	$ -	$ 929,390.00	$ 140,250.00	$ 372,130.00	$ 811,580.00	$ -
Clearing		$ 45,150.00	$ 253,050.00	$ 9,750.00	$ 164,850.00	$ 347,550.00	$ 102,000.00	$ 224,850.00	$ 201,600.00	$ 7,650.00	$ 39,150.00	$ 62,250.00	$ -
Ponds / Dam Liner - Options RS 2, 5, 6, 7, & 8													
HDPE Liner, 60 mil.		$ -	$ 58,174,200.00	$ -	$ -	$ 74,388,800.00	$ 53,378,600.00	$ 45,657,000.00	$ -	$ -	$ -	$ -	$ -
Geotextile, Terrafix 270R or equivalent		$ -	$ 17,981,000.00	$ -	$ -	$ 22,942,000.00	$ 16,703,000.00	$ 14,073,000.00	$ -	$ -	$ -	$ -	$ -
Sand		$ -	$ 4,506,000.00	$ -	$ -	$ 5,676,000.00	$ 4,477,500.00	$ 3,471,000.00	$ -	$ -	$ -	$ -	$ -
Washed stone		$ -	$ 3,708,000.00	$ -	$ -	$ 4,671,000.00	$ 3,685,500.00	$ 2,857,500.00	$ -	$ -	$ -	$ -	$ -
PVC Pipe, 150 mm		$ -	$ 33,400,000.00	$ -	$ -	$ 42,080,000.00	$ 33,200,000.00	$ 25,740,000.00	$ -	$ -	$ -	$ -	$ -
Class 'A'		$ -	$ 1,002,000.00	$ -	$ -	$ 1,262,000.00	$ 995,000.00	$ 772,000.00	$ -	$ -	$ -	$ -	$ -
Pit-run gravel		$ -	$ 1,602,400.00	$ -	$ -	$ 2,018,400.00	$ 1,592,000.00	$ 1,234,400.00	$ -	$ -	$ -	$ -	$ -
Clearing		$ -	$ 1,001,100.00	$ -	$ -	$ 1,261,200.00	$ 994,950.00	$ 771,300.00	$ -	$ -	$ -	$ -	$ -
Pond - Option RS 12													
Excavation - Rock		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 374,000,000.00
Excavation - Common		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 56,100,000.00
Clearing		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 1,200,000.00
Dam Access Road													
Excavation		$ 805,970.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Fill		$ 496,800.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Road surface granular, 10 - 50 mm		$ 303,800.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Clearing		$ 133,123.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Access Road		$ -	$ 1,120,000.00	$ 205,000.00	$ 516,000.00	$ 410,000.00	$ 1,185,000.00	$ 890,000.00	$ 1,120,000.00	$ 1,510,000.00	$ 2,190,000.00	$ 2,760,000.00	$ 120,000.00
Construction Road		$ -	$ 91,000.00	$ -	$ 156,000.00	$ -	$ 87,100.00	$ -	$ -	$ 214,500.00	$ 292,500.00	$ 416,000.00	$ -
Diversion Channel													
Excavation		$ 84,150.00	$ -	$ -	$ -	$ -	$ -	$ 125,290.00	$ -	$ -	$ 1,071,510.00	$ 955,570.00	$ -
Concrete, 25MPa		$ 20,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Rip - Rap, 200 mm minus		$ 76,800.00	$ -	$ -	$ -	$ -	$ -	$ 67,200.00	$ -	$ -	$ 556,800.00	$ 499,200.00	$ -
Geotextile, Terrafix 270R or equivalent		$ 65,000.00	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Clearing		$ 7,170.00	$ -	$ -	$ -	$ -	$ -	$ 13,384.00	$ -	$ -	$ 114,242.00	$ 101,814.00	$ -
Emergency Spillway													
Excavation		$ 71,060.00	$ 158,950.00	$ 26,180.00	$ 24,310.00	$ 153,340.00	$ 59,840.00	$ 80,410.00	$ 89,760.00	$ 54,230.00	$ 54,230.00	$ 48,620.00	$ 13,090.00
Concrete, 25MPa		$ 40,000.00	$ 88,888.89	$ 14,444.44	$ 13,333.33	$ 85,555.56	$ 33,333.33	$ 44,444.44	$ 50,000.00	$ 30,000.00	$ 30,000.00	$ 26,666.67	$ 6,666.67
Rip - Rap, 200 mm minus		$ 57,600.00	$ 115,200.00	$ 19,200.00	$ 19,200.00	$ 115,200.00	$ 48,000.00	$ 57,600.00	$ 67,200.00	$ 48,000.00	$ 48,000.00	$ 38,400.00	$ 9,600.00
Geotextile, Terrafix 270R or equivalent		$ 14,700.00	$ 32,200.00	$ 5,600.00	$ 4,900.00	$ 31,500.00	$ 12,600.00	$ 16,100.00	$ 18,200.00	$ 11,200.00	$ 11,200.00	$ 9,800.00	$ 2,800.00
Clearing		$ 5,497.00	$ 12,428.00	$ 2,151.00	$ 1,912.00	$ 11,950.00	$ 4,780.00	$ 6,214.00	$ 6,931.00	$ 4,302.00	$ 4,302.00	$ 3,824.00	$ 956.00
Pipeline													
Residue - 250 mm NB 3LNA HDPE Lined Steel		$ 3,615,200.00	$ 5,061,280.00	$ 926,395.00	$ 2,331,804.00	$ 1,852,790.00	$ 5,355,015.00	$ 4,021,910.00	$ 5,061,280.00	$ 6,823,690.00	$ 9,896,610.00	$ 12,472,440.00	$ 542,280.00
Spare - 250 mm NB 3LNA HDPE Lined Steel		$ 3,615,200.00	$ 5,061,280.00	$ 926,395.00	$ 2,331,804.00	$ 1,852,790.00	$ 5,355,015.00	$ 4,021,910.00	$ 5,061,280.00	$ 6,823,690.00	$ 9,896,610.00	$ 12,472,440.00	$ 542,280.00
Off spec - 400 mm NB PE100 PN20		$ 3,932,720.00	$ 5,505,808.00	$ 1,007,759.50	$ 2,536,604.40	$ 2,015,519.00	$ 5,825,341.50	$ 4,375,151.00	$ 5,505,808.00	$ 7,423,009.00	$ 10,765,821.00	$ 13,567,884.00	$ 589,908.00
Decant - 450 mm NB PE100 PN16		$ 4,516,520.00	$ 6,323,128.00	$ 1,157,358.25	$ 2,913,155.40	$ 2,314,716.50	$ 6,690,095.25	$ 5,024,628.50	$ 6,323,128.00	$ 8,524,931.50	$ 12,363,973.50	$ 15,581,994.00	$ 677,478.00
Deposition System		$ 1,000,000.00	$ 1,005,000.00	$ 2,240,000.00	$ 1,386,000.00	$ 1,359,000.00	$ 1,005,000.00	$ 774,000.00	$ 938,000.00	$ 2,353,000.00	$ 2,912,000.00	$ 1,689,000.00	$ 870,000.00
Mobilization and Demobilization		$ 300,000.00	$ 100,000.00	$ 300,000.00	$ 300,000.00	$ 400,000.00	$ 100,000.00	$ 200,000.00	$ 200,000.00	$ 100,000.00	$ 200,000.00	$ 300,000.00	$ -
Monitoring Equipment		$ 100,000.00	$ 748,151.54	$ 6,387.05	$ 506,595.76	$ 992,898.04	$ 303,316.27	$ 719,441.42	$ 500,627.75	$ 4,410.24	$ 55,520.59	$ 60,086.37	$ -
Engineering Design		$ 4,109,300.00	$ 24,898,700.00	$ 1,070,100.00	$ 9,839,500.00	$ 30,133,400.00	$ 18,247,600.00	$ 21,301,500.00	$ 11,445,700.00	$ 3,720,100.00	$ 6,589,200.00	$ 8,514,100.00	$ 43,467,500.00
QA/QC Supervision		$ 870,480.00	$ 291,736.96	$ 653,633.48	$ 905,850.75	$ 1,641,033.96	$ 549,984.21	$ 283,959.24	$ 177,474.52	$ 139,214.62	$ 270,232.72	$ 456,384.88	$ 396,856.42
Subtotal		**$ 46,473,000.00**	**$ 275,025,000.00**	**$ 12,731,000.00**	**$ 109,947,000.00**	**$ 334,501,000.00**	**$ 201,677,000.00**	**$ 235,520,000.00**	**$ 126,781,000.00**	**$ 41,165,000.00**	**$ 73,007,000.00**	**$ 94,472,000.00**	**$ 478,539,000.00**
Operational Costs (Period up to Final Closure)													
Surveillance Costs		$ 675,000.00	$ 675,000.00	$ 675,000.00	$ 675,000.00	$ 675,000.00	$ 675,000.00	$ 675,000.00	$ 675,000.00	$ 675,000.00	$ 675,000.00	$ 675,000.00	$ 675,000.00
Annual WQ Monitoring		$ 525,000.00	$ 525,000.00	$ 525,000.00	$ 525,000.00	$ 525,000.00	$ 525,000.00	$ 525,000.00	$ 525,000.00	$ 525,000.00	$ 525,000.00	$ 525,000.00	$ 525,000.00
Maintenance Costs (Access Roads)		$ 300,000.00	$ 420,000.00	$ 76,875.00	$ 193,500.00	$ 93,750.00	$ 444,375.00	$ 333,750.00	$ 420,000.00	$ 566,250.00	$ 821,250.00	$ 1,035,000.00	$ 45,000.00
Maintenance Costs (Containment)		$ 150,000.00	$ 150,000.00	$ 150,000.00	$ 150,000.00	$ 150,000.00	$ 150,000.00	$ 150,000.00	$ 150,000.00	$ 150,000.00	$ 150,000.00	$ 150,000.00	$ 150,000.00
Deposition System		$ 750,000.00	$ 750,000.00	$ 3,043,000.00	$ 1,875,000.00	$ 1,846,000.00	$ 779,000.00	$ 808,000.00	$ 808,000.00	$ 3,202,000.00	$ 3,952,000.00	$ 2,293,000.00	$ 663,000.00
Shoreline Stabilization		$ 100,000.00	$ 100,000.00	$ 100,000.00	$ 100,000.00	$ 100,000.00	$ 100,000.00	$ 100,000.00	$ 100,000.00	$ 100,000.00	$ 100,000.00	$ 100,000.00	$ 100,000.00
Subtotal		**$ 2,500,000.00**	**$ 2,620,000.00**	**$ 4,570,000.00**	**$ 3,519,000.00**	**$ 3,390,000.00**	**$ 2,673,000.00**	**$ 2,592,000.00**	**$ 2,678,000.00**	**$ 5,218,000.00**	**$ 6,223,000.00**	**$ 4,778,000.00**	**$ 2,158,000.00**
Final Closure Costs													
Cap (300mm Granular mix)		$ 6,624,000.00	$ 6,660,000.00	$ 14,841,000.00	$ 9,180,000.00	$ 9,000,000.00	$ 6,660,000.00	$ 5,130,000.00	$ 6,210,000.00	$ 15,588,000.00	$ 19,287,000.00	$ 11,187,000.00	$ 5,760,000.00
Spillway Re-configuration		$ 50,000.00	$ 50,300.00	$ 112,000.00	$ 69,300.00	$ 67,900.00	$ 50,300.00	$ 38,700.00	$ 46,900.00	$ 117,700.00	$ 145,600.00	$ 84,400.00	$ 43,500.00
Mobilization and Demobilization		$ 300,000.00	$ 100,000.00	$ 300,000.00	$ 300,000.00	$ 400,000.00	$ 100,000.00	$ 200,000.00	$ 200,000.00	$ 100,000.00	$ 200,000.00	$ 300,000.00	$ -
Engineering		$ 667,400.00	$ 671,000.00	$ 1,495,300.00	$ 924,900.00	$ 906,800.00	$ 671,000.00	$ 516,900.00	$ 625,700.00	$ 1,570,600.00	$ 1,943,300.00	$ 1,127,100.00	$ 580,400.00
QA/QC Supervision		$ 290,160.00	$ 97,245.65	$ 217,877.83	$ 301,950.25	$ 547,011.32	$ 183,328.07	$ 94,653.08	$ 59,158.17	$ 46,404.87	$ 90,077.57	$ 152,128.29	$ 132,285.47
Subtotal		**$ 7,932,000.00**	**$ 7,579,000.00**	**$ 16,966,000.00**	**$ 10,776,000.00**	**$ 10,922,000.00**	**$ 7,665,000.00**	**$ 5,980,000.00**	**$ 7,142,000.00**	**$ 17,423,000.00**	**$ 21,666,000.00**	**$ 12,851,000.00**	**$ 6,516,000.00**
Post Closure Costs (100 years post operation)													
Surveillance Costs		$ 1,000,000.00	$ 1,000,000.00	$ 1,000,000.00	$ 1,000,000.00	$ 1,000,000.00	$ 1,000,000.00	$ 1,000,000.00	$ 1,000,000.00	$ 1,000,000.00	$ 1,000,000.00	$ 1,000,000.00	$ 1,000,000.00
Annual WQ Monitoring		$ 1,500,000.00	$ 1,500,000.00	$ 1,500,000.00	$ 1,500,000.00	$ 1,500,000.00	$ 1,500,000.00	$ 1,500,000.00	$ 1,500,000.00	$ 1,500,000.00	$ 1,500,000.00	$ 1,500,000.00	$ 1,500,000.00
Subtotal		**$ 2,500,000.00**	**$ 2,500,000.00**	**$ 2,500,000.00**	**$ 2,500,000.00**	**$ 2,500,000.00**	**$ 2,500,000.00**	**$ 2,500,000.00**	**$ 2,500,000.00**	**$ 2,500,000.00**	**$ 2,500,000.00**	**$ 2,500,000.00**	**$ 2,500,000.00**
Environmental Compensation and Monitoring													
Environmental Compensation and Monitoring		$ 3,000,000.00	$ 1,750,000.00	$ 4,500,000.00	$ 3,000,000.00	$ 1,750,000.00	$ 1,500,000.00	$ 1,500,000.00	$ 1,750,000.00	$ 5,000,000.00	$ 3,000,000.00	$ 4,500,000.00	$ 500,000.00
Subtotal		**$ 3,000,000.00**	**$ 1,750,000.00**	**$ 4,500,000.00**	**$ 3,000,000.00**	**$ 1,750,000.00**	**$ 1,500,000.00**	**$ 1,500,000.00**	**$ 1,750,000.00**	**$ 5,000,000.00**	**$ 3,000,000.00**	**$ 4,500,000.00**	**$ 500,000.00**
Total		**$ 62,405,000.00**	**$ 289,474,000.00**	**$ 41,267,000.00**	**$ 129,742,000.00**	**$ 353,063,000.00**	**$ 216,015,000.00**	**$ 248,092,000.00**	**$ 140,851,000.00**	**$ 71,306,000.00**	**$ 106,396,000.00**	**$ 119,101,000.00**	**$ 490,213,000.00**

APPENDIX D
SCORING MATRIX

Counter	Criteria Description	Definitions/Rationale	Master Criteria	Score					
				Best					Worst
				5	4	3	2	1	0
Environmental									
1	**Distance from Plant Site.**	Longer distance - greater footprint, higher potential for spill, more affected habitat. Additional/larger emergency spill collection pond requirements. Pipeline and pumping systems increased size, complexity.	C1-1:C2-1	Less than 2 km	2-5 km	5-8 km	8-11 km	11-14 km	More than 14 km
2	**Total Watershed Area (km2).**	Size of affected watershed indicates potential environmental impact .	C1-12	0 - 10 km2	11 - 20 km2	21 - 30 km2	31 - 40 km2	41 - 50 km2	> 51 km2
3	**Quantity of Aquatic Habitat Disturbed.**	Size and quality of natural water bodies, riverine habitat, capacity.	C1-9/11/13	Assessment based on ranking individual components (lacustrine, riverine and downstream habitat loss) which are then summed and the mean (integer) value is taken as representative. In assessing downstream habitat loss the greater of the respective lacustrine or riverine value for the area was used in the ranking.	Assessment based on ranking individual components (lacustrine, riverine and downstream habitat loss) which are then summed and the mean (integer) value is taken as representative. In assessing downstream habitat loss the greater of the respective lacustrine or riverine value for the area was used in the ranking.	Assessment based on ranking individual components (lacustrine, riverine and downstream habitat loss) which are then summed and the mean (integer) value is taken as representative. In assessing downstream habitat loss the greater of the respective lacustrine or riverine value for the area was used in the ranking.	Assessment based on ranking individual components (lacustrine, riverine and downstream habitat loss) which are then summed and the mean (integer) value is taken as representative. In assessing downstream habitat loss the greater of the respective lacustrine or riverine value for the area was used in the ranking.	Assessment based on ranking individual components (lacustrine, riverine and downstream habitat loss) which are then summed and the mean (integer) value is taken as representative. In assessing downstream habitat loss the greater of the respective lacustrine or riverine value for the area was used in the ranking.	Assessment based on ranking individual components (lacustrine, riverine and downstream habitat loss) which are then summed and the mean (integer) value is taken as representative. In assessing downstream habitat loss the greater of the respective lacustrine or riverine value for the area was used in the ranking.
4	**Quality of Aquatic Habitat Disturbed.**	The relative amount of noted aquatic species which are impacted indicates the quality of the effect.	C1-22/23/24/25/26	No noted aquatic species disturbed.	One noted aquatic species disturbed.	Two noted aquatic species disturbed.	Three noted aquatic species disturbed.	Four noted aquatic species disturbed.	Five or more noted aquatic species disturbed.
5	**Quantity of Terrestrial Habitat Disturbed.**	Size and quality of terrestrial habitat affected.	C1-10	No terrestrial habitat within the footprint	Low quantity of terrestrial habitat within the footprint (0-20ha)	Moderate quantity of terrestrial habitat within the footprint (20-40ha)	High quantity of terrestrial habitat within the footprint (40-60ha)	High quantity of terrestrial habitat within the footprint (60-80ha)	Considerable quantity of terrestrial habitat within the footprint (80+ha)
6	**Quality of Terrestrial Habitat Disturbed.**	The relative amount of noted terrestrial species which are impacted indicates the quality of the effect.	C1-27/28/29	No noted terrestrial species disturbed.	One noted terrestrial species disturbed.	Two noted terrestrial species disturbed.	Three noted terrestrial species disturbed.	Four noted terrestrial species disturbed.	Five or more noted terrestrial species disturbed.
7	**Dam Failure Consequences.**	Extent of affected watershed and fish habitat.	C1-3	No habitat affected	Low quantity of habitat affected (1-50ha water body or 0-1000m stream)	Moderate quantity of habitat affected (50-100ha water body or 1000-2000m stream)	Moderate quantity of habitat affect (100-150ha water body or 2000-3000m stream)	High quantity of habitat affected (150-200ha water body or 3000-4000m stream)	Considerable quantity of habitat affected (>200ha water body or >4000m stream)
8	**Compensation Effort and Monitoring.**	The greater the area and quality of fish habitat the more habitat compensation required. Compensation planning and monitoring.	C1-19/20/21	No habitat affected. No fish habitat compensation likely. No fish habitat compensation monitoring likely.	Low quantity of habitat affected (1-50ha or 0-1000m). Fish habitat compensation effort likely low. Fish habitat compensation monitoring effort likely low.	Moderate quantity of habitat affected (50-100ha or 1000-2000m). Fish habitat compensation effort likely moderate. Fish habitat compensation monitoring effort likely moderate.	Moderate quantity of habitat affect (100-150ha or 2000-3000m). Fish habitat compensation effort likely high. Fish habitat compensation monitoring effort likely high.	High quantity of habitat affected (150-200ha or 3000-4000m). Fish habitat compensation effort likely considerable. Fish habitat compensation monitoring effort likely considerable.	Considerable quantity of habitat affected (>200ha water body or >4000m stream). Fish habitat losses not likely to be authorized. Fish habitat compensation monitoring not likely possible/feasible.
9	**Water Quality.**	Supernatant water quality and treatment - re-use potential for the process. Water quality based on ratio of watershed and residue areas. A higher ratio will result in better water quality during operation. Also ARD potential and atmospheric criteria are considered since wave action affects particle suspension and therefore oxidation.	C1-4/15/16	Small residue area, dilution factor of 5 or more. Relatively negligible total fetch distance along prevailing wind (SW and NE) direction (0-2km).	Small residue area, dilution factor of 1 to 5. Relatively minor total fetch distance along prevailing wind (SW and NE) direction (2-4km).	Medium residue area, dilution factor of 5 or more. Relatively low total fetch distance along prevailing wind (SW and NE) direction (4-6km).	Medium to large residue area, dilution factor of 5 or more. Relatively moderate total fetch distance along prevailing wind (SW and NE) direction (6-8km).	Large residue area, dilution factor of 5 or more. Relatively high total fetch distance along prevailing wind (SW and NE) direction (8-10km).	Large residue area, dilution factor of 1 to 5. Considerable total fetch distance along prevailing wind (SW and NE) direction (>10km).
10	**Post Closure Rehabilitation and Land Use.**	Ability to return land to original use or acceptable alternative use. Least change for natural water bodies.	C1-9/10/11/18	80-100% rehabilitation of site to former condition.	61 - 80 % of site rehabilitated.	41 - 60 % of site rehabilitated.	21 - 40 % of site rehabilitated.	0 - 20 % of site rehabilitated.	No rehabilitation of site to former use.
11	**Dam Failure Potential - Geotechnical and Seismic.**	Related to size of structure, upstream affected watershed, location of known geological faults. The entire area is not considered seismically active and has one of the lowest ratings in the National Building Code. Dam reliability considered for the extreme long term duration (in perpetuity). Topographical nature of terrain is also incorporated into the assessment.	C1-2/6	* See below Assessment based on ranking individual components (dam failure potential and topographical aspects) which are then summed and the mean (integer) value is taken as representative.	Assessment based on ranking individual components (dam failure potential and topographical aspects) which are then summed and the mean (integer) value is taken as representative.	Assessment based on ranking individual components (dam failure potential and topographical aspects) which are then summed and the mean (integer) value is taken as representative.	Assessment based on ranking individual components (dam failure potential and topographical aspects) which are then summed and the mean (integer) value is taken as representative.	Assessment based on ranking individual components (dam failure potential and topographical aspects) which are then summed and the mean (integer) value is taken as representative.	Assessment based on ranking individual components (dam failure potential and topographical aspects) which are then summed and the mean (integer) value is taken as representative.

Counter	Criteria Description	Definitions/Rationale	Master Criteria	Score					
				Best					Worst
				5	4	3	2	1	0
Technical and Operational									
1	**Dam Design Details.**	Dam size - volume of fill, requirement for borrow pits, grout curtain, base, dam wall LLDPE and GCL lining. Number of dams required for residue storage capacity. Total length of all dams (m) Height of tallest dam structure (m) above grade. Total volume of material for construction of dams (m3).	C2-2	* See below Assessment based on ranking individual components which are then summed and the mean (integer) value is taken as representative.	Assessment based on ranking individual components which are then summed and the mean (integer) value is taken as representative.	Assessment based on ranking individual components which are then summed and the mean (integer) value is taken as representative.	Assessment based on ranking individual components which are then summed and the mean (integer) value is taken as representative.	Assessment based on ranking individual components which are then summed and the mean (integer) average value is taken as representative.	Assessment based on ranking individual components which are then summed and the mean (integer) value is taken as representative.
2	**Ratio of Dam Volume to Residue Storage Capacity.**	Ratio of dam volume to residue storage capacity. Measure of storage efficiency.	C2-2	Ratio 0 - 0.1	Ratio 0.11 - 0.2	Ratio 0.21 - 0.3	Ratio 0.31 - 0.4	Ratio 0.41 - 0.5	Ratio > 0.51
3	**Dam, Access Road and Quarry - Total Footprint.**	Related to size and type of structure, distance from the plant site. Constructability. Total affected area (ha).	C2-2/4:C1-14	0 - 100 ha	101 - 125 ha	126 - 150 ha	151 - 175 ha	176 - 200 ha	> 201 ha
4	**Construction Risk.**	Accessibility, number of structures, design assumption and site data, site layout, working conditions, artificial liners	C1-7:C2-2/7	* See below Assessment based on ranking individual components (accessibility, upgrade watershed and requirement for synthetic liner) which are then summed and the mean (integer) value is taken as representative.	Assessment based on ranking individual components (accessibility, upgrade watershed and requirement for synthetic liner) which are then summed and the mean (integer) value is taken as representative.	Assessment based on ranking individual components (accessibility, upgrade watershed and requirement for synthetic liner) which are then summed and the mean (integer) value is taken as representative.	Assessment based on ranking individual components (accessibility, upgrade watershed and requirement for synthetic liner) which are then summed and the mean (integer) value is taken as representative.	Assessment based on ranking individual components (accessibility, upgrade watershed and requirement for synthetic liner) which are then summed and the mean (integer) value is taken as representative.	Assessment based on ranking individual components (accessibility, upgrade watershed and requirement for synthetic liner) which are then summed and the mean (integer) value is taken as representative.
5	**Operational Risk.**	Relocation of deposition points, watershed/ water and deposition management - supply of initial water cover and maintenance of supernatant water levels, dam access road length and accessibility.	C2-2/6/8	* See below Assessment based on ranking individual components (accessibility and pipeline length, upgrade watershed and water management and deposition potential) which are then summed and the mean (integer) value is taken as representative.	Assessment based on ranking individual components (accessibility and pipeline length, upgrade watershed and water management and deposition potential) which are then summed and the mean (integer) value is taken as representative.	Assessment based on ranking individual components (accessibility and pipeline length, upgrade watershed and water management and deposition potential) which are then summed and the mean (integer) value is taken as representative.	Assessment based on ranking individual components (accessibility and pipeline length, upgrade watershed and water management and deposition potential) which are then summed and the mean (integer) value is taken as representative.	Assessment based on ranking individual components (accessibility and pipeline length, upgrade watershed and water management and deposition potential) which are then summed and the mean (integer) value is taken as representative.	Assessment based on ranking individual components (accessibility and pipeline length, upgrade watershed and water management and deposition potential) which are then summed and the mean (integer) value is taken as representative.
6	**Closure Risks/Uncertainties.**	Most sites have water retaining structures and will require monitoring and maintenance in the long term.	C2-2/9	Assessment of long term dam stability, maintenance and monitoring requirement. Moderately high.	Assessment of long term dam stability, maintenance and monitoring requirement. Moderately high.	Assessment of long term dam stability, maintenance and monitoring requirement. Moderate.	Assessment of long term dam stability, maintenance and monitoring requirement. Moderately low.	Assessment of long term dam stability, maintenance and monitoring requirement. Moderately low.	Assessment of long term maintenance and monitoring requirement. Moderately low.
Economic									
1	**Total Capital and Operating Cost.**	Sum of all related costs - Capital, Operating, Closure, Post Closure and Environmental Compensation and Monitoring.	C3-6	0 - 50 M$	51 - 100 M$	101 - 150 M$	151 - 200 M$	201 - 250 M$	> 251 M$
Socio-economic									
1	**Perceived Community Response.**	Concerns about loss of current use, feedback, environmental concerns. The larger and more well used the area, the less favourable the response.	C1-2/3/5/12/13/14/16/18/19:C2-9/10:C4-3/4/5	It is considered that the community response is that the selected site is acceptable.	It is considered that the community response is that the selected site is generally acceptable.	It is considered that the community response is that the selected site is of moderate acceptability.	It is considered that the community response is that the selected site is of low acceptability.	It is considered that the community response is that the selected site is of poor acceptability.	It is considered that the community response is that the site is not acceptable.
2	**Visual Impact.**	Sites with higher dams which are visible from a community, highway, or recreational use area are of more concern.	C1-6/10:C2-2:C4-5	The site is not visible from community, roads or trails.	-	The site is visible from trails only.	-	The site is visible from the highway.	The site is visible from any of the local communities.
3	**Resource Use and Recreation.**	Use of the area for activities such as berry picking, hunting, hiking, ATV use, cabins, boating.	C1-9/10/11/14:C4-6	No loss to resource use or recreation.	Loss of one recreational activity or resource use.	Loss of two recreational activities or resource uses.	Loss of three recreational activities or resource uses.	Loss of four recreational activities or resource uses.	Loss of five or more recreational activities or resource uses

*** For a full description of the individual ranking for these criteria see attached table.**

Scoring Matrix Table – Attachment.

The following tables provide a detailed explanation for scoring of environmental criterion #11 and for technical/operational criteria 1, 4 and 5.

Environment #11: Dam Failure Potential(based on location in watershed and topography)

Location in Watershed	Topography
At height of watershed - 5	Natural depression in bedrock - 5
High in watershed – 4	Relatively contained at downgradient end; in bedrock - 4
Mid-watershed – 3	Bedrock outcrops, relatively contained – 3
Low to mid-watershed – 2	Till material, convoluted perimeter – 2
Low in watershed - 1	High overburden/till; open at downgradient end - 1

Technical/Operational #1 – Dam Design Details (based on number, length and height of dams and volume of material to construct dams)

Number of Dams	Length of Dams	Height of Dams	Volume of Material (m3)
None – 5	0 to 500m – 5	0 to 6 m – 5	0 to 500,000 - 5
One – 4	501 to 1000m – 4	7 to 12m – 4	500,000 to 1 million - 4
Two – 3	1001 to 1500m – 3	13 to 18m – 3	1 to 1.5 million – 3
Three – 2	1501 to 2000m – 2	19 to 24 m – 2	1.5 to 2 million - 2
Four - 1	2001 to 2500m - 1	25 to 32m – 1	2 to 2.5 million – 1
	>2500 m - 0	> 32m - 0	>2.5 million - 0

Technical/Operational #4 – Construction Risk (based on upstream watershed, accessibility/pipeline length and need for liner)

Upstream Watershed	Need for Liner	Accessibility/Pipeline Length
Minimum – 4	Yes	Short – 4
Moderate – 3	No	Medium – 3
Large – 2		Long – 2
Very Large - 1		

Technical/Operational #5 – Operational Risk (based on accessibility/ pipeline length, water management and residue deposition)

Accessibility/Pipeline Length	Water Management	Residue Deposition
Short – 4	Very good – 5	Very good – 5
Medium – 3	Good – 4	Good – 4
Long – 2	Fair – 3	Fair – 3
	Poor – 2	Poor – 2
		Very poor – 1

APPENDIX E

SENSITIVITY ANALYSIS

SENSITIVITY ANALYSIS

Site Number	Site RS-1	Site RS-2	Site RS-3	Site RS-4	Site RS-5	Site RS-6	Site RS-7	Site RS-8	Site RS-9	Site RS-10	Site RS-11	Site RS-12
Site (Location) Decription **Condition**	Sandy Pond	East Tributary - Rattling Brook	Rattling Brook Lakes	South Tributary - Rattling Brook	Ship Harbour - Watershed	Ship Harbour - Hillside	Little Rattling Brook - Watershed	Rattling Brook - Watershed	Ship Harbour Big Pond	Railway Lakes	Rocky Pond	Excavated Pit
Environment Only Ratio	0.67	0.47	0.51	0.42	0.45	0.49	0.56	0.40	0.42	0.29	0.36	0.60
Environment Only Ranking	**1**	**6**	**4**	**8**	**7**	**5**	**3**	**10**	**8**	**12**	**11**	**2**
Technical and Operational Only Ratio	0.87	0.53	0.67	0.60	0.53	0.60	0.57	0.70	0.70	0.60	0.70	0.70
Technical and Operational Only Ranking	**1**	**11**	**6**	**7**	**11**	**7**	**10**	**2**	**2**	**7**	**2**	**2**
Economic Only Ratio	0.80	0.00	1.00	0.60	0.00	0.20	0.20	0.60	0.80	0.60	0.60	0.00
Economic Only Ranking	**2**	**10**	**1**	**4**	**10**	**8**	**8**	**4**	**2**	**4**	**4**	**10**
Socio-Economic Only Ratio	0.80	0.47	0.53	0.40	0.67	0.27	0.47	0.87	0.13	0.60	0.40	0.80
Socio-Economic Only Ranking	**2**	**7**	**6**	**9**	**4**	**11**	**7**	**1**	**12**	**5**	**9**	**2**
Score Exclusive of Environment Factor	2.47	1.00	2.20	1.60	1.20	1.07	1.23	2.17	1.63	1.80	1.70	1.50
Ranking Exclusive of Environment Factor	**1**	**12**	**2**	**7**	**10**	**11**	**9**	**3**	**6**	**4**	**5**	**8**
Score Exclusive of T & O Factor	2.27	0.94	2.04	1.42	1.12	0.96	1.23	1.87	1.35	1.49	1.36	1.40
Ranking Exclusive of T & O Factor	**1**	**12**	**2**	**5**	**10**	**11**	**9**	**3**	**8**	**4**	**7**	**6**
Score Exclusive of Economic Factor	2.34	1.47	1.71	1.42	1.65	1.36	1.60	1.97	1.25	1.49	1.46	2.10
Ranking Exclusive of Economic Factor	**1**	**8**	**4**	**10**	**5**	**11**	**6**	**3**	**12**	**7**	**9**	**2**
Score Exclusive of Socio-Economic Factor	2.34	1.01	2.18	1.62	0.99	1.29	1.33	1.70	1.92	1.49	1.66	1.30
Ranking Exclusive of Socio-Economic Factor	**1**	**11**	**2**	**6**	**12**	**10**	**8**	**4**	**3**	**7**	**5**	**9**