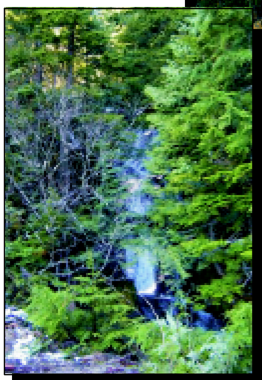

BRITISH COLUMBIA

Province of British Columbia Ministry of Water, Land and Air Protection

Britannia Mine Water Treatment Plant Sludge Disposal Options Study

U824A - February 2003

amec

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ABBREVIATIONS, ACRONYMS and SYMBOLS

$/kWh	Dollars per kilowatt hour
$/y	Dollars per year
%	Percent
±	Plus or minus
°	Degrees
AMEC	AMEC E&C Services Ltd., Mining & Metals
ARD	Acid rock drainage
CEMI	Canadian Environmental and Metallurgical Inc.
BMRC	Britannia Mining and Reclamation Corporation
c/kWh	Cents per kilowatt hour
$CaCO_3$	Calcium carbonate
CaO	Calcium oxide
CBEL	Copper Beach Estates Ltd.
Cdn	Canadian

EPCM	Engineering, procurement and construction management
FOB	Free on board
g/L	Grams per litre
Golder	Golder Associates Ltd.
h/m	Hours per month
h/y	Hours per year
HDS	High density sludge
I/O	Input/output
in.	Inch
kg	Kilogram(s)
km	Kilometre(s)
L	Litre(s)
m	Metre(s)
m^3	Cubic metres
m^3/d	Cubic metres per day
m^3/h	Cubic metres per hour
mg/L	Milligrams per litre
mm	Millimetre(s)
pH	Hydrogen-ion activity
Province	Province of British Columbia, Ministry of Water, Land and Air Protection
SRK	Steffen Robertson and Kirsten (Canada) Inc.
t	Tonnes
tpd	Tonnes per day
tpy	Tonnes per year
URS	URS Norecol Dames & Moore
V	Volt(s)
WTP	Water treatment plant

1. EXECUTIVE SUMMARY

1.1 Background

The Britannia Mine is located approximately 48 km north of Vancouver at the town of Britannia Beach, on the shore of Howe Sound. The mine was one of the biggest copper producers in the British Empire, operated from 1902 to 1963 by the Britannia Mining and Smelting Company Ltd. and by Anaconda Mining Company from 1963 until permanent shutdown in 1974.

The Crown Grants and freehold rights to the Britannia Mine lands were transferred from Anaconda to Copper Beach Estates Ltd. (CBEL), a real estate development company, in 1978. CBEL changed their name to Britannia Mining and Reclamation Corporation (BMRC), in 2002.

During operation, approximately 80 km of underground workings and five open pits were excavated, with the ore processed in the milling facilities at Britannia Beach. Much of the bedrock in the Britannia area, once exposed to air by mining or other excavation activities, is susceptible to sulphide oxidation and bacterial leaching. The resultant acid rock drainage (ARD) flows into Howe Sound.

The ARD problems at Britannia, and possible solutions, have been studied extensively over the years, often funded through both federal and provincial initiatives.

1.2 Terms of Reference

AMEC was retained by The Province of British Columbia to undertake a feasibility study for a water treatment plant (WTP), utilizing the high density sludge (HDS) process. Part of the terms of reference for the study included:

- Review of earlier studies to develop the preliminary sludge disposal concepts and a screening level option list.
- Present the preliminary sludge disposal options, identify the evaluation criteria and solicit any ideas for additional options from the stakeholders.
- Develop options for short, medium and long-term sludge disposal and handling, including the following activities:

- Contact local landfill operators, metals processing facilities and other parties to determine interest in receiving this sludge
- Analyze the effectiveness, economics and residual risks associated with sludge management
- Develop sludge handling and disposal design criteria
- Develop order-of-magnitude construction and operating costs for the sludge disposal options that are identified.

The items listed above were completed in July 2002, and the results presented in a report titled "Britannia Mine Water Treatment Plant Sludge Disposal Alternatives".

As there was no clear optimal sludge disposal solution, the Province requested that AMEC prepare a feasibility study of capital and operating costs for three of the options identified in the previous report as well as two temporary solutions. This would then provide information enabling a final option to be selected for detailed design. The terms of reference for this additional work were as follows:

- Prepare a design and operating strategy based on regulatory requirements and industry standards.
- Prepare design criteria summarizing the sludge generation rates and characteristics.
- Prepare a flowsheet and mass balance for each of the options.
- With existing information and site visits, evaluate the access route from the WTP via the BMRC road to Mt. Sheer, for the transportation of dewatered sludge in off-road trucks. Prepare plans and profiles for the entire route, including quantity take-offs for required modifications/upgrades to the roads and bridges.
- Identify a sludge pipeline route from the WTP to Mt. Sheer. Examine routes that do not necessarily follow existing roads, but are capable of allowing access for maintenance and repairs. Prepare plans and profiles for the entire route including quantity take-offs for the pipe installation and any modifications/upgrades required to the roads and bridges.

- Supply geotechnical input to the feasibility design of the roads, pipeline routes, ponds and landfills.
- Prepare a general site plan showing the location of the exfiltration ponds and landfills at Mt. Sheer as well as pipeline routes and roads from the WTP.
- Prepare a separate general arrangement drawing for each of the following:
  - WTP exfiltration ponds
  - WTP emergency storage pond
  - Mt. Sheer exfiltration pond
  - Mt. Sheer landfill
  - Off-site landfill – conceptual only.
- Prepare quantity take-offs for the ponds and landfills in the various options.
- Prepare feasibility level capital costs for each option.
- Evaluate the operating costs associated with each of the options including labour, trucking, power, equipment rental, landfill closure and post closure.
- Prepare a financial analysis of the options.
- Prepare a design and construction schedule.

1.3 Project Description

The sludge disposal options examined in this study were:

1.3.1 Option 1 – Pump Sludge to Mt. Sheer

Sludge from the WTP will be pumped via a 6.7 km pipeline using positive displacement pumps to an exfiltration basin at Mt. Sheer. To allow for emergency situations where the pipeline may be out of commission for short periods of time, a pond capable of holding up to one month of sludge at the design generation rate will be built close to the WTP.

1.3.2 Option 2 – Truck Sludge to Mt. Sheer

Sludge from the WTP will be pumped to two exfiltration ponds close to the WTP. Each exfiltration pond will be designed to take three months of sludge at the design generation rate. This will allow each pond to dewater the sludge for a period of approximately three months before being emptied with loaders and transported to Mt. Sheer on a campaign basis using off-road trucks. The trucks will use the existing road through BMRC property, upgraded where necessary. A containment pond will be constructed at Mt. Sheer to hold the dewatered sludge.

1.3.3 Option 3 – Truck Sludge to Off-Site Landfill

Filter presses at the WTP will dewater the sludge to a 50% solids cake, which will be transported by truck to an off-site landfill, dedicated to taking sludge from the WTP only. There will be no storage of sludge on-site other than the ability to store sludge in the clarifier for several days. This alternative requires trucks to pass through the community to Highway 99. This landfill will be a “generic” landfill design, as it was not possible to investigate and select a site in the time available for this study.

1.3.4 Options 4 and 5 - Temporary Sludge Storage at the WTP Site

The draft Sludge Disposal Options Study identified some risks and uncertainties with the three sludge disposal options examined. The AMEC recommendation was to consider temporary sludge storage adjacent to the WTP that would allow storage of sludge for a short period of time, in the order of 1 to 2 years. During this time, further information on sludge characteristics from full-scale plant operation could be gathered, as well as further study of the sludge disposal options. After a review meeting of the draft study with the Technical Advisory Committee and Golder representatives, it was agreed that two additional options for temporary sludge disposal would be added to the study. These options were:

- Option 4: Temporary sludge storage pond adjacent to the WTP, to hold cake from filter presses installed in the WTP

- Option 5: Temporary sludge storage in an ex-filtration pond adjacent to the WTP, to hold sludge directly pumped from the HDS clarifier.

1.4 Battery Limits

The WTP feasibility study was prepared assuming the use of filter presses, and only allowed for the capital and operating cost of the filter presses, not the cost of sludge transportation and disposal.

This study expands the battery limit to include the following:

- Total estimated capital cost of the WTP including sludge disposal
- Total operating cost including sludge transportation and disposal
- Sustaining capital involved with pond construction or facility closure.

1.5 Design Basis

The design basis for sludge disposal is provided in detail in the Design Criteria and Verification Plan contained in Appendix D.

The following table lists the key design parameters that were utilized in preparing this feasibility study, including the source. The sludge production volumes are calculated based on the WTP design and average flow rates and feed chemistry as described in the WTP feasibility study. If these are changed, the sludge production will also change.

Table 1.1: Sludge Design Criteria

Design Parameter	Design Value			Source
Sludge production rates	**Wt% solids**			
	25%	**40%**	**50%**	
Design (m^3/d)	59	32	24	CEMI/AMEC
Average (m^3/d)	28	15	11	CEMI/AMEC
Average (m^3/y)	10,200	5,600	4,100	CEMI/AMEC
Design plant life	25 years			Golder/Province
Installed spares	Critical equipment has installed spare where practical			Golder/Province/AMEC
Automation & control	High level of automation including provision for remote control			Golder/Province/AMEC

The design criteria for sludge storage includes:

- Flood protection for the 200-year return event
- Stability assured for an operating basis earthquake (1 in 475 year event) during facility operation and a design basis earthquake (1 in 2,475 year event) upon facility closure
- Minimum static load factor of safety of 1.5 for containment dykes throughout operation and through facility closure.

1.6 Opportunities

There are some opportunities that could result in lower capital and/or operating costs. These opportunities include:

- Disposal of sludge to an industrial end-user who can utilize the sludge in their manufacturing process
- Due to uncertainties of slope stability and sludge fate, Jane Basin was excluded as a potential sludge disposal area until further study has been done on these issues. Placement of sludge in Jane Basin could potentially assist in capping the area, leading to a reduction in the amount of water infiltration into the mine workings. This would result in an eventual reduction in flow to the WTP. However, there is a concern that if sludge enters the workings in an uncontrolled or unpredictable fashion, there could be adverse effects on the mine hydrology, including potential plugging.
- Depending on the sludge disposal option chosen, it may be possible to reduce the WTP building size and reduce the building cost.
- During detail design, it may be possible to reduce the capital cost by optimizing the design of the ponds in the various options, including the use of geosynthetic fabrics.
- Option 5 would allow the addition of filter presses at a later date, providing the building was either installed with the space for filter presses, or designed to allow the addition of a building extension. There would be a cost penalty in re-mobilizing a contractor to do this work after the main construction activities have been completed.

- Operating labour has been estimated based on AMEC's experience, and not reviewed in depth with the stakeholders. There may be opportunities to share operations staff, or reduce the staffing levels depending on the final option chosen.

- As the WTP and sludge disposal options involve considerable earthworks, it is recommended that a cost-benefit assessment be conducted for sources of construction materials for earthworks during detailed engineering.

- It may be possible to reduce the WTP building size and cost depending on the sludge disposal option chosen.

1.7 Risks

Option 1

The design of a pumping system with a long pipeline relies heavily on the sludge characteristics including the viscosity and particle size distribution. A single sample of pilot plant sludge was tested to determine viscosity and calculate the friction losses for the pipeline. However, it is important to note that HDS sludge generated from pilot plant studies can differ markedly with respect to viscosity and percent solids from sludge generated by a full-scale optimized HDS plant. Typically, particle size distribution and specific gravity are used to determine the minimum velocity in the pipeline to prevent sludge particles from settling and plugging the pipeline. No particle size analysis was conducted on the pilot plant sludge, as it is not considered representative of full-scale plant sludge.

The Mt. Sheer storage site has some natural hazard risks associated with the location. If eventual inundation or partial removal from debris torrent or rock avalanche activity was allowable, then the risk may be acceptable for development in this area. However, if the project design criteria requires a very low risk site from a natural hazard perspective *and* requires structural integrity for perpetuity, then development in the Britannia Creek valley in the vicinity of Mt. Sheer may be excluded.

In addition to the hazards listed above, there are some risks associated with the stability of the Jane Basin area which could impact the Mt. Sheer storage site. This subject has been studied separately by SRK in a report titled "Engineering Geology Mapping of Disturbed West Slopes of Jane Basin", dated January 2003.

The sizing of the exfiltration basins at Mt. Sheer is based on expected sludge settling and dewatering characteristics, based on AMEC's previous experience.

Actual rates from the full-scale plant may differ resulting in less storage space than anticipated if the rates are less favourable than expected.

Option 2

The same comments on natural hazard risks at the Mt. Sheer site apply to this option also.

The sizing of the exfiltration basins at the WTP, and the containment ponds at Mt. Sheer is based on expected sludge settling and dewatering characteristics, based on AMEC's previous experience. Actual settling and dewatering rates from the full-scale plant may differ resulting in higher trucking costs and less storage space than anticipated if the rates are less favourable than expected, and higher volumes of sludge are produced.

Option 3

The major risks expected from an off-site landfill if constructed and operated by a third party are:

- Guaranteed access
- Long-term assured cost basis for sludge disposal
- Public concern over sludge transport.

It is assumed that the location for the off-site landfill would not have similar geohazard risk levels to those present at Mt. Sheer.

Option 4

The sizing of the containment pond at the WTP is based on expected sludge dewatering characteristics, based on one sample of pilot plant sludge and AMEC's previous experience. Actual rates from the full-scale plant may differ resulting in less storage space than anticipated if the rates are less favourable than expected.

Option 5

The sizing of the exfiltration basins at the WTP is based on expected sludge settling and dewatering characteristics, based on AMEC's previous experience. Actual rates from the full-scale plant may differ resulting in less storage space than anticipated if the rates are less favourable than expected.

1.8 Cost Summary

1.8.1 Capital Cost

The capital cost estimate has been prepared assuming that the project will proceed on a design/build basis. If the project were not to proceed on this basis, most of the costs contained in the "Design/Build Contractors Risk and Fee" would be transferred to "Owner's Costs".

The basis of the capital cost estimate is described in detail in Section 5. The WTP feasibility study (base case) included the use of filter presses, but did not include any capital costs for sludge disposal. The base case estimate has been revised to reflect the total capital cost of the WTP and sludge disposal for each option. Table 1.2 provides the capital cost summary presented in 4th Quarter 2002 Canadian dollars.

It should be noted that the capital cost estimates for all five options do not include the costs of land acquisition, which could significantly increase the capital costs. As Option 3 was estimated using an assumed site, with ideal geotechnical, access and topographical conditions, its capital cost could vary significantly from that estimated when suitable candidate sites are investigated further.

Options 4 and 5 do not represent the final cost of the WTP and sludge disposal because they are only temporary solutions. As the final sludge disposal option is not known, it is not possible to say what the final total cost of these options would be. There may also be costs associated with closure of the the temporary pond that have not been included.

Table 1.2: Capital Cost Summary – 4th Quarter 2002 Cdn$

	Total Capital Cost*
Base Case - WTP Feasibility Study	12,180,000
Option 1 - Pump to Mt. Sheer	14,930,000
Option 2 - Truck to Mt. Sheer	13,110,000
Option 3 - Truck to off-site landfill	12,640,000
Option 4 - Cake to temporary landfill	12,460,000
Option 5 - Sludge to temporary landfill	11,200,000

* Excludes land acquisition costs

1.8.2 Sustaining Capital Cost

In addition to initial capital cost, sludge disposal Options 1, 2 and 3 will require construction of additional sludge storage ponds as time progresses, and also capping and closure activities at the end of the assumed 25 year life of the sludge storage facility. These costs, and the time that they occur in the life of the project, are shown in the tables below.

Options 4 and 5 do not have identified sustaining capital costs as they are only temporary solutions. No costs have been allowed for capping and closure of these ponds.

Table 1.3: Sustaining Capital Cost Summary – 4th Qtr 2002 Cdn$

	Option 1	Option 2	Option 3
Year 5	744,000	872,000	229,000
Year 10	744,000	872,000	229,000
Year 15	744,000	872,000	229,000
Year 20	744,000	872,000	229,000
Year 25	175,000	175,000	104,000

1.8.3 Operating Cost

The operating cost summary from the WTP feasibility study was taken as the base case for each option. The base case was then examined for each option and updated to reflect the particular requirements of each, to arrive at a total estimated operating cost for the WTP and the sludge disposal. A summary is shown in Table 1.6 below.

The basis of the operating cost estimate is described in detail in Section 5.

The operating costs for sludge disposal has been based on an average plant flow of 585 m^3/h.

Operating and maintenance labour and capital have been estimated based on AMEC's experience with similar plants.

A contingency of 10% has been allowed.

Table 1.4: Annual Operating Cost Summary - November 2002 Cdn$

	Option 1	Option 2	Option 3	Option 4	Option 5
Total	983,000	1,098,000	1,104,000	1,085,000	917,000

1.9 Financial Analysis

An analysis has been prepared that evaluates the net present value for the WTP as a whole, including the cost of sludge disposal for Options 1, 2 and 3. In order to perform this evaluation, the total capital, operating and sustaining capital cost of the WTP was determined for these sludge disposal options. A discount rate of 3%, and an inflation rate of 0% and 25 year project life was assumed to determine the net present value. The details of this analysis are described in Section 7. A net present value analysis for Options 4 and 5 is not possible as the permanent sludge disposal option is not known

Table 1.5: Net Present Value Comparison - Cdn$

Option	NPV*
Option 1 – pumping to Mt. Sheer	34,700,000
Option 2 – trucking to Mt. Sheer	35,300,000
Option 3 – trucking to off-site landfill	33,100,000

* Excludes land acquisition costs

1.10 Project Schedule

Options 1 and 2 involve construction activities at Mt. Sheer, that cannot be completed during winter months. Excluding any constraints imposed by a project start date requiring winter construction, any of the sludge disposal options should be able to be constructed in a 12 month window after design/build contract award.

An engineering, procurement and construction schedule is described in more detail in Section 7, and the detailed schedule is contained in Appendix C.

1.11 Conclusions

Evaluation of the capital, sustaining capital and operating costs for the Options 1, 2 and 3 resulted in comparable NPV, within 7% of each other. Inclusion of land acquisition costs could spread the values significantly.

Option 1 has process risks that would make it difficult to design optimally without the availability of sludge for testing from the full scale WTP. Therefore, it is recommended that this option not be considered until after the WTP has been running at least one year to enable the appropriate testwork to be completed in order to provide the data to design the sludge pumping system. As Option 1 involves the installation of ponds at Mt. Sheer that are similar to those in Option 2, if Option 2 were selected, then the addition of a pump and pipeline to Mt. Sheer would not be excluded at a later date.

Options 1 and 2 involve pond construction at Mt. Sheer. Building ponds at this location would include assuming the risk of a debris torrent or avalanche impacting and compromising the pond structure at some point in time. It is recommended that further study be conducted on these risks to better define them.

Option 3 involves the least risk from a geohazard perspective, provided a low risk site, with accessibility to Highway 99, can be located close to the WTP. This option also allows for the disposal of filtered sludge to an industrial end user, if they deem the sludge acceptable.

Options 4 and 5 would provide a relatively inexpensive method of sludge disposal during the initial operations of the WTP; the ability to determine the full-scale WTP sludge characteristics; and allow the most flexibility in terms of future sludge disposal options, allowing disposal on or off-site; including potential industrial end-users.

Finally, it should be recognized that this report has examined the sludge disposal options to a feasibility level only, to compare the various options and help in making a selection of the final disposal method. After a sludge disposal method is chosen, the detail design process will examine the issues and optimize the design to minimize capital, operating and sustaining costs.

2. DESIGN BASIS

2.1 Introduction

This section outlines the process design criteria, which form the basis for the design of the sludge disposal facilities. The detailed list of all the design criteria are contained in the Design Criteria and Verification Plan, contained in Appendix D.

2.2 Climate

The following data has been used for the plant design, and has been derived from the data listed in the National Building Code of Canada for Squamish, BC.

Table 2.1: Climatic Conditions

Parameter	Units	Design Value
Design temperature	January 2.5%	-11°C
	January 1%	-13°C
	July 2.5%	29°C
Precipitation	Annual precipitation	2,285 mm
	One day rain	112 mm
	15 minute rain	10 mm
Snow load	Ss	2.9 kPa
	Sr	0.6 kPa
Seismic load	Za	3
	Zv	3
	Zonal velocity ratio v	0.15
Wind load	1/10	0.38 kPa
	1/30	0.50 kPa
	1/100	0.65 kPa

2.3 Plant Design

Critical plant design criteria were reviewed and approved by the Province. These criteria are summarized in the Design Criteria and Verification Plan (DCVP) contained in Appendix D, and include:

- Plant design flow rate is 1,050 m^3/h
- Plant design life (25 years)

- Installed spares required for critical equipment.

In addition, the plant is to have a high level of automation and provision for remote monitoring and control.

The design criteria for sludge storage includes:

- Flood protection for the 200 year return event
- Stability assured for an operating basis earthquake (1 in 475 year event) during facility operation and a design basis earthquake (1 in 2,475 year event) upon facility closure
- Minimum static load factor of safety of 1.5 for containment dykes throughout operation and through facility closure.

2.4 Process Design

2.4.1 Process Selection

The process design selected for the Britannia treatment facilities is the conventional high density sludge (HDS) process, the full details of which have been described in the WTP feasibility study. Revised flow diagrams included with this study for Options 1, 2 and 3 are shown on Drawings No. A1-U824-100-N-0101, 0103, 0201, 0203, 0301 and 0303. Flow diagrams for Options 4 and 5 were not prepared. However, the flow sheet for Option 4 is similar to that of Option 3, and the flow sheet for Option 5 is similar to that of Option 2. As this study is examining sludge disposal, only the sections of the WTP feasibility study process design relating to sludge have been repeated below.

2.4.2 Sludge Characteristics and Stability

The sludge will be a mixture of precipitated metals, gypsum and calcium carbonate at typical HDS plant sludge densities. Density can be maximized through manipulation of the mass sludge recycle ratio, however, there is a limit to the maximum density that can be achieved when the sludge particles are amorphous and not crystalline as could be the case at Britannia. Zinc, aluminum and copper tend to form amorphous hydroxide type sludges with relatively low densities while sludges containing gypsum ($CaSO_4{\bullet}2\ H_2O$) or manganese dioxide (MnO_2) tend to be crystalline and have higher densities. The maximum density that can be achieved with an HDS plant at Britannia will be highly dependent on actual feed chemistry, especially with respect to iron, manganese and sulphate. Based on both the pilot plant results and experience with other HDS plants, the sludge produced at Britannia will have a typical density in the range of 25 to 35% solids and have good physical and chemical stability.

If the sludge is stored in an impoundment, there should be sufficient residual lime in the sludge to keep porewater pH high and maintain good long-term chemical stability. Alternatively, lime slurry could be added directly to the sludge prior to dewatering if it is deemed necessary to improve chemical stability. During storage, chemical stability will improve due to equilibrium reactions between the sludge solids and porewater, resulting in the densification and crystallization of particles such as $CaCO_3$. If left exposed for a long period of time, sludge porewater pH would be expected to drop due to exposure to atmospheric carbon dioxide, therefore long-term remediation measures for the sludge should include a final cover, if deposited in an impoundment. For Options 1, 2 and 3 a final cover of 30 cm of topsoil over the sludge has been included for this purpose and to encourage revegetation.

Standard BC Special Waste Extraction Process (SWEP) Leachate Analysis (Schedule 4 of "Special Waste Regulation") was performed on a clarifier underflow sludge test sample from the pilot program. As shown below the metal concentrations are well below the acceptable limits. Based on this test, sludge disposed is not considered as "special waste" and complies with Schedule 3 of "Special Waste Regulation" on waste disposal.

Table 2.2: Pilot Plant Clarifier Underflow Sludge Characteristics

Sample Name	Unit	Clar. U/F BBRun #4 Sludge	SWEP Leachate Quality Criteria
As	mg/L	<0.05	5.0
Ba	mg/L	0.005	100
B	mg/L	0.083	500
Cd	mg/L	<0.002	0.5
Cr	mg/L	<0.005	5.0
Cu	mg/L	0.09	100
Pb	mg/L	<0.03	5
Hg	mg/L	<0.00005	0.1
Se	mg/L	<0.03	1
Ag	mg/L	<0.01	5
Zn	mg/L	0.074	500

Based on pilot plant results and projected plant feed, the following metal concentrations have been calculated for the HDS sludge at 50% solids, as could be expected to be produced by a filter press.

Table 2.3: Sludge Metal Composition at 50% Solids

Metal	Percentage (%)
Al	6.28
Cd	0.019
Cu	4.78
Fe	2.51
Mg	3.33
Zn	4.16
SO_4	8.79

2.4.3 Sludge Generation Rates

The design case sludge generation rate was set at 0.70 g/L. This rate was based on the pilot plant results obtained with a 2,600 mg/L sulphate feed, adjusted to reflect a lower design feed sulphate level of 2,200 mg/L. The design case is used to size dewatering equipment.

The average sludge generation rate was set at 0.6 g/L, based on the pilot plant results obtained with a 1,380 mg/L sulphate feed, adjusted to reflect a higher average feed sulphate level of 1,710 mg/L. The average condition was used to determine the annual sludge volumes for disposal and to size the containment facilities.

2.4.4 Sludge Production

The key sludge production parameters are summarized below while additional detailed design information on sludge production is provided in the Design Criteria and Verification Plan in Appendix D.

Table 2.4: WTP Sludge Production

	Units	Average	Design
Sludge generation rate	g/L	0.60	0.70
Sludge production dry wt basis	tpd	8	18
	tpy	3,075	N/A
Sludge percent solids (design)	w/w	25%	25%
Sludge production wet wt basis @ 25% solids	tpd	34	71
Sludge disposal rate	m^3/d	28	59
	m^3/y	10,249	N/A

2.4.5 Turndown and Plant Flexibility

Typically, HDS plants are designed for turndown ratios of 4 to 5, equivalent to 210 to 260 m^3/h for this plant, but are often capable of operating at lower flow conditions. The WTP could see flows this low during portions of the winter months. However, as an alternative to operation at very low flows, the plant design will be sufficiently flexible to allow for short-term shutdown followed by operation on a campaign basis. During these periods, feed would be shut off at the plug in the 4100 level adit and water allowed to collect in the existing mine workings. During these periods, no sludge would be wasted from the WTP.

2.5 Sludge Dewatering and Disposal Method and Operating Philosophy

Definition of terms used in this section:

Exfiltration Basin – a basin designed to allow free pore water from sludge to permeate through some, or all of the basin walls, resulting in a gradual de-watering of the sludge. Depending on the length of time the sludge resides in the pond, and the characteristics of the sludge, the final density of the dewatered sludge will vary. The quality of the permeate is expected to be the same as that of the final treated water discharge from the HDS plant to the outfall. The permeate is typically allowed to enter the groundwater system because it meets the discharge criteria.

For this area of British Columbia, rapid dilution in either the surface or groundwater system would occur within a short distance of any exfiltration pond.

Containment Pond – a pond designed to accept dewatered sludge, constructed at the Mt. Sheer location, to be developed in cells and capped.

Off-Site Landfill – a containment designed to accept dewatered sludge, constructed at a location to be determined, but assumed to be within 10 km of the WTP, and accessible from Highway 99.

Positive Displacement Pumps – the type of pump that is needed to develop the high pressures required to pump slurry from the WTP to Mt. Sheer.

2.5.1 Option 1

Sludge from the WTP clarifier will be pumped by a positive displacement pump through a pipeline to an exfiltration basin at Mt. Sheer. To allow for emergency situations where the pump or pipeline may be out of commission for short periods of time, a pond capable of holding up to one month of sludge at the design generation rate will be built close to the WTP.

The pump system will not operate on a constant basis, as the amount of sludge requiring disposal is not large enough to provide the minimum velocity required for the smallest acceptable pipeline size recommended for pumping this material. Consequently, when sludge wasting from the clarifier is required, the operator will initiate pumping sludge from the clarifier to the agitated sludge holding tank until it is full.

While filling the tank, the operator will check the percent solids of the sludge to ensure it is suitable for pumping (not too thick as to cause pipeline plugging). If the sludge is too high in solids, dilution water can be added while the tank is filling. The pump will then be started and the contents of the tank pumped to the exfiltration pond at Mt. Sheer. After the tank is empty, the tank will be re-filled with treated water and the contents of the tank pumped through the pipeline. As the volume of the tank is the same as the volume contained in the full pipeline, this will result in leaving the pipeline full of treated water, with all the sludge being displaced to the exfiltration pond.

At this stage, the pump will be stopped and the contents of the pipeline emptied in a controlled manner back to the WTP building sump pump and then back to the process for re-treatment. Under design conditions, it will take 5 hours to pump the sludge to Mt. Sheer, 5 hours to flush the pipeline, and 2 hours to empty the pipeline. This would result in a daily 12 hour operation during periods when the plant is running at design capacity. When the plant is running at less than design capacity, wasting need not be done on a daily basis as the sludge will be stored in the clarifier, and the pumping cycle will only be started when there is sufficient sludge stored to require wasting, allowing a full tank of sludge to be pumped to the exfiltration basin.

Table 2.5: Option 1 Design Parameters

	Units	Average	Design
Sludge pumping rate @ 25% solids	m^3/d	28	59
Emergency pond storage volume (1 month at design flow)	m^3	-	1,800
Expected ultimate sludge percent solids after dewatering in the exfiltration ponds	w/w	-	40
Sludge volume @ 40% solids	m^3/y	5,600	-
Exfiltration basin volume for 5 year cell	m^3	28,000	
Permeate flow rate from the exfiltration pond	m^3/d	13	-

Pipeline sizing and minimum velocity has been set assuming that the sludge is a non-segregating slurry with a minimum viscosity of 200 centipoise.

2.5.2 Option 2

Sludge from the WTP will be pumped from the clarifier to two exfiltration ponds close to the WTP. Each exfiltration pond will be designed to take three months of sludge at the design generation rate. This will allow each pond to dewater the sludge for a period of approximately three months, after transfer of sludge to it is stopped. At this point it would be emptied on a campaign basis using loaders with the cake transported to Mt. Sheer for final disposal. A containment pond would be constructed at Mt. Sheer to hold the cake. The dewatered sludge would be transported through BMRC property by off-road trucks on an existing upgraded road to Mt. Sheer.

This operation is expected to be done by a contractor who would mobilize the appropriate equipment to site to empty the pond. The following strategy would be used:

- Prior to the starting of sludge hauling, a grader (equivalent to a Caterpillar 14G Grader) would upgrade and repair the haul road from the treatment plant to the exfiltration pond. The grader would then be available for road repair during the haul operation.

- Pond ramps will be constructed to allow the dump trucks to enter the exfiltration pond for filling. One loader (equivalent to a Caterpillar 966F loader) would be utilized at the exfiltration pond for this purpose.

- Four off-road trucks (equivalent to Caterpillar D300 rock trucks) would be utilized to haul the sludge with an expected round trip time of 80 minutes.

- One dozer (equivalent to a Caterpillar 14G dozer) would be utilized at the containment pond for leveling the dumped sludge. This dozer has low ground pressure and is suitable to maneuver on the sludge.

The operation to empty one exfiltration pond is expected to take 4 days, including the first day of road repair.

Each pond is designed to hold three months of sludge at the design generation rate, and the average sludge production rate is less than half of this. This means that the time between pond emptying will vary depending on the time of year, the mine water flow and characteristics. On average, each pond will require emptying once per year.

Table 2.6: Option 2 Design Parameters

	Units	Average	Design
Sludge pumping rate from clarifier @ 25% solids	m^3/d	28	59
Exfiltration pond storage volume (each) at WTP (3 months at design flow)	m^3	-	5,300
Expected ultimate sludge percent solids after dewatering in the exfiltration ponds	w/w	-	35
Sludge volume @ 35% solids	m^3/y	6,740	-
Sludge specific gravity @ 35% solids		1.3	-
Permeate flow rate from the exfiltration ponds	m^3/d	10	-
Containment pond volume for 5 year cell	m^3	34,000	

2.5.3 Option 3

Sludge from filter presses at the WTP would be transported by truck to an off-site landfill dedicated to taking sludge from the WTP. There would be no storage of sludge on-site other than the ability to store sludge in the clarifier for several days, unless extra containers are purchased, which can be covered and left on site for later disposal. This alternative requires trucks to pass through the community to Highway 99. This landfill would be a “generic” landfill design, as it was not possible to investigate and select a site in the time available for this study.

The landfill would be developed in stages, at 5 year intervals. Each stage would consist of excavating the cell, building the berms, and piling the excess material for final cover.

It is anticipated that a contractor would be utilized to haul the sludge to the landfill, spread the material and cover it periodically. The contractor would supply all equipment, including the haulage containers required underneath the filter presses.

Each round trip would consist of:

- removing the full container from below the filter press
- placing an empty container in its place
- driving the full container to the landfill and dumping
- returning empty container to WTP.

Table 2.7: Option 3 Design Parameters

	Units	Average	Design
Sludge pumping rate from clarifier @ 25% solids	m^3/d	28	59
Expected ultimate sludge percent solids from the filter presses	w/w	-	50
Sludge volume @ 50% solids	m^3/y	4,100	-
	m^3/d	-	24
Sludge specific gravity @ 50% solids		1.5	-
Landfill volume for 5 year cell	m^3	20,500	

2.5.4 Option 4

Sludge from filter presses at the WTP would be transported by truck to a temporary landfill constructed at the 4100 level, adjacent to the WTP.

It is anticipated that a contractor would be utilized to haul the sludge to the temporary landfill, spread the material and cover it periodically. The contractor would supply all equipment, including the haulage containers required underneath the filter presses.

Each round trip would consist of:

- removing the full container from below the filter press
- placing an empty container in its place
- driving the full container to the landfill and dumping
- returning empty container to WTP.

Table 2.8: Option 4 Design Parameters

	Units	Average	Design
Sludge pumping rate from clarifier @ 25% solids	m^3/d	28	59
Expected ultimate sludge percent solids from the filter presses	w/w	-	50
Sludge volume @ 50% solids	m^3/y	4,100	-
	m^3/d	-	24
Sludge specific gravity @ 50% solids		1.5	-
Temporary landfill life with 50% solids cake	years	3.4	-
Temporary landfill life with 40% solids cake	years	2.5	-

2.5.5 Option 5

Sludge from the WTP will be pumped from the clarifier to a temporary exfiltration pond close to the WTP.

Table 2.9: Option 5 Design Parameters

	Units	Average	Design
Sludge pumping rate from clarifier @ 25% solids	m^3/d	28	59
Exfiltration pond storage volume	m^3	-	13,800
Expected ultimate sludge percent solids after dewatering in the exfiltration ponds	w/w	-	35
Sludge volume @ 35% solids	m^3/y	6,740	-
Sludge specific gravity @ 35% solids		1.3	-
Temporary landfill life with 35% solids cake	years	2.0	-

2.6 Permit Criteria

2.6.1 Options 1, 2, 4 and 5

If Options 1, 2, 4 or 5 are selected, permitting will be required for an on-site storage facility. Since the facility would be located on mine property, it is expected that a permit would be obtained under the Mines Act. The design for the proposed storage facility is consistent with the expectations of Part 9 of the British Columbia Health, Safety and Reclamation Code for Mines, and generally in accordance with existing facilities in British Columbia. It is not envisioned that permitting would affect either the projected cost or schedule.

2.6.2 Option 3 – Off-Site Landfill

The off-site disposal option will involve development of a dedicated landfill to receive only dewatered sludge from the WTP. It is anticipated that a permit would be required for from the Ministry of Water, Land and Air Protection. Since the sludge has been determined to pass the BC SWEP test, it would not be considered a Special Waste. The containment performance requirements for the landfill are expressed in the groundwater and surface water quality impairment requirements of the BC Landfill Criteria, are as follows:

"Landfills must not be operated in a manner such that ground or surface water quality in existing or potential future water supply aquifers or surface waters decreases beyond that allowed by the Approved and Working Criteria for Water Quality prepared by the Water Management Division of the Ministry of Water, Land and Air Protection, or other appropriate criteria, at or beyond the landfill property boundary."

It is expected that water draining through the landfill will be similar to the WTP effluent. This option is presumed to be located in an area where the leachate could be discharged directly to the environment without a risk to the quality of groundwater or surface water beneath or around the site. In addition, the quantity of leachate expected to be generated at the landfill is relatively small due to the expected low permeability nature of these materials. It is assumed that lining and leachate collection systems would not be required.

If Option 3 is selected the Province will need to acquire rights to a location for the landfill so that a site-specific permit application can be prepared and submitted for regulatory approval. Obtaining the permit is not expected to affect the schedule.

3. DESCRIPTION OF FACILITIES

3.1 Option 1 Facilities

3.1.1 Site Selection

The Mt. Sheer site was selected to build an exfiltration basin to which the sludge will be pumped. This location was previously a town site close to the top of the mountain, where mine workers and families lived. The most suitable location was determined to be a relatively flat area, close to Britannia Creek and the Tunnel Dam. The site is shown on Drawing No.'s A1-U824-500-C-0108 and A1-U824-500-C-0114 contained in Appendix A.

3.1.2 Plant Description

The pumping system will be located in the area where the filter presses are presently located in the WTP feasibility study. The plant description below reflects only the additional equipment required for the pumping option compared to the filter presses in the feasibility study.

Sludge Holding Tank TK-006

This tank will replace the previous filter feed tank, and will act as a feed tank for the sludge pump. The tank will be fed from the sludge recycle pumps. The contents of the tank will be agitated to ensure the solids are kept in suspension.

Sludge Holding Tank Agitator AG-005

The sludge holding tank agitator will replace the filter feed tank agitator, and will be a top mounted agitator rated for solids suspension. The agitator drive will be mounted on a platform across the top of the tank.

Sludge Waste Pump PU-002

This pump will be a positive displacement pump designed for pumping slurry at high pressure. Due to the high cost of this pump, no spare will be installed. Critical, long lead spare parts will be stored at the WTP to enable pump repair. While the pump is down, excess sludge will be wasted to the emergency storage pond if necessary.

3.1.3 Yards and Services

The overall site plan is shown on Drawing No. A1-U824-500-C-108 and the WTP site plan on Drawing No. A1-U824-500-C-103 in Appendix A.

Roads, Bridges and Pipelines

In order to lay a pipeline up the steep grade from the WTP to Mt. Sheer, a routing has been chosen that follows the existing road through BMRC property. There may be opportunities to shorten the pipeline length by cutting out some of the switchbacks. However, this may result in a pipeline that is difficult to install and maintain.

Towards the upper section of the road, there is a section with a dip that would result in a low spot if the pipeline were to follow this route. To alleviate this problem, the pipeline will be routed below the existing road (with a simple maintenance road constructed) to allow for a constantly upward sloping grade, leading to the crossing of Britannia Creek. At the creek crossing, the existing single lane bridge will be upgraded to a 5 m wide bridge. In addition, the road from the creek to Mt. Sheer will be re-routed to avoid the existing switchback, which is not negotiable by trucks.

Site Preparation at Mt. Sheer

Site preparation will include clearing, stripping and grading of the site to the elevations shown on Drawing No. A1-U824-500-C-0114 in Appendix A. It will also include construction of ditches and installation of culverts and other associated work.

Sludge Exfiltration Ponds

Sludge ponds will be constructed at Mt. Sheer to contain the sludge pumped from the WTP via a pipeline. The ponds will be constructed in cells capable of holding 5 years of sludge, with only the first two cells being constructed initially. After each cell is filled, it will be covered with a geosynthetic liner and 30 cm of topsoil to encourage revegetation.

The exfiltration ponds will be constructed in an area selected as having relatively less steeply dipping topography. There are avalanche and debris flow issues with any development in this area of the Britannia Creek Valley. The nature of the concern is described in the geotechnical report in Appendix D.

The lack of assured free-draining rockfill for exfiltration dykes in the colluvial materials that make up the foundation area, and the lack of coarse (rockfill) material in the WTP development spoil, requires that either a quarry is developed on site in some location where sulphide oxidation concerns were not present or the concept is modified to meet the materials present. A combined approach was adopted where the local excavated material would be selectively used for dyke construction and augmented, as required, with the spoil from the WTP excavation works. For cross-dykes between operating cells, quarried rockfill would be used to provide exfiltration. The combined overflow weir and coarse rockfill for the cross-dykes will provide sufficient drainage potential.

Given that the in-situ material at the Mt. Sheer site is quite variable there is the potential that some of the dyke construction material may be quite permeable. In order to ensure that there is negligible migration of fines from the sludge pond, the estimate allows for the placement of a non-woven geotextile filter cloth along the inside face of the southern containment dyke.

Runoff diversion ditches will be provided along the northern perimeter of the ponds together with seepage collection ditches along the toes of the dykes.

The selection of fill materials, placement requirements and areas for geotextile placement would be as directed by an experienced geotechnical engineer in cooperation with the field representative for the design civil engineer. This field approach to design will allow the most cost-effective development as the excavated materials from both the Mt. Sheer area and the WTP development can be maximized for construction use.

The location is generally above the projected floodplain of Britannia Creek. As indicated in Appendix D, the 200 year flood level from Britannia Creek would be 602.1 m and this would result in nearly 6 m of freeboard to the top of any given cell. The base of the cells will require some riprap protection to the 602.1 m elevation.

Site Preparation at the Emergency Pond

Site preparation will include clearing, stripping and grading of the site to the elevations shown on Drawing No. A1-U824-500-C-0113 in Appendix A. It will also include construction of ditches and installation of culverts and other associated work.

Emergency Pond

A pond will be constructed close to the WTP at the 4100 level. If the pumping system should fail, resulting in an extended shut-down, the pond will be utilized to store up to a month of sludge production at the design flow rate while the system is being repaired. After the repairs are complete, the sludge in the pond will be excavated and hauled by truck for disposal in the exfiltration pond.

Buildings

No changes have been made to the pre-engineered structural steel building included in the feasibility study for this option, other than to remove the platform previously required for the filter presses. It may be possible to optimize the plant layout and reduce the building size slightly if this option is chosen for sludge disposal.

Security Fencing

To prevent unauthorized access to exfiltration basins, a 2.44 m high chain link fence with three strands of barbed wire has been included around the periphery of the basins. Also included is a double gate and single gate for access.

Pipelines

The sludge pipeline will consist of carbon steel pipe. The first 1,300 m of pipe from the pump discharge will be 90 mm (3-1/2 in.) diameter Schedule 80 carbon steel pipe (7.6 mm or 0.30 in. wall thickness). After this, the pipe will be reduced to 90 mm (3 1/2 in.) diameter Schedule 40 carbon steel pipe (5.3 mm or 0.21 in. wall thickness) for the next 5,400 m.

The carbon steel pipeline will be covered with a layer of plastic that is factory installed to prevent corrosion (“yellow jacket pipe”). At welded connections, the plastic layer is applied in the field to complete the corrosion protection system.

To protect the pipeline from rock and debris slides as well as vandalism, the pipeline will be buried beside the access road. In case the pipeline ever plugs, clean out points will be installed at regular intervals to enable locating the pluggage and cleaning out the pipeline.

No frost protection has been allowed, other than that provided by the ground cover over the pipe, as the pipeline operation does not involve long periods of time when the sludge sits in the pipeline and could freeze.

3.1.4 Electrical

The installation of the sludge waste pump increases the connected load at the plant by 180 kW. Compared to the WTP feasibility study, this will result in a larger transformer being required, as well as a special type of motor starter called a "soft-start" for the pump.

3.1.5 Process Control System

There is no change to the process control system as described in the WTP feasibility study.

3.1.6 Instrumentation

The only change to the instrumentation system described in the WTP feasibility study is the cost of the additional instrumentation required to control the sludge waste pump.

3.2 Option 2 Facilities

3.2.1 Site Selection

The site selected to build a sludge containment pond to which the sludge will be trucked from the exfiltration ponds at the WTP site is referred to as Mt. Sheer. This location was previously a town site close to the top of the mountain, where mine workers and families lived. The most suitable location was determined to be a relatively flat area, close to Britannia Creek and the Tunnel Dam. The site is shown on Drawing No.'s A1-U824-500-C-0108 and A1-U824-500-C-0114 contained in Appendix A.

3.2.2 Plant Description

This option will not require any sludge dewatering equipment inside the WTP building other than the small pumps required to waste sludge from the clarifier to the exfiltration ponds. The plant description below reflects only the additional equipment required for the pumping option compared to the filter presses in the feasibility study.

Sludge Waste Pumps PU-002A/B

The sludge waste pumps will be rubber-lined slurry pumps. One pump will be operating and the other a standby. Pump speed will be controlled by a variable speed drive to maintain the flow set point. The sludge pipeline will have automatic recycle water flushing valves to flush the line on pump shutdown.

3.2.3 Yards and Services

The overall site plan is shown on Drawing No. A1-U824-500-C-108 and the WTP site plan on Drawing No. A1-U824-500-C-103 in Appendix A.

Roads and Bridges

In order to truck sludge to Mt. Sheer, the existing road through BMRC property will be used. The road profile is shown on Drawing No's. A1-U824-500-C-109, 110, 111 and 112 in Appendix A.

Towards the upper section of the road, there is a very steep section prior to crossing Britannia Creek, and there is also a narrow single lane bridge. To alleviate this problem, the road will be re-routed to allow for a constantly upward sloping grade, leading to the crossing of Britannia Creek. At the creek crossing, the existing single lane bridge will be upgraded to a 5 m wide bridge. In addition, the road from the creek to Mt. Sheer will be re-routed to avoid the existing switchback, which is not negotiable by trucks.

Site Preparation at the WTP

Site preparation will include clearing, stripping and grading of the site to the elevations as shown on Drawing No. A1-U824-500-C-0115 in Appendix A.

Site Preparation at Mt. Sheer

Site preparation will include clearing, stripping and grading of the site to the elevations as shown on Drawing No. A1-U824-500-C-0114 in Appendix A. It will also include construction of ditches, culverts and other associated work including supply and installation of the granular materials for the intermediate berms.

Sludge Exfiltration Ponds

Sludge ponds will be constructed adjacent to the WTP at the 4100 level. The ponds will be constructed in two cells, each capable of holding 3 months of sludge at the design production rate.

Waste material from the WTP site preparation will be used in part to construct the sludge pond dykes.

Sludge Containment Ponds

Sludge ponds will be constructed at Mt. Sheer to contain the sludge trucked from the WTP exfiltration ponds. The ponds will be constructed in cells capable of holding 5 years of sludge, with only the first two cells being constructed initially. After each cell is filled, it will be covered with a geosynthetic liner and 30 cm of topsoil to encourage revegetation.

The containment ponds will be constructed in an area selected as having relatively less steeply dipping topography. There are avalanche and debris flow issues with any development in this area of the Britannia Creek Valley. The nature of the concern is described in the geotechnical report in Appendix D. Also, as noted in Section 8 (Risks), the risks assumed by developing a storage facility at the Mt. Sheer site are proportional to the time period of exposure, or the operating life of the facility.

Exfiltration will not be as important for Option 2 as for Option 1, as the material will have been partially dewatered in the exfiltration ponds at the WTP site. Consequently, lesser emphasis on locating free-draining material for cross-dykes, or perimeter walls is required in Option 2 compared to Option 1.

The lack of assured free-draining rockfill for exfiltration dykes in the colluvial materials that make up the foundation area, and the lack of coarse (rockfill) material in the WTP development spoil, requires that either a quarry is developed on site in some location where sulphide oxidation concerns were not present or the concept is modified to meet the materials present. A combined approach was adopted where the local excavated material would be selectively used for dyke construction and augmented, as required, with the spoil from the WTP excavation works. For cross-dykes between operating cells, quarried rockfill would be used to provide exfiltration. The combined overflow weir and coarse rockfill for the cross-dykes will provide sufficient drainage potential.

Given that the in-situ material at the Mt. Sheer site is quite variable there is the potential that some of the dyke construction material may be quite permeable. In order to ensure that there is negligible migration of fines from the sludge pond, the estimate allows for the placement of a non-woven geotextile filter cloth along the inside face of the southern containment dyke.

Runoff diversion ditches will be provided along the northern perimeter of the ponds together with seepage collection ditches along the toes of the dykes.

The selection of fill materials, placement requirements and areas for geotextile placement would be as directed by an experienced geotechnical engineer in cooperation with the field representative for the design civil engineer. This field approach to design will allow the most cost-effective development as the excavated materials from both the Mt. Sheer area and the WTP development can be maximized for construction use.

The location is generally above the projected floodplain of Britannia Creek. As indicated in Appendix D, the 200 year flood level from Britannia Creek would be 602.1 m, resulting in nearly 6 m of freeboard to the top of any given cell. The base of the cells will require some riprap protection to the 602.1 m elevation.

Buildings

No changes have been made to the pre-engineered structural steel building included in the feasibility study for this option, other than to remove the platform previously required for the filter presses. It may be possible to optimize the plant layout and reduce the building size if this option is chosen for sludge disposal.

Security Fencing

To prevent unauthorized access to exfiltration basins and sludge containment ponds, a 2.44 m high chain link fence with three strands of barbed wire has been included around the periphery of the basins. Also included is a double gate and single gate for access at each site.

Pipelines

There will be one short sludge pipeline from the WTP to the exfiltration ponds. This pipe will be designed with mechanical couplings to allow the pipe to be re-located to change the spigot point for distributing the sludge into the ponds.

3.2.7 Electrical/Process Control System/Instrumentation

There is no change to the electrical, process control and instrumentation system described in the WTP feasibility study, other than the deduction of the filter presses.

3.3 Option 3 Facilities

3.3.1 Site Selection

The selection of a specific off-site landfill location was not possible in the time available for this study, therefore a generic location has been assumed based on the typical soil conditions found in the Squamish area. The landfill has been assumed to be located with easy access to Highway 99.

3.3.2 Plant Description

The WTP study contained filter presses and is unchanged for this option.

3.3.3 Yards and Services

The overall WTP site plan is shown on Drawing No. A1-U824-500-C-101 and the WTP site plan on Drawing No. A1-U824-500-C-103 in Appendix A.

Roads and Bridges

No new roads or bridges are required for this option at the WTP site, other than the WTP access road already included with the WTP feasibility study.

Site Preparation at the WTP

There is no change to the site preparation at the WTP from the WTP feasibility study.

Off-site Landfill

An off-site landfill will be developed in a presently undefined suitable area, presumed to be within 5 km of the WTP. The landfill will be developed in stages. The ultimate footprint and cross-section of the landfill at closure in year 25 is shown on Drawing No. A1-U824-500-C-116.

For the assumed off-site landfill, the general quaternary geology of the Squamish Valley was reviewed. The available information indicates that glaciofluvial and fluvial processes have dominated the veneer of near surface materials over other glacial materials and/or bedrock. Consequently, it was assumed that a relatively pervious foundation condition would exist for the generic landfill and that granular construction material would be readily available.

Buildings

There will be no change to the building from the WTP feasibility study.

Security Fencing

To prevent unauthorized access to the off-site landfill, a 2.44 m high chain link fence with three strands of barbed wire has been included around the periphery of the landfill. Also included are a double gate and a single gate for access.

Pipelines

There will be no additional pipelines than already identified in the WTP feasibility study.

3.3.4 Electrical/Process Control System/Instrumentation

There is no change to the electrical, process control and instrumentation system described in the WTP feasibility study.

3.4 Option 4 Facilities

3.4.1 Site Selection

The temporary exfiltration pond will be constructed at the 4100 level, close to the WTP site. The site is shown on Drawing No. A1-U824-500-C-0117 contained in Appendix A.

3.4.2 Plant Description

The WTP study contained filter presses and is unchanged for this option.

3.4.3 Yards and Services

The overall WTP site plan is shown on Drawing No. A1-U824-500-C-101 and the WTP site plan on Drawing No. A1-U824-500-C-103 in Appendix A.

Roads and Bridges

No new roads or bridges are required for this option at the WTP site, other than the WTP access road already included with the WTP feasibility study.

Site Preparation at the WTP

There is no change to the site preparation at the WTP from the WTP feasibility study.

Temporary Sludge Exfiltration Pond

The exfiltration ponds will be constructed adjacent to the WTP at the 4100 level.

Waste material from the WTP site preparation will be used in part to construct the sludge pond dykes.

Buildings

There will be no change to the building from the WTP feasibility study.

Security Fencing

To prevent unauthorized access to the temporary exfiltration pond, a 2.44 m high chain link fence with three strands of barbed wire has been included around the periphery. Also included are a double gate and a single gate for access.

Pipelines

There will be no additional pipelines than already identified in the WTP feasibility study.

3.4.4 Electrical/Process Control System/Instrumentation

There is no change to the electrical, process control and instrumentation system described in the WTP feasibility study.

3.5 Option 5 Facilities

3.5.1 Site Selection

The temporary exfiltration pond will be constructed at the 4100 level, close to the WTP site. The site is shown on Drawing No. A1-U824-500-C-0117 contained in Appendix A.

3.5.2 Plant Description

This option will not require any sludge dewatering equipment inside the WTP building other than the small pumps required to waste sludge from the clarifier to the exfiltration pond. The plant description below reflects only the additional equipment required for the pumping option compared to the filter presses in the feasibility study.

Sludge Waste Pumps PU-002A/B

The sludge waste pumps will be rubber-lined slurry pumps. One pump will be operating and the other a standby. Pump speed will be controlled by a variable speed drive to maintain the flow set point. The sludge pipeline will have automatic recycle water flushing valves to flush the line on pump shutdown.

3.5.3 Yards and Services

The overall WTP site plan is shown on Drawing No. A1-U824-500-C-101 and the WTP site plan on Drawing No. A1-U824-500-C-103 in Appendix A.

Roads and Bridges

No new roads or bridges are required for this option at the WTP site, other than the WTP access road already included with the WTP feasibility study.

Site Preparation at the WTP

There is no change to the site preparation at the WTP from the WTP feasibility study.

Temporary sludge Exfiltration Pond

The exfiltration ponds will be constructed adjacent to the WTP at the 4100 level.

Waste material from the WTP site preparation will be used in part to construct the sludge pond dykes.

Buildings

There will be no change to the building from the WTP feasibility study.

Security Fencing

To prevent unauthorized access to the temporary exfiltration pond, a 2.44 m high chain link fence with three strands of barbed wire has been included around the periphery. Also included are a double gate and a single gate for access.

Pipelines

There will be no additional pipelines than already identified in the WTP feasibility study.

3.5.4 Electrical/Process Control System/Instrumentation

There is no change to the electrical, process control and instrumentation system described in the WTP feasibility study, other than the deduction of the filter presses.

4. RISK ASSESSMENT REVIEW

4.1 Introduction

In May 2002, a risk assessment workshop was held involving stakeholders from the Technical Advisory Committee, the Province, Environment Canada, BMRC, SRK, Golder and AMEC. The purpose of this workshop was to identify the major project risk elements and the various issues that could lead to unfavourable project risk exposure. The methodology used enabled the identified issues to have their risk assigned and screened on the basis of the likelihood and consequence of each event occurring. The results of this analysis were presented in a report titled “WTP Risk Assessment Workshop”.

4.2 Review of Workshop Results

As the risk assessment workshop was conducted early in the WTP feasibility study, the results and recommendations from the workshop report were reviewed after the feasibility study design was further developed to ascertain if any of the identified risks had been eliminated or reduced in any way. This was not meant to be an exhaustive review, as the first steps of the next stage, detailed design, should include further workshops and commensurate risk mitigative strategies.

For this review, the risk summary and tables from the report for the sludge disposal portions only were examined. Review of WTP risks were covered in the WTP feasibility study.

As described in the workshop report, with the five-by-five likelihood and consequence matrix used for risk assignment, there are nine separate “zones” of approximately equivalent risk. These zones are denoted I to IX with I being essentially zero risk (very low consequence coupled with negligible likelihood) and IX representing extreme risk and a likely fatal flaw to the project without an appropriate mitigative strategy(s).

From risk management experience, the items in Zones VI to IX are those that require mitigative strategies at the feasibility project stage. As the project develops, it often becomes prudent to examine lower risks. However, without detailed project definition, it is typically acceptable to identify these lower risks as an aide to the design process without a formal mitigation strategy review for each risk.

Table 4.1 presents a summary of issues identified for the WTP with Risk Level 6 or above. In each case, the mitigative strategy, if any, is identified.

The main issues identified with respect to sludge disposal were:

- Effects of low density sludge
- Transient nature of sludge
- Slope stability and avalanche concerns at Mt. Sheer/Jane Basin
- Social/political objections and concerns
- Snow does not allow year round access to disposal area.

4.3 Recommendations

With the transient nature of the sludge and sludge density issues largely addressed by the plug development works and pilot plant, respectively, focus during detailed engineering should largely be on the other potential project risks.

For the slope stability, debris flow and avalanche concerns with the Mt. Sheer area (see Section 8 and Appendix D), some risk assumption is inevitable if the Mt. Sheer area is chosen for eventual sludge storage. Better quantification of this risk can be completed during detailed engineering by means of a more detailed geohazard assessment. Furthermore, clarity on the consequences of storage area inundation with either avalanche or debris flow material can be refined following input from salient regulators. Such clarity should be sought as part of the detailed engineering phase of the project. The risks associated with the stability of the Jane Basin area which could impact the Mt. Sheer storage site have been studied separately by SRK in a report titled "Engineering Geology Mapping of Disturbed West Slopes of Jane Basin", dated January 2003.

As far as social/political issues/concerns, it is difficult to indicate likely further work required to address this project risk area. If an off-site storage area is selected, entirely different sets of social risks exist in comparison to an on-site solution. It is recommended that once the permit granting agencies confirms the preferred storage alternative, thorough public consultation be instigated and maintained throughout the detailed engineering and construction phases of the project.

Access issues for the Mt. Sheer site were evaluated as being manageable by use of traditional snow plowing road and maintenance in winter months. For an off-site location, it is envisioned that the location would be relatively close to sea level elevation and the number of days where snow may have an impact on material placement or site access would be very limited. During the feasibility assessment, it was determined that a sludge storage staging area would not be required for either the Mt. Sheer site or an off-site location.

For the remainder of the risks identified as requiring active risk management, it is recommended that the mitigation plans proposed are reviewed during the detailed engineering phase. In addition, as noted above, an additional risk workshop(s) should take place at the outset of the detailed engineering phase to assess relevancy of the issues and management plan identified in Table 4.1 and the identification of other issues that will require an effective risk management plan.

Table 4.1: Mitigative Strategy for Water Treatment Plant Risk

Issue Stewardship (Zone)	Bining Code	Potential Issue Of Concern	Potential Effect (S)
IX	1.7	Groundwater chemistry not adequately addressed by water treatment plant.	Treatment plant is not appropriately designed for de variability in groundwater.
	2.18	Inability to fund plant operations.	Lack of ability to keep plant operating.
VIII	1.3	Stormwater inflow combines to exceed the 1,330 m^3/h.	Too much water coming to plant.
	1.12	Storage dramatically alters water chemistry.	Storage of water increases inflow concentrations in t term.
VII	1.4	Stormwater inflow changes flow rate suddenly but less than plant capacity.	
	1.9	Actual mine storage volume may result in treatment requirements of greater than 1,330 m^3/h.	Plant must be much larger to deal with peak inflows
	1.11	Storage dramatically alters water chemistry.	Storage of water increases inflow concentrations in t term.
	4.1	Integrity of existing outfall line.	Requires upgrading but may be unrepairable.
	4.7	Integrity of new outfall.	Outfall line fails on tailings or sub-marine slide.
	4.9	Debris flows from Britannia Creek impacting stability of delta.	Instability on delta impacts outfall.
	6.9	Snow does not allow access to basin year round for sludge disposal.	Need a staging area.
VI	1.1	Average flow 500 m^3/h, design flow is 1,000 m^3/h - hydraulic capacity of 1,330 m^3/h - if influent flow is greater than 1,330 m^3/h.	System cannot take flow and proper treatment cann
	1.5	Groundwater inflow rate combines to exceed the 1,330 m^3/hr.	
	1.8	Refusal of owner to allow storage of mine water within the mine workings.	Inability to modulate the flow.
	1.14	Slug of sediment laden inflow from the mine workings.	Effluent water quality is impacted.
	2.1	Failure of plug valves - won't close.	Flow can come at you in uncontrolled fashion.
	2.4	Adit failure destroys the piping for the water from the plug.	Uncontrolled flow.
	2.5	Failure of clarifier.	Mechanism (rakes etc.) fails. Massive failure that re complete shutdown of plant and minimum >one wee

Table 4.1: Mitigative Strategy for Water Treatment Plant Risk (cont'd)

Issue Stewardship (Zone)	Bining Code	Potential Issue Of Concern	Potential Effect (S)
	2.8	Loss of power <24 hours.	Plant shutdown.
	2.12	General mechanical failure.	Small equipment, pumps, etc. fail and require repair/replacement.
	2.13	Outfall pipe – slumpage or failure.	Plant shut down.
	2.14	Failure of Jane Basin diversion.	Increase flows into system.
	2.22	Earthquake issues – foundation liquefaction, Howe Sound tsunami.	Catastrophic.
	2.23	Low density sludge.	Much higher storage volume requirements. Increase plant equipment sizes. General increase in material issues.
	2.25	Poor effluent quality - off specification.	Effluent permit not met leading to a range of penaltie
	2.26	Effluent permit requirements are changed and treatment plant requires modification.	Installed plant inadequate.
	4.5	Location of new outfall not optimal.	Located in area that leads to similar issues with curr
	5.1a	Continuity of sludge receipt location.	Receiver no longer desires/is able to accept the sluc new location is required.
	5.4a	Transient nature of sludge impact on receiver.	Sludge changes resulting in receiver not wanting to receive…voids contract.
	6.4	Stability of natural slopes.	Failure impacts landfill and access to landfill.
	6.5	Avalanche concerns.	Landfill impacted.
	6.12	Social/political objections/concern.	Inability to permit permanent landfill in any other loca site other than Jane Basin.

Notes:

1. Potential concerns that bordered two or more stewardship categories were put into the more critical category.

5. COST ESTIMATE

5.1 Capital Cost Summary

The estimated costs to construct, install and commission the facilities for the three options are included in Table 5.1 below. The amounts cover the direct field costs of executing the project, plus the indirect costs associated with design, construction and commissioning. All costs are expressed 4th Quarter 2002 Canadian dollars. A 1.5% escalation to 4th Quarter 2003 Canadian dollars on materials and equipment has been included in the estimate.

The capital cost estimate has been prepared assuming that the project will proceed on a design/build basis. If the project were not to proceed on this basis, most of the costs contained in the “Design/Build Contractors Risk and Fee” would be transferred to “Owner’s Costs”.

The WTP feasibility study (base case) included the use of filter presses, but did not include any capital costs for sludge disposal. The base case estimate has been revised to reflect the total capital cost of the WTP and sludge disposal for each option. This report does not contain a full listing of the basis of estimate for the WTP, including the associated assumptions and exclusions, as this was included in the WTP feasibility study. Table 5.1 provides the capital cost summary presented in 4th Quarter 2002 Canadian dollars.

Table 5.1: Capital Cost Summary – 4th Quarter 2002 Cdn$

Description	Base Case (WTP Feas. Study)	Option 1 – Pump to Mt. Sheer	Option 2 – Truck to Mt. Sheer	Option 3 – Truck to Off-Site Landfill	Option 4 – Truck to temporary landfill	Option 5 – Pump to temporary pond
Direct Costs						
Access road to WTP	443,000	443,000	443,000	443,000	443,000	443,000
HDS plant	6,109,000	6,120,000	6,109,000	6,109,000	6,109,000	6,109,000
Filter press system	953,000	0	0	953,000	953,000	0
WTP pipelines	296,000	296,000	296,000	296,000	296,000	296,000
Sludge disposal facilities at WTP	0	586,000	135,000	0	0	0
Access road to Mt. Sheer	0	149,000	149,000	0	0	0
Sludge pipeline	0	1,251,000	0	0	0	0
Sludge disposal facilities – Mt. Sheer	0	839,000	1,110,000	0	0	0
Off-site landfill	0	0	0	220,000	91,000	0
Ancillary facilities	0	38,000	38,000	38,000	38,000	38,000
Outfall	0	0	0	0	0	0
Sub-Total of Direct Costs	**$7,801,000**	**$9,722,000**	**$8,280,000**	**$8,059,000**	**$7,930,000**	**$6,977,000**
Indirect Costs						
Owner's costs	0	0	0	0	0	0
Construction indirects	388,000	394,000	480,000	388,000	388,000	363,000
First fills & spare parts	119,000	109,000	86,000	119,000	119,000	119,000
Freight	150,000	198,000	149,000	150,000	150,000	150,000
Start-up & commissioning	119,000	119,000	119,000	119,000	119,000	119,000
Vendor representatives	20,000	20,000	20,000	20,000	20,000	20,000
Taxes	0	0	0	0	0	0
Escalation	60,000	75,000	56,000	60,000	60,000	60,000
Engineering, procurement & construction management	1,430,000	1,550,000	1,520,000	1,500,000	1,500,000	1,500,000
Contingency	1,093,000	1,523,000	1,328,000	1,185,000	1,134,000	1,021,000
Design/build contractor risk & fee	1,000,000	1,220,000	1,072,000	1,040,000	1,040,000	1,040,000
Sub-Total of Indirect Costs	**$4,379,000**	**$5,208,000**	**$4,830,000**	**$4,581,000**	**$4,530,000**	**$4,223,000**
Total Project Capital Cost	**$12,180,000**	**$14,930,000**	**$13,110,000**	**$12,640,000**	**$12,460,000**	**$11,200,000**

5.1.1 Basis of Capital Cost Estimate

The capital cost estimates were based on the following project data:

- Design criteria
- Process flowsheets
- Preliminary equipment list
- Preliminary general arrangement drawings
- Supplemental sketches as required
- Budget quotations from vendors
- Regional climatic data
- In-house data base
- Geotechnical assessment and recommendations
- Project execution strategy and schedule.

The estimates are categorized as feasibility level with an expected accuracy of ±15%. The estimates were prepared using a combination of budgetary equipment quotations and quantity take-offs for civil, concrete, piping, steel and materials.

5.1.2 Direct Costs

Quantities

Engineering material takeoffs were based on “neat” line quantities derived from project drawings and sketches. Normal and acceptable allowances have been included for each discipline as appropriate by the project estimator.

Civil – Estimates of earthworks quantities do not include an allowance for bulking or compaction of materials. These allowances were made in the unit prices. Quantities in the plant site were based on current topography.

Concrete – Concrete quantities and classifications were determined from preliminary drawings, with a 5% allowance made for over-pour and wastage. The costs include transport, placing and finishing of concrete, formwork, reinforcing steel and embedded metal.

Structural Steel – Steel quantities and breakdowns were based on material take-offs derived from preliminary steel drawings and sketches. The unit price includes steel purchase, detailing, fabrication and erection labour.

Mechanical (Equipment) – Equipment was itemized and priced as per the preliminary equipment list. Motors were identified and are included with equipment cost. Installation hours were obtained from in-house data.

Process Piping – Preliminary material takeoffs were derived from general arrangement drawings.

Electrical – The electrical estimate was based on preliminary connected loads detailed in the equipment list. Major electrical equipment prices were based on current in-house data. Within the battery limits of the process area an average cable run length to each drive has been used to calculate wiring, terminations and cable tray. Building high bay lighting is included in the pre-engineered building quotation. Building grounding has been based on a $/m^2 basis.

Instrumentation – Field instrumentation has been priced based on take-offs from the preliminary instrument index. An allowance has been made to include for supports, tubing, wiring and terminations. The process control system is based on an I/O count and includes cabinets, console, workstation, software, fiber optics, patch panels, switches and transceivers.

Direct Field Labour

Labour rates were calculated using information from previous projects. The average all-in rate of $60.00/h was based on the following criteria:

- 40 hour work week
- Base labour wage rate
- Benefits and burdens - 35%

- Small tools and consumables allowance - $4.00/h
- Supervision and field office overheads - 30%
- Home office overheads - 5%
- Contractors' profit - 10%
- Travel - $3.00/h.

Direct Field Materials

Bulk materials components were priced with a base cost FOB point of manufacture. Freight cost to transport materials to site is included in the indirects. Pricing is based on previous projects.

5.1.3 Project Indirect Costs

Temporary Construction Facilities and Services

Contractors' field distributable costs have been allowed for in the built-up labour rate cost.

Construction Equipment

An allowance of $8.00/h of construction hours has been made for the rental of construction equipment.

Freight

An allowance of 4% of material and equipment costs has been included for freight.

Security

An allowance of $50,000 has been made for security during construction.

Start-Up and Commissioning

An allowance of four contractors' personnel for 7 days has been included in the estimate. Also, there is an allowance for four engineering personnel during this time frame. An allowance of $10,000 has been made for start-up supplies and materials.

Engineering, Procurement and Construction Management (EPCM)

Activities included in the EPCM are:

- Process engineering
- Civil engineering
- Structural engineering
- Mechanical and piping engineering
- Electrical engineering
- Instrumentation engineering
- Procurement
- Vendor quality control
- Expediting
- Cost control
- Scheduling
- Construction management
- Construction inspection and quality control
- Site safety plan and implementation
- Construction trailer and first aid room
- Certified first aid attendant
- First aid vehicle where required by the WCB code
- Construction management vehicle living and accommodation allowance.

Taxes and Duties

All taxes and duties are excluded from the estimate.

Design/Build Contractors Risk and Fee

An allowance has been added to cover the following items:

- Design/build contractor fee
- Process risk, including the cost of providing a performance guarantee
- Sub-contractors performance and completion risk, including items such as bankruptcy of the subcontractor or having to hire a new subcontractor if they are not performing their contract.
- Execution risk, including cost and schedule risk.

These items are normally carried under Owner's risk in an EPCM project execution. Items not included are acts of God and force majeure.

Owner's Cost

Owner's costs are excluded from the estimate. The capital cost estimate has been prepared assuming the project will proceed on a design/build basis. If the project were not to proceed on this basis, most of the costs contained in the "Design/Build Contractors Risk and Fee" would be transferred to "Owner's Costs".

Capital Spares and First Fills

Capital spares are based on 5% of mechanical equipment purchase price. First fill is based on the initial purchase of 75 t of lime and 2 t of flocculant.

Contingency

The contingency amount is an allowance added to the capital cost estimate to cover unforeseeable costs within the scope of the estimate. These can arise due to currently undefined items of work or equipment, or to the uncertainty in the estimated quantities and unit prices for labour, equipment and materials. Contingency does not cover scope changes or project exclusions.

For Options 1,2 and 3 contingency has been calculated using a risk analysis program (@ RISK) to generate a range of probable costs for each option. Contingency has been applied to all the capital cost items excluding contractor's fee and risk. Input variables used in calculating the contingency are shown in Tables 5.2, 5.3 and 5.4 for the three options and represent information gathered from all parties involved in the basis of estimate. The contingency utilized in each case corresponds to an 85% probability that the estimated costs will not be exceeded. The contingency amount is calculated as the difference between the probable final cost for the 85% selected probability and the base estimate, and corresponds to what is commonly referred to as a ±15% cost estimate.

Table 5.2: Risk Analysis Input Option 1 – December 11, 2002

Item	Current Estimate ($)	Minimum (%)	Maximum (%)
Civil labor and other	1,993,909	-10	30
Mechanical labor	188,362	-5	20
Structural/arch labor and other	1,755,989	-10	20
Electrical labor & other	346,916	-10	25
Piping labor & other	404,894	-5	30
Instrumentation labor & other	96,000	-5	25
Civil materials	573,938	-5	20
Structural/arch material	742,995	-10	20
Electrical materials	388,410	-5	25
Piping materials	1,065,876	-5	30
Instrumentation materials	370,000	-5	25
Process & other mechanical equipment	1,795,720	-5	15
Total Direct Costs	**$9,723,009**		
EPCM & vendor reps	1,570,000	-5	15
Escalation	75,000	-5	15
Freight	198,000	-10	20
Construction Equipment & temp.	393,800	-5	25
Commission & start up	118,800	-5	25
First fill & spare parts	108,550	-5	15
Total Indirect Costs	**$2,464,150**		
Total Cost (not including EPC fee and risk)	**$12,187,159**		
EPC fee & risk	1,220,000		

Table 5.3: Risk Analysis Input Option 2 – December 11, 2002

Item	Current Estimate ($)	Minimum (%)	Maximum (%)
Civil labor & other	2,008,200	-10	30
Mechanical labor	168,894	-5	20
Structural/arch labor & other	1,755,989	-10	20
Electrical labor & other	328,616	-10	25
Piping labor & other	222,382	-5	25
Instrumentation labor & other	90,000	-5	25
Civil materials	613,008	-5	20
Structural/arch material	742,995	-10	20
Electrical materials	352,710	-5	25
Piping materials	267,716	-5	25
Instrumentation materials	360,000	-5	25
Process & other mechanical equipment	1,369,730	-5	15
Total Direct Costs	**$8,280,240**		
EPCM & vendor reps	1,540,000	-5	15
Escalation	56,000	-5	15
Freight	149,000	-10	20
Construction equipment & temp.	479,560	-5	25
Commission & start-up	118,800	-5	25
First fill & spare parts	86,550	-5	15
Total Indirect Costs	**$2,429,910**		
Total Cost (not including EPC fee and risk)	**$10,710,150**		
EPC fee & risk	1,072,000		

Table 5.4: Risk Analysis Input Option 3 – December 11, 2002

Item	Current Estimate ($)	Minimum (%)	Maximum (%)
Civil labor & other	2,008,200	-10	30
Mechanical labor	168,894	-5	20
Structural/arch labor & other	1,755,989	-10	20
Electrical labor & other	328,616	-10	25
Piping labor & other	222,382	-5	25
Instrumentation labor & other	90,000	-5	25
Civil materials	613,008	-5	20
Structural/arch material	742,995	-10	20
Electrical materials	352,710	-5	25
Piping materials	267,716	-5	25
Instrumentation materials	360,000	-5	25
Process & other mechanical equipment	1,369,730	-5	15
Total Direct Costs	**$8,280,240**		
EPCM & vendor reps	1,540,000	-5	15
Escalation	56,000	-5	15
Freight	149,000	-10	20
Construction equipment & temp.	479,560	-5	25
Commission & start-up	118,800	-5	25
First fill & spare parts	86,550	-5	15
Total Indirect Costs	**$2,429,910**		
Total Cost (not including EPC fee & risk)	**$10,710,150**		
EPC fee & risk	1,040,000		

The range of probable costs at different probability levels for each option are shown on Figures 5.1, 5.2 and 5.3 below.

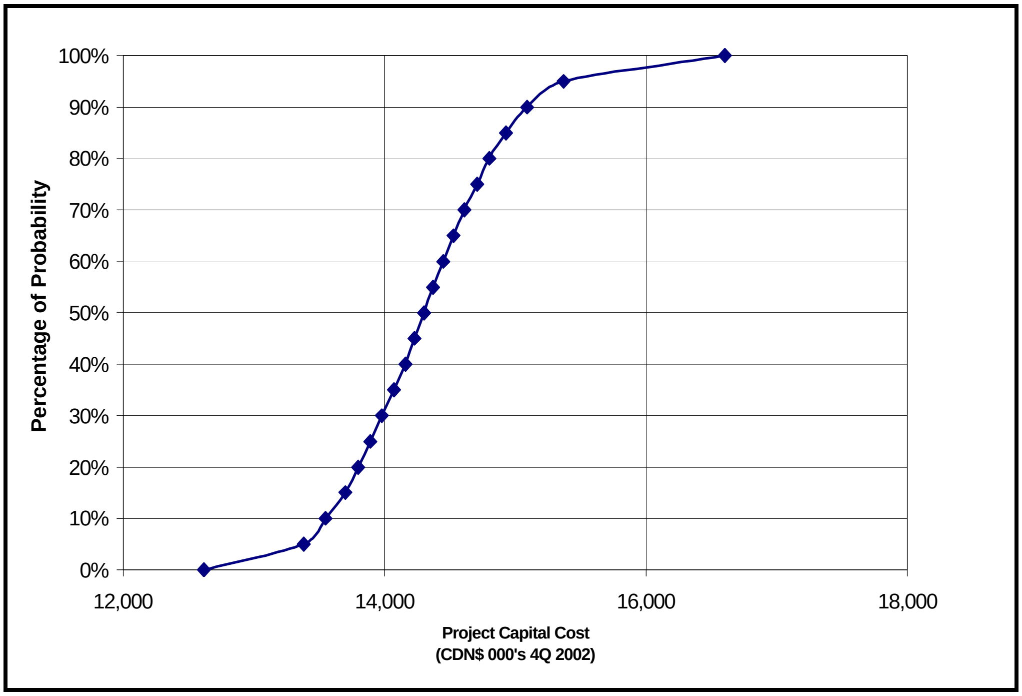

Figure 5.1: **Range of Probable Costs – Option 1**

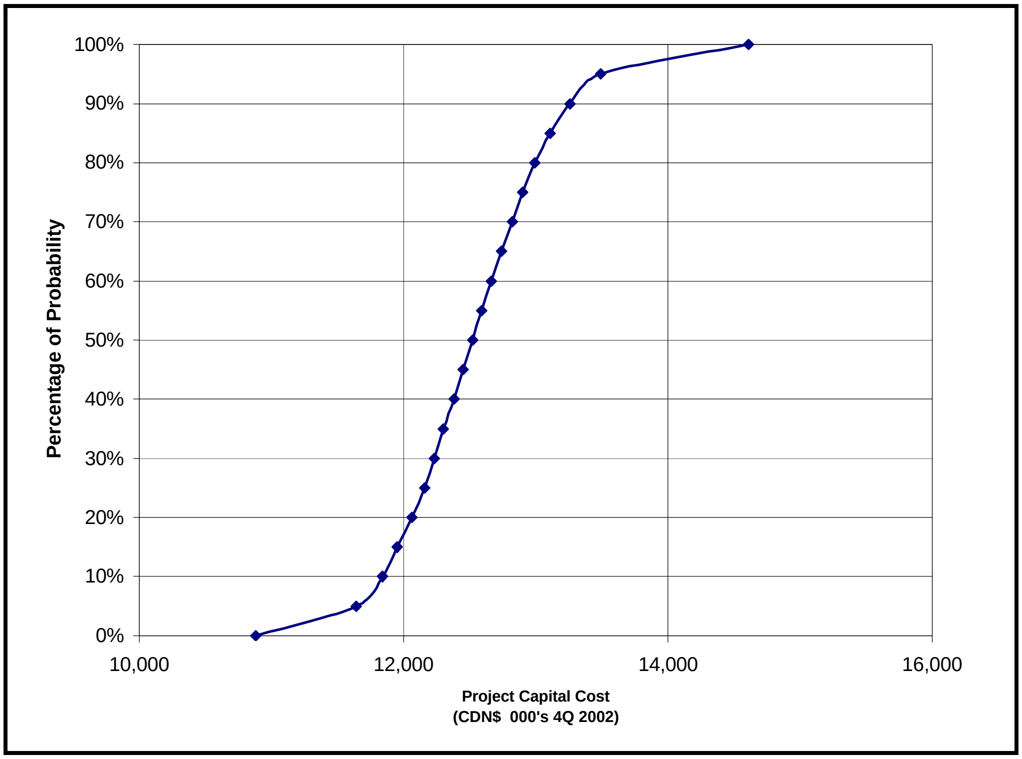

Figure 5.2: **Range of Probable Costs – Option 2**

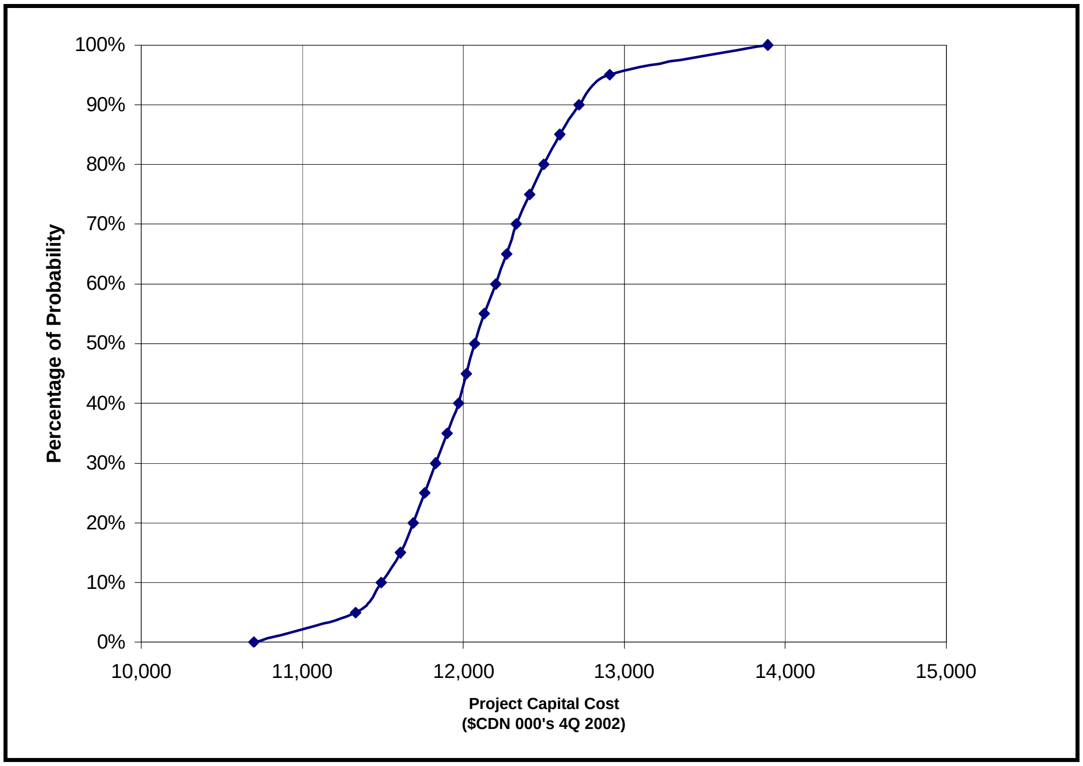

Figure 5.3: Range of Probable Costs – Option 3

Due to time constraints, a risk analysis was not conducted for Options 4 and 5. However, as Option 3 is very similar in risk analysis input to Options 4 and 5, the same contingency percentage was applied to these options, which was 10%.

5.1.4 Capital Cost Exclusions

- Costs resulting from schedule delays and associated costs such as those caused by:
  - scope changes
  - unidentified ground conditions
  - labour disputes
  - permit applications
  - inclement weather.
- Sunk costs
- Owner's costs

- P.S.T.
- G.S.T.
- Permits
- Cost of training plant personnel
- Removal of contaminated or hazardous material and equipment
- No allowance has been made for the possibility of unmapped/abandoned tunnels, adits or portals that may be discovered during construction.
- No allowance has been made for the cost of acquiring the land for the options examined.

5.1.5 Assumptions

- The estimate has been derived on a design/build basis.
- Soil bearing conditions for the sludge disposal facilities are as the conditions estimated in the geotechnical report in Appendix D. The WTP feasibility study contains the geotechnical conditions for the WTP facilities.
- Labour is based on open shop.
- Workweek for construction will be 40 hours per week.

5.2 Sustaining Capital Cost

In addition to initial capital cost, the sludge disposal options will require construction of additional sludge storage ponds as time progresses, and also capping and closure activities at the end of the assumed 25 year life of the sludge storage facility. These costs and the time that they occur in the life of the project are shown in the tables below. No costs have been allocated for capping and closure of these ponds.

Options 4 and 5 do not have identified sustaining capital costs, as they are only temporary solutions.

Table 5.5: Option 1: Sustaining Capital Cost Summary – 4th Quarter 2002 Cdn$

Description	5 Yrs	10 Yrs	15 Yrs	20 Yrs	25 Yrs
Pond const./capping	699,000	699,000	699,000	699,000	175,000
Vehicle replacement	40,000	40,000	40,000	40,000	0
Relocate Spigot	5,000	5,000	5,000	5,000	0
Total	**$744,000**	**$744,000**	**$744,000**	**$744,000**	**$175,000**

Table 5.6: Option 2: Sustaining Capital Cost Summary – 4th Quarter 2002 Cdn$

Description	5 Yrs	10 Yrs	15 Yrs	20 Yrs	25 Yrs
Pond const./capping	832,000	832,000	832,000	832,000	175,000
Vehicle replacement	40,000	40,000	40,000	40,000	0
Total	**$$872,000**	**$872,000**	**$872,000**	**$872,000**	**$175,000**

Table 5.7: Option 3: Sustaining Capital Cost Summary – 4th Quarter 2002 Cdn$

Description	5 Yrs	10 Yrs	15 Yrs	20 Yrs	25 Yrs
Pond const./capping	189,000	189,000	189,000	189,000	104,000
Vehicle replacement	40,000	40,000	40,000	40,000	0
Total	**$229,000**	**$229,000**	**$229,000**	**$229,000**	**$104,000**

5.3 Operating Cost Estimate

5.3.1 Operating Cost Summary

The operating cost estimate is based on the process and facilities descriptions contained in this report, and AMEC's experience with similar plants.

The operating cost summary from the WTP feasibility study was taken as the base case for each option. The base case was then examined for each option and updated to reflect the particular requirements of each, to arrive at a total operating cost for the WTP and the sludge disposal.

Tables 5.8, 5.9 and 5.10 show the summary of the operating costs based on the above basis of estimate, assumptions and exclusions.

Table 5.8: Operating Cost Estimate – Option 1 – Pump to Mt. Sheer

Acid mine drainage average flow: 585 m^3/h

Reagents	**Dosage**		**Consumption**		**Unit Cost ($/Unit)**	**Total Cost (Avg. Flow) ($/y)**
Lime (avg.)	0.41	g/L (CaO)	2,108	t/y	131.25	277,000
Flocculant (avg.)	2	mg/L	10.2	t/y	3,826.12	39,000
Total Reagents						**$316,000**
Utilities	**Total Connected (kW)**	**Avg. Draw (kW)**			**Power ($/kWh)**	**Total Cost (Avg. Flow) ($/y)**
Power (avg. flow)	760	240			0.046	97,000
Total Utilities						**$97,000**
Operating & Maintenance Labour	**Labour (h/m)**	**Total Hrs (h/y)**	**Labour ($/h)**			**Total Cost (Avg. Flow) ($/y)**
Supervisor (1)	173	2,080	43.20			90,000
Operators (2)	182	2,184	33.75			147,000
Mechanical maintenance allowance	16.7	200	100.00			20,000
Electrical/instrumentation contract	34.7	416	65.00			27,000
Process consulting services						5,000
Total Labour		**4,880**				**$289,000**
Operating & Maintenance Capital						**Total Cost (Avg. Flow) ($/y)**
Operations Supply						
Analytical						24,000
Analytical services - sample analyses						20,000
Licences/permits/ taxes						0
Training allowance						2,000
Misc. - spares, maintenance *						134,000
Total Operations & Maintenance Capital						**$180,000**
Sludge Disposal						**Total Cost (Avg. Flow) ($/y)**
Plant vehicle fuel						3,000
Vehicle insurance & Maintenance						3,000
Relocate spigot point in ponds						1,000
Road maintenance to Mt. Sheer						5,000
Total Sludge Disposal						**$12,000**
Sub-Total Direct Annual Operating Costs						**$894,000**
Contingency@10%						89,000
Total Direct Annual Operating Costs						**$983,000**

* 3% purchased equipment cost

Table 5.9: Operating Cost Estimate – Option 2 – Truck to Mt. Sheer
Acid mine drainage average flow: 585 m^3/h

Reagents	Dosage		Consumption		Unit Cost ($/Unit)	Total Cost (Avg. Flow) ($/y)
Lime (avg.)	0.41	g/L (CaO)	2,108	t/y	131.25	277,000
Flocculant (avg.)	2	mg/L	10.2	t/y	3,826.12	39,000
Total Reagents						**$316,000**

Utilities	Total Connected (kW)	Avg. Draw (kW)			Power ($/kWh)	Total Cost (Avg. Flow) ($/y)
Power (avg. flow)	630	220			0.046	89,000
Total Utilities						**$89,000**

Operating & Maintenance Labour	Labour (h/m)	Total Hrs (h/y)	Labour ($/h)			Total Cost (Avg. Flow) ($/y)
Supervisor (1)	173	2,080	43.20			90,000
Operators (2)	182	2,184	33.75			147,000
Mechanical maintenance allowance	8.3	100	100.00			10,000
Electrical/instrumentation contract	34.7	416	65.00			27,000
Process consulting services						5,000
Total Labour		**4,780**				**$289,000**

Operating & Maintenance Capital						Total Cost (Avg. Flow) ($/y)
Operations Supply						
Analytical						24,000
Analytical services - sample analyses						20,000
Licences/permits/ taxes						0
Training allowance						2,000
Misc. - spares, maintenance *						118,000
Total Operations & Maintenance Capital						**$164,000**

Sludge Disposal	Sludge Prod. (m^3/y)	Cost ($/$m^3$)				Total Cost (Avg. Flow) ($/y)
Clean out ponds, truck & spread sludge	6,740	21				142,000
Relocate spigot point in pond						2,000
Plant vehicle fuel						3,000
Vehicle insurance & maint.						3,000
Total Sludge Disposal						**$150,000**

Sub-Total Direct Annual Operating Costs						**$998,000**
Contingency@10%						100,000
Total Direct Annual Operating Costs						**$1,098,000**

* 3% purchased equipment cost

Table 5.10: Operating Cost Estimate – Option 3 – Off-Site Landfill

Acid mine drainage average flow: 585 m^3/h

Reagents	**Dosage**		**Consumption**		**Unit Cost ($/Unit)**	**Total Cost (Avg. Flow) ($/y)**
Lime (avg.)	0.41	g/L (CaO)	2,108	t/y	131.25	277,000
Flocculant (avg.)	2	mg/L	10.2	t/y	3,826.12	39,000
Total Reagents						**$316,000**
Utilities	**Total Connected (kW)**	**Avg. Draw (kW)**			**Power ($/kWh)**	**Total Cost (Avg. Flow) ($/y)**
Power (avg. flow)	623	210			0.046	85,000
Total Utilities						**$85,000**
Operating & Maintenance Labour	**Labour (h/m)**	**Total Hrs (h/y)**	**Labour ($/h)**			**Total Cost (Avg. Flow) ($/y)**
Supervisor (1)	173	2,080	43.20			90,000
Operators (2)	182	2,184	33.75			147,000
Mechanical maintenance allowance	12.5	150	100.00			15,000
Electrical/instrumentation contract	34.7	416	65.00			27,000
Process consulting services						5,000
Total Labour		**4,830**				**$284,000**
Operating & Maintenance Capital						**Total Cost (Avg. Flow) ($/y)**
Operations Supply						
Analytical						24,000
Filter cloth						27,000
Analytical services - sample analyses						20,000
Licences/permits/ taxes						0
Training allowance						2,000
Misc. - spares, maintenance *						114,000
Total Operations & Maintenance Capital						**$187,000**
Sludge Disposal	**Sludge Prod. (m^3/y)**	**Cost ($/$m^3$)**				**Total Cost (Avg. Flow) ($/y)**
Sludge trucking to landfill & spreading	4,100	24				98,000
Sludge spreading	4,100	7				28,000
Plant vehicle fuel						3,000
Vehicle insurance & maint.						3,000
Total Sludge Disposal						**$132,000**
Sub-Total Direct Annual Operating Costs						**$1,004,000**
Contingency@10%						100,000
Total Direct Annual Operating Costs						**$1,104,000**

* 3% purchased equipment cost

Table 5.11: Operating Cost Estimate-Option 4–Truck to Temporary Landfill

Acid mine drainage average flow: 585 m^3/h

Reagents	**Dosage**		**Consumption**		**Unit Cost ($/Unit)**	**Total Cost (Avg. Flow) ($/y)**
Lime (avg.)	0.41	g/L (CaO)	2,108	t/y	131.25	277,000
Flocculant (avg.)	2	mg/L	10.2	t/y	3,826.12	39,000
Total Reagents						**$316,000**
Utilities	**Total Connected (kW)**	**Avg. Draw (kW)**			**Power ($/kWh)**	**Total Cost (Avg. Flow) ($/y)**
Power (avg. flow)	623	210			0.046	85,000
Total Utilities						**$85,000**
Operating & Maintenance Labour	**Labour (h/m)**	**Total Hrs (h/y)**	**Labour ($/h)**			**Total Cost (Avg. Flow) ($/y)**
Supervisor (1)	173	2,080	43.20			90,000
Operators (2)	182	2,184	33.75			147,000
Mechanical maintenance allowance	12.5	150	100.00			15,000
Electrical/instrumentation contract	34.7	416	65.00			27,000
Process consulting services						5,000
Total Labour		**4,830**				**$284,000**
Operating & Maintenance Capital						**Total Cost (Avg. Flow) ($/y)**
Operations Supply						
Analytical						24,000
Filter cloth						27,000
Analytical services - sample analyses						20,000
Licences/permits/ taxes						0
Training allowance						2,000
Misc. - spares, maintenance *						112,000
Total Operations & Maintenance Capital						**$185,000**
Sludge Disposal	**Sludge Prod. (m^3/y)**	**Cost ($/$m^3$)**				**Total Cost (Avg. Flow) ($/y)**
Sludge trucking to landfill & spreading	4,100	20				82,000
Sludge spreading	4,100	7				28,000
Plant vehicle fuel						3,000
Vehicle insurance & maint.						3,000
Total Sludge Disposal						**$116,000**
Sub-Total Direct Annual Operating Costs						**$986,000**
Contingency@10%						99,000
Total Direct Annual Operating Costs						**$1,085,000**

* 3% purchased equipment cost

Table 5.12: Operating Cost Estimate–Option 5 – Pump to Temporary Pond
Acid mine drainage average flow: 585 m^3/h

Reagents	Dosage		Consumption		Unit Cost ($/Unit)	Total Cost (Avg. Flow) ($/y)
Lime (avg.)	0.41	g/L (CaO)	2,108	t/y	131.25	277,000
Flocculant (avg.)	2	mg/L	10.2	t/y	3,826.12	39,000
Total Reagents						**$316,000**

Utilities	Total Connected (kW)	Avg. Draw (kW)			Power ($/kWh)	Total Cost (Avg. Flow) ($/y)
Power (avg. flow)	623	210			0.046	85,000
Total Utilities						**$85,000**

Operating & Maintenance Labour	Labour (h/m)	Total Hrs (h/y)	Labour ($/h)			Total Cost (Avg. Flow) ($/y)
Supervisor (1)	173	2,080	43.20			90,000
Operators (2)	182	2,184	33.75			147,000
Mechanical maintenance allowance	12.5	100	100.00			10,000
Electrical/instrumentation contract	34.7	416	65.00			27,000
Process consulting services						5,000
Total Labour		**4,780**				**$279,000**

Operating & Maintenance Capital						Total Cost (Avg. Flow) ($/y)
Operations Supply						
Analytical						24,000
Analytical services - sample analyses						20,000
Licences/permits/ taxes						0
Training allowance						2,000
Misc. - spares, maintenance *						101,000
Total Operations & Maintenance Capital						**$147,000**

Sludge Disposal	Sludge Prod. (m^3/y)	Cost ($\$/m^3$)				Total Cost (Avg. Flow) ($/y)
Plant vehicle fuel						3,000
Vehicle insurance & maint.						3,000
Relocate spigot point in ponds						1,000
Total Sludge Disposal						**$7,000**

Sub-Total Direct Annual Operating Costs						**$834,000**
Contingency@10%						83,000
Total Direct Annual Operating Costs						**$917,000**

* 3% purchased equipment cost

A summary of the operating costs for the options is included in Table 5.11 below:

Table 5.11: Operating Cost Summary - November 2002 Cdn$

Description	Option 1	Option 2	Option 3	Option 4	Option 5
Reagents	316,000	316,000	316,000	316,000	316,000
Utilities	97,000	89,000	85,000	85,000	85,000
Operating & maintenance labour	289,000	279,000	284,000	284,000	279,000
Operating & maintenance capital	180,000	164,000	187,000	185,000	147,000
Sludge disposal	12,000	150,000	132,000	116,000	7,000
Sub-Total Direct Annual Operating Costs	**$894,000**	**$998,000**	**$1,004,000**	**$986,000**	**$834,000**
Contingency	89,000	100,000	100,000	99,000	83,000
Estimated Annual Total Operating Cost	**$983,000**	**$1,098,000**	**$1,104,000**	**$1,085,000**	**$917,000**

5.3.2 Basis of Estimate

Reagents

The cost of reagents is the same for all five sludge disposal options, and is unchanged from the WTP feasibility study.

Electricity

Power costs have been estimated on total connected load, with an assumed utilization percentage that allows for actual power draw, installed spares and intermittent operation. In addition, a factor for motor efficiency and power factor has been allowed. A rate of 4.6 c/kWh has been used, based on the rate presently charged to BMRC for the power they use. The actual rate may vary from this assumption.

Operating Labour

Operating labour has been estimated based on AMEC's assessment and experience with similar water treatment plants. With the level of automation included with the feasibility design, it should be possible under normal conditions to run the plant with a single operator in attendance for day shift only, seven days per week. To provide this level of coverage, two operators have been allowed, working 12 hour shifts, on a 4 day on/4 day off basis.

The operators' duties will include plant tours to ensure equipment is operating correctly, cleaning/replacing critical instruments, minor equipment maintenance and adjustment, checking reagent levels and filling the dry polymer hopper. In addition, a full time supervisor has been allowed on an 8 hour per day, 5 days per week basis. This is considered the minimum requirement for operating labour for all five sludge disposal options.

During periods of plant upset, or demands from sludge disposal operations are high, the supervisor will be required to assist in the operation of the WTP. Similarly, three full time staff should be sufficient to cover sick time and holidays.

A small annual allowance has been included for ongoing operator training.

Maintenance Labour

The WTP is not large or complex enough to warrant full time mechanical or electrical/instrument maintenance personnel. Operations staff will carry out minor adjustments, repairs and replacement of consumable components. Scheduled and breakdown maintenance has been assumed to be provided on a contract basis, using local contractors.

During off-shift hours, the plant control system will provide alarms to one of the on-call personnel. They will assess if a trip to the plant is warranted, and if the plant will be allowed to operate or shut down.

An allowance of 200 hours has been included for Option 1, because of the demands from the maintenance of the pumping system, 100 hours for Options 2 and 5, and 150 hours for Options 3 and 4.

Operating and Maintenance Capital

Based on experience at similar plants, an allowance has been included for analytical supplies.

Spare parts have been estimated at 3% of the direct cost of equipment on an annual basis for each option.

For Options 3 and 4, the filter presses will require replacement of the filter clothes at regular intervals, predicted to be after 1,000 press cycles, which has been allowed for.

Assumptions

- Cost of electrical power is the same as presently charged to BMRC (4.6 c/kWh).
- No escalation of operating costs has been allowed.
- An operating labour payroll burden of 35% has been allowed.
- A contingency of 10% has been added to all estimated costs.
- An additional allowance of $5,000/y has been included to allow for ongoing treatment plant process consultation.
- Operating labour will be non-union.

5.3.3 Operating Cost Exclusions

- No allowance has been made for rental of a crane if a major breakdown requires this.

6. FINANCIAL ANALYSIS

An analysis has been prepared that evaluates the net present value for the WTP as a whole, including the cost of sludge disposal for Options 1, 2 and 3. In order to perform this evaluation, the total capital, operating and sustaining capital cost of the WTP was determined for these sludge disposal options. A discount rate of 3%, and an inflation rate of 0% and 25 year project life was assumed to determine the net present value. A net present value analysis for Options 4 and 5 is not possible as the permanent sludge disposal option is not known

The input to the model is summarized in the tables below:

Table 6.1: Capital Cost Summary – 4th Qtr 2002 Cdn$

	Option 1	Option 2	Option 3
Total WTP and sludge disposal capital cost	14,930,000	13,110,000	12,640,000

Table 6.2: Sustaining Capital Cost Summary – 4th Qtr 2002 Cdn$

	Option 1	Option 2	Option 3
Year 5	744,000	872,000	229,000
Year 10	744,000	872,000	229,000
Year 15	744,000	872,000	229,000
Year 20	744,000	872,000	229,000
Year 25	175,000	175,000	104,000

Table 6.3: Operating Cost Summary – 4th Qtr 2002 Cdn$

	Option 1	Option 2	Option 3
Total WTP and sludge disposal operating cost	983,000	1,098,000	1,104,000

The results of the NPV evaluation are summarized in the table below:

Table 6.4: NPV Analysis – 4th Qtr 2002 Cdn$

	Option 1	Option 2	Option 3
NPV	34,700,000	35,300,000	33,100,000

A comparison of capital, sustaining and operating cost sensitivity to change was conducted on the Options 1, 2 and 3. The results are shown in Figures 6.1, 6.2 and 6.3.

In all three cases, the NPV was insensitive to changes in the sustaining capital cost.

All three cases were sensitive to changes in the capital and operating costs.

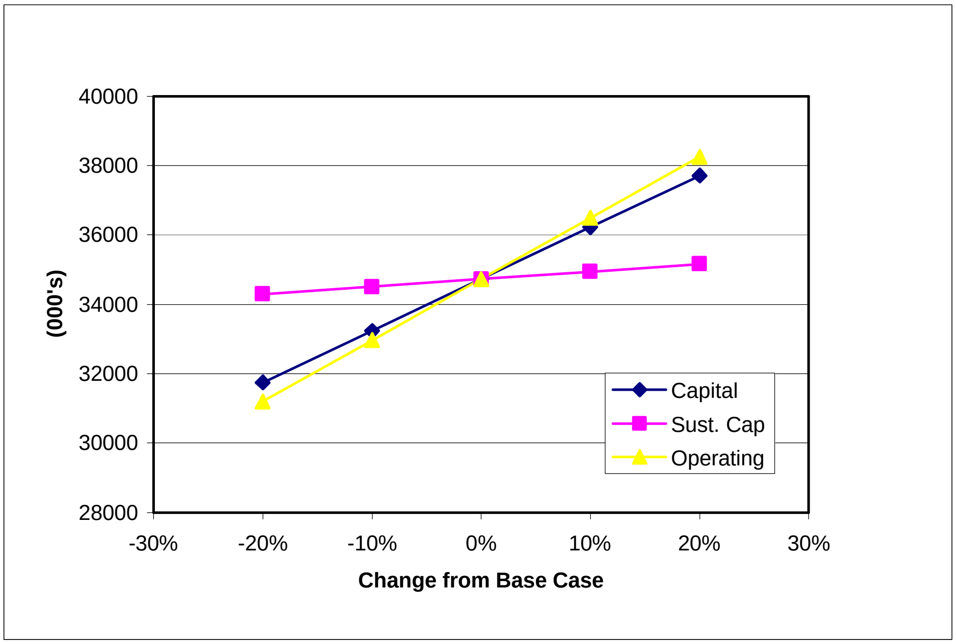

Figure 6.1: Sensitivity of NPV – Option 1

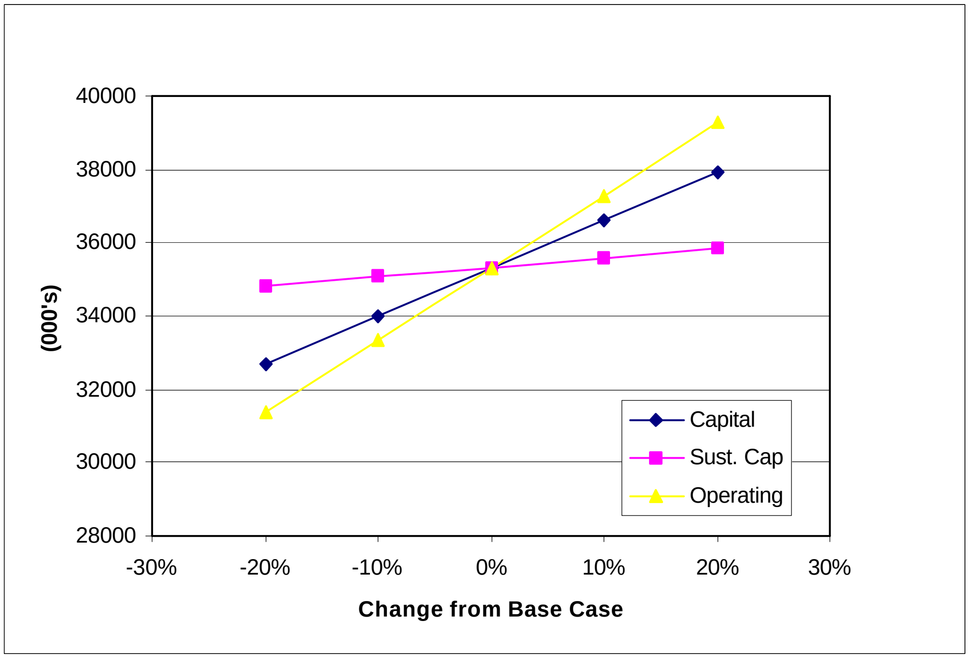

Figure 6.2: Sensitivity of NPV – Option 2

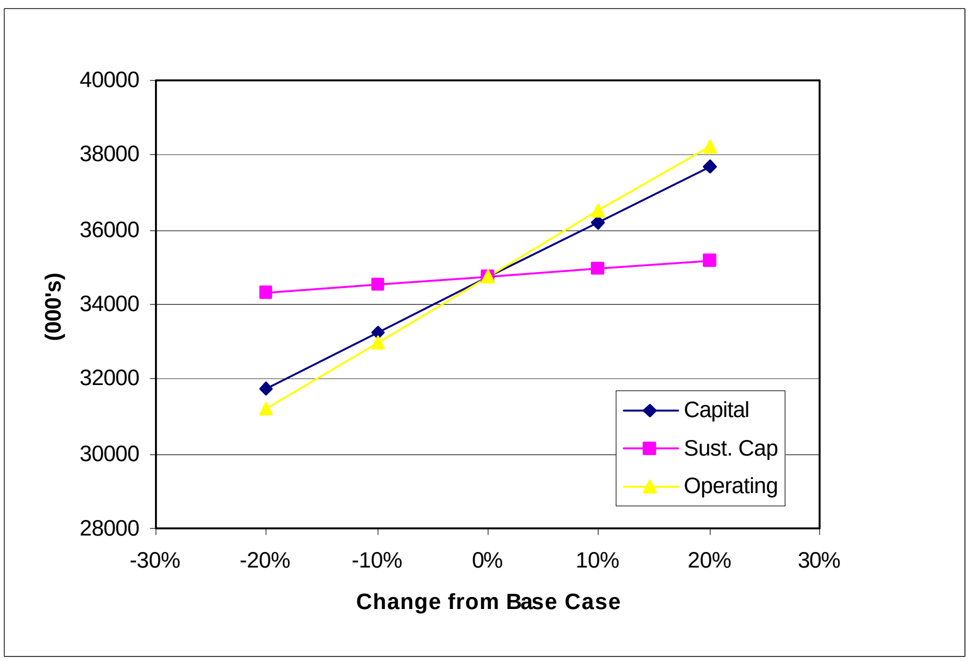

Figure 6.3: Sensitivity of NPV – Option 3

7. SCHEDULE

An engineering, procurement and construction schedule has been prepared for Options 1, 2 and 3, and is contained in Appendix C.

Due to time constraints, schedules were not prepared for Options 4 and 5. However, it is expected that if either Options 4 or 5 are selected, that they can be constructed within the same time frames as the other options. Options 4 and 5 do however require that the final sludge solution be selected quickly as they can only accomodate sludge for 2 to slightly more than 3 years after plant start-up, then the final solution must be ready to accept sludge.

The schedule has been prepared assuming the project will proceed on a design/build basis.

To arrive at an overall schedule, including the sludge disposal facilities, the WTP feasibility study schedule was used, and modified where necessary. The text and key dates below are also from the WTP feasibility study, with sections on sludge disposal added where appropriate.

At the time of award of the design/build contract, it has been assumed that the plant and process design criteria for the WTP has been finalized, and that procurement of all the major equipment can proceed immediately. This assumption is critical, as key information coming from the major equipment vendors is vital to allowing civil, structural and mechanical engineering to proceed. Any delay in awarding the major equipment packages, or changes to the design of the plant after award will have a direct affect on the start-up date of the WTP, as there is no float in this activity.

In order to access the WTP site with heavy construction equipment, the upper bridge will require replacement and the lower bridge some minor modifications. For all the sludge disposal options, it will be necessary to upgrade the BMRC road to Mt. Sheer and widen the bridge over Britannia Creek prior to excavation of the bench at Site A to enable excess cut to be transported to Mt. Sheer for disposal or pond construction. Therefore, these activities have been scheduled first, followed by demolition of the existing mine dry, excavation of the bench at the 4150 level, and then construction of the new road through the community.

It is assumed there are no schedule constraints due to construction of on-site ponds in any of the options at Mt. Sheer from winter conditions prohibiting access.

Construction of ponds at the WTP or the off-site landfill are not constrained by season/weather and could be completed at any time prior to the WTP start-up.

After the site excavation and access road to the WTP from Highway 99 is completed, the foundations for the clarifier tank, reactor tank, pre-engineered building and lime silo will be constructed.

In order to avoid blocking access to the site, the concrete clarifier and reactor tanks will then be constructed. Immediately following this activity, the pre-engineered building will be erected.

After the pre-engineered building is closed in, the installation of internal steel and equipment can commence. The clarifier mechanism installation will proceed as soon as the concrete clarifier tank is completed.

After the majority of the mechanical installation is completed, the platforms, piping, electrical and instrumentation installations will proceed.

Commissioning of the plant is expected to take three weeks, followed by start-up.

The following key dates are extracted from the schedule:

- Time from design/build contract award
- Major equipment packages award..........................6 weeks
- Preliminary vendor drawings available ....10 weeks
- Pre-engineered building enclosed ....35 weeks
- WTP ready for commissioning.............................40 weeks
- WTP start-up..52 weeks

All of the above dates assume that permitting approval for the WTP, sludge disposal option and plant discharge do not delay the engineering, procurement and construction of the plant.

8. OPPORTUNITIES

There are some opportunities that could result in lower capital and/or operating costs. These opportunities include:

- Disposal of sludge to an industrial end-user who can utilize the sludge in their manufacturing process.
- Due to uncertainties of slope stability and sludge fate, Jane Basin was excluded as a potential sludge disposal area until further study has been done on these issues. However, placement of sludge in Jane Basin could potentially assist in capping the area, leading to a reduction in the amount of water infiltration into the mine workings. This would result in an eventual reduction in flow to the WTP. However, there is a concern that if sludge enters the workings in an uncontrolled or unpredictable fashion, that there could be adverse effects on the mine hydrology, including potential plugging.
- It may be possible to reduce the WTP building size and cost depending on the sludge disposal option chosen.
- During detail design, it may be possible to reduce the capital cost by optimizing the design of the ponds in the various options including the use of geosynthetic fabrics.
- Option 5 would allow the addition of filter presses at a later date, providing the building was either installed with the space for filter presses, or designed to allow the addition of a building extension. There would be a small cost penalty in re-mobilizing a contractor to do this work after the main construction activities have been completed.
- Operating labour has been estimated based on AMEC’s experience, and not reviewed in depth with the stakeholders. There may be opportunities to share operations staff, or reduce the staffing levels depending on the final option chosen.
- As the WTP and sludge disposal options involve considerable earthworks, it is recommended that a cost-benefit assessment be conducted for sources of construction materials for earthworks during detailed engineering.

9. RISKS

Option 1

The design of a pumping system with a long pipeline relies heavily on the sludge characteristics including the viscosity and particle size distribution. A single sample of pilot plant sludge was tested to determine viscosity and calculate the friction losses for the pipeline. However, it is important to note that HDS sludge generated from pilot plant studies can differ markedly, with respect to viscosity and percent solids, from sludge generated by a full-scale optimized HDS plant. Typically, particle size distribution and specific gravity are used to determine the minimum velocity in the pipeline to prevent sludge particles from settling and plugging in the pipeline. No particle size analysis was conducted on the pilot plant sludge, as it is not considered representative of full-scale plant sludge.

The Mt. Sheer storage site has some natural hazard risks associated with the location. If eventual inundation or partial removal from debris torrent or rock avalanche activity was allowable, then the risk may be acceptable for development in this area. However, if the project design criteria requires a very low risk site from a natural hazard perspective *and* requires structural integrity for essentially perpetuity, then development in the Britannia Creek valley in the vicinity of Mt. Sheer may be excluded.

Option 2

The same comments on natural hazard risks at the Mt. Sheer site apply to this option also.

The sizing of the exfiltration basins at the WTP, and the containment ponds at Mt. Sheer is based on expected sludge settling and dewatering characteristics, based on AMEC's previous experience. Actual rates from the full-scale plant may differ resulting in higher trucking costs and less storage space than anticipated if the rates are less favourable than expected.

Option 2 involves pond construction at Mt. Sheer. Building ponds at this location would include assuming the risk of a debris torrent or avalanche impacting and compromising the pond structure.

Option 3

The major risks expected from an off-site landfill if constructed and operated by a third party are:

- Guaranteed access
- Long-term assured cost basis for sludge disposal
- Public concern over sludge transport.

It is assumed that the location for the off-site landfill would not have similar geohazard risk levels to those present at Mt. Sheer.

Option 4

The sizing of the containment pond at the WTP is based on expected sludge dewatering characteristics, based on one sample of pilot plant sludge and AMEC's previous experience. Actual rates from the full-scale plant may differ resulting in less storage space than anticipated if the rates are less favourable than expected.

Option 5

The sizing of the exfiltration basins at the WTP is based on expected sludge settling and dewatering characteristics, based on AMEC's previous experience. Actual rates from the full-scale plant may differ resulting in less storage space than anticipated if the rates are less favourable than expected.

10. CONCLUSIONS

Evaluation of the capital, sustaining capital and operating costs for the Options 1, 2 and 3 resulted in comparable NPV, within 7% of each other. Inclusion of land acquisition costs could spread the values significantly.

Option 1 has process risks that would make it difficult to design optimally without the availability of sludge for testing from the full scale WTP. Therefore, it is recommended that this option not be considered until after the WTP has been running at least one year to enable the appropriate testwork to be completed in order to provide the data to design the sludge pumping system. As Option 1 involves the installation of ponds at Mt. Sheer that are similar to those in Option 2, then the addition of a pump and pipeline to Mt. Sheer would not be excluded at a later date if Option 2 were selected.

Options 1 and 2 involve pond construction at Mt. Sheer. Building ponds at this location would include assuming the risk of a debris torrent or avalanche impacting and compromising the pond structure at some point in time. It is recommended that further study be conducted on these risks to better define them.

Option 3 involves the least risk from a geohazard perspective, provided a low risk site, with accessibility to Highway 99, can be located close to the WTP. This option also allows for the disposal of filtered sludge to an industrial end user, if they deem the sludge acceptable.

Options 4 and 5 would provide a relatively inexpensive method of sludge disposal during the initial operations of the WTP; the ability to determine the full-scale WTP sludge characteristics; and allow the most flexibility in terms of future sludge disposal options, allowing disposal on or off-site; including potential industrial end-users.

As the WTP and sludge disposal options involve considerable earthworks, it is recommended that a cost-benefit assessment be conducted for sources of construction materials for earthworks during detailed engineering.

Finally, it should be recognized that this report has examined the sludge disposal options to a feasibility level only, to compare the various options and help in making a selection of the final disposal method. After a sludge disposal method is chosen, the detail design process will examine the issues and optimize the design to minimize capital, operating and sustaining costs.

Appendix A

Equipment List

Drawings

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Appendix B

Capital Cost Estimates

Memo

To	**Gerry O'Hara**	File No.	**U824A**
From	**Doug Lee**	cc	**Sean Lynn**
Tel	**604-664-3248**		
Fax			
Date	**December 16, 2002**		

Subject **WTP Feasibility Study**

The review of the WTP Feasibility study on November 29, raised some questions regarding possible changes to the design, and what impact this would have on plant design and capital costs. These items are discussed below:

1. Impact of relocating the plant to the 4100 level, rather than being situated at the 4150 level as presently allowed in the study.

   All the civil design and quantity take-offs have been based on the WTP being located on an excavated bench at the 4150 level. A revised site layout, and re-calculation of all the quantities would be required to determine the effect on the capital cost of relocating the plant. As this would take a considerable amount of extra engineering and time to accomplish, only a listing of the possible consequences of this move are shown below:

   - The present design includes a gravity flow pipeline from the blow-down tank at the plug, to the WTP. Raising the WTP to the 4100 level would not allow this concept, and would probably mean that the piping from the plug would carry the full pressure generated by storage in the mountain all the way to the WTP,where the pressure drop would be taken in a more expensive elevated blow-down tank. Due to the pressure, the pipeline to the WTP would have to be made of stainless steel or rubber lined pipe in place of the much less expensive HDPE presently allowed. In addition, this long pressure pipeline would require some form of water-hammer protection, as it would be very susceptible to this phenomenon.
   - The feed to the plant would have a low spot in the pipeline where solids can settle during low flow periods (low pipe velocity). Some form of low point drain would have to be devised.
   - Placing the WTP at the 4100 level would drastically reduce the amount of storage available for sludge dewatering ponds, depending on the method of sludge disposal chosen, this could be a serious concern.
   - Site preparation costs could be lower, but the overall civil design has to be re-done to determine this (as an example, the present road upgrade through the community uses excavated material from construction of the bench – if no excavation is required at the 4100 level, then material would have to be imported for road construction at extra cost)

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2. Effect of removing gantry crane from the WTP building

   The design of the building is dependent on the loads hung from the structure. If the gantry crane were removed, there would still be a requirement for monorails and chain blocks over the major equipment like the filter presses and lime slakers for maintenance. The loads from the monorails would have to be supported from the pre-engineered building, or from steel support columns independent of the building structure. Either way, there is a cost involved in providing this support. The cost of the gantry crane alone, excluding effects on building design, is approximately $50,000. It is estimated that removing the gantry crane and adding monorails would result in a direct cost reduction of $30,000.

3. Replacement of septic tank and tile field for sewage disposal with a holding tank

   The WTP feasibility study cost estimate has $7,500 in direct costs for the installation of a septic tank, sewage pipeline and tile field. The addition of a larger sewage holding tank in place of the septic tank and field, to allow pump out by vacuum truck, would consume most of the $7,500. The major reduction in cost could arise from not having to remediate the old sludge holding pond that was planned as the location for the tile field. Instead, perhaps this site could be capped only.

4. Effect of reducing the building size by one bay

   By re-arranging the equipment in the building, or re-locating some tanks outside, it may be possible to remove a bay from the pre-engineered building. The probable reduction in direct cost is $50,000

5. Effect of removing lunch room, control room and laboratory

   If the lunchroom and laboratory were eliminated, and the control room incorporated with the electrical room, there would be a direct cost reduction of approximately $50,000. There is still $15,000 of laboratory equipment in the estimate that would be located on a bench inside the open portion of the building. An office is still included.

6. Allowances for future items

   There was a question with regard to what was included in the present cost estimate that was not necessary at plant start-up, but is for some future requirement. The only items identified from further review are:

   - The design criteria calls for a future allowance for a reagent storage tank, should an additional reagent be required to remove metals to lower levels. The present layout would allow for a small storage tank, but not a system that would make up solution from dry crystals if that were required. If the building size were reduced as described in 4.) above, the effect would be that no space would be available for further reagent storage in the building. It may be possible to locate the tank outside in the future.

   - A lime slurry addition valve into Reactor #2 was included in the estimate, and will not be required at plant start-up. Eliminating this valve and piping would take out approximately $5000 of direct costs.

7. Use of treated water for lime slaking

It would be possible to use treated water for lime slaking. However, it is not recommended that this be done as it may cause scaling in the slakers and associated lime slurry piping, as well as reduced efficiency of lime slaking. In addition, fresh water is required for emergency showers, potable uses and is advisable for flocculant make-up. Fresh water is available from the present town water supply. The use of the water directly from the town supply without the need for a storage tank and booster pump may be possible, if treated water is used as a temporary back-up in the event of fresh water supply being interrupted. This could remove the fresh water pumps and tank, estimated at $60,000 direct cost. owH

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Appendix C

Project Schedule

Appendix D

Design Criteria and Verification Plan

Geotechnical Information

Geotechnical Considerations – Sludge Storage

General

The sludge storage concept described in the sludge disposal study requires a competent geotechnical foundation and relatively convenient source of dyke construction material. For Options 1 and 2, the Mt. Sheer town site would be used and the geotechnical considerations described in the following is applicable to both options. For Option 3, a generic landfill has been assumed north of Britannia Beach in the Squamish Valley.

Mt. Sheer

The Mt. Sheer site was evaluated by aerial photography, ground reconnaissance and some limited subsurface investigation work. The subsurface work was completed by URS as part of contaminated site inventory work being carried out on the overall Britannia Mine property.

The aerial photographic assessment indicated that the bench area of the Mt. Sheer townsite consists of coalescing debris fans with the hazard appearing to be somewhat greater to the east of the currently proposed sludge pond location. This comparative level of hazard could change in the future in response to any logging practices that occur.

In addition to the debris flow concerns, there appears to be both rock and snow avalanche issues on the slopes above the candidate sludge pond area. The latter issue would probably not be a major threat to the sludge pond(s) and common mitigative strategies for snow avalanches should be sufficient. For the rock avalanche hazard, the degree of concern is related to the length of time the sludge ponds are intended to be both active and have assured structural integrity.

In the immediate area of the proposed sludge storage cells, two boreholes were completed using a sonic vibration rig and three test pits/trenches were also completed with a backhoe.

The drilling indicated a large degree of material heterogeneity including silty material with organic content to depths of more than 4 m. It was clear from the drilling results that colluvial/debris processes had dominated the recent surficial geology in the area of the proposed sludge storage facility. The test pits confirmed the general heterogeneity in the upper few metres but also showed that some portion of the material could be candidate dyke construction material.

The drilling logs and test pit logs are included in this report.

Consequently, while the limited site investigation work did not indicate ideal conditions for site development for sludge containment, it did offer:

- In opposition to a suggestion by others during the project tenure, the area is not predominately cohesionless sands, gravels and cobbles but instead has quite a variety of materials including silts, clayey silts and other materials

- There appears to be remnants of organics and deleterious materials at depth in the candidate storage area

- Some of the cohesionless materials are classified as having very low physical integrity which is inconsistent with an energetic fluvial deposition mode and subsequent subaerial residence

- Acceptable foundation conditions for the low bearing pressures of the proposed storage cells can, in spite of the findings, be developed

- Potential for partial use of excavated material in constructing the storage cell dykes does exist – from the limited information, approximately 40 to 70% of the excavated material may be able to be appropriately handled and compacted to form containment dykes

- It is unlikely that riprap material and rockfill for cross-dykes for the cells will be able to be developed from Mt. Sheer area.

Based upon the results of the site investigation work, If the Britannia Creek valley is to be used for sludge storage it is recommended that once detailed engineering commenced a cost-benefit borrow source study should be initiated.

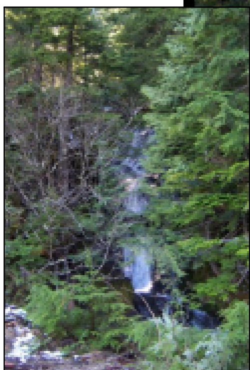
It is assumed there will be an overriding assumption of risk by the regulatory agency(s) granting a site permit for sludge disposal. The degree of quantifiable geohazard concern is dependent upon the time of exposure for the operating and structurally assured closure period for the sludge pond(s). It does not appear that there is an immediate threat from either debris torrent or rock avalanche but, at the same time, any number of changes (weather, seismic activity, logging etc.) can alter this situation. The proposed sludge storage site for Options 1 and 2 does appear to be in a better location relative to locations to the East (towards the historic copper launders). If eventual inundation or partial removal from debris torrent or rock avalanche activity was deemed acceptable, then the risk may be acceptable for development in this area. If the project criteria includes a very low risk site from a natural hazard perspective *and* requires structural integrity for essentially perpetuity, any development in the Britannia Creek valley in the vicinity of Mt. Sheer appears to contraindicate such a criteria. Given the site setting at the base of coalescing debris fans and the potential for rock avalanche hazards, assured structural integrity in perpetuity is not possible at the Mt. Sheer site.

Off-Site Landfill

For the generic off-site landfill, the general quaternary geology of the Squamish Valley was reviewed. The available information indicates that glaciofluvial and fluvial processes have dominated the veneer of near surface materials over other glacial materials and/or bedrock. Consequently, it was assumed that a relatively pervious foundation condition would exist for the generic landfill and that granular construction material would be readily available.

Appendix E

PD Pump Drawing



BRITISH COLUMBIA

Province of British Columbia Ministry of Water, Land and Air Protection

Britannia Mine Water Treatment Plant Outfall Hydraulics

U824A - December 2002

amec

This report was prepared exclusively for the Province of British Columbia, Ministry of Water, Land and Air Protection by AMEC E&C Services Limited (AMEC). The quality of information, conclusions and estimates contained herein is consistent with the level of effort involved in AMEC's services and based on: i) information available at the time of preparation, ii) data supplied by outside sources and iii) the assumptions, conditions and qualifications set forth in this report. This report is intended to be used by the Province of British Columbia, Ministry of Water, Land and Air Protection only, subject to the terms and conditions of its contract with AMEC. Any other use of, or reliance on this report by any third party is at that party's sole risk.

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1. INTRODUCTION

AMEC was requested to evaluate the condition and hydraulic capacity of the existing on-land portion of the outfall from the 4150 level for a maximum flow of 3,600 m^3/h.

Mar-Tech was retained to inspect portions of the inside of the pipeline with a video camera. The inspections were carried out in two separate visits to the site. It was not possible to get the camera into all sections of the pipe due to obstructions from debris that had been deposited. Reports and copies of the video inspections were supplied by Mar-Tech, and have been issued to the project.

As the pipeline is buried for its entire length, the pipe diameter, location and elevation could only be determined at manholes where the pipe is exposed, or by using historical records. The manholes were surveyed for this study, and the locations and elevations shown on Drawing No.'s A1-U824-500-C-200 and A1-U824-500-C-201. The location between manholes was assumed from historical drawings.

2. DESCRIPTION OF EXISTING OUTFALL

The existing 700 m outfall runs from the 4150 level down to Howe Sound. It comprises of a number of different pipeline types and pipeline diameters including sections of the original 27 in. diameter and 36 in. diameter concrete pipes, which are believed to have been constructed back in the 1950's, as well as newer sections of 24 in. diameter PVC pipe and 24 in. diameter HDPE pipe, installed more recently.

From the first manhole (Manhole 1) at the 4150 level, at an elevation of approximately 65 m, the first section of primarily 24 in. diameter PVC pipe drops steeply (40%) to the west, over the bank and down to the lower town site area at an elevation of approximately 15 m.

At this point, the pipeline type changes to 36 in. diameter concrete pipe, which then runs in a northerly direction for about 200 m at a slope of 1.6%. Just before Manhole 2, the pipe changes to 27 in. diameter concrete pipe. After Manhole 2, this pipe runs for a short distance (31 m) at a slope of 1.8% down to Manhole 3. This manhole is located on the south side of the access road just east of the ballpark area.

From Manhole 3, the pipe changes to 24 in. diameter HDPE pipe, which then runs to the west along the south side of Britannia Creek for approximately 350 m at a slope of about 3%. The pipe passes under Highway 99 and railway bridges and finally connects to the existing submarine outfall.

It should be noted that the lower sections of the existing outfall presently run through the 1 in 200 year flood plane. (Ref: Water Management Consultants Report dated April 2002). This applies primarily to the section of pipeline below, or to the west of Manhole 2. Any scour action from a flood could remove portions of the pipeline in this area if no mitigative measures are performed.

3. HYDRAULIC REVIEW

The existing outfall does appear to have adequate hydraulic capacity to handle 3,600 m^3/h, but is marginal in certain locations, as described below:

- The section of pipe between Manholes 2 and 3 presently limits the capacity. This short (31m) section of 27 in. diameter concrete pipe is in very poor condition and partially blocked with gravel and other debris.

- These same comments also apply to the first 12.6 m section of pipe just upstream of Manhole 2.

- Upstream of Manhole 2, the pipe diameter changes abruptly to 36 in. The 27 in. diameter pipe appears to be inserted into the 36 in. diameter pipe, thereby resulting in an upstream drop from the invert of the 27 in. diameter pipe to the invert of the 36 in. pipe. This in turn has resulted in a partial blockage of the 36 in. pipe due to a buildup of gravel and debris is this area.

4. DETAILS OF CALCULATIONS AT EACH SECTION of PIPE

The following findings are based upon a design flow = 3600 m^3/hr.

Manhole 1 is located at the 4150 level. Manholes 2 and 3 are located adjacent to the road in the lower town site area and Manhole 4 is taken to be the outfall.

1. Upper section between Manholes 1 and 2 – 24 in. diameter PVC pipe; 39.3% slope; length 120 m:

   – Adequate hydraulic capacity

   – Depth of flow will be approximately 175 mm (7 in.)

   – Velocity will be approximately 15 m/sec (49 ft /sec).

2. Lower section between Manholes 1 and 2 – 36 in. diameter concrete pipe; 1.62% slope; length 179 m:

   – Adequate hydraulic capacity

   – Depth of flow will be approximately 16 in.

   – Velocity will be approximately 3.5 m/sec (11.5 ft/sec).

3. Upstream of Manhole 2, short section of 27 in. diameter concrete pipe, approximately 12.6 m long, poorly connected to the 36 in. diameter concrete pipe:

   – Marginal hydraulic capacity

   – Depth of flow will be approximately 20 in.

   – Velocity will be approximately 3.4 m/sec (11.2 ft/sec)

   – It is recommended that this 12.6 m long section be removed and replaced with 36 in. diameter HDPE pipe.

4. Between Manholes 2 and 3 – 27 in. diameter concrete pipe; 1.77% slope; length 31m:

   – Marginal hydraulic capacity

- Depth of flow will be approximately 19 in.
- Velocity will be approximately 3.5 m/sec (11.6 ft/sec)
- It is recommended that this section be removed and replaced with 36 in. diameter HDPE pipe.

5. Between Manholes 3 and 4 and the outfall – 24 in. diameter DR 32.5 HDPE pipe; 3.04% slope; length 344 m:
   - Adequate hydraulic capacity
   - Depth of flow will be approximately 14.4 in.
   - Velocity will be approximately 6 m/sec (19 ft/sec)

6. Assumptions used in performing these calculations:
   - Elevations of the inverts at the manhole locations and other key locations were surveyed. It was then assumed that there was a uniform slope between those points.
   - The entire pipeline was not inspected (by Mar-Tech). It has been assumed that the hydraulic capacity of the pipelines not inspected, will not be impaired by blockages or other unidentified deficiencies.

5. CONCLUSIONS AND RECOMMENDATIONS

The majority of the existing outfall from Manhole 1 down to the outfall is adequately sized to handle a flow of 3,600 m^3/h.

It is recommended that a new manhole be constructed approximately 13 m upstream of Manhole 2 to eliminate deficiencies and flow restrictions between Manholes 2 and 3 and just upstream of Manhole 2. Also, that a new section of 36 in. diameter HDPE pipe be installed between the new manhole and Manhole 3.

Removing debris from the pipeline is recommended. After the cleaning is performed, it should be possible to inspect portions of the pipe that were not camera accessible due to the debris blocking the way.

The deficiencies identified in the Mar-Tech report and any others subsequently identified, should be addressed and all necessary repairs completed.

The existing outfall is located within the 1 in 200 year flood plain. There is a risk that a flood could destroy portions of the pipeline if it is left in its present location and nothing is done to mitigate the flood risk. It is recommended that any new pipeline alignment be south of Britannia Creek and south of the flood plain if a new outfall location is chosen that requires the existing on-land portion of the pipeline to be replaced.

6. REFERENCES

- Water Management Consultants Report dated April 2002
- TV Inspection Report by Mar-Tech Underground Services Ltd. July 30, 2002.
- Utility drawings of Britannia Area.