BRITANNIA MINE REMEDIATION PROJECT
Water Management

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Scope of Presentation

- Overview of the Britannia Mine Remediation Project
  - Background
  - Summary of environmental problems at Britannia
  - Province’s remediation concept
- Water Management – the Key to Remediation
  - Surface water
  - Mine water
  - Groundwater
- Lessons Learned/Next Steps
- Questions
Where and What is Britannia?

- Located on Sea-to-Sky Hwy
- Copper Mine from 1904 to 1974
- Was the ‘Largest copper mine in British Empire’
- Ore produced: 48 million tonnes
Mine Levels defined in feet measured downwards from highest elevation in mine
What’s the Problem?

- Naturally occurring metal sulphide orebody
  - Many underground openings
  - Massive disturbance of rock from historical mining
  - Most of the workings not permanently flooded
  - Almost unrestricted flow of surface drainage into workings
  - Mining voids convey water to 4100 Level

- “The largest point source of metal pollution in North America discharging to a marine environment”
What’s the Problem?

Issues:

- ~5 million m³/year ARD from mine workings
  - copper, zinc, cadmium, pH~3.5
- Metal-contaminated groundwater discharging to Howe Sound:
  - Alluvial Fan of Britannia Creek
  - Waste dump leaching
- Metal-contaminated surface water (run-off)
- Impact of aquatic life in Howe Sound and local waterways:
  - Squamish River salmon run
Howe Sound Metal Loading Estimates

(URS, 2002)

Additional Areas: ~4kg/d Cu, ~5kg/d Zn

Mine Discharge: ~3kg/d Cu, ~4kg/d Zn

Mine Discharge: ~293kg/d Cu, ~287kg/d Zn

Groundwater: ~10kg/d Cu, ~16kg/d Zn

Outfall

Furry Creek: ~1kg/d Cu, ~1kg/d Zn)
Remedial Concepts

Prevention: Inflow diversion

Additional Areas: ~4kg/d Cu, ~5kg/d Zn
Risk Management: Tailings (Env. Can.)
Mine Discharge: ~3kg/d Cu, ~4kg/d Zn

Collection: 2200 Level Plug

Management: Contaminated wasterock and groundwater
~267kg/d Zn

Use of mine void as storage/balancing reservoir

Plug with control valve

Mine Discharge: ~293kg/d Cu, ~287kg/d Zn

Groundwater: ~10kg/d Cu, ~16kg/d Zn

Treatment: Mine drainage

Howe Sound
Outfall
Water Management

- Management of mine water, groundwater & surface water:
  - **Key** to the Province’s remediation plan for the site

- Three main components:
  - Reduce volume of clean water becoming contaminated:
    - In the mine
    - In surface water courses
  - Capture and treat contaminated groundwater to prevent its discharge to the shallow marine environment
  - Manage mine water storage to allow efficient treatment (and generate micro-hydro power)
Surface Water Diversions

- 80% of mine water enters through the open pits in Jane Basin (SRK study)
- Three catchment areas had the potential for partial diversion of surface flows:
  - Likely that the diversions would be most effective at ‘shaving’ the peak inflows during freshet and summer/fall rainstorm events
  - Up to 15% of the mine inflow had the potential to be captured and diverted as clean water
  - Cost benefits
- Three diversions constructed
  - Upper Jane Creek
  - East Bluff
  - Victoria
Surface Water Diversions

Upper Jane Creek Diversion

Intake Structure

Pipe Bundle

Energy Dissipator Chamber
East Bluff Diversion Performance

- Water treatment cost savings ~$35,000/annum
- Payback in treatment costs ~6 years
Water Treatment Plant

- Treat mine water and groundwater
- Design capacity  - 1,050m³/hr
  Hydraulic capacity  - 1,400m³/hr
- Province opted for a Design-Build-Finance-Operate (DBFO) contract in a Public Private Partnership:
  - Single entity responsible to design, build, operate and finance plant
  - Province pays periodic operating fee when discharge within permit limits
  - Contract includes 20 year operation
Water Treatment Plant

- Selected contractor (EPCOR)
  - HDS technology
  - Committed to reviewing alternates for future
- Construction commenced March 3, 2005
  - First water treated (24hr operation) October 20, 2005,
  - Tests up to 1,400m³/hr (~400L/s) indicate successful treatment
Mine Reservoir Management

- WTP capacity based on estimated mine inflows and reservoir modelling
- Mine inflows estimated for 25 year period using:
  - Records of historical mine outflows
  - Simulations and correlations linked to historical meteorological data ('UBC watershed model' applied by SRK)
Estimate Of Mine Inflows Over 25 Years

Mine Inflow (L/s)

Month

Mine Inflow L/s

Design Capacity

Hydraulic Capacity

25 Year Record

Ministry of Agriculture and Lands

Golder Associates
Estimate Of Mine Inflows Over 25 Years

25 Year Record

Mine Inflows

Design Capacity

Hydraulic Capacity

Snow Pack

Inflow as a result of rainfall

Mine Inflow L/s

SWE (mm)
Mine Reservoir Management

Goal: to minimize number and duration of by-pass events, with paramount importance placed on preventing overtopping of the mine reservoir (uncontrolled discharge)
Mine Reservoir Management

Tests in 2002 & 2004 by SRK confirmed/indicated:

- Approximately 430,000m³ of ‘dynamic’ storage available between 4100 Level and 3250 Level
- Some restrictions to flow that change with time and discharge rate:
  - Possibly the result of silting-up/release of sediments, and/or debris accumulation and release
- The mine is a dynamic system that is subject to change over time:
  - Internal flow regime may change from the time to time
  - Contingencies considered and engineering concepts developed for problems that may develop
- Water chemistry changes with storage
  - Effect reduces with reservoir operation
Mine Reservoir Management

Storage 1000 m³

~ 430,000 m³ ‘dynamic’ storage available
Mine Reservoir Management

Reservoir Operation Simulation

- Proposed reservoir operating plan
  - Design Capacity - 1050 m$^3$/hr
  - Hydraulic Capacity - 1400 m$^3$/hr
  - Maximum possible flow through Plug – 3276 m$^3$/hr
  - Up to 1400 m$^3$/hr released through plug when available from 0-150m head in mine
  - Release rate increased quickly up to 3276 m$^3$/hr from >150m head in mine

- Percentage of outflow by-passed/untreated by WTP – 96.9%
Mine Reservoir Simulation

- By-pass – untreated by WTP, though pH adjusted to precipitate metals
- Water treated by WTP

25 Year Record
Mine Reservoir Simulation

No overtopping
In 1999 1:50 year event

Water Level In Mine m

25 Year Record

Water level in mine (m)

Date

Discharge Permit

- Permit discharge limits (dissolved, mg/L):
  - copper $\leq 0.1$
  - iron $\leq 0.1$
  - zinc $\leq 0.2$
  - aluminium $\leq 1$
  - manganese $\leq 0.4$
  - cadmium $\leq 0.01$
  - total suspended solids $\leq 30$

- No overtopping predicted for 25 year history and 1:200 mine inflow event

- Permit acknowledges controlled by-passes as ‘emergency conditions’
  - Predicted $\sim 3\%$ of outflow will be by-passed
  - Untreated but pH adjusted to precipitate metals mixed with fully-treated water: blended water discharged to deep outfall/diffuser
## WTP Discharge Quality

<table>
<thead>
<tr>
<th>Parameter (mg/L)</th>
<th>Permit Limit</th>
<th>Plant (July 2006)</th>
</tr>
</thead>
<tbody>
<tr>
<td>dissolved copper</td>
<td>≤ 0.1</td>
<td>&lt; 0.0005</td>
</tr>
<tr>
<td>dissolved iron</td>
<td>≤ 0.1</td>
<td>&lt; 0.0005</td>
</tr>
<tr>
<td>dissolved zinc</td>
<td>≤ 0.2</td>
<td>0.008</td>
</tr>
<tr>
<td>dissolved aluminium</td>
<td>≤ 1</td>
<td>0.61</td>
</tr>
<tr>
<td>dissolved manganese</td>
<td>≤ 0.4</td>
<td>0.265</td>
</tr>
<tr>
<td>dissolved cadmium</td>
<td>≤ 0.01</td>
<td>&lt; 0.0002</td>
</tr>
<tr>
<td>total suspended solids</td>
<td>≤ 30</td>
<td>&lt; 4</td>
</tr>
</tbody>
</table>

- pH range: 6.5 to 9.5
- 96HRLC50 fish bioassay: 100% (non-acutely toxic)
- Authorized discharge: 25,200m³/day
New Deep Outfall

- Old outfall extends to only 26 metres depth
  - Is located on unstable sub-sea terrain
  - Susceptible to blockages
- Requires 50 m depth and diffuser to meet receiving environment criteria
- Geotechnically stable location required to reduce risk of future failures:
  - Cost of replacement
  - Environmental effects
- Site selected south of Britannia Beach
New Outfall Under Construction
Fan Area Surface Water Management

- Storm water system upgraded in 2003/4 to divert most run-off away from beach;
- Assessment underway to identify further improvements;
- Proposed actions include:
  - Diversion of streams from leachable mine waste on Mill slope;
  - Collection of mine water seepage from West Mill slope.
Fan Area Groundwater Management

- Modelling (Feflow)
Fan Area Groundwater Remedial Options

Operational Constraints:

- Saline water corrosive to treatment plant components/may affect process
- Capacity and Operational requirements of treatment plant:
  - Limit pumping rate (100m3/hr)
  - Limit chlorides concentration (1000ppm)
- Physical constraints on system installation:
  - Hwy99
  - BCRail
GMS System Design

- Pumping Wells
- Monitoring Wells
- BC Rail Line
Groundwater Management Status

- System constructed by EPCOR between March and May, 2005
- Pumping trials commenced in May, 2005
- System operational and currently in optimization phase:
  - Correlation of chlorides to conductivity
  - Maximise (fresh) groundwater capture efficiency within design constraints and minimise salt water pumping
  - Identify control and/or installation improvements
Groundwater Management System

Transfer Pumps

Flow monitoring equipment
## Phase 1 – Operation Data

### Electrical Conductivity (mS/cm) Before of Pumping

<table>
<thead>
<tr>
<th>Location</th>
<th>Conductivity (mS/cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EX04-4</td>
<td>1.5</td>
</tr>
<tr>
<td>EX-3</td>
<td>4.5</td>
</tr>
<tr>
<td>EX-1</td>
<td>4.3</td>
</tr>
<tr>
<td>MW01-21I</td>
<td>2.6</td>
</tr>
<tr>
<td>MW01-21D</td>
<td>15.1</td>
</tr>
<tr>
<td>MW01-21DD</td>
<td>28.6</td>
</tr>
</tbody>
</table>

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**Diagram Notes:**
- South Fan
- Howe Sound
- Saltwater Interface
- E-W South Fan Howe Sound
- EX-04, EX-3, EX-1, MW01-21I, MW01-21D, MW01-21DD
- Conductivity values are measured in mS/cm.
Phase 1 – Operation Data

Electrical Conductivity (mS/cm) End of Pumping

South Fan

Saltwater Interface

Howe Sound

EX04-4

EX-3

MW01-21I

MW01-21D

MW01-21DD

EX-1

MW01-22

MW01-21

Other stations and measurements marked as relevant.
Phase 1 System Performance

High pumping rate (system controlled by flowrate set point):
- Very high capture efficiency of plume
- High salinity (>1000ppm chlorides)

July 7, 2005 Capture Zone
$Q_{\text{total}} = 1339 \text{ m}^3/\text{day}$
August 10, 2005 Capture Zone
\[ Q_{\text{total}} = 567 \text{ m}^3/\text{day} \]

Lower pumping rate (system controlled by salinity set point):
- \(~50\%\) capture of plume, system inefficient at northern end of array due to higher permeability zone and connection to Howe Sound
- Low salinity (<1000 ppm chlorides)
Capture zone with 1 new well.

- Higher plume capture efficiency
- Reduced saline intrusion but >1000ppm for >90% plume capture
Capture zone with 2 new wells.

- Still higher plume capture efficiency
- Further reduced saline intrusion ($<1000$ppm for $>90\%$ plume capture)

Phase 2 System Optimization
2006 GMS Monitoring Data
Howe Sound Metal Loading Improvements

Additional Areas: ~4kg/d Cu, ~5kg/d Zn

Mine Discharge: ~3kg/d Cu, ~4kg/d Zn

2200 L Tunnel

4100 L Tunnel

Old outfall

Howe Sound

New deep outfall with diffuser

Groundwater: ~10kg/d Cu, ~16kg/d Zn

<2kg/d Cu, <2kg/d Zn

<0.07kg/d Cu, <0.1kg/d Zn

<293kg/d Cu, <287kg/d Zn

<4kg/d Cu, <5kg/d Zn

Improvements planned to groundwater and surface water management

Furry Creek: ~1kg/d Cu, ~1kg/d Zn
Some Lessons Learned

- Cost benefit of surface water diversions must be balanced against desirability of undertaking this for long-term ‘sustainability’ or other reasons.

- The availability of the mine reservoir greatly benefited the project, though efficient management is critical.

- Automated groundwater management of the saline/freshwater blend linked to the WTP control systems needed a long period of optimization (>2 years).
Ongoing Water Management Work

- Additional Areas Review/Implementation
  - Other portal seeps
  - Waste dump seeps

- Environmental Monitoring and Risk Assessment
  - Have we done enough/do we need to do more/
    if so, what?

- Surface Water Drainage Review/Implementation
  - 4100 Level and Britannia Creek Fan Area

- Groundwater Management Optimization
  - Program will continue following planned system enhancements
Information Sources

- Province’s website (MAL):
  - [www.britanniamine.ca](http://www.britanniamine.ca)
  - Contains progress reports, technical reports, regulatory correspondence, permits, background information, contact details and correspondence with Province

Questions?