

REMEDIAL WORKS IMPLEMENTATION AT THE BRITANNIA MINE REMEDIATION PROJECT

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ABSTRACT

The BC Ministry of Agriculture and Lands (the Province), is undertaking a program of environmental remediation at Britannia Mine, located 45 km north of Vancouver, BC. The Britannia Mine operated for 70 years and produced mainly copper and zinc concentrates. During its operating life, and since its closure in 1974, the mine has discharged large volumes of acidic water, elevated in metals toxic to aquatic life, including copper, zinc and cadmium. Metal loadings to Howe Sound average some 300 kg/day each of copper and zinc. The Province's remedial concept uses the mine workings as a storage reservoir balancing seasonal flows to a water treatment plant prior to discharge to Howe Sound. In addition to the acid rock drainage (ARD) from the mine, mine infrastructure and mineral processing activities provide secondary sources of metal contamination of soils, groundwater and surface water. The major investigation phase of the project completed in 2002 and remedial planning and implementation commenced in early-2003. Remediation works include a novel groundwater management system, surface and storm water drainage, relocation and management of ~35,000m³ of metal-contaminated soils, surface water diversions and construction of a high-density sludge water treatment plant and deep outfall, the latter scheduled for completion in November, 2005.

1.0 INTRODUCTION

The Britannia Mine is located at Britannia Beach on the east shore of Howe Sound, approximately 45 km north of Vancouver (Fig.1). The main mining activity was some 5 to 7 km inland from Britannia Beach, with mineral processing activities taking place at Mount Sheer, around 5 km inland, and the Britannia Beach town area on the coast, to the south of Britannia Creek. The mine site covers an extensive area, with mineral tenure associated with the mine extending over some 36.5 km² (approximately 9,000 acres).

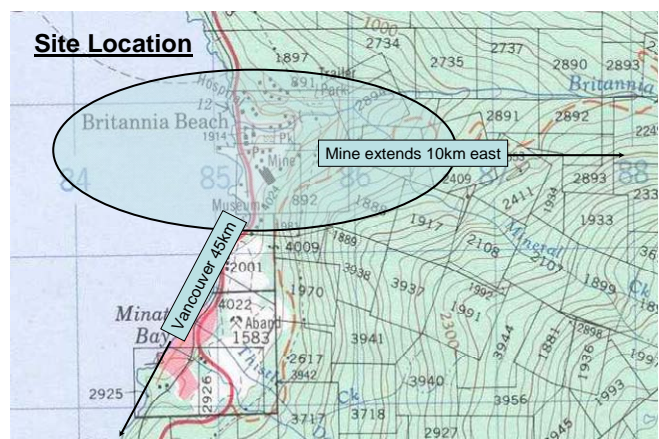


Figure 1 – Site Location

1.1 Topography

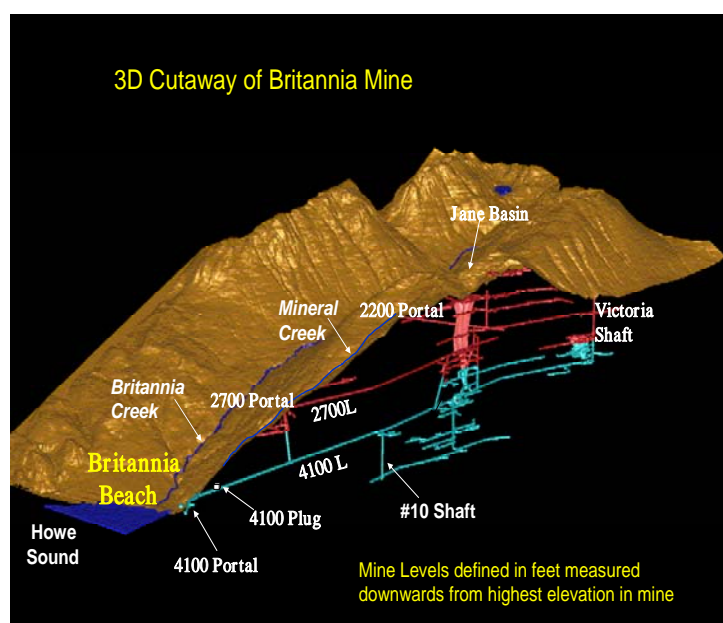
Elevation markers at the mine ascend with decreasing elevation above sea level. The zero level datum used by the mine is 1,310 metres (4,300 ft.) above sea level, representing the elevation of the initial surface outcrop and shallow workings in the open pit mining complex located at the top of Britannia Ridge. Zero feet above sea level corresponds to the '4300 (foot) Level', with, for example, the '2200 Level' being around half way down the

hillside in the mine's nomenclature [note: all references to elevation markers in the mine in this paper keep to this standard reference system as used throughout the available literature on the mine, and for consistency, are given in feet, rather than metric equivalent]. The ore body at the mine is contained within Britannia Ridge which is flanked to the north by the Britannia Creek valley and to the south by the Furry Creek valley. The main orebody crops out at Jane Basin, near the top of the Ridge. The Ridge drops sharply to the west into the Howe Sound fjord with only a small level alluvial fan area ('Fan Area') proximal to the mouth of Britannia Creek, traversed by Highway 99 and a BC Rail track (Fig. 1).

1.2 Mine Geology

The geology of this area can be divided into two major components: older volcanic and sedimentary rocks belonging to the Lower Cretaceous Gambier Group, and younger, plutonic rocks of the Coast Plutonic Complex. In the Howe Sound area, the plutonic rocks range in composition from diorite to granodiorite. A major feature of the mine is a broad zone of complex shear deformation and metamorphism known as the Britannia Shear Zone. This structure dips steeply south and strikes north westerly across the roof pendent and hosts all of the Britannia orebodies. The orebodies comprise a heterogeneous mixture of sulphides, remnant altered host rocks and discrete mineralized veins. The sulphides occur both as massive and as stringer deposits and are widely disseminated or concentrated along bedding and fracture planes (Ref. 1).

1.3 Mine History



The Britannia Mine was operated from 1905 to 1963 by the Britannia Mining and Smelting Company Ltd. and from 1963 to 1974 by the Anaconda Mining Company. At its pre-World War II peak, the mine was the largest producer of copper in the British Empire. The mine was closed in 1974 and since that time has remained largely derelict. A concrete plug was installed in the lowest major entry to the mine (400 metres into the 4100 Level adit) in 1978, to allow the control of water flowing from the mine to a copper precipitation system located nearby and for safety reasons, to prevent sudden and uncontrolled rushes of water, silt and debris emerging from the mine ('mudrushes'). The 4100 Level (Fig. 2) exits immediately to the east of the concentrate mill (Fig. 3).

Figure 2 - 3-D Cutaway View of Britannia Mine (SRK)



Figure 3 – The southern Fan Area (former main mineral processing area), showing the distinctive concentrate mill structure

Seven ore bodies were mined through a combination of open pit, glory hole and underground developments. Approximately 80 km of underground workings, numerous stopes and four open pits were developed to extract the ore. The main access points to the mine were through the open pits and glory holes associated with Jane Basin, various portals at the 2200, 2700 and 4100 Levels and Victoria shaft, the latter located in the Furry Creek watershed (Fig. 2).

Since the mine ceased operations, surface water continues to enter the mine workings, predominantly through the open pits and glory holes in the Jane Basin area. Drainage is routed through the underground workings, eventually discharging at the 4100 Level. Drainage from this Level is directed via a raise to a sub-level (local to the 4100 Level portal), at the 4150 Level, to a discharge pipe into Howe Sound at a depth of approximately 26 m below sea level.

1.4 Regulatory Background

The mine is currently out of compliance with both Provincial (Environmental Management Act and Contaminated Sites Regulation) and Federal (Fisheries Act) legislation. The Provincial regulator, the BC Ministry of Environment (BCMoE) is responsible to ensure that the remediation activities undertaken at the mine bring the mine into compliance with the requirements of the BC Contaminated Sites Regulation and other pertinent provincial legislation. Environment Canada and the Department of Fisheries and Oceans (DFO) are responsible to ensure that Federal requirements are satisfied by the remedial actions implemented at the site.

1.5 Remediation Funding

In 2001, the Province of BC secured a fund of \$30 million from the former mine owners and operators in exchange for their indemnity against future environmental liability associated with the mine. These funds are to be used solely in connection with activities linked to the environmental remediation of the mine site, including technical studies, capital remediation works and long term operation and maintenance of such works. In April, 2003, responsibility for undertaking the Britannia Mine Remediation Project was passed from the BC Ministry of Water, Land and Air Protection (BCMWLAP), now BC Ministry of Environment (MoE), to the BC Ministry of Sustainable Resource Management (BCMSRM), now BC Ministry of Agriculture and Land (BCMAaL).

Studies and current contract prices show that the net present value of the remediation works required at Britannia are some \$80 million, due primarily to the long-term operation and maintenance costs associated with a water treatment plant needed to treat the acid rock drainage emanating from the mine workings and metal-contaminated groundwater in perpetuity. The shortfall from the \$30 million fund is being addressed by the

Province using a combination of government funding provision, pursuit of other potentially responsible parties and environmental levies and/or payment in kind from landowners and/or future developers of the mine property. For example, in September, 2003, ownership of the majority of the mine site land was transferred to the Province under an agreement with the then mine landowners, Britannia Bay Properties Ltd., which benefits the Province when development occurs on the non-transferred land.

1.6 Technical Studies

The Province appointed Golder Associates Ltd. (Golder) as overall Project Manager for the Britannia Mine Remediation Project in 2001. Technical consultants were subsequently appointed to evaluate four major technical areas associated with the Province's remedial concept (Section 3.1). These consultants were: SRK (Mining and Hydrogeology), URS (Contaminated Sites), AMEC (Water Treatment) and WMC (Flood Risk Assessment). A number of additional technical studies were also undertaken by these and other contractors, including an assessment of the marine outfall and associated dilution modelling (Komex, Ref. 19 and 30, Westmar, Ref. 31), a pilot HDS water treatment program (CEMI, Ref. 20) and various ancillary technical studies by Golder and others. A brief summary of the scope of work of each major technical consultant and some of the more significant findings can be found in Ref. 33, and technical reports can be downloaded from the Province's website (www.britanniamine.ca).

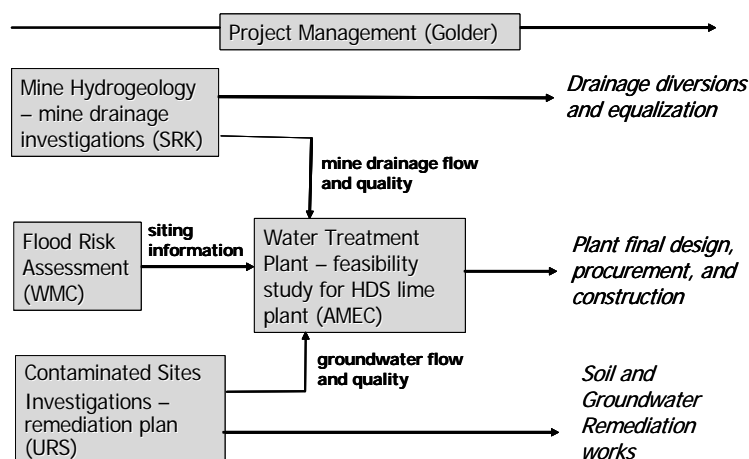


Figure 4 - Project Structure

The major technical studies all couple into a water treatment plant feasibility study, as illustrated in Fig. 4. The SRK mining and hydrogeology scope dealt primarily with surface and underground mine hydrology, hydrogeology and chemistry, including the potential for water storage in the mine, all of which have a direct bearing on the quality and quantity of water (ARD) being fed to the water treatment plant. The contaminated sites investigations, undertaken by URS, included a preliminary assessment as to whether contaminated groundwater should be captured (extracted) from the Fan Area as a remedial action and, if so, what quality and quantity would require treatment in the plant. The need for a flood risk assessment was also identified, as some of the locations identified for the water treatment plant, as well as other remedial measures, were potentially to be located within the flood plain of Britannia Creek (Fan Area). The mining and hydrogeology and contaminated sites studies also input into developing additional remedial measures, for example, surface water diversions around Jane Basin and soil/groundwater remediation in the Fan Area.

The major technical studies were completed in late-2002 and were followed in 2003 by implementation of a number of interim remediation measures and long-term remedial planning discussed in 4.1, below).

2.0 ENVIRONMENTAL ISSUES

2.1 Acid Rock Drainage

The quality of water draining from the mine workings was both a concern and a benefit during the life of the mine: it was a benefit by way of the concentration of copper being such as to allow direct precipitation of large amounts of copper from the discharge water (Ref. 2). However, the negative aspect of the mine water discharge, which typically has a pH of around 3.5, with elevated concentrations of dissolved copper, zinc and cadmium, is the adverse impact of these metals in the aquatic environment, as they are harmful to aquatic life.

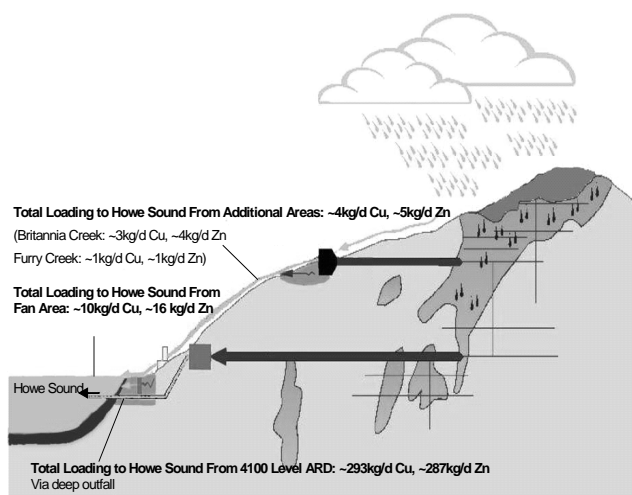


Figure 5 – Contaminant Loading Estimates
(SRK and URS)

Following mine closure, the majority of this water discharged from the 4100 Level (to Howe Sound) and the 2200 Level (to Britannia Creek). Around 5 million cubic metres of water typically drains through the mine annually (Ref. 5). Typical (not average) concentrations of these metals in the 4100 Level discharge water are 30 mg/L copper, 25 mg/L zinc and 0.1 mg/L cadmium, though concentrations fluctuate with rate of water flow through the mine and volume of stored water in the mine. SRK has assessed that of an average of almost 300 kg/day each of copper and zinc discharge to Howe Sound via the outfall pipe from the 4100 Level (Fig 5), (Ref.s 4, 5, 8, 9, 10).

2.2 Contaminated Sites

The second environmental issue at the mine site is the presence of large quantities of mineralized rock, waste rock, tailings, remnant concentrate and other process wastes found at various locations around the mine property. The largest accumulation of these materials (with the exception of Jane Basin) is in the southern portion of the Britannia Beach area, referred to as the 'Fan Area' (Fig.3). Other areas of note are the 2200 Level; 2700 Level and Victoria camp areas, the latter being adjacent to Furry Creek (Ref.s . 9, 10, 11, 12, 13, 14). The primary transport pathway for contaminants found in soils is leaching and groundwater flow. This issue is of particular concern along the shoreline of Howe Sound, with an estimated average of 10kg/day of copper and 16 kg/day of zinc discharging daily from the site.

2.3 Offshore

Offshore of the site in the deeper waters of Howe Sound, some 40 million tonnes of mine process waste ('tailings') were deposited during the operational life of the mine. Environment Canada has undertaken a program of investigation and evaluation of the nature and distribution of these tailing deposits to establish whether remediation effort should be expended on these. The Province's remediation project does not currently include addressing these materials. The assessment by Environment Canada indicates that no intrusive remedial

action is recommended as these deposits are beneath the photic zone, the metals contained therein are generally not bio-available, and are being gradually buried by sediments from the Squamish river. A report on this subject was issued by Environment Canada in 2004 (Ref. 34).

3.0 REMEDIATION PROJECT

3.1 Remedial Concept

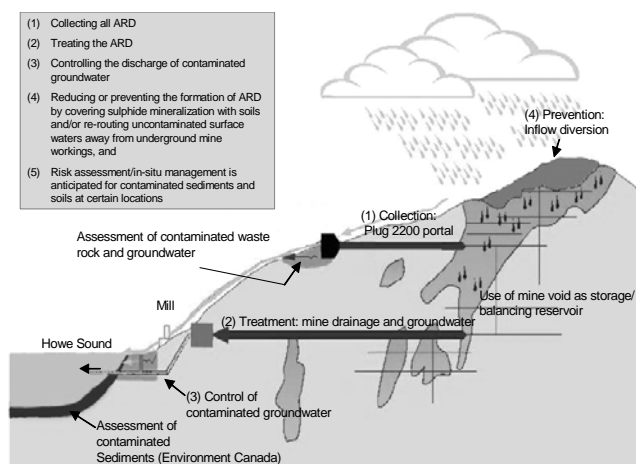


Figure 6 – The Province’s Remedial Concept

Fig. 6 illustrates the remedial concept developed by the Province for the mine.

The primary environmental issue at the site, as noted above, is the acid rock drainage (ARD) discharging from the 4100 Level, representing around 95% of the metal contaminant loading to Howe Sound from the mine. Dealing with this issue was therefore identified as the primary component of the remedial concept.

Although an apparently obvious remedial action would be to prevent surface water inflow into Jane Basin, and therefore minimize ARD discharge from the mine, evaluation by SRK indicated that this is very problematic due to the physical nature of the open pit and glory hole mining complex, which has resulted in an extensive area of talus slopes and fractured bedrock over the area of infiltration. Following a preliminary site reconnaissance and desk-study in 2001/2002, it was concluded that additional fieldwork would be required to adequately evaluate the feasibility of surface water diversions in the Jane Basin and Victoria camp areas, including seasonal measurements of creek flows into the glory holes and observations of ephemeral water flows during the early-summer snow melt period.

Associated with the above issue is the need to ensure that the majority of the ARD reports to a single discharge point (at the 4100 Level) by re-directing mine water discharging from the 2200 Level portal back into the mine. This re-direction had been achieved previously in the mid-1980’s by installing a dam in the 2200 Level adit, however this structure had later overtopped due to changes in local flow patterns within the mine, likely due to collapse of parts of the workings. Satisfactory re-direction of this water was achieved in late-2001 by the installation of a concrete plug in the 2200 Level adit by a combined effort of the University of British Columbia (UBC/CERM3) and the then mine landowner (Britannia Mining and Reclamation Corp.).

The volume of the ARD discharge from the mine varies seasonally (Ref. 5), peaking in the early summer due to snow melt (freshet) and then again in late fall, at the onset of the early winter rains and prior to freezing conditions and snow accumulation in Jane Basin. To mitigate this seasonal variation in mine discharge rate (up to an order of magnitude, typically ranging from 40 to 400 L/sec), the Province identified that part of the mine workings could, potentially, be utilized as a storage reservoir, regulating the flows to the water treatment plant.

Using the mine as a reservoir, however, requires a detailed knowledge of the passage of water through the mine workings, coupled with establishing an elevation versus volume relationship for the part of the mine to be used for storage, together with the evaluation of a number of safety concerns associated with this concept. The latter included the integrity of the 25 year old concrete plug located in the 4100 Level adit, stability issues associated with other mine entries and the general water-tightness of the mine host rock under elevated pressures resulting from water storage in the mine workings (the mine is located in a natural shear-zone (Ref.s 1,15)). In addition, storing water in the mine by flooding sections of previously un-wetted mine workings was identified as having the potential to affect the chemistry of the stored water prior to discharge. These issues needed careful investigation, including a full-scale flooding exercise of the mine workings (Ref. 5, 8, 23, 24).

The use of the mine for water storage would allow control and regulation of flow of the ARD discharge to a water treatment plant located in the Britannia Beach area. Flow to the plant would be controlled by valves located on pipes installed in the existing concrete plug located in the 4100 Level adit. Regulation of flow would allow optimization of plant size and operating methodology to allow the most economic plant design to be adopted.

Earlier work on water treatment technologies appropriate to ARD were evaluated by the Province and others prior to commencing the current project. The accepted approach to ARD water treatment is that of a high density sludge technology (HDS), developed in the mid-1970's. This technology comprises adding lime to the ARD influent water which precipitates dissolved metals by pH adjustment. The water is then clarified and the supernatant is discharged as treated effluent and the denser sludge is partly recycled into the influent water in order to seed crystal growth and increased efficiency of the clarification process. Surplus sludge, a stable metal hydroxide at 25% to 50% solids, must be disposed appropriately or, potentially, re-used, e.g., in cement manufacture (Ref.s 6, 7, 35). A number of alternate water treatment technologies are available that have been developed in recent years, including sulphide reduction technology. The assessment program also included some evaluation of these technologies.

The second major component of the Province's remedial concept is to address the various contaminated sites issues. A risk-based approach to investigation and remediation under the BC Environmental Management Act and Contaminated Sites Regulation was adopted by URS (Ref.s 10, 11, 12, 13, 14, 16, 17, 18). A major component of this secondary environmental issue is that of groundwater and soil contamination resulting from the former mineral processing operations and associated mine infrastructure, in particular, discharge of groundwater through the metal-contaminated alluvial fan of Britannia Creek ('Fan Area') to the environmentally sensitive shallow marine environment of Howe Sound.

Use of a risk based approach requires that a thorough understanding of baseline environmental conditions is gained and that an appropriate system of monitoring improvements effected by implementation of remedial measures is adopted (Ref. 4).

4.0 REMEDIAL WORKS IMPLEMENTATION

The remedial works are being implemented in a staged approach. A Stage 1 Remedial Action Plan (Stage 1 RAP) was developed by Golder in March, 2003 (Ref. 27) with implementation commencing in June, 2003. The Stage 2 RAP commenced in early-2004 and will continue through 2007.

4.1 Stage 1 Remedial Action Plan

The Stage 1 RAP included:

- Interim soil management activities in and around the Fan Area. These comprised excavation of shallow metal-contaminated soil hot-spots and consolidation of the materials removed into temporary, managed, stockpiles for the 2003/4 winter season. The open pit and glory hole areas within Jane Basin were identified as the final disposal site for these soils, as studies identified that any associated leachate would be directed through the mine workings to the water treatment plant. Permitting of the Jane Basin facility and reconstruction of the access road to Jane Basin were therefore components of the plan, with the first phase of the road upgrade completed in late-2003;
- Additional groundwater investigations in the Fan Area to help ascertain whether a groundwater capture system would be the most appropriate and cost effective long-term remedial action to deal with the Fan Area contaminated sites issues. A new pumping well was installed and a long-term groundwater pumping test undertaken, coupled with a groundwater modelling program, designed to establish the feasibility and most appropriate method of groundwater control, pumping rates necessary to affect this control and the quality of the pumped groundwater. Water from the test program was discharged to the existing ARD outflow pipe into Howe Sound;
- The detailed site investigation identified that a significant contribution to metal loading of the surface waters of Howe Sound was from the Fan Area storm water drainage system. Installation of surface and shallow groundwater drainage improvements in the southern Fan Area was therefore a component of the Stage 1 RAP, comprising a system of lined surface swales, catch pits, sediment traps, pipework and the installation of a storm water interceptor sewer. This system collects run-off water from metal-contaminated mine waste materials accumulated on the slopes above and adjacent to the concentrate mill and from surficial soils across the southern half of the Fan Area, discharging to the deep outfall; and
- Identification of surface water diversion opportunities in the Jane Basin and Victoria mine areas and undertaking the associated engineering design.

An Overall Mine Closure and Remediation Plan for the site (ORP), was developed by Golder in 2003 and submitted to the BCMoE. The ORP (Ref. 29) addresses all aspects of the site remedial planning, including the contaminated sites remediation, water treatment plant, outfall and disposal of contaminated soils and water treatment plant waste products (e.g., sludge), with the exception of the mine tailings deposits in Howe Sound.

The Stage 2 RAP was developed as part of the ORP, including:

- Procurement, construction, commissioning and operation of the ARD water treatment plant and its associated infrastructure, including:
 - Access road;
 - Influent water control and Stage 2 mine rehabilitation;
 - Sludge disposal facilities; and,
 - Outfall system;

In mid-2003, the Province elected to procure the water treatment plant through a design-build-finance-operate (DBFO) contract within a Public Private Partnership, or 'P3'. The plant to be supplied on a performance-based approach, whereby although the technology is not specified (thus giving greater opportunity for innovation and reduced risk to the Province), any proposed system must be technologically sound and proven in the industry. The water treatment plant contractor would finance the construction of the plant and would, once operational, receive periodic payments from the Province related to volume of water treated to the specified standards, together with capital/debt service and other fixed operational costs;

- Selection of a groundwater control system for the Fan Area, together with its implementation. The Stage 1 RAP identified a number of options for groundwater capture, including various arrangements of pumping wells, scavenger wells and barrier walls. One of the technical challenges posed is the high chloride level of groundwater in the coastal margin of the Fan Area and therefore its potential to be highly corrosive [to the well, pumps, infrastructure and water treatment plant components] and to affect the water treatment process;
- Permitting issues, including those associated with soil and sludge disposal in Jane Basin, road construction, water treatment plant discharge and outfall construction;
- Construction of surface water diversions in and around the Jane Basin area and Victoria mine; and,
- Completion of the Jane Basin access road and haulage of the temporarily stockpiled soils to Jane Basin.

4.2 Implementation of the Stage 2 Remedial Action Plan

Building on the Stage 1 RAP components outlined above, the Stage 2 RAP focuses on the two priority items:

- construction and commissioning of the water treatment plant; and,
- the groundwater management system in the Fan Area.

Implementation of these two major components incorporates a number of secondary remedial actions however, including management of large volumes of metal-contaminated soils, underground rehabilitation, drainage improvements and a new outfall system.

4.2.1 Water Treatment Plant

As noted above, the Province elected to procure the water treatment plant under a DBFO contract. The basic scope of this contract includes:

- Construction of a 1050 m³/hour water treatment plant (1400m³/hr hydraulic capacity) to be located on the 4100 Level bench, immediately east of Britannia Beach;
- New deep water outfall, south of Britannia Beach;
- Rehabilitation of the 4100 Level tunnel from portal to plug;
- All ancillary facilities for the plant;
- Operation of the plant for 20 years.

As noted above, the technology for the plant was not prescribed by the Province, however, proponents had to prove the viability of any proposed technology. The DBFO procurement process was administered on behalf of the Province by Partnerships BC (PBC) and a Request for Expression of Interest for the water treatment plant was issued in January, 2004 and a Request for Proposal issued to shortlisted proponents in May, 2004. The successful proponent, EPCOR Water Services Inc. (EPCOR), was announced by the Province in November, 2004. EPCOR proposed a high density sludge (HDS) technology for the plant, part-powered by a micro-hydro plant from the mine water. However, the EPCOR team are committed to reviewing alternate technologies (e.g., sulphide-reduction) for potential implementation at the site, supplemental to the HDS process.

Work relating to the water treatment plant actually started in advance of the DBFO process, with the Province electing to construct the access road in cooperation with the local property developer (Britannia Bay Properties Ltd). Road construction commenced in summer, 2004, with completion, apart from final surfacing, in spring-2005. This decision allowed deliveries to the water treatment plant construction site to by-pass a large part of the Britannia Beach community. Other advance works undertaken in 2004 included a program of demolition, site clearance and contaminated soil removal across the water treatment plant site (Fig. 7).



The ground-breaking ceremony for the water treatment plant took place on March 3, 2005. By the time of preparing this paper (July, 2005), all major concrete structures at the plant site had been completed, including a 33 m diameter concrete clarifier tank and reactor tanks, and the plant building was under construction (Fig. 7). The water treatment plant is scheduled to be operational by mid-November, 2005.

Figure 7 – Water Treatment Plant Clarifier and Reactor Construction, June, 2005

As noted above, EPCOR's proposal includes a micro-hydro power plant deploying turbines powered by the mine water discharging from the workings via a penstock from the 4100 Level plug. The DBFO contract also includes a new (50 m) deep outfall for the treated effluent from the plant. This will comprise some 1.2 km of onshore pipework and around 200 m of offshore pipework, replacing the dilapidated outfall currently in use for the (untreated) mine water. At the time of preparation of this paper, excavation work for the onshore section of the new outfall was about to commence and the offshore component was being tendered.

4.2.2 Groundwater Management System

Design of the Fan Area groundwater management system was developed by Golder and OMNI Engineering in mid-2004. System concepts considered included various combinations of barrier walls, injection wells and pumping wells, targeting best-value maximum fresh groundwater capture efficiency, while limiting pumping rate of the system to 100 m³/hr with a salinity of <1000 ppm, in order to meet design criteria for the water treatment plant. The adopted system concept was one of 7 pumping wells in a linear array sub-parallel to the shore line, coupled with an associated monitoring well array. The pumping rate for the individual wells in the array is determined by conductivity, flow and pressure sensors feeding data to a PLC (Figs. 8 and 9).

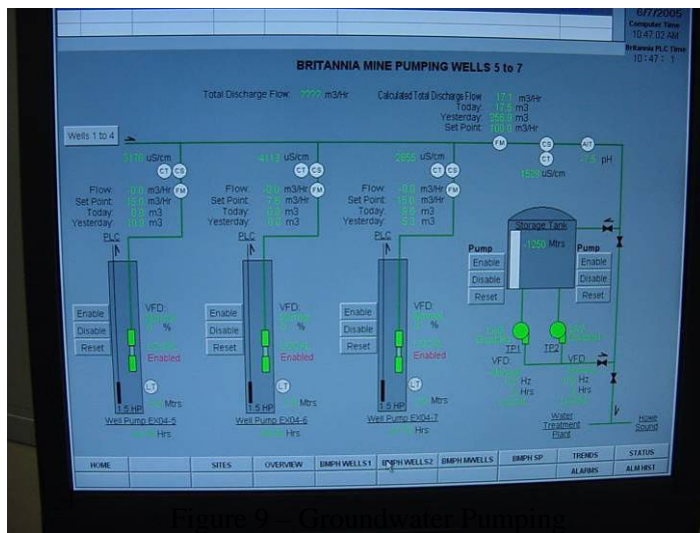


Figure 8 – Groundwater Pumping System –
Flowmeter and Conductivity Sensor Array

Except for the well installations themselves, the groundwater management system was procured by an extension of the DBFO contract: this approach holds several advantages to the Province, in particular the DBFO contractor will be responsible for maintaining and operating the groundwater system and therefore it is logical for that contractor to help in the design, construct and commission the system and ensure full compatibility of the control and data management systems with that of the water treatment plant.

For expediency, the pumping wells were installed in late-2004, in advance of the DBFO contract, and construction of the groundwater management system proper commenced in March, 2005, with the system being commissioned in late-May, 2005. By the time of preparing this paper, programs of individual well step and 8-hour pumping tests had been completed and a program of full array testing had begun, together with correlation of salinity versus electrical conductivity of the groundwater.

The system is temporarily discharging untreated groundwater to the existing deep outfall in Howe Sound, however, a transfer pumping system and forcemain is being installed in summer-2005 to take the pumped groundwater to the water treatment plant.



System SCADA display

It is anticipated that optimization of the groundwater management system will be ongoing for at least a year, with iterations of observed versus modelled data being used to assess and maximize capture efficiency. In the longer-term, the environmental monitoring and ecological risk assessment programs will determine if the capture is achieving the desired environmental endpoints or whether additional wells or other measures are required to enhance the system. Allowance was made in the system design and construction for future upgrades, e.g., up to 4 additional pumping wells may be added easily.

4.2.3 Underground Rehabilitation

As noted above, acid water exits the mine via pipes passing through a plug located some 400m inside the 4100 Level tunnel (Fig. 10). Historically this water flows in open channel along the 4100 Level tunnel and passes down a 'raise' to the 4150 Level below, before being routed to a pipe and the existing deep outfall. The



Figure 10 – Acid Rock Water Discharging From the 4100 Level Plug During Underground Rehabilitation Works

condition of sections of the underground working is poor and entry is only possible if accompanied by a mine 'Shift Boss'. As workers will need to access the tunnel in the long-term for maintenance and inspection duties, and as the tunnel will contain a pressurized penstock, bypass pipe, controls and instrumentation, a program of rehabilitation was included in the DBFO contract as a cash allowance. This work program, developed by Golder, commenced in May, 2005 (RokTek) and includes roof support (rock bolting), shotcreting, treatment of two raises and installation of a barricade. The rehabilitation work is scheduled for completion in mid-summer, 2005.

4.2.4 Contaminated Soils Management

The Fan Area of the mine site contained historic mineral processing and materials storage and handling operations. In addition, during the life of the mine, ready availability of mine tailings and waste rock for use as fill resulted in extensive and widespread metal



Figure 11 – Management of Metal-contaminated Soils in Jane Basin

contamination in this area. The Stage 1 program of managing these soils was extended in Stage 2 to fully open the 11km haul road to Jane Basin for 6-wheel drive trucks and implementation of a program of excavation and transport of these soils to Jane Basin under a Waste Disposal Permit issued by BCMoE. This work program commenced in the summer of 2004 and re-commenced in summer, 2005. Materials shipped to Jane Basin included copper ore from the ore bins, sludges, metal-contaminated soils, mineralized rock, tailings and concentrate, totaling around 35,000 m³ at the time of preparing this paper (Fig. 11).

4.2.5 Surface Water Diversions

The Stage 1 RAP included studies assessing the feasibility of a series of possible surface water diversions around Jane Basin and at Victoria Mine (the latter within the Furry Creek watershed). The Stage 2 RAP includes the construction and ongoing evaluation of these diversions. A diversion was constructed along East Bluff in the fall of 2004 and monitored through the winter (Fig. 12). The diversion proved to be more effective than anticipated and further works in this area are anticipated in 2005. At the time of preparing this paper, construction of the Upper Jane Creek diversion is underway in difficult terrain south of Jane Basin, expected to be completed in late-summer, 2005, and a proposal for a diversion above Victoria Mine in the Furry Creek watershed is with the Province for consideration.



Figure 12 – Tracer Test - East Bluff
Surface Water Diversion

5.0 MONITORING PROGRAM AND ECOLOGICAL RISK ASSESSMENT

An initial site-wide monitoring program was established in late-2001 to establish baseline conditions prior to commencement of intrusive site investigation activities, in particular the mine reservoir test program undertaken by SRK. In addition, a program of monitoring for the site was devised (Ref. 4) and a baseline survey associated with this program was completed in 2003 (Ref. 32), designed to establish the baseline environmental conditions at the site for comparison to conditions during and after implementation of the major remedial actions. A long-term (3 year) environmental effects monitoring (EEM) program and Tier 2 risk assessment commenced in late-summer, 2004 (Golder) and is ongoing through 2007. The objectives of the long-term environmental monitoring program are to measure success of remediation effort and optimize environmental protection, together with habitat and biota recovery conditions.

An improved understanding of the following was identified in the URS risk assessment as being necessary (Ref.s 16, 17):

- Relative contributions from contaminant transport pathways;
- Inter-tidal near-surface, mid-column, and near-bottom water quality under various tidal conditions;
- Inter-tidal habitat and biota;
- Groundwater and pore water quality and movement through the inter-tidal hyporheic zone; and,
- Acute and chronic toxic effects through additional bioassays from metals-containing sediments in Britannia Creek and within the inter-tidal zone.

The ongoing monitoring therefore includes conducting detailed assessments of the above to enhance understanding and to ensure that the available information is sufficient to allow detection of changes during and after remediation is implemented. The Tier 2 risk assessment is designed to identify the need for and to focus any additional remediation efforts at the site and to assist in establishing monitoring and reporting requirements after the 3 year EEM program.

6.0 SCHEDULE

The major investigation phase of the remediation project was completed in late-2002 with evaluation of the results of the investigations and the development of remediation plans in 2003. Implementation of the Stage 1 RAP commenced in June, 2003 and was completed in January, 2004. The Stage 2 RAP commenced in December, 2003 and will be completed in 2007, with submission of the Tier 2 ecological risk assessment.

As noted in Section 4, the Province implemented a DBFO form of contract for the water treatment plant, including the outfall system and mine rehabilitation works, and was subsequently extended to include the groundwater management system. Water treatment plant operation is scheduled for mid-November, 2005. Commissioning of the groundwater management system in the Fan Area commenced in May, 2005. At the time of preparation of this paper, this system was operational and entering the optimization phase.

Remedial actions in the Additional Areas are pending the Tier 2 risk assessment, however, some works may be implemented at the 2200 Level waste dump prior to 2007.

Monitoring programs associated with the remediation activities commenced in June 2003, with the Tier 2 ecological risk assessment due for completion in 2007. However, it is expected that monitoring of environmental conditions at Britannia Mine will continue for many years after that date.

7.0 CONCLUSION

The Britannia Mine Remediation Project is addressing the environmental issues summarized in this paper with a comprehensive program of remedial actions and a combined monitoring program and risk assessment designed to confirm that these actions have been successful in remediating the mine site to the requirements of Provincial and Federal regulatory agencies. The program is well advanced (now into the latter stages of the implementation phase) and it is anticipated that the major capital programs will have been completed by the end of 2005. The results of the risk assessment will be used to determine if additional remedial actions are necessary. Thereafter, an ongoing program of operation and maintenance of the remedial systems, and in particular the water treatment plant and groundwater management system, together with environmental monitoring, will continue for the foreseeable future.

In addition to the environmental remediation work at Britannia discussed in this paper, there are many other improvements planned or underway local to Britannia Mine. These include a large amount of subdivision development work being undertaken by Britannia Bay Properties Ltd. within and adjacent to Britannia Beach, resulting in upgraded roads, bridges, new potable water supply and sewage treatment facilities, and other infrastructure enhancements. Also, the BC Museum of Mining has commenced their 'Britannia Project' which includes rehabilitation of the iconic Mill #3 at the site (Fig. 3), which will be rendered structurally sound and will receive new cladding, glazing and roofing in the next couple of years courtesy of government and private funding. Golder has contributed towards the Museum's Mill #3 project by providing assistance with the assessment, planning and implementation of planting the ore-covered slopes either side of the mill building.

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