

# ENVIRONMENTAL JOURNEYS – THE MISSING YEARS

## BRITANNIA 1967 TO 2005

### ABSTRACT

In the late 1960s, new environmental protection laws were introduced in British Columbia that initiated significant changes to mining practices in the province. For Anaconda, the owners of the Britannia Mine, it introduced the need to address how the town and the Mine disposed of waste. This included sewage, solid domestic waste (garbage), mine tailings (waste rock), and acid mine drainage.

While the new laws required approval for waste disposal, there was not a set standard yet. In essence, the standards could not be set until the impacts were understood. Working with the government, Anaconda produced a plan to manage its tailings, acid mine drainage, and sewage, but the plan was not implemented. The Mine closed in 1974, requiring a new look at what would be needed.

With the Mine closed, tailings were no longer an issue. Only the acid mine drainage and sewage would require management. Anaconda and the government worked together to arrive at a plan that would meet the needs of both. In 1978, a system to capture and discharge the mine water into Howe Sound at a depth of 100 feet below sea level went into operation. This deep discharge system also addressed a significant environmental problem that was identified right from the beginning – discharge of acid mine water into Britannia Creek. Discharge into the creek proved to be a recurring issue for the Mine post closure.

In 1979, Anaconda sold the land. The new owner, Copper Beach Estates, took over responsibility for the Mine's discharge. The ensuing 20 years would see several issues arise which would see the waters of Howe Sound at Britannia Beach as well as Britannia Creek heavily impacted by acid mine drainage.

In 2001, the first signs of change were on the ground. A UBC project was begun to address the issue of acid mine drainage entering Britannia Creek high on the mountain. This discharge issue, first identified in the early 1970s, addressed by Anaconda, and not maintained by Copper Beach Estates, was going to be solved with the construction of a 'Millennium Plug' – a plug placed in the mine portal that would last for a millennium. While this long lasting plug was not built, the research plug was. The result was an elimination of acid mine drainage entering the creek. This was the beginning of the restoration of Britannia's waterways.

In 2005, the EPCOR Britannia Mine Water Treatment Plant opened. With the acid mine drainage now captured in the mine and redirected to the lower mine portal for treatment, Howe Sound has recovered from the impacts of the mine discharge. The plant uses the same processes as the one proposed by Anaconda in the early 1970s, and every other plant proposed between then and 2001.

The reason it took so long for a solution to be built came down to legislation and enforcement. One of the key pieces of law that led to the successful remediation was introduced in 1997. It enabled the government to hold all previous land owners financially responsible for the environmental impact of the Mine.

This is a story of thirty years of learning on environmental remediation. The success at Britannia is the Mine is now a model for environmentally sound mine closure.

## **BACKGROUND**

The Britannia Mines operated for 70 years from 1904 through 1974. At its peak, it was providing 17% of the world's copper supply and claimed the title of the largest copper mine in the British Empire. Over its lifespan, it produced over 50,000 tonnes of metals.

It produced far more waste.

From day one through to closure, the Mine was dumping solid waste from the Mills into the ocean. This formed some of the land that is now Britannia Beach.

Heavy metal contaminated acidic water flowing from the Mine also entered Howe Sound. Beginning in the 1920s however, the Company was recovering copper from the water for economic reasons.

Over its life, the discharges always met the regulations of the day.

Prior to 1967 however, there was little regulation and even less enforcement.

In 1967 however, the British Columbia Government introduced its Pollution Control Act, setting the stage for a change in how waste is discharged into the environment.

## **CHANGE BEGAN WITH AN ACT**

With the Pollution Control Act of 1967, any form of waste dumping required a permit. This impacted Anaconda (owners of the Britannia mine at the time) in several ways. The Company now required permits for the discharge of its garbage, sewage, mill tailings, and mine water.

The standards required by each permit were set by the Pollution Control Board (PCB). The Director of the Pollution Control (often referred to simply as the Director) held the authority for issuing permits. A permit granted discharge rights and limits for a set time period.

The Director was also granted the authority to issue orders as deemed necessary to ensure adherence to the requirements of the Act.

The Pollution Control Board was also responsible for determining the causes of and remedies for pollution.

***To examine the act, see '1967 – pollution control act'***

## **THE ANACONDA YEARS – 1967 TO 1979**

### **INTRODUCTION**

In the simplest of terms, Anaconda always operated within the requirements of the Act. To do so required a great deal of effort, as both the Company and Government in the first years of permitting were still working to identify the impact of the industrial waste discharge and subsequently identify suitable discharge requirements.

More than anything else, the Anaconda years provide a case study in how Government and Industry can work together to achieve a desired outcome.

### **PERMITTING BEGINS**

In 1970, enforcement of the act began. For Anaconda, it began with a request from the Pollution Control Branch for a permit application for the discharge of Mine-Mill process waste. To be included with the application was a plan illustrating the plant layout, works, points of discharge, existing and proposed waste disposal systems, and a report outlining the milling process including what waste control measures have or could be taken.

At this point, the impact of mine-mill discharge was still not clear. In 1971, the Pollution Control Branch informed Anaconda they had registered their discharges in compliance with the requirements of the Act and as such applications for permit would not be required until required by the Director.

*To examine the first application response see ‘1970 - anaconda application under pollution control act’.*

### **THE FIRST IMPACT STUDIES**

In 1973, studies of the Sound provided some indication of the impact of the Mine. Environment Canada identified specific issues based on data from the Pacific Environment Institute which included the identification of tailings discharge on subtidal communities & the recommendation of locating a ‘more suitable disposal area for either total or part of the effluent.’ More suitable meant discharging at a depth where there is less benthic life.

*To examine the Environment Canada concerns see ‘1973 - application for pollution control permit - note of affluent impact’.*

What is clear is that in 1973, the full impact of Mine discharge was not yet understood. In a study of that year, thesis research on the effect of copper on crustacean larvae concluded the levels were not high enough to effect survival of the organisms.

*To examine this note see ‘1973 - Cu levels not high enough to affect crustacean larvae’.*

To determine the effects of the Mine's discharges, Anaconda had its own assessment done. The tailings discharge was identified as an issue. Among the issues was discharge at shallow depths smothered benthic life. The solution was to extend the discharge to deeper water, deep enough to not be effected by wave action. The depth proposed was 50 feet.

The bigger issue identified was the issue Britannia became known for post mine closure – Acid Mine Drainage (AMD). Of key significance was the identification the impact of AMD discharge from an upper portal of the mine (known as the 2200 portal). Britannia Creek was identified as having suffered damage over its lower 6 km (3.7 miles).

In closing, however, the report indicated that 'no serious progressive deterioration of the receiving environment seems to be indicated.' The environment had adapted to the Mines discharge.

**To examine this study see '1973 - preliminary environmental assessment'.**

Two reports were produced by the Fisheries Research Board in 1973<sup>1</sup> and 1974<sup>2</sup> that corroborated the findings of the Anaconda study regarding the impacts on Howe Sound.

It was clear a waste management program would be needed. As Howe Sound falls under Federal jurisdiction, recommendations could not be made without the input of Environment Canada.

In February 1974, Environment Canada provided its recommendations. Of note is that Environment Canada agreed to continued marine disposal of tailings after recognizing it to be the most workable solution given the geographic constraints of the Mine. Nonetheless, minimizing the impact of discharge was still identified as important. To achieve this, they recommended a minimum discharge depth of 150 feet, and a preferred depth of 200 feet. The conclusion was that disposal at depth would not only minimize the impact on the intertidal zone but the shape of the Sound's floor would act to contain the tailings.

Environment Canada also recommended combining Launder (mine water) and mill tailings discharges to reduce the number of discharge points. It was felt that the fewer the discharge points, the lower the environmental impact.

**To examine this document see '1974 - env canada statement on tailings and ard dumping'.**

## **WORKING TOWARDS A SOLUTION**

In the following months, several discussions were held between the Pollution Control Branch and Anaconda to arrive at a solution for the discharge permit. During this time, more advice was solicited on the impact of the Mine's discharge into the Sound.

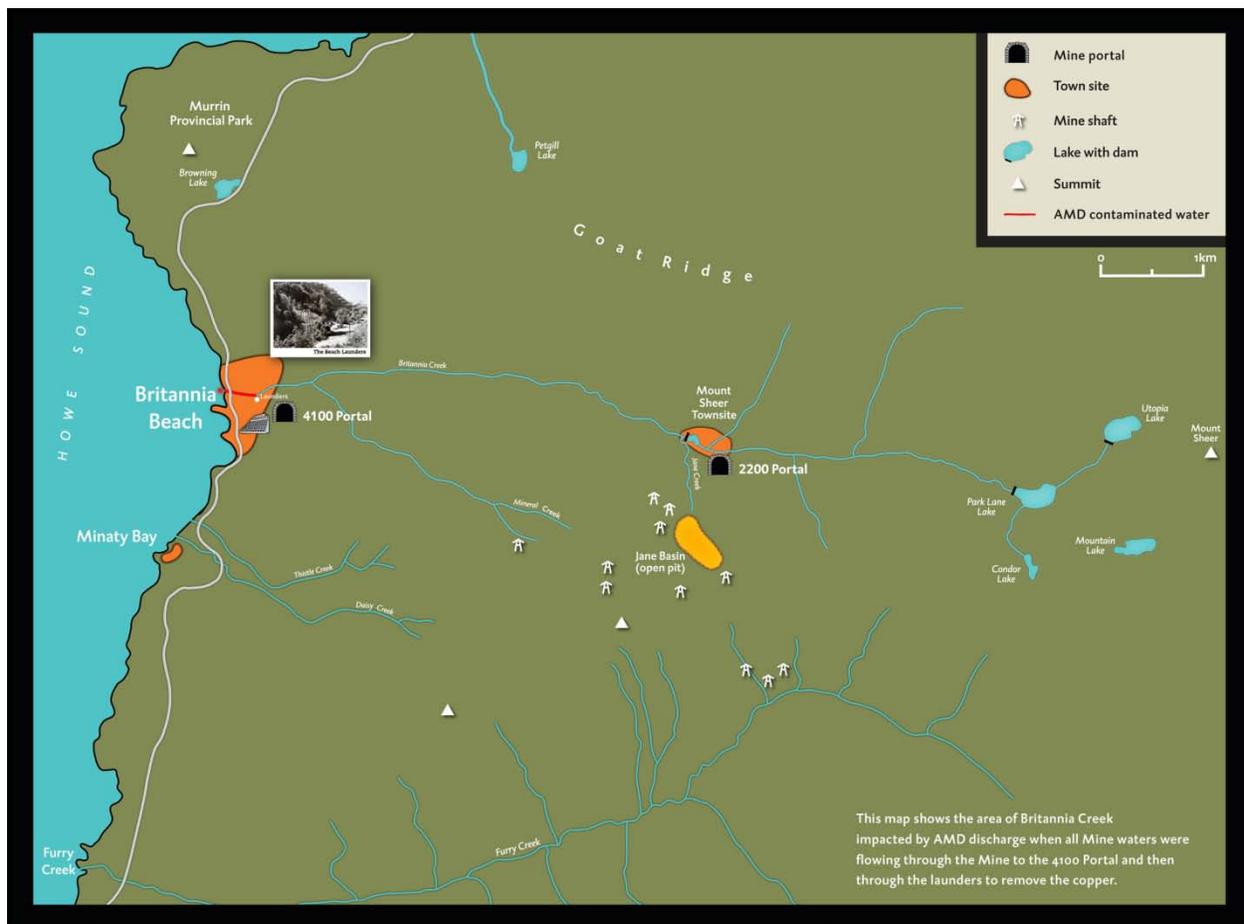
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<sup>1</sup> N.G. McDaniel, Pacific Environment Institute, Fisheries Research Board of Canada Technical report No. 385, A Survey of the Benthic Macroinvertebrates Fauna and Solid Pollutants in Howe Sound, 1973. (<http://www.dfo-mpo.gc.ca/Library/20924.pdf>)

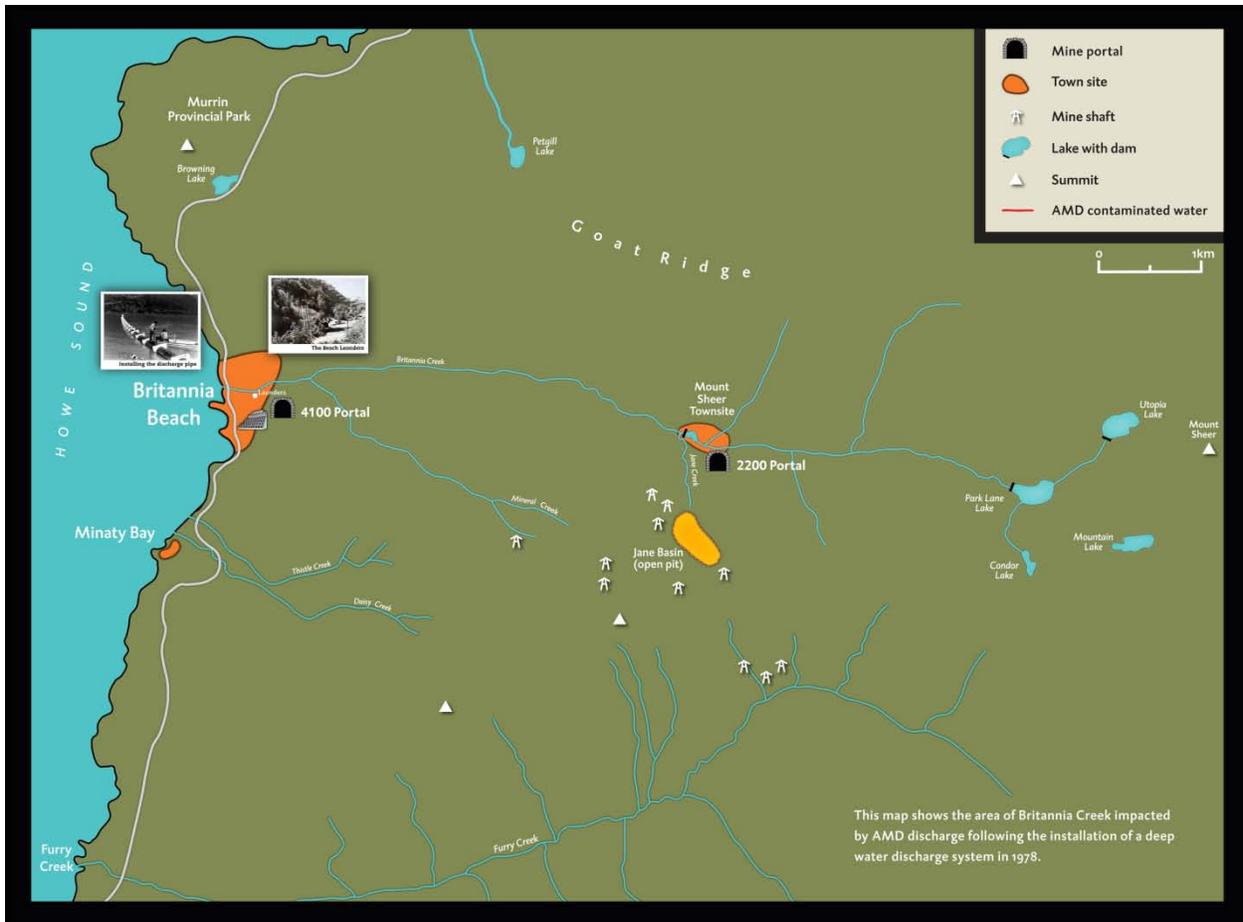
<sup>2</sup> J.A.J. Thompson and F. Terrence McComas, Pacific Environment Institute, Fisheries Research Board of Canada Technical report No. 437, Copper and Zinc Levels in Submerged Mine Tailings at Britannia Beach, B.C., 1974. (<http://www.dfo-mpo.gc.ca/Library/23155.pdf>)

Among the topics that were discussed was the creation of a pilot treatment plant for acid mine drainage, future considerations, and alternative disposal methods. Primary concern however was on design parameters and costs for the required discharge system. One thing became quite clear from these discussions - it was a complex issue that would require finding 'best fit' solutions within the limitations of all parties. For example, it was agreed that discharge should be at a 100 foot depth. This was agreed upon because it was the maximum depth divers could go to. Of concern to the Government, however, was the possibility of a visible plume. It became apparent that any design had to ensure there would not be a visible plume in Britannia Creek or Howe Sound.

To prevent any visible plume, it was identified that discharge into Britannia Creek would have to be addressed. Mine water would have to be prevented from entering the creek at the 2200 level and Beach level. At this point, the Beach Launderers were discharging into Britannia Creek.



The end result of the discussions was an agreement of a submarine discharge system that would combine both mine water and tailings discharges into one at a 100 foot depth. Water from the 2200 level would be redirected to the 4100 level (Beach level) where all mine waters would go through the launders to remove copper.



Sewage would also be released through this discharge.

Plans were developed by Anaconda for a mine water treatment system to be built at the Beach to ensure conformity to the discharge regulations.

Then in November of 1974, the Mine shut down. Planning would need to start over.

### POST CLOSURE – A SOLUTION IS FOUND

In 1975, two factors slowed the adoption of the deep water discharge solution. First, there was talk of the Government purchasing the Britannia Beach property for use as a coal port. Second, the Provincial Government was considering the option of a Provincial/Federal/Anaconda funded mine water treatment facility. Neither of these projects went ahead, which brought the government and Anaconda back to the table to find a solution to what was now only a mine water and sewage problem.

In 1976, the Federal Government was indicated as being more directly involved in a solution due to the passage of the Ocean Dumping Act. In a meeting between Anaconda and the Pollution Control Board it was suggested that mixing sewage and mine water for final discharge could alleviate too much input from the Federal level. There remained, however, the risk the Federal

Government could impose its own requirements. How it would play out was not clear to the Provincial Pollution Control Branch, which was a concern for Anaconda. This concern became more concrete in 1977, when the Federal position on the copper recovery plant (Launder) was “there may be opportunity for increased copper recovery”.

If uncertainty about Federal requirements was not enough, there was also the possibility the Pollution Control Board could impose new requirements following completion of the discharge system. It was recommended Anaconda make a request to the Director for assurances this would not happen. The response was no such assurances could be given, but it was not seen as likely upgrades would be necessary in the immediate future.

After several revisions, on April 26, 1977 a final plan was approved for the discharge of treated mine water through a submerged outfall. In October of that year, the order was given by the Director to build the discharge system and have it operating by June 1, 1978. A monitoring program was also included as a requirement of the permit. The first report was due March 31, 1978.

In 1979, a new order was issued with an updated monitoring program and requirements for the copper recovery plant. The plant was now only required to operate when the mine water exceeded 15 mg/L.

## **THE COPPER BEACH ESTATES (CBE) YEARS – 1980 TO 2000**

### **CBE ASSUMES RESPONSIBILITY**

Copper Beach Estates purchased the Mine’s lands in 1979 with the agreement to turn over a portion for the formation of the Museum. Following this purchase, they requested transfer of the orders from the Director from Anaconda to CBE.

In what is now perhaps a foretelling of the events that were to happen, the PCB responded asking for clarification that CBE understood the full ramifications of assuming such responsibility.

***To view this correspondence see ‘1980 - min of env response to cbe request to assume responsibility for treatment’.***

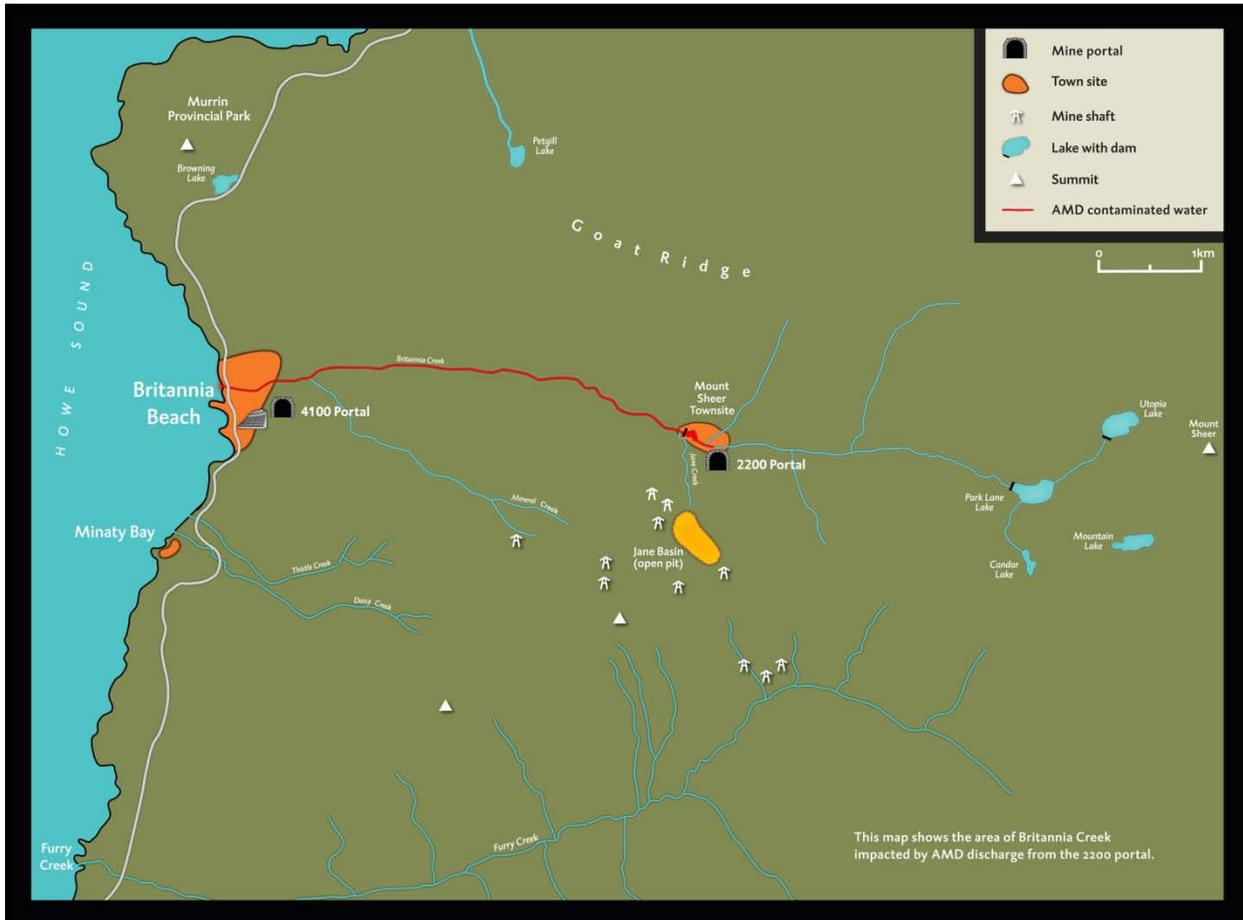
CBE did assume responsibility for the Mine’s discharge in 1980. In the following years, CBE would repeatedly fail to meet the requirements of the orders.

### **THE TREATMENT SYSTEM BEGINS TO FAIL**

In 1984, the issue with the 2200 level that was identified repeatedly during the Anaconda years came to a head. As a result of cave-in or debris blockage, water was no longer being redirected through the mine from the 2200 level to the 4100 level for treatment. Instead, the water was now escaping from the mine at the 2200 level and entering Britannia Creek. This highly acidic water

was then causing the damage identified as a concern in the early 1970s. At this time, CBE was also failing to submit its monitoring reports.

**To view correspondence related to this see ‘1984 - cbe to min of env regarding 2200 portal issues’.**



In January 1985, CBE identified its failure to report was a result of an oversight. They also claimed they had been having problems determining the cause of the water outflow from the 2200 level, but they were still attempting to address it.

A study of the impact of the Mine on the environment was also released in 1985. The good news was the levels of dissolved copper in the water had dropped drastically since the mine closed. The bad news was the lower copper levels rendered the copper recovery plant less efficient. The conclusion was that even had the water from the 2200 level been captured and treated, the treatment would not have had a major impact on the amount of copper entering the Sound. It would have however prevented the water in Britannia Creek from becoming toxic, and reduced the amount of copper present in the surface waters of Howe Sound (Environmental Assessment of The Britannia Mine – Howe Sound; D. Goyette, K. Ferguson, February 1985).

**To view the report see ‘1985 - env assessment of britannia mine’.**

## **THE SEARCH FOR A NEW SOLUTION**

While failure to comply with orders from the Director continued, CBE searched for alternative solutions. In 1988, they approached UBC on building a research facility at Britannia Beach to address the acid mine drainage, of which nothing materialized.

In 1990, CBE approached the government for assistance in stabilizing the Britannia Creek bed. In their response, the ministry of the environment stated the deposition issue with the creek was a result of the failure of a dam built by the Mine and now the responsibility of CBE. As such, creek maintenance was solely the responsibility of CBE.

The following year CBE was listed for the third time on the annual listing of companies in noncompliance with the pollution control board.

*To see the noncompliance listing see '1991 - cbe noncompliance listing'.*

## **DISASTER STRIKES – THE PROBLEM GETS WORSE**

The events of August 29, 1991 only made things worse. Heavy rainfall caused flooding and debris torrent to wash through Britannia Beach. To restore the creek, the Government removed part of the ARD outflow piping and one of the sewer lines. A battle over who was responsible for replacing these lines ensued. In the meantime, sewage and ARD flowed untreated through the bottom portion of Britannia Creek.



Britannia Beach during the 1991 flood

In 1993, the Provincial Government announced it would replace the removed outflow pipe. It also called on CBE to comply with a new Pollution Abatement Order requiring the development of a long-range remediation plan by July 21, 1994.

*To view the news release, see 'bc gov news release - britannia clean up – 1993'.*

## **MONITORING BEGINS & PROPOSALS ARE MADE BUT STILL NO PROGRESS ON THE POLLUTION PROBLEM**

In 1995, BC Environment began a weekly surface water monitoring program.

In 1999, CBE was listed on the annual noncompliance list for the eleventh time. CBE was still attempting to find a solution to the AMD discharge issue, however. In March of 1999 they released a proposal for a treatment facility. The key elements of this proposal remained the same as in previous ones. What was new was the proposal to use the open pits of the Mine for contaminated soil disposal. The intent was to offset the cost of AMD treatment with dumping fees. This proposal did not go ahead.

## **A NEW MILLENNIUM, A NEW BEGINNING – 2001 TO 2005**

By the year 2000 the issues with mine water escaping from the 2200 level were well documented.

In 2001, a research project headed by UBC was initiated to address this ongoing issue.

### **THE MILLENNIUM PLUG**

Called the Millennium Plug, the plan was to construct a plug in the 2200 portal that would withstand the acidic conditions of the water behind it for 1000 years. A standard concrete plug would last less than 100.

UBC stabilized the 2200 portal to allow for the research to commence, and installed the concrete plug necessary to allow construction and testing of the Millennium Plug.

The installation of the research station resulted in the redirection of all mine water back through the mine to the 4100 level, as was recommended and later required by every order issued by the Director of Pollution Control. The concrete plug installed by UBC was the first full plug installed at this level. Earlier installations did not seal the portal. With an opening for overflow, the water was able to exit when it got too high, as it did during the 1980s and 1990s.

While the Millennium Plug was not constructed, the concrete plug successfully allowed Britannia Creek to begin to recover. Within six months of its installation, blue mussels were repopulating the mouth of the creek.

*To learn more about the Millennium Plug project see '<http://www.cerm3.mining.ubc.ca/millennium.htm>'.*

### **HOLDING PREVIOUS LAND OWNERS ACCOUNTABLE**

In that same year, the Provincial Government reached a settlement with all previous landowners for \$30 million in exchange for no future liability. This was accomplished via the Contaminated Sites Regulation of 1997. CBE performed the investigative work of determining who the previous

landowners were. While CBE was one of the previous landowners, it did not have the capacity to contribute to the settlement financially. Instead, the provincial government agreed that CBE would contribute through future land sales and a transfer of a portion of its Britannia land holdings to the government.

Two years later, CBE faced foreclosure. McDonald Development assumed ownership of the land and transferred most of the land to the provincial government in exchange for the credit for the transfer agreed to by CBE and the government.

The \$30 million dollar settlement will not cover the total costs of remediating the mine site and operating the water treatment plant in perpetuity. Estimates between \$75 and \$100 million dollars have been put forth as the total cost for the first 20 years.

### **A NEW PLAN, JUST LIKE THE OLD ONES**

The next step of the remediation was installation of a water treatment plant. The plant uses the same basic principles as proposed first by Anaconda and in all subsequent proposals.

The water treatment plant is a private public partnership. The provincial government concluded it would be cheaper to have a private company build and operate the plant than for the government to do it.

EPCOR won the plant contract. Construction began in the spring of 2005 and the plant was operation in October of that year. By summer the following year, positive changes were seen in the Britannia intertidal zone.

In November 2011, forty-one years after the first action to address the mine's pollution issue, pink salmon were spotted spawning 4 km up Britannia Creek.

**For more on the Private Public Project see**

**'[http://www.partnershipsbc.ca/pdf/Britannia\\_Value\\_for\\_Money\\_Report\\_March\\_05\\_FINAL.pdf](http://www.partnershipsbc.ca/pdf/Britannia_Value_for_Money_Report_March_05_FINAL.pdf)'.**

**For more on the environmental monitoring see**

**'<https://circle.ubc.ca/bitstream/handle/2429/8304/05%20Wernick%20%20final.pdf?sequence=1>'**

## **IN SUMMARY**

When the Mine was operating, AMD was a secondary issue. It is only post closure AMD took the spotlight. It then took over 25 years before a solution was properly implemented.

Over the years, many studies reached the same conclusions and recommendations. The final treatment process is essentially the same as all previously proposed solutions.

There were several factors which contributed to the delays in installing a treatment solution. They include:

1. Establishing the impact the discharge had on Howe Sound and Britannia Creek
2. Establishing safe discharge levels and appropriate discharge depths
3. Complications over jurisdiction. The mine and its waste was a provincial issue while depositing in the ocean was a federal issue.
4. Complications over potential future treatment requirements. Anaconda wanted assurances that whatever solution they built would not require future updating.
5. Cost. Anaconda invested over \$100,000 into a closed mine to meet regulations. CBE insisted it did not have the finances to meet the discharge regulations.
6. Legislation. Nothing could happen so long as legislation lacked the ability to enforce compliance and hold responsible parties financially accountable.

## **THE OUTCOME**

Britannia is now a model for AMD remediation. The lessons from the Britannia Remediation can and are being applied to other mine sites around the world.

## **SOURCE DOCUMENTS FROM THE MUSEUM ARCHIVES:**

- 1967 - pollution control act
- 1970 - anaconda application under pollution control act
- 1970- anaconda app for tailings disposal permit
- 1971 - anaconda application for discharge under pollution control act
- 1973 - application for pollution control permit - note of affluent impact
- 1973 - Cu levels not high enough to affect crustacean larvae
- 1973 - preliminary environmental assessment
- 1974 - discussion of ard treatment plans - pre closure
- 1974 - env canada statement on tailings and ard dumping
- 1974 - environmental progress report
- 1974 - gambier island shrimp assessment for heavy metals
- 1974 - indication there will be no discharges to creek
- 1974 - long term reclamation requirements should include ard management
- 1974 - memo regarding biodiversity and heavy metal testing
- 1974 - mention of what a monitoring program should include
- 1974 - monitoring planning - note of lack of data
- 1974 - pre closure mention of a reclamation plan post closure that accounts for ard
- 1974 - pre closure treatment plans memo - lime tank to be neutralizing tank
- 1974 - reduction in mine water flow would prove difficult
- 1974 - regarding high Cu and Zn levels in oysters
- 1974 - request for opinion on impact of heavy metals and solids
- 1974 - treatment and testing requirements
- 1975 - disc of treatment plant and concern over wooden components in treatment plan
- 1975 - disc on depth of submarine outfall
- 1975 - discussions on final plan for water discharge
- 1975 - PCB anaconda discussion on no plume problem
- 1975 - PCB anaconda notes on no plume problem
- 1975 - preliminary design of water treatment system

1975 - talk of shelving outfall plan

1976 - disc on issues with submarine outfall

1976 - PCB and anaconda discussions on treatment

1976 - pricing of treatment system and future guarentees

1976 estimate for effluent outflow pipe

1976 -min of env request for clarification on treatment plans

1976 mine water disposal project outline

1976 outfall pipe estimate

1977 - min of env pollution requirement order to anaconda

1977 - order for water treatment from ministry and june 1 78 deadline

1977 - PCB and anaconda discussion on permitting

1977 - PCW and andaconda meeting re plug installation and construction

1978 - first monitoring report due march 31 1978

1978 - pics of install of deep water discharge system as per requirements

1978 - pictures of concrete flume installed at 4150 portal

1979 - treatment order updated from 1977

1980 - min of env response to cbe request to assume responsibility for treatment

1981 - treatment order to cbe

1984 - cbe to min of env regarding 2200 portal issues

1984 - min of env to cbe - 2200 outflow puts cbe in noncompliance

1984 - min of env to cbe re 2200 level flows

1985 - cbe to min of env re 2200 level outflow and pollution

1985 - env assessment of britannia mine

1985 - min of env to cbe re discharge from 2200

1985 report describing 2200 portal and blockages

1988 - cbe to ubc re building a wtp

1988 - cbe to ubc request to build experimental wtp

1990 - min of env response to request by cbe for creek stability aid

1991 - cbe noncompliance listing

1991 - report on mine cave stability – pre-flood  
1992 - min of env letter listing non compliance issues  
1992 meeting re cbe noncompliance  
bc gov news release - britannia clean up – 1993  
enviro protection noncompliance report letter 1999  
enviro protection violation 1999  
surface water sampling requirements 1995

### **EXTERNAL REPORTS:**

A Survey of the Benthic Macroinvertebrates Fauna and Solid Pollutants in Howe Sound, 1973

<http://www.dfo-mpo.gc.ca/Library/20924.pdf>

Copper and Zinc Levels in Submerged Mine Tailings at Britannia Beach, B.C., 1974

<http://www.dfo-mpo.gc.ca/Library/23155.pdf>

Proposed Britannia Mine Reclamation and Remediation Project Summary, March 1999:

[http://technology.infomine.com/enviromine/ard/Case%20Studies/reclamation\\_plan.pdf](http://technology.infomine.com/enviromine/ard/Case%20Studies/reclamation_plan.pdf)

Project Report: Achieving Value for Money; Britannia Mine Water Treatment Plant, March 2005:

[http://www.partnershipsbc.ca/pdf/Britannia\\_Value\\_for\\_Money\\_Report\\_March\\_05\\_FINAL.pdf](http://www.partnershipsbc.ca/pdf/Britannia_Value_for_Money_Report_March_05_FINAL.pdf)

Britannia Mine Remediation Project – Integrating Ecological Monitoring With Reclamation Activities

<https://circle.ubc.ca/bitstream/handle/2429/8304/05%20Wernick%20%20final.pdf?sequence=1>

For a more in-depth look at the pollution issues related to Britannia, please see:

Forensic History: Ending Pollution at Canada’s Britannia Mine; Robert G. McCandless P. Geo

<http://www.imhc.co.za/assets/pdf/Robert%20McCandless.pdf>

Factual Record: BC Mining Submission:

[http://www.cec.org/Storage/68/6172\\_98-4-FFR\\_en.pdf](http://www.cec.org/Storage/68/6172_98-4-FFR_en.pdf)

Britannia Contaminated Site Investigation: Stage I Preliminary Site Investigation; URS Norecol  
Dames & Moore Inc.

[http://www.agf.gov.bc.ca/clad/britannia/downloads/reports/tech\\_reports/CSIR\\_britannia\\_stage1\\_PS1.pdf](http://www.agf.gov.bc.ca/clad/britannia/downloads/reports/tech_reports/CSIR_britannia_stage1_PS1.pdf)