PM003

AN ASSESSMENT OF PRINCE COLLIERY EFFLUENTS AND THEIR TREATMENT

Final Report

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under subcontract to:

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1. Introduction

In operation since 1975 by the Cape Breton Development Corporation, the Prince Mine is located on Cape Breton Island at Point Aconi (Map 1). The mine site is surrounded by the ocean which receives discharges via two drainage basins, Coal Hollow Brook and Jim MacDonald's Brook. A third discharge from the site is the underground mine water which is pumped to the surface directly at Point Aconi.

Dearborn Environmental Group was retained by Devco to develop treatment options for these three discharges. Boojum Research Limited assessed the site under subcontract to Dearborn to determine whether Ecological Engineering measures could be used to improve the site conditions.

In order to select the most suitable treatment option to meet the regulatory requirements, the environmental conditions of the site and the discharge characteristics had first to be determined and appreciated. Treatment options must address environmental considerations not only during operation of the mine site, but also at the time of shut down of the mine.

2. Methods

Boojum Research carried out two field trips. One sampling campaign addressed the underground workings to determine the characteristics and origin of the mine discharge water. The underground samples were collected on March 3, 1992.

All available historical water quality data and mine working records were used to assess mine water composition and potential changes in its quality with time. The BALANCE program of geochemical calculations was used to determine the probable mixing ratios of sea water/fresh water.

A second sampling campaign addressed surface water from contaminant sources and water discharging to the ocean from all major drainage basins. Water was collected for metal analysis and determination of acidity and alkalinity. Water sampling included the determination of location flows. This field trip was carried out on May 11, 1992. Flows were determined with a Monteray Whitney velocity meter. The cross sections were measured at intervals of 10 cm in width and 5 to 10 cm in depths.

All surface water samples were analyzed for their elemental composition and the nutrient content unfiltered by Dearborn Environmental Services. The underground water samples were filtered through 0.45 um and acidified with nitric acid prior to chemical analysis and were analyzed by XRAL laboratory. Anion/cation balances were used as a QA\QC check on the analytical results as unfiltered samples frequently produce erroneous results due to the presence of particulates. Acidities and alkalinities were determined in the Boojum laboratory using a Brinkmann autotitrator TITRINO.

3. Results and Discussion

As there are essentially three different discharges from the Prince Mine operations, several treatment perspectives could be explored. Dearborn Environmental has considered the option of collecting all three discharges together and providing one central treatment plant, using lime neutralization. Those findings are reported under separate cover.

Large effluent volumes require space for settling ponds and storage for sludge. Space for such retention structures is sparse in the vicinity of the Prince Mine waste rock pile, either for conventional treatment or for Ecological Engineering. Biological processes require a full season's water retention in either a single large containment or several large areas where various retention structures can function in sequence.

To assess the viability of biological treatment, we therefore addressed the contaminant sources separately, reducing the effluent volume for each location.

The acid mine drainage from the waste rock pile reports to a collector ditch through bush. The collector ditch is located adjacent to the sewage lagoon. Here, it was decided to seek a solution by reducing the seepage volume reaching the collector ditch.

The East Tunnel effluent (also referred to as the Water Level), is located directly behind a dwelling. At this location, it was thought that treatment options could be applied directly into the bootleg workings. For the mine water, treatment in the underground workings prior to discharge to the ocean seemed to be the reasonable choice.

3.1 The underground mine water

In Map 2, the water sampling locations covered the area underground around the central sump and other seepage collection points and the inactive workings. In Table 1, the elements listed are present in concentrations above the analytical detection limit, namely 0.01 mg/L. The complete analytical results are enclosed in Appendix 1. In Table 2, the sample site description is given for all of the underground samples taken on March 3, 1992, including intake and outflow water from the East Tunnel.

When the elemental composition of the mine discharge water is compared to that of the samples collected in different locations underground, one notes large differences in the concentrations of aluminum which is 2 x higher in Sample #3 collected in the East low Main, representing running water compared to the discharge. On the other hand, aluminum concentrations in Samples #7 and #8 are 3 to 6 times lower in aluminum concentrations than the mine discharge. Sample #7 was collected from inactive workings in the West bottom of the mine and Sample #8 originated from the sump below 10 West top. In Sample #5, a large difference exists for iron. The discharge concentrations are around 200 mg/l and Sample #5 has only around 50 mg/l of iron. All other underground samples display concentrations higher than 100, but not more than the discharge concentration.

These differences in iron concentrations are due to precipitation processes. Ferric iron hydroxide precipitates at a pH range from 2 to 3. Therefore, if iron precipitation is allowed to proceed underground, lower concentrations can be expected in the mine water discharge. The differences in the concentrations of aluminum are not clear.

In Figures 1a and 1b, the behaviour of the water samples is displayed as they are neutralized with 0.01 N NaOH. These curves represent the amount of hydroxyl ion consumed as the pH is raised in the sample. A significant difference can be noted for Sample #5, where 0.7 mL of 0.01N NaOH brought the sample to pH 7 as compared to 1.4 ml of 0.01 N NaOH which was required to reach the same pH for Sample #6 (Figure 1a). This sample contained much higher concentrations of reduced iron. Reduction in iron concentrations is achieved through iron oxidation, but pH is lowered at the same time.

The electrical conductivities in the underground water range from 60,000 to 29,500 umhos/cm (Table 1). It is clear that along with the concentrations of chloride, the acid mine drainage is mixed with sea water. Sea water or water entering the mine is represented by Sample #4, which has a pH of 6.8 and no acidity (Table 1 and Figure 1a), as indicated by the titration curve of Sample #4.

Sampling sites were determined based on pH and conductivity measurements as the crew walked through the mine workings. Two observations are interesting. At Stations X and X1, (Map 2), the pH values were 5.0 and 4.9, respectively. In retrospect, it was noted that in these locations where the pH was high, field notes indicated the presence of lime dust in the vicinity of the observation points.

In hindsight, it is unfortunate that water samples were not collected at these locations. Water quality may be significantly improved through the application of fire suppressant. Since the application of dolomitic limestone is a regular activity, it should be possible to make use of the lime application distribution system throughout the inactive workings. This would result in better mine water discharge. For the flooded levels where large volumes of water have accumulated behind a bulkhead, it may be possible to use a drip tank of caustic treatment.

In Figure 1b, the titration curves are shown for Sample #8 which, on arrival in the laboratory, had a pH value of 5, an increase from the measured underground pH of 3.9.

The consumption of 0.01 N NaOH, compared to that of the water from the East Tunnel, suggests that only one-third of lime consumption could be expected.

Assuming that the dolomitic limestone applied underground for fire suppression is the cause for the increase in pH values (5.0 and 4.9) observed in sampling locations X and X1, the same may be true for Sample #8. The dolomitic limestone may react slowly, but a significant improvement in water quality might be achieved.

If the water could be retained underground for a longer period to facilitate iron oxidation and hydroxide precipitation, one could expect a stable sludge. This might be achieved through installation of additional storage tanks connected to the existing sumps.

When considering underground treatment, the difficulty of steadily increasing effluent volumes to be expected from the mine must be taken into account. As more void space is created underground, the volume of mine discharge will increase. Figure 2 gives the mine discharge in litres per day since the mine started operating. The details on the manner in which the curves were derived is given in Appendix 2. If it is assumed that the freshwater intake to the mine is to stay at the same ratio as that required during operations, then a progressive increase in mine discharge volume due to the increase in underground void space can be expected. For example, it is reasonable to expect that discharge will increase from 730,000 m^3 in 1990 to just over 1,000,000 m^3 in 1993 (based on mine flow volume available for September 28, 1990 at 1.35 million US gal/week).

The "water making" capacity of the mine workings itself is plotted in Figure 2. Three curves are presented: one representing operating conditions where fresh water and the sea water together make up the flow. The second and third curves represent different ratios of fresh water and sea water, being the flow at the time of decommissioning. The higher percentage of 54% is based on geochemical calculations carried out with the mine discharge water collected on September 28, 1990. Details of the calculations are found in Appendix 2. The lower mixing ratio of 32% fresh water is based on discussions with Prince Mine operators (personal communication Gerrard Shaw, Devco).

Not only will the volume of discharge increase, but its characteristics can be expected to change as the mixing ratio of sea water from unmined areas changes. If the sea water contribution is higher, given its desirable quality (see Sample #4 on Figure 1a and Appendix 1) a better effluent will be apparent. A treatment facility would have to be designed which is capable of handling not only the seasonal differences in effluent volume, but its steady increase as well.

The onset of acid generation is not known. However, from the titration curves (Figures 1a and 1b), the underground oxidation process is occurring slowly. Nearly all underground samples still contain reduced iron which only precipitates around pH 5 to 7. If this water is treated without prior oxidation of iron, the precipitated ferrous hydroxide will continue to oxidize. The oxidation of the ferrous hydroxide proceeds according to the following reaction:

$$4Fe(OH)_2 + 2H_2O + O_2 = 4Fe(OH)_3$$

An unstable sludge, either in a pond on the surface or discharged to the ocean, is less desirable than underground production and storage. Bringing the water to the surface will allow more oxidation to take place, resulting in more acid generation. The oxidation of ferrous iron hydroxide to ferric iron hydroxide is non-acid generating.

If reduced iron is allowed to oxidize, oxidation proceeds according to the following formula:

$$4Fe^{+2} + 10H_2O + O_2 = 4Fe(OH)_3 + 8H^+$$

Although this will result in a reduction of iron concentration due to ferric hydroxide precipitation, it will also decrease the pH. The lower pH AMD will further increase the dissolution of more contaminants. Other elements which contribute to the acidity of the water and hence pH changes are Al and Mn.

At the time of decommissioning, the fresh water contribution to the mine will cease and the volume of potential acid mine drainage water generated underground will be reduced. The flooding of the workings will reduce the acid generation rate, as lower oxygen concentrations prevail in flooded mine workings.

It may be possible to pursue treatment and precipitation of iron underground through installation of additional storage in the vicinity of the existing sumps, accompanied with treatment by either dust suppressant or caustic of the flooded inactive workings.

3.2 The waste rock piles

In Table 3, all flows for the surface water samples are given along with the pH, electrical conductivity and the temperature of the water measured in the field. The time of the field trip in mid-May could be considered the tail end of the 1992 spring run-off. Therefore, it is reasonable to assume that all significant seepages existing on the site were detected during the field investigation.

A survey of the foot of the old waste rock pile failed to identify any sources of acidic seepages or any other seepages. It was therefore concluded that the old waste rock pile is not producing acid mine drainage to the surface water. This is not the case, however, for the new waste rock pile. A total of 4 seeps were discovered, 3 of which seem to be contaminated (A2, A3 and A4). Their respective flows are of 0.18 l/sec, 6.49 l/sec and 0.04 l/sec. Seepage from A4 is essentially a puddle which might dry up completely during the summer. Plate 1 presents the view downstream from B3 and the iron hydroxide precipitation is evident.

In Table 4, the elemental concentrations of those elements above the analytical detection limit are given for the four water samples from the foot of the new waste rock pile. Water at Station A1 appears to be clean water but presents with a flow of 2.6 l/sec (Table 3), one- third of the flow of Station A3 which is downstream. The pH of the water at A1 is 5.5, with a low electrical conductivity of 78 umhos/cm. It clearly dilutes the acid mine drainage generated in its path through the waste rock pile, which produces a pH of 3.3 with elevated zinc, iron and aluminum concentrations at Station A2. The most contaminated seep is Station A4, however, which has the lowest flow with 0.04 l/sec and is essentially a puddle. It can be expected to dry up entirely during the summer.

The conditions of the seeps from the new waste rock pile strongly suggest that diversion of the fresh water source at A1 should be undertaken. This will result in a reduction of the seepage volumes and thus the contaminant loadings to the receiving ditch system at locations A6 to A9 (Map 3). In fact, if the old waste rock pile can serve as an example, no visible acid seepage is created if it is kept dry.

Table 5 gives the elemental composition of the AMD in the collector ditches. The final sampling point for the drainage basin containing the waste rock pile is location A10. After this point, the creek joins Jim MacDonald's Brook which reaches the ocean through Morrison's pond. This sampling Station A10 represents the joint quality of the effluents from the sewage lagoon and the AMD, either seeping through the bush below the New waste rock pile or being collected in the ditches parallel to the sewage lagoon.

Samples A 6 and A 8 are clearly significantly contaminated which may not only be due to receiving waste rock seepage, but also to the coal debris in the collector ditch.

A comparison of the water quality and the flows between Stations A9 and A10 should show whether other contaminant loadings emerge from the drainage basin containing the waste rock pile. All reported elemental concentrations are essentially the same (Table 5) between these two stations and the flows represent a slight increase, from 14.7 l/sec to 20 l/sec. This suggests that no other significant seepages enter from the bush into the creek.

From the titration curves presented in Figures 3a and 3b, three types of surface water exist. They represent different degrees of dilution with fresh water. (Note the difference in scale between Figure 3a and 3b).

The flow path of all the surface waters in this drainage basin is as follows. Run-off during the spring from A11 enters a ditch which flows via station A5 to join up with A6 in one stream. This stream then receives effluent from the sewage lagoon at Station A7 and, on the other side, is joined by A8. These combined streams result in the water of A9.

In Table 5a, acidity and alkalinity are summarized from all those samples which have very low acidities and also have alkalinities. It is noted that water from A11 has a very low acidity. When the field and laboratory pH's are compared, they rise from 3.89 (Table 3) in the field to 5.5 in the laboratory (Table 5a). Such changes can be expected in carbonate rich waters. The highest value of this group of low acidity water is B2, which represents the yard run-off from the Prince Mine pit, entering the East Tunnel.

The water has a higher pH similar to the drainage from drainage basin C1 on the East side of the Point Aconi peninsula (Map 3). The low acidity samples are arranged in Table 5a by decreasing acidity. Alkalinity in these waters can generally be expected from either carbonate or ammonia. It is suggested, therefore, that the ditching system be altered.

The flow during spring run-off should go into the East Tunnel which would reduce the flows during spring run-off to Station A9, thereby eliminating any flow in the ditch with Station A5. As these ditches are loaded with coal, it would reduce the production of contaminated water. The water from A11 originates from the bush outside of the Prince Mine pit. Further improvement could be achieved by diverting A1, the fresh water input to the waste rock pile, as discussed above.

3.3 Jim MacDonald's Brook and Morrison's Pond

The drainage basin in which the waste rock piles is located is about 47 ha and is a sub-drainage which is located within a much larger drainage basin of MacDonald's Brook, covering an area of approximately 190 ha (Ao and A, Map 3). At Station A12, the brook represents all of the drainage entering Morrison's Pond. The view towards Morrison's Pond from Station A12 on the road above the culvert, is given in Plate 2. It is evident from the country-side that it is impossible to define a good channel to determine flow. The measured flow of 17 l/sec (Table 3) will, therefore, only represent part of the flow.

Morrison's Pond is depicted in Plate 3. It is populated by submerged semi-aquatic vegetation, dominated by Riverbank Quillwort (Isoetes riparia ex. A. Brown). Although it appears that Jim MacDonald's Brook is the main source of water to Morrison's Pond, it could be said that the discharge from Station A10 represents the main contaminant source to the pond. However, at least 2 other main flows enter Morrison's Pond on the east side, designated as Stations A14 and A15. In order to improve the final discharge to the ocean or the conditions in Morrison's Pond, the relative improvement which could be achieved through improvement of the water leaving the waste rock pile drainage basin at Station A10 should be evaluated.

Table 6 presents a summary of those elements which were present in significant concentrations. The complete analytical results are included in Appendix 1. A comparison of the concentrations of iron and sulfur in A13 and A14 to A12 (representing those concentrations entering Morrison's Pond from Jim MacDonald's Brook and the effluents from the Prince Mine waste rock pile) suggests that A12 has generally lower concentrations than the outflow of Morrison's Pond. In fact, the concentrations of most elements present are in the same or higher range (Figure 4).

Figure 4 includes the elemental concentrations of Station A10 and it is clear that these waters are quite similar. The concentrations of A10 are generally in the middle range of concentrations of A15 and A16.

In Plate 4, seepage A16 is depicted, entering the ocean some 100 meters to the north of the outflow of Morrison's Pond (A15). The seep emerges directly out of the cliff. Given that the flows from these stations is not insignificant, with 27.5 l/sec and 6.5 l/sec, respectively, they should be treated if treatment is required for Station A9. With the recommended rerouting of the surface waters, it can be expected that Station A9 will improve, but only a slight improvement can be expected for Morrison's Pond and, therefore, to the discharge to the ocean.

It is likely that a coal seam is the source of the seepage, and this may'or may not be mined. At this point however, it is not possible to connect these contaminant sources to the Prince Mine. Generally, it is expected that during spring run-off, acid water is not only due to the coal seams, but could also be due to atmospheric fall-out, i.e. acid rain and coal dust which is probably dispersed. In Plate 5, snow is depicted in the pit of the Prince Mine, suggesting that coal dust might indeed be quite mobile. Dust control measures in the Prince Mine pit should be considered to reduce coal dust loading to the drainage basins.

3.4 The Water Level or the East Tunnel discharge

In Table 7, the water characteristics for the outlet from the East Tunnel (B3) and the inlet (B2 and B1) are presented for all dates where data are available. With the exception of the water collected on May 11 in the inlet (B2, Map 3), the elemental concentrations of Iron, Cl, Al, Mn, Mg as well as S and Zn are changing over this short time period sampled.

The May 11 sample likely represents dilution by yard run-off. However, although the sample set is small, seasonal changes in this effluent can be expected as the contribution from the Prince Mine pit will depend on rain, whereas the AMD generated in the Tunnel will be constant. B1 sampling station is located about 100 m into the Tunnel. The flow measurement at that location and on the outflow (B3) indicate that the Turlnel is " making water", increasing at the outflow to 5.5 l/sec from 1.2 l/sec inside the Tunnel (Table 3).

It appears that sea water is a minor contributor, as indicated by the relatively low electrical conductivities and the low sodium chloride concentrations. It is suggested that the water contributions is infiltrations from the fields above the Tunnel. Evidence for infiltrating water from the surface is also given by the ammonia concentrations noted in B1 and B3 which are compared to B2, the run-off from the Prince Mine Pit 0.44 mg/L; 0.46 mg/L and 0.08 mg/L, respectively.

Given the presence of dwellings in the area around the Tunnel discharge, this is not surprising. The selection of water treatment options for the East Tunnel should be based on a complete sampling throughout all seasons. As the volume of discharge can also be expected to fluctuate, both the water quality of the effluent and the volume discharged should be monitored prior to the selection to the treatment options.

In Figure 3a, the titration curves for the East Tunnel have been presented in comparison to those of the A drainage basin, containing the waste rock seepage. It is evident that the water from the East tunnel is lower in neutralization requirements compared to the A4 seepage from the waste rock pile (A2 and A4). Compared to all other surface waters however, East Tunnel AMD is stronger than most A waters.

In Table 8, the East Tunnel water samples are presented, together with those samples collected downstream in the drainage basin and those from other drainage basins discharging to the ocean from the Point Aconi peninsula. The sampling locations for the drainage basins are given in Map 3.

An abandoned coal pit, associated with a small waste rock pile is located just slightly above the East Tunnel discharge. In Plate 6, the abandoned workings are shown, below which seepage at B5 was collected. B4 water represents the water of Coal Hollow Brook, above both the East Tunnel discharge and discharge of B5 to the brook. B6 is that water quality entering the ocean. The samples collected at the end of three drainage basins, C, D and E, (considered "background drainage basins") can be compared to the water sampled directly below the Prince Mine discharge at the shore (O5). Drainage basin C does contain reclaimed old mine workings, indicated by the high sulfur concentrations and the higher Fe and Mg concentration.

In effect, the definition of background concentrations is difficult. It is possible that D1 drainage and B4 water represent undisturbed fresh water conditions.

If improvement in the East Tunnel drainage can be achieved through the addition of A11 run-off, particularly during spring and fall, the contaminant loading and environmental impact on Coal Hollow Brook might be reduced. However, this can only be determined with a complete sampling program covering an entire year and with the A11 diversion in place.

The results and recommendations given in this paper arise from one sampling campaign. The surface water samples were analyzed unfiltered to represent prevailing conditions in the stream. Although these values represent the environmental conditions and the true discharge, whole samples can frequently produce unusually high numbers for some elements, due to particulate matter. QA\QC evaluations can be carried out through a complete cation/ anion balance, which is presented in Table 9. The largest errors are noted in the relatively clean waters and more so in those which have some alkalinity. On the other hand, the clean water samples are also those where error contribution is greatest, due to the analytical detection limit. The errors presented in Table 9 indicate that although only one surface sample campaign is used to arrive at the recommendations, the analytical results are very reliable.

As a final evaluation of the relativity of the environmental impact of the Prince Mine discharge from all three contaminant discharges, loadings to the ocean from all the brooks and creeks from the Point Aconi peninsula have been derived for those elements which might be of environmental concern. Table 10 presents the results.

From an environmental point of view, it is immediately evident that the loadings from the Mine Discharge are high for aluminum, iron, sulfur, magnesium and manganese when compared to the loadings of the other drainage basins. Average metal concentrations from all samples reported in Table 1 were used with the flow of 750,000 l/day, reported for September 28, 1990 for the calculation of the mine discharge loadings. The loadings for the other drainage basins were calculated using the concentrations determined and the flows reported in Table 3. The contaminant loadings from A15 and A16 are similar to B6 but they are lower than those from the drainage basin in which open cast mining is carried out.

4. Conclusions and Recommendations

The results from the surface water and underground water examination lead to the conclusion that the only significant effluent is the mine water discharge. Dilution in the ocean is great and immediate as indicated by Sample 05 (Table 8) which was collected on the shore below the discharge point. The treatment options selected should be based on the impact of the discharge of the same tonnages in the form of sludge and evaluated against the impact of the dilution which takes place in the ocean.

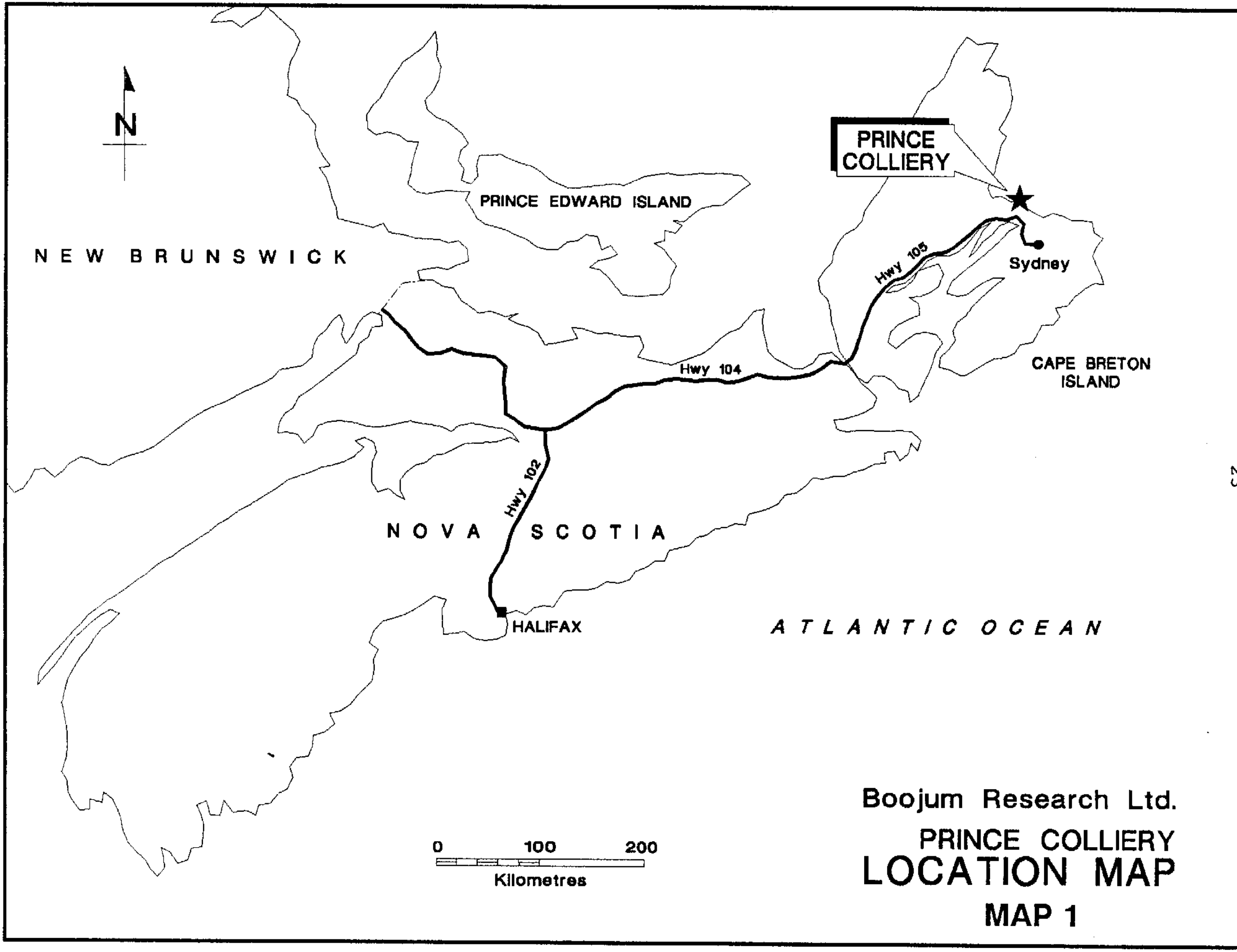
It should be noted that although some elements represent a significant load to the environment, metal loadings, the main cause of concern, are relatively low. The environmentally best solution would clearly be underground treatment.

It is recommended that tests be carried out with lime applications in the same fashion as fire suppressant. The neutralization for the seepages emerging from inactive flooded workings should be considered. This would result in immediate improvement of the mine water discharge.

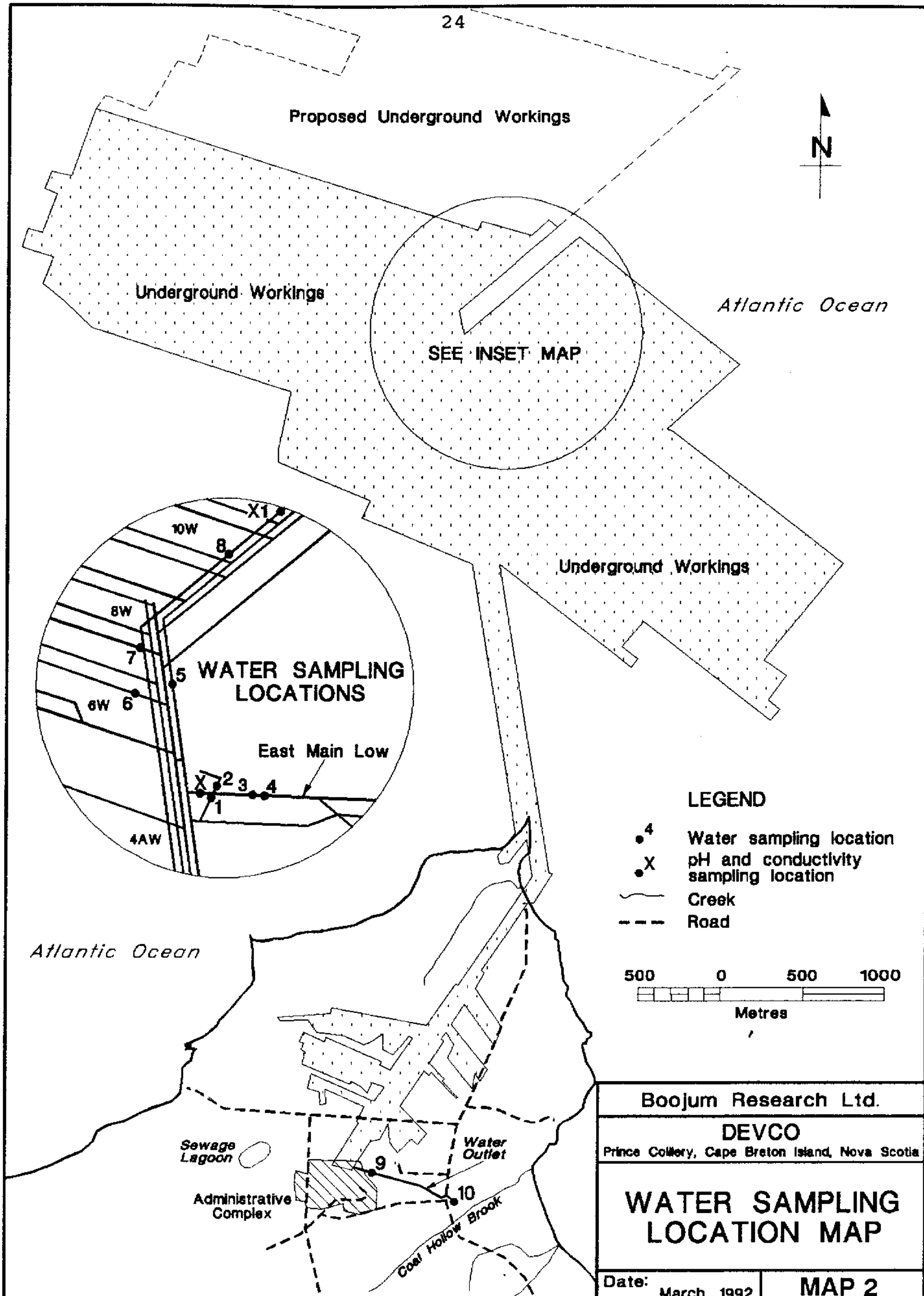
The conditions at the foot of the new waste rock pile lead to the conclusion that, through the diversion of the fresh water away from the pile, the seepage from the pile can be significantly reduced. This would result in improved conditions at Station A10. The old waste rock pile serves as an example. There are no water sources in the vicinity of the pile and hence no seepage is evident.

The data collected with respect to the East Tunnel are insufficient for the selection of a treatment option, since the flows and the seasonal variation in AMD characteristics are not known. However, it can be concluded that although phosphate rock was considered, based on bench scale work presented in the proposal, most of the iron in the Tunnel is reduced, which makes phosphate rock ineffective as an option. Even at the point of discharge into the ocean, iron oxidation has not progressed. The most environmentally effective option therefore,would be to consider neutralization in the East Tunnel. As it is recommended to divert the clean water run-off from location A11 into the East Tunnel, this measure should be taken as a first step. A slight improvement might be noted, at least as long as A11 water is available. Some iron and aluminum can be expected to precipitate in the Tunnel due to the mixing of the flows. This would result in improvements during periods of high flows. Monitoring of the effluent characteristics and the flows should be carried out over one full year.

Ecological Engineering measures for the site are not suggested at this point since significant improvements in the effluent are to be expected through the diversion of the water and reduction of seepages, and they are not suitable for the underground and the East Tunnel discharges.



Boojum Research Ltd.
PRINCE COLLIERY
LOCATION MAP
MAP 1



Boojum Research Ltd.

DEVCO

Prince Colliery, Cape Breton Island, Nova Scotia

WATER SAMPLING LOCATION MAP

Date: March, 1992

MAP 2

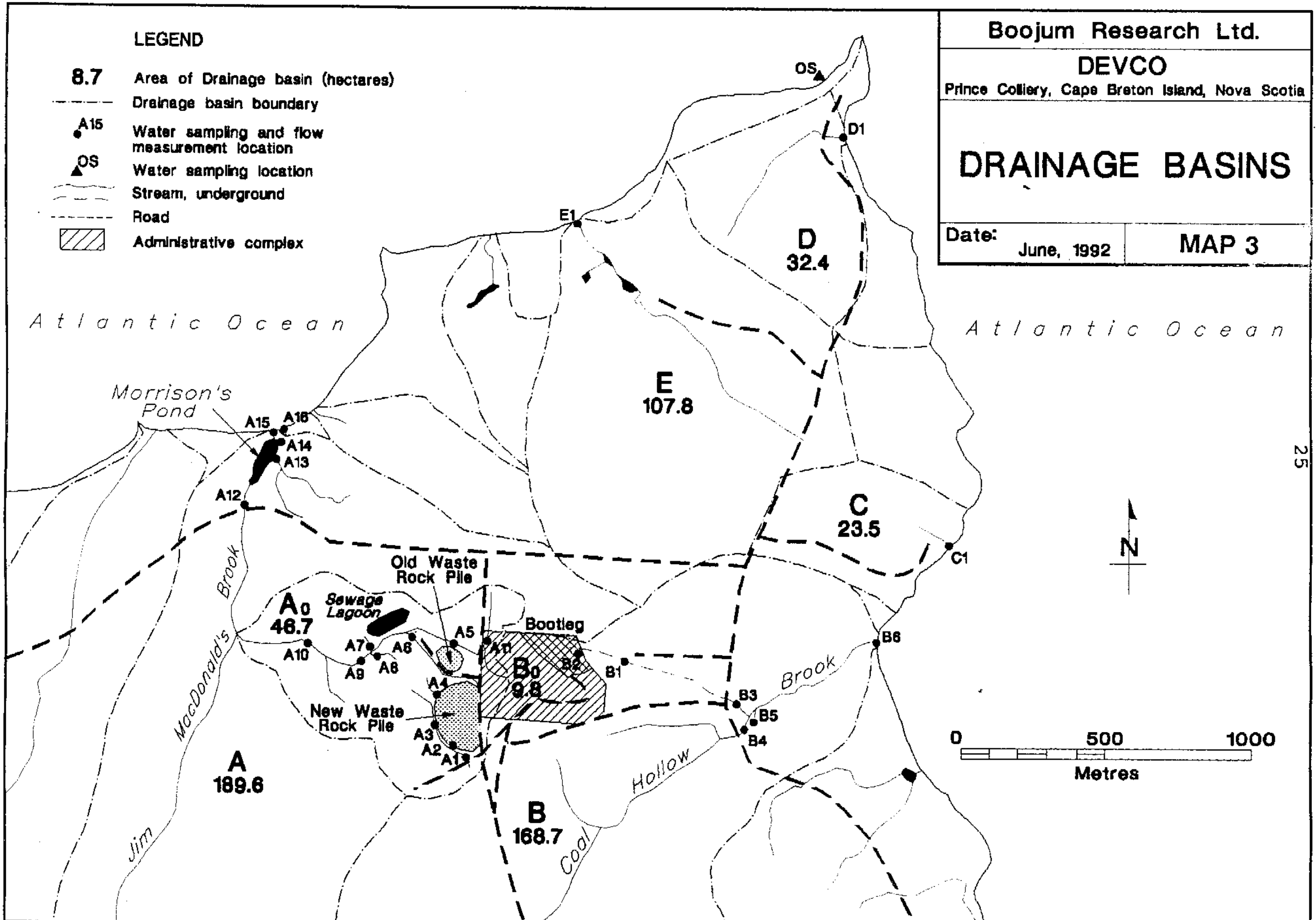

Boojum Research Ltd.
DEVCO
Prince Colliery, Cape Breton Island, Nova Scotia
DRAINAGE BASINS
Date: June, 1992
MAP 3
LEGEND
8.7 Area of Drainage basin (hectares)
Drainage basin boundary
A15 Water sampling and flow measurement location
OS Water sampling location
Stream, underground
Road
Administrative complex
Atlantic Ocean
Atlantic Ocean
Morrison's Pond
A15
A16
A14
A13
A12
E1
OS
D1
D
32.4
E
107.8
C
23.5
C1
N
Old Waste Rock Pile
Sewage Lagoon
A0
46.7
A5
A7
A6
A10
A9
A8
A11
Bootleg
B0
9.8
B2
B1
A4
New Waste Rock Pile
A3
A2
A1
B3
B5
B4
B6
Brook
MacDonald's Brook
Jim
A
189.6
B
168.7
Coal Hollow
0
500
1000
Metres

Table 1: Underground Water Samples

Source	Devco	Dearborn	Dearborn	Boojum	Boojum	Boojum	Boojum	Boojum	Boojum	Boojum
Sample ID		Discharge #1 composite	Discharge #1 grab	#1 3633	#2 3634	#3 3635	#5 3637	#6 3638	#7 3639	#8 3640
pH	2.7	2.6	2.8	3.13	3.15	3.2	2.96	3.52	4.02	3.94
Conductivity	29500	33800	36200	37300	30300	36600	38100	33700	60000	46700
Chloride (Cl)	8340	12000	12600	12100	12500	13000	13600	17350	25900	15200
Aluminum (Al)	19.4	24.3	19.6	26.2	11.8	43.2	21	14.7	7.6	2.8
Arsenic (As)		<0.069	<0.069	<0.03	<0.03	<0.03	0.1	<0.03	<0.03	0.08
Calcium (Ca)	1160	1600	1660	1620	1720	1700	1650	1980	3710	1970
Cobalt (Co)	<0.1	0.573	0.673	0.67	0.55	1.31	0.42	0.96	1.15	0.81
Copper (Cu)	0.05	0.09	0.011	0.2	0.1	0.11	0.07	0.03	0.02	0.02
Iron (Fe)	107	203	206	173	133	131	51.6	209	153	100
Lead (Pb)	<0.5	0.08	0.04	0.35	0.17	0.12	0.26	0.25	0.28	0.1
Magnesium (Mg)	550	671	720	650	658	745	538	902	135	775
Manganese (Mn)	28	27.6	26.9	35.9	36.1	47.1	24.5	36	46	27.6
Nickel (Ni)	<0.2	1.23	1.28	1.73	1.3	2.45	0.97	2.45	2.67	1.78
Phosphorus (P)	<0.01	<0.03	<0.3	0.2	0.2	0.2	0.1	0.2	0.4	0.2
Pottasium (K)	59	80.9	103	78	87.6	80.6	83.7	147	226	148
Sodium (Na)	4520	5510	5940	5180	5380	5440	6050	7050	9370	6350
Sulphur (S)				600	577	713	483	603	490	497
Strontium (Sr)		22.6	23.2	25.8	28.4	26.4	27.1	32	63.3	34.6
Zinc (Zn)	3.86	3.76	2.56	3.21	7.72	7.22	6.26	2.98	3.43	2.79

Conductivity in umhos/cm, elements in mg/L

Table 2: Underground Water Sample Site Description

Sample #	Description	pH	Conduct. umhos/cm	Temperat. C
1	Last sump	3.13	37300	10.5
2	6th slope below East Low Main sump below tanks	3.15	30300	10.5
3	East Low Main, 200 feet in past sump towards Exploratory flowing water	3.2	36600	8.6
4	Drop sample from ceiling with no working above	6.8	(**)	(*) 17
5	Sump on 2nd 5th slope above to Exploratory	2.96	38100	12.2
6	6th West bottom, flooded level	3.5	33700	11.5
7	West bottom, closed workings	4.02	60000	14.4
8	Sump below 10 West Top	3.94	46700	13.6
9	East Tunnel, water level intake (Bootleg)	2.9	2980	(*) 18
10	East Tunnel, outflow (Bootleg)	2.9	2240	18

(*) - measured in laboratory 24h after sampling
(**) - volume of sample to small for measurement

Table 3: Flows, pH, Conductivity, Temperature at all Water Sampling Stations

Location	Flow		pH	Cond	Temp
	l/sec	l/min		umhos/cm	C
A 1	2.64	158.4	5.54	78	11.3
A 2	0.18	10.8	3.33	3270	11.7
A 3	6.49	389.4	4.81	273	9.5
A 4	0.04	2.4	2.68	7070	15.2
A 5	6.15	369.0	5.28	172	13.3
A 6	4.38	262.8	2.68	2300	13.5
A 7	3.42	205.2	7.47	270	13.2
A 8	8.60	516.0	3.15	799	7.5
A 9	14.70	882.0	3.59	486	12.7
A 10	20.64	1238.4	3.5	453	13.3
A11	10.00	600.0	3.89	136	10.1
A12	16.92	1015.2	4.2	170	6.5
A13	2.63	157.8	2.9	911	7.5
A14	4.12	247.2	2.5	1040	6.5
A15	27.57	1654.2	3.41	347	7.9
A 16	6.47	388.2	2.7	906	5.8
B 1	1.21	72.6	2.91	3280	13.9
B 2	0.11	6.6	5.77	1600	15.7
B 3	5.46	327.6	3.02	2920	13.4
B 4	90.97	5458.2	5.82	1153	11.7
B 5	0.18	10.8	4.16	530	13.2
B 6	27.90	1674.0	4.1	280	15.9
C 1	0.80	48.0	5.6	2080	15.7
D 1	6.09	365.4	6.3	148	14.9
E 1	22.90	1374.0	6.6	400	14.7

Table 4: Water Samples around New Waste Rock Pile

Source	Boojum	Boojum	Boojum	Boojum
Sample ID	A-1 3737	A-2 3738	A-3 3739	A-4 3740
pH	5.54	3.33	4.81	2.68
Conductivity	78	3270	273	7070
Chloride (Cl)	7.8	33	5.4	188
Aluminum (Al)	0.43	46.3	2.61	2.75
Arsenic (As)	<0.069	<0.069	<0.069	<0.069
Calcium (Ca)	6.71	130	10.2	410
Cobalt (Co)	<0.009	0.522	0.024	3.273
Copper (Cu)	<0.006	0.061	0.007	1.67
Iron (Fe)	0.765	300	21.6	310
Lead (Pb)	<0.039	<0.039	<0.039	0.086
Magnesium (Mg)	1.4	82.6	4.47	380
Manganese (Mn)	0.241	72.5	3.84	230
Nickel (Ni)	0.02	0.99	0.05	6.1
Phosphorus (P)	<0.3	<0.3	<0.3	<0.3
Pottasium (K)	1.5	4.87	1	0.826
Sodium (Na)	6.01	41.1	5.2	245
Sulphur (S)	3.7	747	30.9	1963
Strontium (Sr)				
Zinc (Zn)	0.032	0.818	0.063	23

Conductivity in umhos/cm, elements in mg/L

Table 5: Seepage Receiving Ditch

SAMPLE DATE	11-May-92	11-May-92	11-May-92	11-May-92	11-May-92	11-May-92	11-May-92
SAMPLE VOLUME	100	100	100	100	100	100	100
ASSAYERS CODE	3741	3742	3743	3744	3745	3746	3747
SAMPLING LOCAT.	PRINCE	PRINCE	PRINCE	PRINCE	PRINCE	PRINCE	PRINCE
	DB-A	DB-A	DB-A	DB-A	DB-A	DB-A	DB-A
	A-5	A-6	A-7	A-8	A-9	A-10	A-11
	stream	stream	stream	stream	stream	stream	stream
Processing code	WH	WH	WH	WH	WH	WH	WH
pH	5.28	2.68	7.47	3.15	3.59	3.5	3.89
Cond. (umhos/cm)	172	2300	270	799	486	453	135.9
Al	2.48	46.7	1.15	12.3	6.05	6.07	0.2
Ca	10.1	109	20.4	31.3	27.7	23.3	2.54
Fe	5.22	160	1.92	6.77	3.42	3.68	0.147
K	1.18	5.18	4.61	1.18	1.45	1.35	5.1
Mg	2.91	51.1	4.62	17	11.8	10	1.01
Mn	0.878	20.3	1.5	11	6.89	6	0.324
Na	9.52	32.4	23.1	11.4	15.4	12.5	6.33
S	7.7	380	8.3	107	61.3	52.3	4
Zn	0.122	2.77	0.092	1.09	0.576	0.494	0.029
Chloride (Cl)	13	24	27	8.8	16	12	10
TDS	110	1640	180	390	330	280	80
Nitrate (NO3)	<0.1	<5	1.2	<0.1	0.2	0.1	<0.1
Ammonia (NH3)	0.04	0.11	0.09	0.07	0.08	0.12	<0.01
SO4	23	1140	25	320	184	157	12

Table 5a: Low Acidity Waters (in mg/L CaCO3)

	pH	Acidity	Alkalinity
B2	6.8	62.5	4
C1	7.25	52.5	9
B6	4.8	34	N.A.
B5	4	31	N.A.
O5	7.3	20	10
A12	4.8	19	0.2
E1	5	16	N.A.
A11	5.7	12.5	0.35
A1	6.9	10.5	4
A7	7.9	7	7
D1	7.9	3	2

N.A. - not applicable

Table 6: Drainages around Morrison's Pond

SAMPLE DATE	11-May-92	11-May-92	11-May-92	11-May-92	11-May-92
SAMPLE VOLUME	100	100	100	100	100
ASSAYERS CODE	3748	3749	3750	3751	3752
SAMPLING LOCAT.	PRINCE	PRINCE	PRINCE	PRINCE	PRINCE
	DB-A	DB-A	DB-A	DB-A	DB-A
	A-12	A-13	A-14	A-15	A-16
	stream	stream	stream	stream	seepage
Processing code	WH	WH	WH	WH	WH
pH	4.2	2.9	2.5	3.41	2.7
Cond. (umhos/cm)	170	911	1040	347	90.6
Al	1.66	7.67	7.8	2.58	6.68
Ca	8.5	19.4	24.1	10.5	23.8
Fe	0.993	10.6	14.1	2.74	19.4
K	1.44	0.55	3.7	1.88	0.66
Mg	3.52	7.93	10.6	4.5	10.1
Mn	1.75	2.84	3.99	1.94	3.75
Na	9.24	9.36	11.8	10.3	12.7
S	16	76	85.7	28	84
Zn	0.161	0.24	0.361	0.162	0.336
Chloride (Cl)	12	12	16	15	15
TDS	130	360	390	160	380
Nitrate (NO3)	0.1	0.2	0.2	0.1	0.1
Ammonia (NH3)	0.12	0.07	0.15	0.01	0.13
SO4	48	228	257	84	252

Table 7: East Tunnel Water Quality

Source	Devco	Dearborn	Boojum	Boojum	Boojum	Boojum	Boojum
Sample ID	Outlet	Outlet	Inlet	Outlet	Inlet	Between	Outlet
			3641	3642	3754	3753	3755
	5-Jun-91	Feb-92	3-Mar-92	3-Mar-92	11-May-92	11-May-92	11-May-92
pH	2.6	2.7	2.91	2.94	5.77	2.91	3.02
Conductivity	3070	2570	2980	2240	1600	3280	2920
Chloride (Cl)	145	190	350	420	105	165	165
Aluminum (Al)	65.46	21.9	34.3	48.6	1.14	43.3	47.3
Arsenic (As)	1.09	<0.069	0.13	0.07	<0.069	0.194	<0.069
Calcium (Ca)	227.7	105	217	203	192	208	164
Cobalt (Co)	0.32	0.119	0.25	0.23	0.048	0.301	0.244
Copper (Cu)	0.03	0.022	0.13	0.1	0.007	0.108	0.049
Iron (Fe)	269.9	83.6	299	282	25.4	300	160
Lead (Pb)	0.38	<0.039	0.15	0.16	<0.039	0.119	<0.039
Magnesium (Mg)	85.51	30.5	60.8	62	35.1	69.8	55.8
Manganese (Mn)	30.34	10.3	24.2	22	6.73	29.3	22.8
Nickel (Ni)	0.76	0.24	0.61	0.58	0.1	0.67	0.56
Phosphorus (P)		<0.3	0.6	0.6	<0.3	1.1	<0.3
Pottasium (K)		3.44	13.9	9.4	5.72	7.35	4.91
Sodium (Na)		402	257	136	73.3	14.1	120
Sulphur (S)			520	517	214	603	473
Strontium (Sr)		0.334	0.82	0.69			
Zinc (Zn)	2.24	0.966	1.69	1.93	0.271	2.01	1.91

Conductivity in umhos/cm, elements in mg/L

Table 8: Drainages into Coal Hollow Brook

SAMPLE DATE	12-May-92	12-May-92	12-May-92	12-May-92	12-May-92	12-May-92	12-May-92	12-May-92	12-May-92	12-May-92
SAMPLE VOLUME	100	100	100	100	100	100	100	100	100	100
ASSAYERS CODE	3753	3754	3755	3756	3757	3758	3759	3760	3761	3762
SAMPLING LOCAT.	PRINCE	PRINCE	PRINCE	PRINCE	PRINCE	PRINCE	PRINCE	PRINCE	PRINCE	PRINCE
	Tunnel	DB-B	DB-B	DB-B	DB-B	DB-B	DB-C	DB-D	DB-E	Ocean
	B-1	B-2	B-3	B-4	B-5	B-6	C-1	D-1	E-1	O-5
	stream	stream	stream	stream	seepage	stream	seepage	stream	stream	shore
Processing code	WH	WH	WH	WH	WH	WH	WH	WH	WH	WH
pH	2.91	5.77	3.02	5.82	4.16	4.1	5.6	6.3	6.6	7.2
Cond. (umhos/cm)	3280	1600	2920	115.3	530	280	2080	148	400	
Al	43.3	1.14	47.3	0.45	1.32	1.82	0.057	0.39	1.25	5.76
Ca	208	192	164	7.83	32.6	13.1	256	8.92	26.7	310
Fe	300	25.4	160	1.32	2.3	6.69	13.3	1.07	2.49	14.1
K	7.35	5.72	4.91	1.13	1.64	0.94	13.5	1.41	1.76	310
Mg	69.8	35.1	55.8	2.31	8.37	4.15	131	2.81	10.2	950
Mn	29.3	6.73	22.8	0.253	7.01	1.08	47.3	0.36	7.57	0.759
Na	14.1	73.3	120	9.98	25.8	14.3	20.5	12.1	9.28	7900
S	603	214	473	7.7	47.7	24.7	407	5.7	44.7	678
Zn	2.01	0.271	1.91	0.024	0.118	0.085	0.159	0.012	0.154	0.134
Chloride (Cl)	165	105	165	16	50	21	14	17	12	15400
TDS	2640	1230	2300	88	310	180	1900	110	240	41600
Nitrate (NO3)	<5	<5	<5	<0.1	1.1	<0.1	<5	<0.5	0.2	<25
Ammonia (NH3)	0.44	0.08	0.46	0.01	0.36	0.05	0.52	0.03	0.31	0.28
SO4	1810	643	1420	23	143	74	1220	17	134	2034

Table 9: QA/QC Calculations for Whole Water Samples

Station	Cation +charge	Anion -charge	Diff.	Ratio	Error%
A-1	0.85	0.49	0.37	1.8	27.3
A-2	39.14	47.71	-8.57	0.8	-9.9
A-3	2.72	2.12	0.61	1.3	12.6
A-4	119.06	128.06	-9.00	0.9	-3.6
A-5	1.79	0.88	0.91	2.0	33.9
A-6	25.86	24.46	1.39	1.1	2.8
A-7	2.82	1.39	1.43	2.0	33.9
A-8	5.67	6.95	-1.28	0.8	-10.1
A-9	4.20	4.37	-0.17	1.0	-1.9
A-10	3.68	3.66	0.03	1.0	0.4
A-11	0.66	0.57	0.10	1.2	7.8
A-12	1.47	1.38	0.08	1.1	3.0
A-13	3.58	5.13	-1.54	0.7	-17.7
A-14	4.47	5.84	-1.37	0.8	-13.3
A-15	1.91	2.21	-0.31	0.9	-7.5
A-16	4.53	5.71	-1.18	0.8	-11.5
B-1	44.52	42.50	2.02	1.0	2.3
B-2	17.57	16.39	1.18	1.1	3.5
B-3	32.88	34.27	-1.39	1.0	-2.1
B-4	1.18	0.97	0.21	1.2	9.7
B-5	4.02	4.43	-0.41	0.9	-4.8
B-6	2.25	2.17	0.08	1.0	1.8
C-1	27.28	25.85	1.43	1.1	2.7
D-1	1.36	0.87	0.49	1.6	21.8
E-1	3.18	3.17	0.02	1.0	0.3
O-5	446.52	477.41	-30.89	0.9	-3.3

Table 10: Contaminant Loadings to Ocean (tonnes/year)

Location	Al	As	Co	Cu	Fe	Mg	Mn	Ni	S	Zn
A-15	2.24	<0.06	0.018	0.01	2.38	3.91	1.69	0.052	24.34	0.141
A-16	1.36	<0.01	0.01	0.003	3.96	2.06	0.77	0.024	17.14	0.069
B-6	1.60	<0.06	<0.01	<0.001	5.89	3.65	0.95	0.026	21.73	0.075
C-1	0.001	<0.002	0.004	<0.001	0.34	3.30	1.19	0.005	10.27	0.004
D-1	0.07	<0.01	<0.002	<0.001	0.21	0.54	0.07	0.004	1.09	0.002
E-1	0.90	<0.05	0.038	0.005	1.80	7.37	5.47	0.072	32.28	0.111
Mine Discharge	5.08	0.005	0.190	0.019	39.08	169.05	8.95	0.423	150.86	1.167

Fig. 1a: Prince Mine Water Titration
Sampled on March 3rd,1992

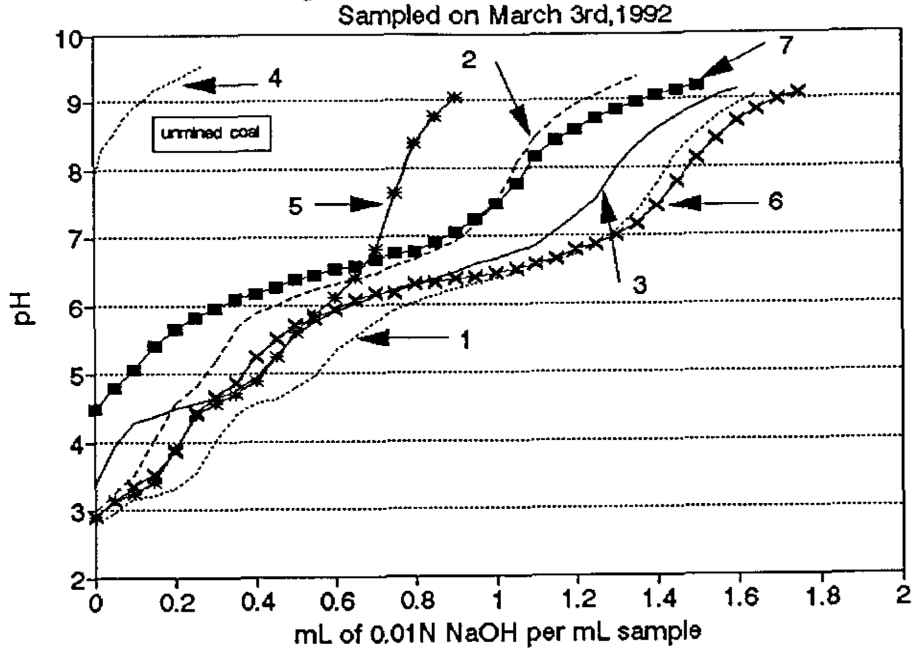


Fig. 1b: Prince Mine Water Titration
Sampled on March 3rd,1992

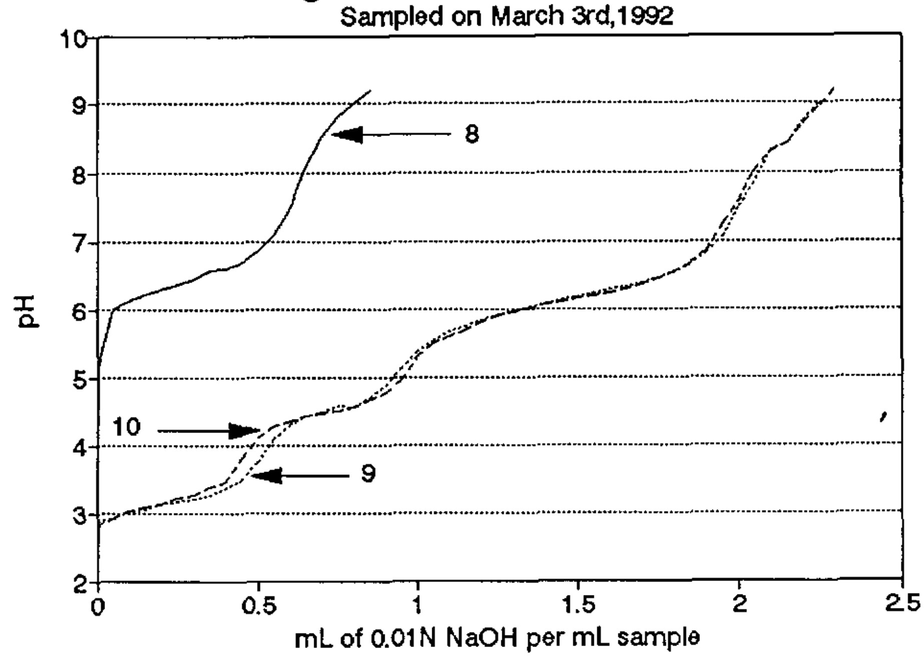


Fig. 2: Prince Mine, N.S.
Cumulative Discharge

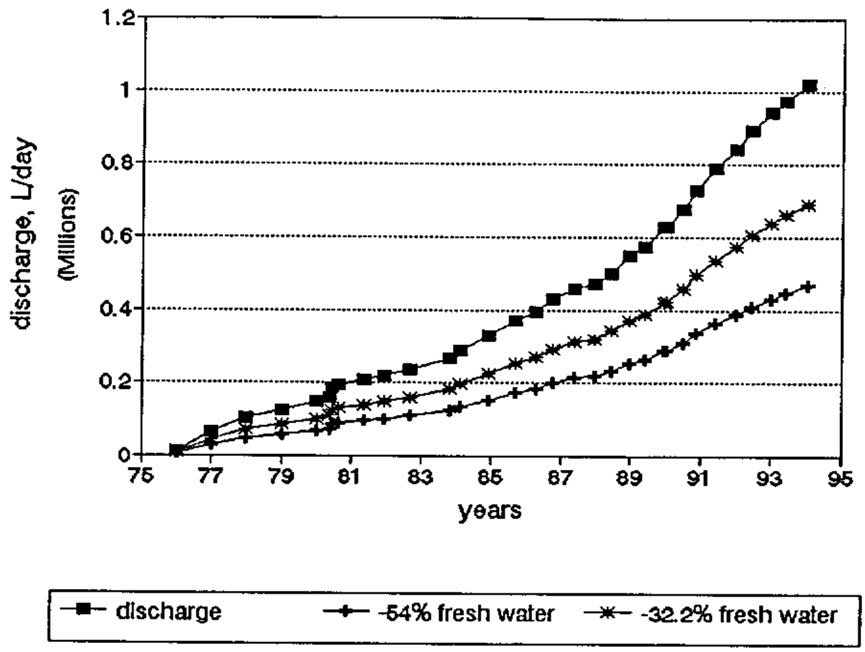


Fig. 3a: Point Aconi Drainage Basins
Acidity in Surface Water

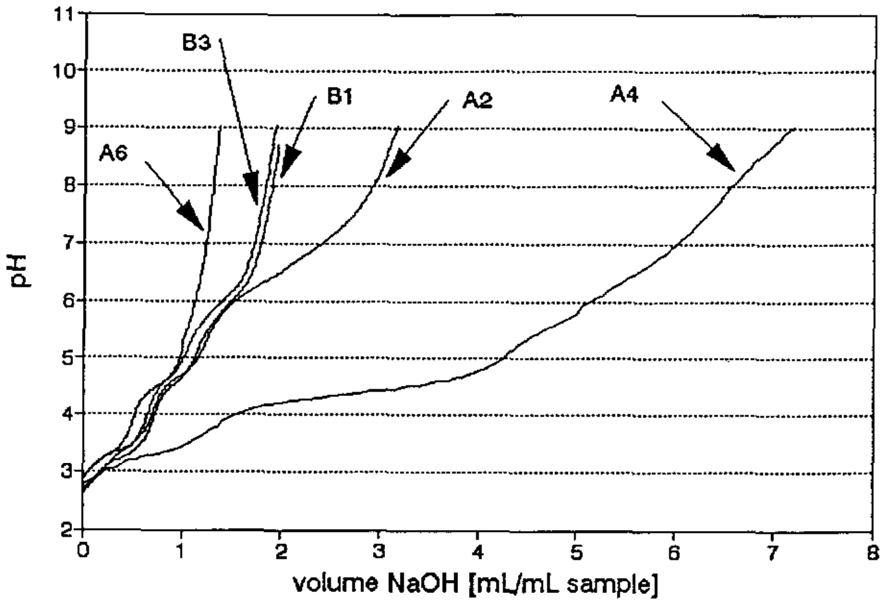


Fig. 3b: Point Aconi Drainage Basins
Acidity in Surface Water

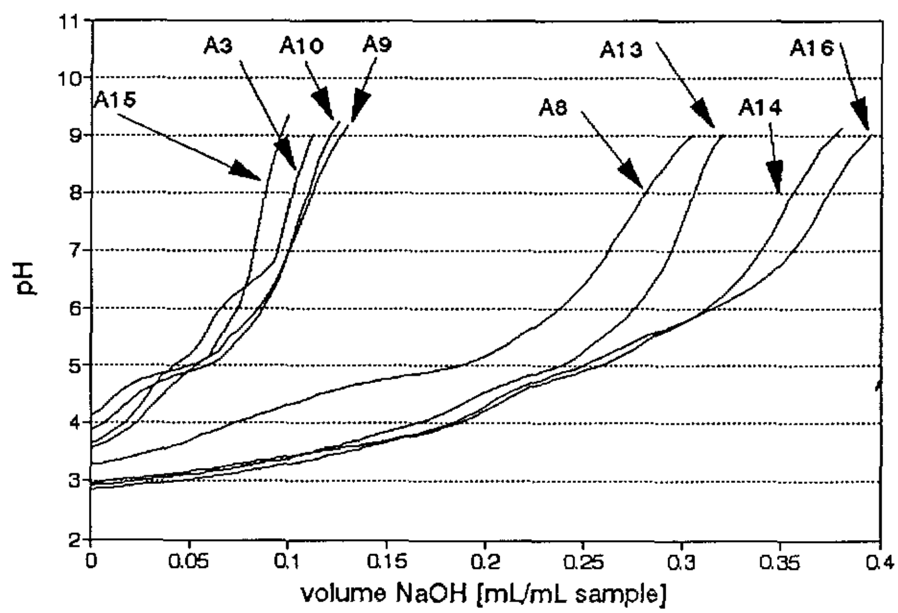


Fig. 4: Elemental Comparison of Waste Rock and Coal Seam Discharges

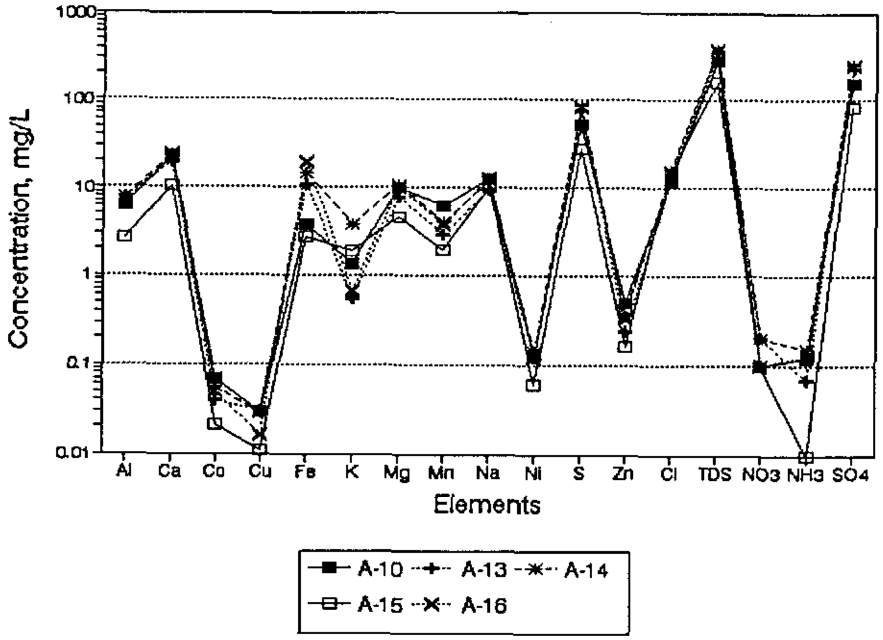


Plate 1: View Downstream from Seepage Station A3 of the New Waste Rock Pile

Plate 2: View towards Morrison's Pond from Station A12

Plate 3: Morrsion's Pond

Plate 4: Station A16 beside Morrison's Pond Outflow

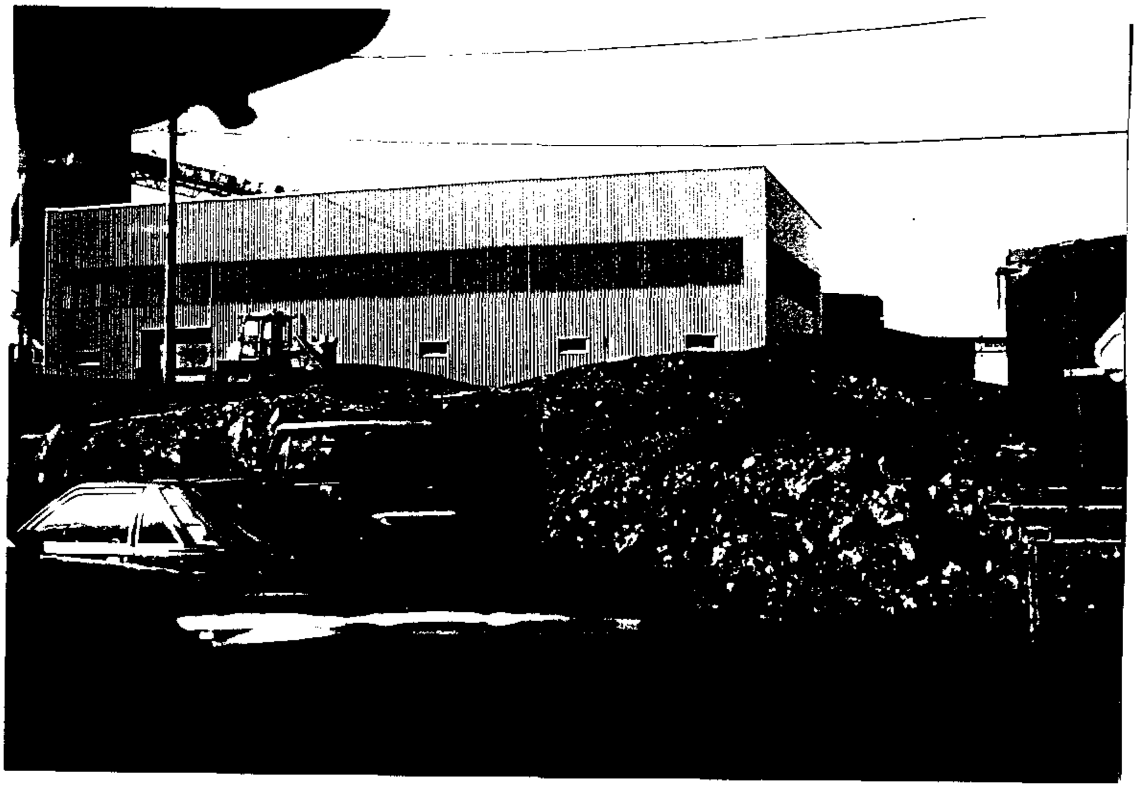


Plate 5: Snow with Coal Dust in the Prince Mine Pit

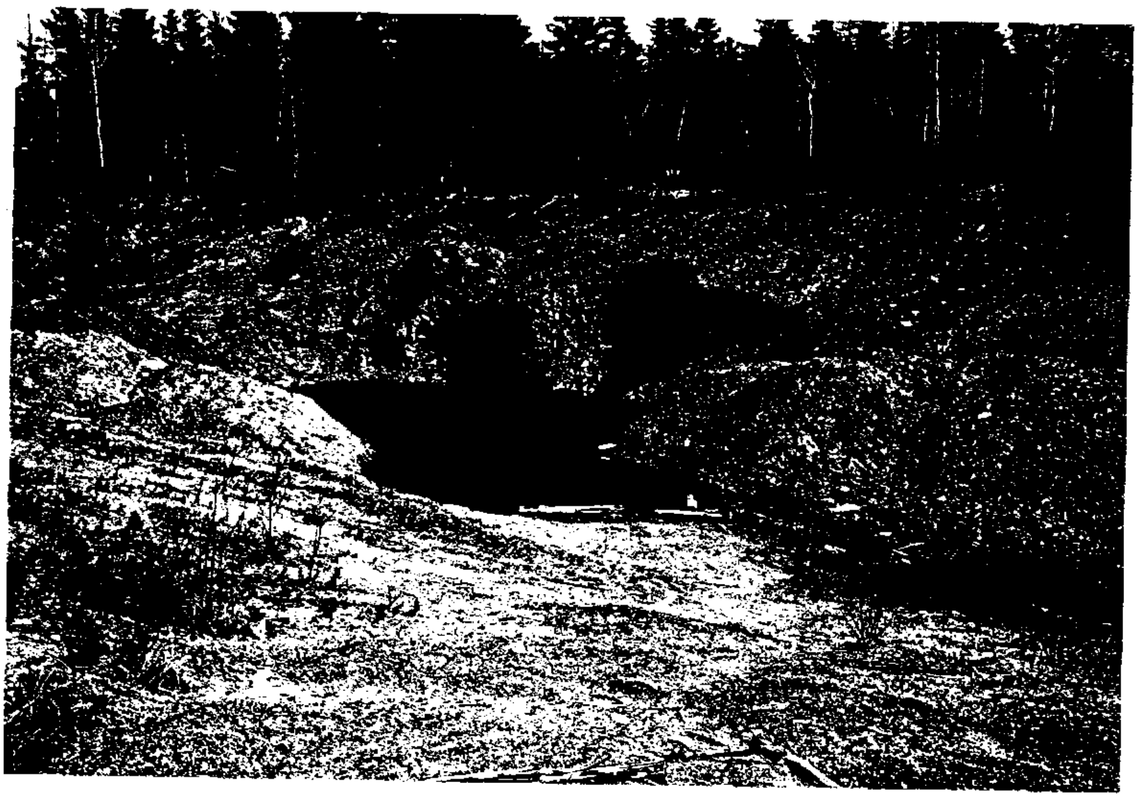


Plate 6: Abandoned Coal Pit above Station B5 on Coal Hollow Brook

APPENDIX 1

PM0392.WKQ [25.1] XRAL 18-03-92 027214.WK1 mg/L

SAMPLE DATE	3-Mar-92	3-Mar-92	3-Mar-92	3-Mar-92	3-Mar-92	3-Mar-92	3-Mar-92	3-Mar-92	3-Mar-92	3-Mar-92
SAMPLE VOLUME	100	100	100	20	100	100	100	100	100	100
ASSAYERS CODE	3633	3634	3635	3636	3637	3638	3639	3640	3641	3642
SAMPLING LOCATION	PRINCE M. 1 Last Sump	PRINCE M. 2 Sump bet. Tanks	PRINCE M. 3 East Low Mine	PRINCE M. 4 Unmined Coal	PRINCE M. 5 Slope	PRINCE M. 6 Flooded Level	PRINCE M. 7 West bott. Seal	PRINCE M. 8 Sump on 2 Slope	PRINCE M. 9 WaterLevel Intake	PRINCE M. 10 WaterLeve Discharge
Processing code	FA	FA	FA	FA	FA	FA	FA	FA	FA	FA
** F I E L D **										
Temp. (C)	10.5	10.5	8.6		12.2	11.5	14.4	13.6		
pH	3.13	3.15	3.2		2.96	3.52	4.02	3.94		
Cond. (umhos/cm)	37300	30300	36600		38100	33700	60000	46700		
Eh (mV)										
Acidity (mg/l)										
Alkalinity (mg/l)										
Ferric (Fe3+)										
Ferrous (Fe2+)										
** L A B **										
Temp. (C)	17	18	18	17	18	18	18	18	18	18
pH	2.84	3.08	3.4	6.81	2.95	2.99	4.01	4.71	2.91	2.94
Cond. (umhos/cm)	23000	20000	21000		20500	21500	30000	25000	2980	2240
Eh (mV)	395	373	328	241	426	379	239	176	389	387
Acidity (mg/l)										
Alkalinity (mg/l)										
Ferric (Fe3+)										
Ferrous (Fe2+)										
ELEMENTS Ag	< 0.005	< 0.005	0.012	< 0.25	0.007	0.008	< 0.005	< 0.005	< 0.005	< 0.005
Al	26.2	11.8	43.2	< 0.5	21	14.7	7.6	2.8	34.3	48.6
As	< 0.03	< 0.03	< 0.03	1	0.1	< 0.03	< 0.03	0.08	0.13	0.07
B	0.22	0.2	0.2	1.5	0.22	0.2	0.22	0.23	0.06	0.05
Ba	0.09	0.14	0.04	6.85	0.12	0.05	0.15	0.12	0.01	< 0.01
Be	0.02	< 0.01	0.03	< 0.05	0.01	0.02	0.02	< 0.01	0.01	0.01
Bi	< 0.05	< 0.05	< 0.05	< 0.25	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
C										
Ca	1620	1720	1700	1895	1650	1980	3710	1970	217	203
Cd	< 0.01	< 0.01	< 0.01	< 0.05	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Ce	< 0.01	< 0.01	0.02	< 0.05	< 0.01	0.01	0.03	< 0.01	0.02	0.04
Co	0.67	0.55	1.31	< 0.05	0.42	0.96	1.15	0.81	0.25	0.23
Cr	< 0.01	< 0.01	< 0.01	< 0.05	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Cu	0.2	0.1	0.11	< 0.05	0.07	0.03	0.02	0.02	0.13	0.1
Fe	173	133	131	6.5	51.6	209	153	100	299	282
Hg										
K	78	87.6	80.6	402	83.7	147	226	148	13.9	9.4
La	0.02	0.02	0.01	< 0.05	< 0.01	< 0.01	0.01	< 0.01	0.06	0.03
Mg	650	658	745	530	538	902	1350	775	60.8	62
Mn	35.9	36.1	47.1	3.65	24.5	36	46	27.6	24.2	22
Mo	< 0.01	< 0.01	< 0.01	< 0.05	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Na	5180	5380	5440	12700	6050	7050	9370	6350	257	136
Nb	0.06	0.06	0.08	0.4	0.07	0.08	0.09	0.04	0.02	0.03
Ni	1.73	1.3	2.45	1.75	0.97	2.45	2.67	1.78	0.61	0.58
P	0.2	0.2	0.2	< 0.5	0.1	0.2	0.4	0.2	0.6	0.6
Pb	0.35	0.17	0.12	1.75	0.26	0.25	0.28	0.1	0.15	0.16
S	600	577	713	150	483	603	490	497	520	517
Sb	< 0.05	< 0.05	0.06	< 0.25	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Se	< 0.1	< 0.1	< 0.1	< 0.5	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Si	12.8	8.9	16.8	10	16.7	8.5	6.2	7.4	17.3	19
Sn	< 0.1	< 0.1	< 0.1	< 0.5	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Sr	25.8	28.4	26.4	40	27.1	32	63.3	34.6	0.82	0.69
Te	< 0.1	< 0.1	< 0.1	< 0.5	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Th	< 0.01	< 0.01	< 0.01	< 0.05	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Ti	< 0.1	< 0.1	< 0.1	< 0.5	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
U	< 2	< 2	< 2	< 10	< 2	< 2	< 2	< 2	< 2	< 2
V	0.02	< 0.02	0.03	< 0.1	< 0.02	0.03	< 0.02	< 0.02	0.04	0.04
W	< 0.1	< 0.1	< 0.1	< 0.5	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Y	0.08	0.05	0.08	< 0.05	0.05	0.09	0.08	0.03	0.08	0.07
Zn	3.21	7.72	7.22	0.25	6.26	2.98	3.43	2.79	1.69	1.93
Zr	< 0.01	< 0.01	< 0.01	< 0.05	< 0.01	< 0.01	< 0.01	< 0.01	0.01	< 0.01
Chloride	12100	12500	13000	23500	13600	17350	25900	15200	350	420

PM1191.WKQ [25.1]   XRAL 10-Apr-92 027322.WK1 ppm

SAMPLE DATE		15-Nov-91	15-Nov-91	15-Nov-91	15-Nov-91
SAMPLE VOLUME		100	100	100	100
ASSAYERS CODE		3653	3654	3655	3656
SAMPLING LOCATION		PRINCE M. Coase waste pile runoff	PRINCE M. Surface runoff	PRINCE M. PM-1 mine discharge	PRINCE M. Water lev tunell discharge
Processing code		FA	FA	FA	FA
** F I E L D **					
Temp. (C)		5.8	7.3	11.7	8
pH		2.72	2.72	2.69	2.9
Cond. (umhos/cm)		3860	2730	27300	2550
Eh (mV)					
Acidity (mg/l)					
Alkalinity (mg/l)					
Ferric (Fe3+)					
Ferrous (Fe2+)					
** L A B **					
Temp. (C)					
pH					
Cond. (umhos/cm)					
Eh (mV)					
Acidity (mg/l)		1550	800	700	775
Alkalinity (mg/l)					
Ferric (Fe3+)					
Ferrous (Fe2+)					
ELEMENTS	Ag	< 1	< 1	< 1	< 1
	Al	135	40	48	47
	As	< 1	< 1	< 1	< 1
	B	< 1	< 1	< 1	< 1
	Ba	< 1	< 1	< 1	< 1
	Be	< 1	< 1	< 1	< 1
	Bi	< 1	< 1	< 1	< 1
	C				
	Ca	244	215	1310	206
	Cd	< 1	< 1	< 1	< 1
	Ce	< 1	< 1	< 1	< 1
	Co	1	< 1	< 1	< 1
	Cr	< 1	< 1	< 1	< 1
	Cu	< 1	< 1	< 1	< 1
	Fe	99	96	60	87
	Hg				
	K	2	5	57	5
	La	< 1	< 1	< 1	< 1
	Mg	156	62	503	68
	Mn	73	23	40	20
	Mo	< 1	< 1	< 1	< 1
	Na	77	62	3600	147
	Nb	< 1	< 1	< 1	< 1
	Ni	3	< 1	2	< 1
	P	< 1	< 1	< 1	< 1
	Pb	< 1	< 1	< 1	< 1
	S	911	520	721	483
	Sb	< 1	< 1	< 1	< 1
	Se	< 1	< 1	< 1	< 1
	Si	21	18	20	16
	Sn	< 1	< 1	< 1	< 1
	Sr	< 1	< 1	20	1
	Te	< 1	< 1	< 1	< 1
	Th	< 1	< 2	< 2	< 1
	Ti	< 1	< 1	< 1	< 1
	U	< 1	< 1	< 2	< 1
	V	< 1	< 1	< 1	< 1
	W	< 1	< 1	< 1	< 1
	Y	< 1	< 1	< 1	< 1
	Zn	12	2	6	2
	Zr	< 1	< 1	< 1	< 1
Chloride		50	72	9400	390

PM0592.WKQ [25.1] Dearborn 3-06-92 mg/L typein from fax to DEAR0592.WKQ

SAMPLE DATE	11-May-92	11-May-92	11-May-92	11-May-92	11-May-92	11-May-92	11-May-92	11-May-92	11-May-92
SAMPLE VOLUME	100	100	100	100	100	100	100	100	100
ASSAYERS CODE	3737	3738	3739	3740	3741	3742	3743	3744	3745
SAMPLING LOCATION	PRINCE DB-A A-1 stream	PRINCE DB-A A-2 seepage	PRINCE DB-A A-3 stream	PRINCE DB-A A-4 seepage	PRINCE DB-A A-5 stream	PRINCE DB-A A-6 stream	PRINCE DB-A A-7 stream	PRINCE DB-A A-8 stream	PRINCE DB-A A-9 stream
Processing code	WH	WH	WH	WH	WH	WH	WH	WH	WH
** F I E L D **									
Temp. (C)	11.3	11.7	9.5	15.2	13.3	13.5	13.2	7.5	12.7
pH	5.54	3.33	4.81	2.68	5.28	2.68	7.47	3.15	3.59
Cond. (umhos/cm)	78	3270	273	7070	172	2300	270	799	486
Eh (mV)									
Acidity (mg/l)									
Alkalinity (mg/l)									
** L A B **									
Temp. (C)									
pH	6.93	2.92	3.65	2.79	5.96	2.64	7.9	3.29	4.12
Cond. (umhos/cm)									
Eh (mV)									
Acidity (mg/l)	11	1505	52.5	3375		660	6.25	143.5	57.5
Alkalinity (mg/l)	4.25				1		6.75		
ELEMENTS Ag	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008
Al	0.43	46.3	2.61	2.75	2.48	46.7	1.15	12.3	6.05
As	< 0.069	< 0.069	< 0.069	< 0.069	< 0.069	0.126	< 0.069	< 0.069	< 0.069
B	0.024	0.294	0.013	0.056	0.019	0.01	0.033	0.013	0.189
Ba	0.009	< 0.003	0.01	< 0.003	0.049	0.126	0.048	0.016	0.143
Be	< 0.003	0.018	< 0.003	0.129	< 0.003	0.014	< 0.003	0.004	< 0.003
Bi	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04
C									
Ca	6.71	130	10.2	410	10.1	109	20.4	31.3	27.7
Cd	< 0.004	0.011	< 0.004	0.008	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
Ce									
Co	< 0.009	0.522	0.024	3.273	< 0.009	0.423	0.011	0.142	0.08
Cr	< 0.007	< 0.007	< 0.007	0.225	< 0.007	0.024	< 0.007	< 0.007	< 0.007
Cu	< 0.006	0.061	0.007	1.67	0.021	0.378	0.017	0.071	0.033
Fe	0.765	300	21.6	310	5.22	160	1.92	6.77	3.42
Hg	< 0.061	< 0.061	< 0.061	< 0.061	< 0.061	< 0.061	< 0.061	< 0.061	< 0.061
K	1.5	4.87	1	0.826	1.18	5.18	4.61	1.18	1.45
La									
Mg	1.4	82.6	4.47	380	2.91	51.1	4.62	17	11.8
Mn	0.241	72.5	3.84	230	0.878	20.3	1.5	11	6.89
Mo	< 0.017	< 0.017	< 0.017	< 0.017	< 0.017	< 0.017	< 0.017	< 0.017	< 0.017
Na	6.01	41.1	5.2	245	9.52	32.4	23.1	11.4	15.4
Nb									
Ni	0.02	0.99	0.05	6.1	0.04	0.86	0.04	0.27	0.17
P	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	1	< 0.3	< 0.3
Pb	< 0.039	< 0.039	< 0.039	0.086	< 0.039	0.084	< 0.039	< 0.039	< 0.039
S	3.7	747	30.9	1963	7.7	380	8.3	107	61.3
Sb	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03
Se	< 0.08	< 0.08	< 0.08	< 0.08	< 0.08	< 0.08	< 0.08	< 0.08	< 0.08
Si									
Sn									
Sr									
Te									
Th	< 0.031	< 0.031	< 0.031	0.1	< 0.031	< 0.031	< 0.031	< 0.031	< 0.031
Ti	0.004	< 0.003	0.005	< 0.003	0.051	0.175	0.011	< 0.003	0.013
U									
V	< 0.024	< 0.024	< 0.024	< 0.024	< 0.024	< 0.024	< 0.024	< 0.024	< 0.024
W									
Y									
Zn	0.032	0.818	0.063	23	0.122	2.77	0.092	1.09	0.576
Zr	0.012	< 0.002	< 0.002	0.045	0.003	0.006	< 0.002	< 0.002	< 0.002
Chloride (Cl)	7.8	33	5.4	188	13	24	27	8.8	16
TDS	98	3500	170	9300	110	1640	180	390	330
Nitrate (NO3)	< 0.1	< 5	0.2	< 10	< 0.1	< 5	1.2	< 0.1	0.2
Ammonia (NH3)	0.01	0.3	0.04	0.33	0.04	0.11	0.09	0.07	0.08
SO4	11	2240	93	5890	23	1140	25	320	184

PM0592.WKQ [25.1]

SAMPLE DATE	11-May-92	11-May-92	11-May-92	11-May-92	11-May-92	11-May-92	11-May-92	12-May-92	12-May-92
SAMPLE VOLUME	100	100	100	100	100	100	100	100	100
ASSAYERS CODE	3746	3747	3748	3749	3750	3751	3752	3753	3754
SAMPLING LOCATION	PRINCE DB-a A-10 stream	PRINCE DB-A A-11 stream	PRINCE DB-A A-12 stream	PRINCE DB-A A-13 stream	PRINCE DB-A A-14 stream	PRINCE DB-A A-15 stream	PRINCE DB-A A-16 seepage	PRINCE Tunnel B-1 stream	PRINCE DB-B B-2 stream
Processing code	WH	WH	WH	WH	WH	WH	WH	WH	WH
** F I E L D **									
Temp. (C)	13.3	10.1	6.5	7.5	6.5	7.9	5.8	13.9	15.7
pH	3.5	3.89	4.2	2.9	2.5	3.41	2.7	2.91	5.77
Cond. (umhos/cm)	453	135.9	170	911	1040	347	90.6	3280	1600
Eh (mV)									
Acidity (mg/l)									
Alkalinity (mg/l)									
** L A B **									
Temp. (C)									
pH	3.88	5.55	4.79	2.92	2.86	3.57	2.97	2.69	6.72
Cond. (umhos/cm)									
Eh (mV)									
Acidity (mg/l)	56	12	18.5	155	181.5	45	189.5	965	60
Alkalinity (mg/l)		0.25							4.25
ELEMENTS Ag	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008
Al	6.07	0.2	1.66	7.67	7.8	2.58	6.68	43.3	1.14
As	< 0.069	< 0.069	< 0.069	< 0.069	< 0.069	< 0.069	< 0.069	0.194	< 0.069
B	0.061	0.031	0.039	0.018	0.013	0.033	0.01	0.072	0.019
Ba	0.028	0.009	0.042	0.01	0.003	0.021	0.006	0.056	0.046
Be	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	0.011	< 0.003
Bi	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04
C									
Ca	23.3	2.54	8.5	19.4	24.1	10.5	23.8	208	192
Cd	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
Ce									
Co	0.07	< 0.009	0.02	0.039	0.056	0.021	0.049	0.301	0.048
Cr	< 0.007	< 0.007	< 0.007	< 0.007	< 0.007	< 0.007	< 0.007	< 0.007	< 0.007
Cu	0.029	< 0.006	0.013	0.03	0.028	0.011	0.016	0.108	0.007
Fe	3.68	0.147	0.993	10.6	14.1	2.74	19.4	300	25.4
Hg	< 0.061	< 0.061	< 0.061	< 0.061	< 0.061	< 0.061	< 0.061	< 0.061	< 0.061
K	1.35	5.1	1.44	0.55	3.7	1.88	0.66	7.35	5.72
La									
Mg	10	1.01	3.52	7.93	10.6	4.5	10.1	69.8	35.1
Mn	6	0.324	1.75	2.84	3.99	1.94	3.75	29.3	6.73
Mo	< 0.017	< 0.017	< 0.017	< 0.017	< 0.017	< 0.017	< 0.017	< 0.017	< 0.017
Na	12.5	6.33	9.24	9.36	11.8	10.3	12.7	14.1	73.3
Nb									
Ni	0.13	0.02	0.04	0.12	0.14	0.06	0.12	0.67	0.1
P	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	1.1	< 0.3
Pb	< 0.039	< 0.039	< 0.039	< 0.039	< 0.039	< 0.039	< 0.039	0.119	< 0.039
S	52.3	4	16	76	85.7	28	84	603	214
Sb	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03
Se	< 0.08	< 0.08	< 0.08	< 0.08	< 0.08	< 0.08	< 0.08	< 0.08	< 0.08
Si									
Sn									
Sr									
Te									
Th	< 0.031	< 0.031	< 0.031	< 0.031	< 0.031	< 0.031	< 0.031	< 0.031	< 0.031
Ti	0.024	< 0.003	0.004	< 0.003	< 0.003	< 0.003	< 0.003	0.095	0.016
U									
V	< 0.024	< 0.024	< 0.024	< 0.024	< 0.024	< 0.024	< 0.024	< 0.024	< 0.024
W									
Y									
Zn	0.494	0.029	0.161	0.24	0.361	0.162	0.336	2.01	0.271
Zr	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	0.005	< 0.002
Chloride (Cl)	12	10	12	12	16	15	15	165	105
TDS	280	80	130	360	390	160	380	2640	1230
Nitrate (NO3)	0.1	< 0.1	0.1	0.2	0.2	0.1	0.1	< 5	< 5
Ammonia (NH3)	0.12	< 0.01	0.12	0.07	0.15	0.01	0.13	0.44	0.08
SO4	157	12	48	228	257	84	252	1810	643

PM0592.WKQ [25.1]

SAMPLE DATE	12-May-92	12-May-92	12-May-92	12-May-92	12-May-92	12-May-92	12-May-92	12-May-92
SAMPLE VOLUME	100	100	100	100	100	100	100	100
ASSAYERS CODE	3755	3756	3757	3758	3759	3760	3761	3762
SAMPLING LOCATION	PRINCE DB-B B-3 stream	PRINCE DB-B B-4 stream	PRINCE DB-B B-5 seepage	PRINCE DB-B B-6 stream	PRINCE DB-C C-1 seepage	PRINCE DB-D D-1 stream	PRINCE DB-E E-1 stream	PRINCE Ocean O-5 shore
Processing code	WH	WH	WH	WH	WH	WH	WH	WH
** F I E L D **								
Temp. (C)	13.4	11.7	13.2	15.9	15.7	14.9	14.7	
pH	3.02	5.82	4.16	4.1	5.6	6.3	6.6	
Cond. (umhos/cm)	2920	115.3	530	280	2080	148	400	
Eh (mV)								
Acidity (mg/l)								
Alkalinity (mg/l)								
** L A B **								
Temp. (C)								
pH	2.89	8.25	4.07	4.83	7.15	7.87	5.03	7.24
Cond. (umhos/cm)								
Eh (mV)								
Acidity (mg/l)	932.5		31	34	54	3	15.5	23
Alkalinity (mg/l)		1			8.5	1.75		9
ELEMENTS Ag	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008
Al	47.3	0.45	1.32	1.82	0.057	0.39	1.25	5.76
As	< 0.069	< 0.069	< 0.069	< 0.069	< 0.069	< 0.069	< 0.069	< 0.069
B	0.017	0.034	0.022	0.01	0.027	0.026	0.018	2.13
Ba	0.007	0.013	0.021	0.014	0.012	0.015	0.015	0.027
Be	0.01	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003
Bi	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04
C								
Ca	164	7.83	32.6	13.1	256	8.92	26.7	310
Cd	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004	< 0.004
Ce								
Co	0.244	< 0.009	0.035	< 0.009	0.169	< 0.009	0.053	0.016
Cr	< 0.007	< 0.007	< 0.007	< 0.007	< 0.007	< 0.007	< 0.007	< 0.007
Cu	0.049	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006	0.007	0.014
Fe	160	1.32	2.3	6.69	13.3	1.07	2.49	14.1
Hg	< 0.061	< 0.061	< 0.061	< 0.061	< 0.061	< 0.061	< 0.061	< 0.061
K	4.91	1.13	1.64	0.94	13.5	1.41	1.76	310
La								
Mg	55.8	2.31	8.37	4.15	131	2.81	10.2	950
Mn	22.8	0.253	7.01	1.08	47.3	0.36	7.57	0.759
Mo	< 0.017	< 0.017	< 0.017	< 0.017	< 0.017	< 0.017	< 0.017	< 0.017
Na	120	9.98	25.8	14.3	20.5	12.1	9.28	7900
Nb								
Ni	0.56	< 0.02	0.06	0.03	0.19	0.02	0.1	0.04
P	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3
Pb	< 0.039	< 0.039	< 0.039	< 0.039	< 0.039	< 0.039	< 0.039	< 0.039
S	473	7.7	47.7	24.7	407	5.7	44.7	678
Sb	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03
Se	< 0.08	< 0.08	< 0.08	< 0.08	< 0.08	< 0.08	< 0.08	< 0.08
Si								
Sn								
Sr								
Te								
Th	< 0.031	< 0.031	< 0.031	< 0.031	< 0.031	< 0.031	< 0.031	< 0.031
Ti	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	0.004	0.007	0.085
U								
V	< 0.024	< 0.024	< 0.024	< 0.024	< 0.024	< 0.024	< 0.024	< 0.024
W								
Y								
Zn	1.91	0.024	0.118	0.085	0.159	0.012	0.154	0.134
Zr	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	0.004
Chloride (Cl)	165	16	50	21	14	17	12	15400
TDS	2300	88	310	180	1900	110	240	41600
Nitrate (NO3)	< 5	< 0.1	1.1	< 0.1	< 5	< 0.5	0.2	< 25
Ammonia (NH3)	0.46	0.01	0.36	0.05	0.52	0.03	0.31	0.28
SO4	1420	23	143	74	1220	17	134	2034

APPENDIX 2

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PRINCE MINE, POINT ACONI, N.S.

(CAPE BRETON DEVELOPMENT CORPORATION)

PRELIMINARY HYDROLOGICAL AND HYDROCHEMICAL DATA

12 March 1992

PRINCE MINE, POINT ACONI, N.S.
PRELIMINARY HYDROLOGICAL AND HYDROCHEMICAL DATA

WEATHER DATA

The nearest weather station for the area of the Prince Mine is the station at the Sydney Airport. Available data at present include "Climate Normals" of precipitation and temperature for the period 1951-1980, and daily weather data for the period 1978-1991 (data for May 1991 are missing and should be added to the data file when they become available).

Precipitation

Table 1 presents data on monthly rainfall, snowfall, total precipitation and mean-daily temperature for the years 1978-1991, and Climate Normals for the period 1951-1980. Calculated 10-year averages for precipitation and mean-daily temperature for the period 1981-1991 are included in the table.

Figure 1 shows that there was a wide range of variation in monthly precipitation during the 1981-1991 period, from about 23 mm (May 1989) to almost 315 mm (December 1990). Highest amounts commonly fall in November, December, January and April, and lowest amounts in May, June, July and August.

Figure 2 shows the variation in annual rainfall, snowfall and total precipitation during the 1981-1991 period. Total precipitation ranged from 1247 mm (1989) to 1913 mm (1983).

Figure 3 shows the monthly averages for rainfall, snowfall and total precipitation for the period 1981-1991; Figure 4 shows the precipitation "Normals" for the 1951-1980 period. Comparison of Figures 3 and 4 indicates higher rainfall for the 1981-1991 period, but little difference in snowfall.

The ranges in monthly precipitation during the 1981-1991 period are further illustrated by Figure 5. The graph for mean monthly precipitation in Figure 5 corresponds to the graph for total precipitation in Figure 4.

24-hour precipitation extremes for individual months range from 56.1 mm (April) to 97.3 mm (November).

Values for mean annual evaporation, evapotranspiration, and runoff (Table 1) have been obtained from the Hydrologic Atlas of Canada; these values are approximate.

Temperature

Temperature "Normals" for the period 1951-1980 are shown in Figure 6. Monthly mean temperatures for the period 1981-1991, added to this plot, indicate only minor differences in monthly mean temperatures between the two periods.

CONTAMINATED DISCHARGES

Mine Water: DISCHARGE #1

Mine-production data for the period 1975-1987, and available maps of the underground workings have been used to estimate the progressive increase in the area covered by the workings ("blocks" in Table 2) and mine tunnels ("deeps", "slopes", and "declines" in Table 2). In Table 2A, mined areas were calculated from the production data; mined areas for the period 1975-1980 (Table 2B) were measured on the maps. As a reasonable agreement was found between the values in the two tables for the cumulative mined area at the end of 1980 (3,065,110 sqft in Table 2A, and 3,090,875 sqft in Table 2B), the annual area values from Table 2A have been used for the period 1975-1980. For the period 1980-1990, areas and completion dates were taken from the maps. For individual blocks, average depths below sealevel or below ground surface were estimated from elevation contours on the maps.

Only one value is available for the rate of discharge from the Prince Mine. It is presumed that this value represents discharge on 28 September 1990. This value of 1.35 million US gallon per week (730,041 L/day) was used, together with the information on mined areas, to calculate approximate values for the progressive increase in mine discharge from 1975 to 1990, and estimates for the next 3 years (Table 2C).

Figure 7 shows a plot of discharge vs. mined area. The steep initial portion of the curve represents the early development stage at relatively shallow depth; the subsequent decrease in the slope of the curve reflects progressive expansion of the mine at gradually increasing depth (below either land or sea). Figure 8 shows the time Of addition of individual mined blocks, as well as the estimated increase in mined area and corresponding mine-water discharge _vs._ time. Both figures suggest that mine-water discharge may increase from about 730 m^3 in late 1990 to just over 1000 m^3 by the end of 1993.

Periodic measurements of the mine-water discharge rate would have to be made to detect any seasonal variation or long-term trend in the rate.

It is certain that the above estimating process has led to inaccuracies. Any significant inaccuracies, as well as significant new information should be brought to our attention as soon as possible, to enable improvement of the estimates and, where necessary, re-interpretation.

East Tunnel: DISCHARGE #2

A flow rate of 39.7 L/min was apparently measured on 5 June 1991 at the East Tunnel outlet. There is as yet no indication whether this represents a minimum, average or maximum discharge. No indication has been received sofar whether or not any discharge from the underground workings contributes to the discharge from the East Tunnel. Flow rates may vary widely, particularly if a large portion of the discharge represents surface runoff from precipitation.

A preliminary outline of the surface area that may contribute to this flow is indicated on a separate map.

Rock Dump(s) and Sewage Lagoon: DISCHAREG #3

No data are available on the rates of discharge from the Rock Dump(s) and the Sewage Lagoon, or on the flow rate in the receiving creek above its confluence with the Rock-Dump and Sewage-Lagoon discharges. Flow rates will likely vary widely, as these discharges represent surface runoff from precipitation.

A preliminary outline of the surface area that may contribute to this flow is indicated on a separate map.

WATER CHEMISTRY

Water Analyses

Available water analyses for the Prince Mine, listed in Table 3, represent 9 samples of mine discharge; 2 samples of discharge from the East Tunnel; 3 samples of drainage from the Rock Dump(s); a sample of discharge from the Sewage Lagoon; and a sample from the brook that receives the combined rock-dump and sewage-lagoon discharge. As the mine discharge shows the characteristics of diluted seawater, a seawater analysis is also listed in Table 3. Included in Table 3 are calculated ratios of K/Na, Na/Cl, Fe/SO_4, and Ca/SO_4 for each of the samples.

For the mine-water samples, all the K/Na ratios, and all but one of the Na/Cl ratios are smaller than those for seawater. All Fe/SO_4 and Ca/SO_4 ratios for the mine-water samples are larger or much larger than those for seawater (representing Fe and SO_4 from pyrite oxidation, and subsequent dissolution of carbonate and some precipitation of secondary Fe-minerals). Elevated concentrations of Al, Fe, Mn and Zn may make treatment of the mine water necessary.

The analytical results are illustrated by Figure 9, showing variations in selected elemental concentrations in the mine water with time; and by Figure 10, showing variations in the four elemental ratios for the mine water with time. The double arrows in Figures 9 and 10 indicate the elemental concentrations and ratios, respectively, for seawater. It is suspected that the low value for [Fe] for the 15 November 1989 sample of mine water represents a transcription error, because none of the other elements show a corresponding decrease in concentration.

Also listed in Table 3, and illustrated by Figure 11, are ratios of [Ca], [SO_4], [Cl], [Na], and [K], and the milimole sum of dissolved solids, for individual samples compared to seawater. As expected, the ratios for [Ca] and [SO_4] are larger than 100%, reflecting the additions of calcium and sulfate, presumably through pyrite-oxidation and related processes. The ratios for Cl range from 27.2 to 66.3 percent. As Cl is one of the most conservative elements in solution, it may be assumed that the Cl ratios reflect different degrees of dilution of seawater seepage (into the off-shore or sub-sea portion of the mine), with relatively fresh water containing little or no Cl. This relatively fresh water could represent seepage into the on-shore portion of the mine.

Periodic sample collection for analysis, and measurements of the mine-water discharge rate would have to be carried out to determine the probably varying proportions of seawater (from the sub-sea portion of the mine) and other water in the mine discharge.

Discharges from the East Tunnel and from the Rock Dump(s) are higher in Al, Fe, Mn, and Zn than the mine discharge, but lower in Ca and K, and much lower in Na and Cl. Mixing of the Rock-Dump discharge with the discharge from the Sewage Lagoon and the surface runoff in the creek reduces all concentrations through dilution and, in the case of Fe, probably through precipitation of Fe-hydroxide. Manganese appears to persist in the creek water at a concentration close to 2 mg/L.

Periodic sample collection for analysis, and measurements of the discharge rates from the East Tunnel, the Rock Dump(s), the Sewage Lagoon, and the creek would have to be carried out to determine the severity and seasonal variation of the metal-contamination.

Geochemical Calculations

A preliminary test, using the BALANCE program, was run to investigate the probable seawater/freshwater mixing ratio and the mineral dissolution/ precipitation represented by the mine water. The results of this test, for the 28 September 1990 sample of mine water (presumed to be a mixture of seawater and "fresh" water), are presented in Table 4.

A mixing ratio of 46 percent seawater with 54 percent "fresh" water would require dissolution (somewhere in the paths of the two waters) of calcite, pyrite, some pyrolusite (or a similar Mn mineral), and some alum (or a similar Al mineral); exchange of Na ions from seawater for Ca ions from clays or shales; and precipitation of jarosite, dolomite, and some gypsum.

The saturation indices for the mine-water with respect to the above minerals should eventually be checked using the PHREEQE program, when complete analyses (including Total Inorganic Carbon), and corresponding field measurements of temperature, pH and Eh become available for the mine water.

Robert O. van Everdingen
12 March 1992

STATION: SYDNEY, Nova Scotia Location: 46*10'N 60*03'W Elevation: 62 m

RAIN, mm

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
1978	165.0	31.0	66.8	94.7	39.5	133.1	41.5	41.5	127.3	122.0	45.9	49.5	957.8
1979	117.2	89.2	131.7	66.5	121.4	42.0	143.0	117.7	75.8	219.7	130.1	172.6	1426.9
1980	56.0	0.6	114.4	160.7	109.6	77.6	91.5	97.3	123.4	147.2	147.2	132.9	1258.4
1981	57.3	60.9	75.8	63.4	181.3	74.4	115.5	156.2	133.6	193.4	135.5	151.0	1398.3
1982	127.6	90.0	67.2	170.0	138.0	153.4	40.4	74.6	95.2	87.8	117.6	81.7	1243.5
1983	152.6	38.2	188.4	181.2	123.6	58.6	218.0	142.0	168.6	103.0	170.0	122.3	1666.5
1984	143.5	89.6	21.4	175.7	114.6	73.6	50.7	183.9	120.1	67.0	97.3	73.9	1211.3
1985	49.0	49.9	64.9	46.8	100.6	182.8	79.0	95.6	42.3	89.8	83.8	50.1	934.6
1986	128.0	5.6	58.0	153.6	55.7	101.5	115.8	76.0	130.4	87.3	116.9	36.2	1065.0
1987	46.0	47.2	25.4	153.2	15.8	147.2	17.9	55.0	180.6	193.5	166.0	78.3	1126.1
1988	51.4	161.8	91.8	230.8	95.0	100.1	143.4	119.7	69.6	196.8	173.0	22.0	1455.4
1989	56.4	58.5	34.6	62.8	22.6	99.2	42.7	61.2	119.6	134.0	150.2	20.2	862.0
1990	65.0	54.1	29.8	161.8	189.7	93.1	48.4	62.5	153.0	177.2	113.2	299.2	1447.0
1991	52.2	54.9	109.4	39.1		33.4	93.0	112.5	167.0	179.3	186.6	52.6	1080.0
10-Y AVG.	84.5	64.6	69.7	130.8	103.7	101.6	87.7	103.6	125.5	137.2	137.3	89.8	1226.3

SNOW, cm

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
1978	82.5	67.0	69.2	45.5	0.2	0.0	0.0	0.0	0.0	0.0	30.3	65.5	360.2
1979	30.9	29.5	31.2	27.6	0.4	0.0	0.0	0.0	0.0	0.0	5.4	43.8	168.8
1980	49.0	68.1	24.3	0.0	2.2	0.0	0.0	0.0	0.0	0.0	25.6	69.4	238.6
1981	105.0	10.2	19.7	38.2	0.0	0.0	0.0	0.0	0.0	0.0	7.4	71.7	252.2
1982	121.6	83.5	35.8	22.0	0.0	0.0	0.0	0.0	0.0	0.2	8.8	48.7	320.6
1983	45.3	158.9	14.6	4.4	0.0	0.0	0.0	0.0	0.0	0.0	3.8	100.6	327.6
1984	68.3	11.0	88.0	28.8	1.4	0.0	0.0	0.0	0.0	2.8	13.4	47.8	261.5
1985	59.9	66.2	56.9	20.5	16.4	0.0	0.0	0.0	0.0	7.2	26.3	115.4	368.8
1986	52.4	151.5	86.6	3.0	0.0	0.0	0.0	0.0	0.0	0.0	42.4	32.9	368.8
1987	119.6	53.1	101.9	10.0	0.0	0.0	0.0	0.0	0.0	0.0	2.8	130.7	418.1
1988	67.1	30.6	54.2	36.6	0.4	0.0	0.0	0.0	0.0	1.0	19.0	53.5	262.4
1989	68.9	92.5	101.2	38.4	0.0	0.0	0.0	0.0	0.0	0.4	58.2	41.8	401.4
1990	87.1	61.3	25.6	7.4	13.2	0.0	0.0	0.0	0.0	0.2	17.2	15.5	227.5
1991	58.2	25.5	55.1	12.1		0.0	0.0	0.0	0.0	4.4	1.6	79.3	236.2
10-Y AVG.	77.6	67.7	58.1	20.1	3.1	0.0	0.0	0.0	0.0	1.5	18.3	67.1	313.2

TOTAL PRECIPITATION, mm

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
1978	245.9	96.4	136.9	147.1	39.7	133.1	41.5	41.5	127.3	122.0	71.9	112.1	1315.4
1979	145.9	117.9	162.4	93.5	121.4	42.0	143.0	117.7	75.8	219.7	135.1	213.4	1587.8
1980	107.1	67.1	139.7	160.7	111.8	77.6	91.5	97.3	123.4	147.1	171.8	200.6	1495.7
1981	160.1	70.3	95.5	104.3	181.3	74.4	115.5	156.2	133.6	193.4	144.5	220.0	1649.1
1982	240.2	171.7	98.0	192.0	138.9	153.4	40.4	74.6	95.2	88.0	125.8	128.9	1547.1
1983	195.2	143.3	203.2	185.6	123.6	58.6	218.0	142.0	168.6	103.0	173.0	199.6	1913.7
1984	205.8	100.4	107.0	204.1	116.0	73.6	50.7	183.9	120.1	69.8	109.7	117.3	1458.4
1985	103.3	114.5	117.9	64.7	117.0	182.8	79.0	95.6	42.3	96.8	105.7	149.6	1269.2
1986	175.8	158.2	114.3	156.2	55.7	101.5	115.8	76.0	130.4	87.3	158.4	67.2	1396.8
1987	159.0	99.9	124.7	163.2	45.8	147.2	17.9	55.0	180.6	193.5	168.6	207.7	1563.1
1988	118.5	191.6	140.6	267.2	95.4	100.1	143.4	119.7	69.6	197.8	191.4	74.5	1709.8
1989	124.1	149.4	135.4	92.4	22.6	99.2	42.7	61.2	119.6	134.4	207.2	58.8	1247.0
1990	148.5	112.1	54.8	169.2	202.9	93.1	48.4	62.5	153.0	177.4	130.4	314.7	1667.0
1991	108.8	80.4	164.5	51.2		33.4	93.0	112.5	167.0	183.7	188.2	129.7	1312.4
10-Y AVG.	158.1	126.5	123.3	150.0	109.9	101.6	87.7	103.6	125.5	138.6	154.8	151.6	1509.5

STATION: SYDNEY, Nova Scotia Location: 46*10'N 60*03'W Elevation: 62 m

MEAN DAILY TEMPERATURE, degree C

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1978	-4.5	-6.4	-3.8	0.8	8.0	13.7	17.9	17.9	11.0	7.8	0.7	-3.2	5.0
1979	-3.2	-8.3	0.3	2.3	9.4	14.5	18.0	16.9	12.9	8.8	5.5	-1.4	6.3
1980	-5.6	-7.1	3.3	2.7	6.2	12.4	16.7	16.8	12.7	7.7	2.6	-4.4	5.3
1981	-6.8	-2.5	-0.1	3.2	9.4	13.5	16.9	17.1	13.6	7.9	4.3	1.1	6.5
1982	-7.0	-7.4	-4.0	2.9	6.7	10.4	18.1	16.0	14.0	7.5	5.0	-0.8	5.1
1983	-3.2	-4.5	-1.0	4.3	8.0	14.3	17.4	16.8	14.8	9.4	4.1	-2.0	6.5
1984	-5.7	-2.7	-3.2	1.8	9.1	12.7	19.4	19.9	12.6	7.4	3.5	-1.1	6.1
1985	-8.2	-6.5	-4.4	0.5	7.1	12.1	18.9	17.4	13.5	7.5	2.3	-4.2	4.7
1986	-3.9	-7.9	-4.4	2.7	7.5	11.8	15.1	16.8	11.1	7.0	1.6	-3.0	4.5
1987	-5.4	-7.4	-3.8	3.1	7.8	12.1	18.1	16.9	13.5	9.0	2.8	-1.9	5.4
1988	-5.7	-5.3	-2.9	1.9	9.9	12.4	17.6	18.1	12.3	7.7	4.2	-3.6	5.6
1989	-5.4	-8.1	-5.2	2.9	10.3	13.2	16.5	19.0	13.8	7.6	3.1	-7.0	5.1
1990	-4.3	-9.1	-4.6	2.8	5.9	14.7	18.0	19.8	13.7	8.4	3.9	-0.3	5.7
1991	-8.8	-5.8	-1.0	1.9		12.7	17.6	17.6	13.3	9.2	5.0	-3.0	5.3
14-Y AVG.	-5.6	-6.4	-2.5	2.4	8.1	12.9	17.6	17.6	13.1	8.1	3.5	-2.5	5.5

CLIMATE NORMALS 1951-1980

Month	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
Precipitation and rain in mm; snow in cm													
RAINFALL	76.0	57.0	66.6	74.5	89.4	82.0	81.4	101.3	87.2	120.0	148.1	99.0	1082.5
SNOWFALL	74.5	68.6	63.9	25.4	5.3	0.0	0.0	0.0	0.0	2.6	12.0	65.6	317.9
TOTAL	149.0	123.6	131.4	102.0	95.2	82.1	81.4	101.3	87.2	122.7	160.4	163.6	1399.9
ST.DEV.	49.7	41.3	42.3	40.7	45.5	41.4	42.5	47.2	37.8	52.1	67.1	50.1	143.7
Mean Temperatures in degree C													
DAILY MAX.	-0.8	-1.6	1.4	6.0	12.5	18.9	23.1	22.6	18.5	12.7	7.3	1.7	10.2
DAILY MIN.	-8.5	-10.1	-6.3	-2.1	2.3	7.5	12.3	12.6	8.5	4.1	0.3	-5.2	1.3
DAILY MEAN	-4.7	-5.9	-2.5	2.0	7.4	13.2	17.7	17.6	13.5	8.4	3.8	-1.8	5.7
ST.DEV.	2.3	2.6	1.5	1.4	1.4	1.2	1.5	1.1	1.2	1.0	1.5	2.1	0.8

Freezing Index: -444.2 degree-day
Thawing Index: 2559.1 degree-day

PRECIPITATION EXTREMES - 24 HOURS (39-40 years)

Month	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
RAIN, mm	57.2	58.4	52.8	56.1	93.5	72.1	63.8	62.2	90.9	58.9	97.3	94.0	97.3
SNOW, cm	44.5	45.2	37.3	29.2	24.9	1.0	0.0	0.0	0.0	15.7	21.6	58.7	58.7
TOTAL, mm	57.2	58.7	67.1	56.1	93.5	72.1	63.8	62.2	90.9	58.9	97.3	95.0	97.3

Mean Annual Precipitation: 1400 mm
Mean Annual Lake Evaporation: 550 mm
Mean Annual Evapotranspiration: 510 mm
Mean Annual Runoff: 900 mm

FIGURE 1. SYDNEY AIRPORT
MONTHLY PRECIPITATION 1981-1991

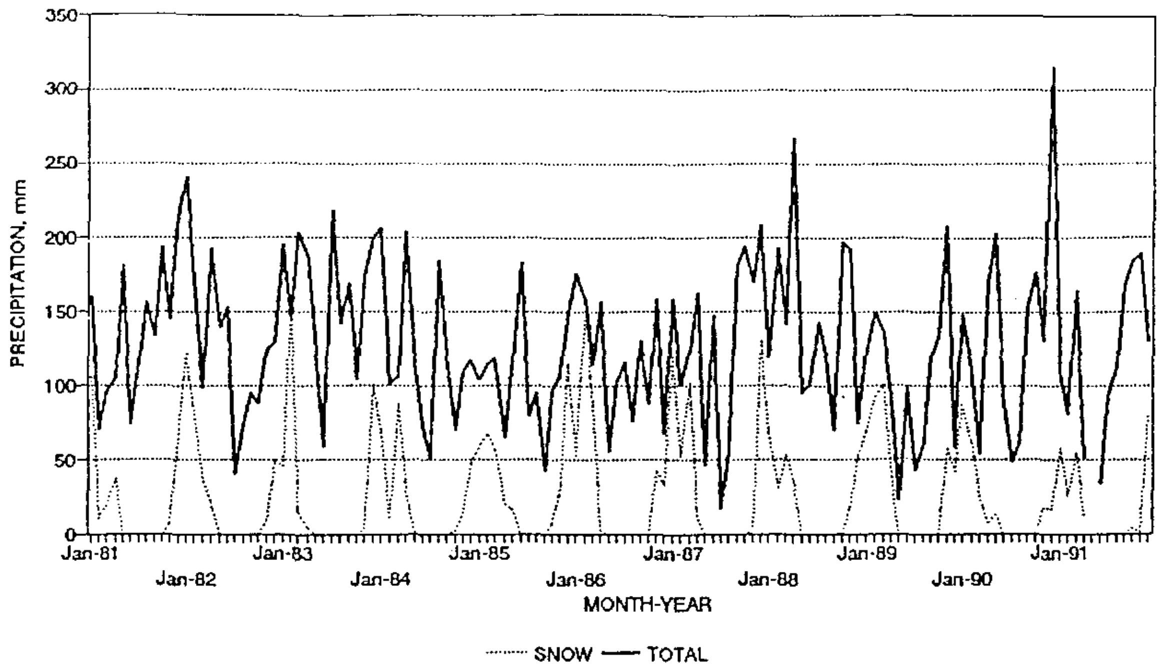


FIGURE 2. SYDNEY AIRPORT
ANNUAL PRECIPITATION 1981-1991

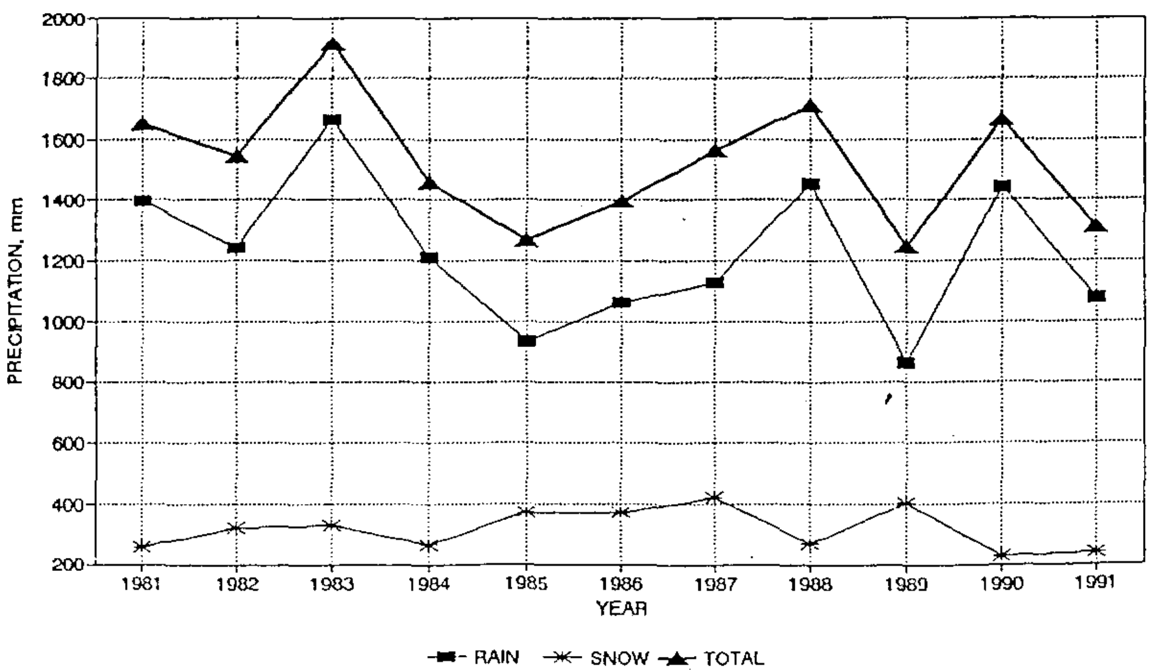


FIGURE 3. SYDNEY AIRPORT
MONTHLY PRECIPITATION MEANS 1981-1991

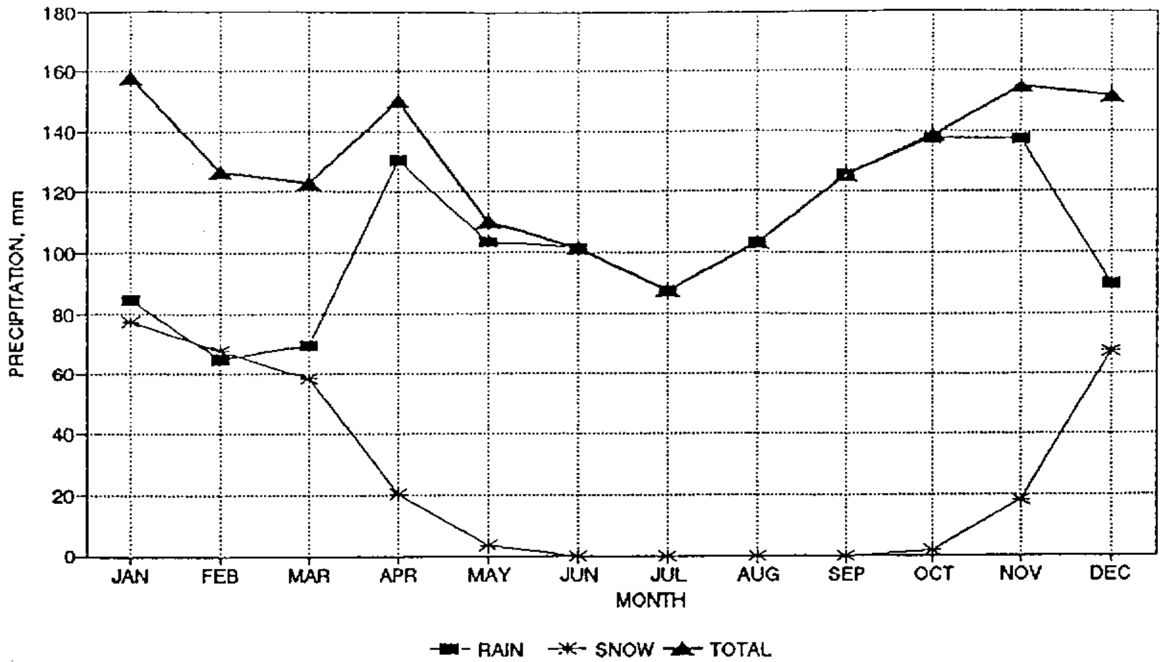
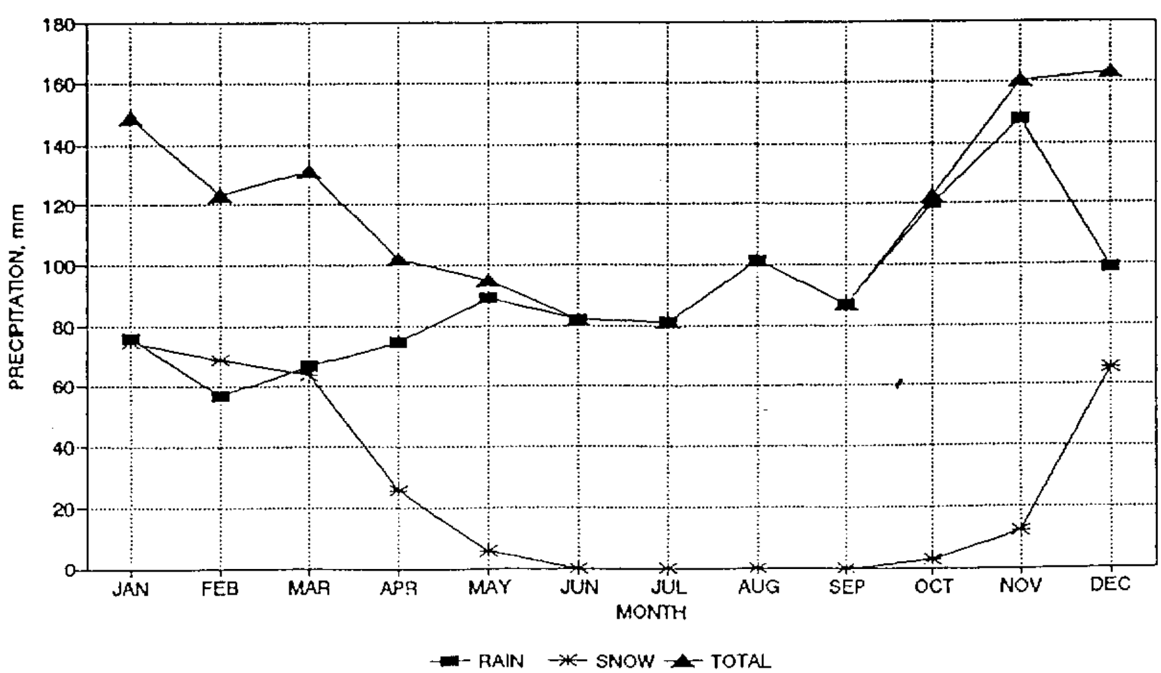


FIGURE 4. SYDNEY AIRPORT
MONTHLY PRECIPITATION MEANS 1951-1980



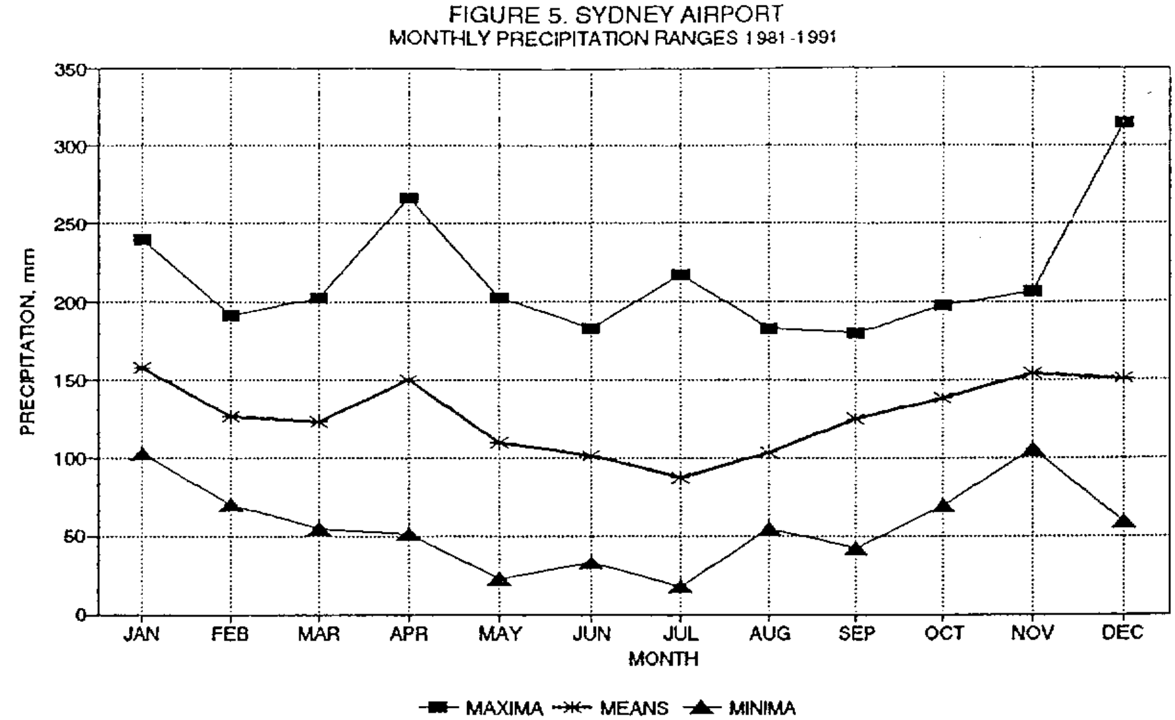


FIGURE 5. SYDNEY AIRPORT
MONTHLY PRECIPITATION RANGES 1981-1991
PRECIPITATION, mm
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTH
MAXIMA
MEANS
MINIMA

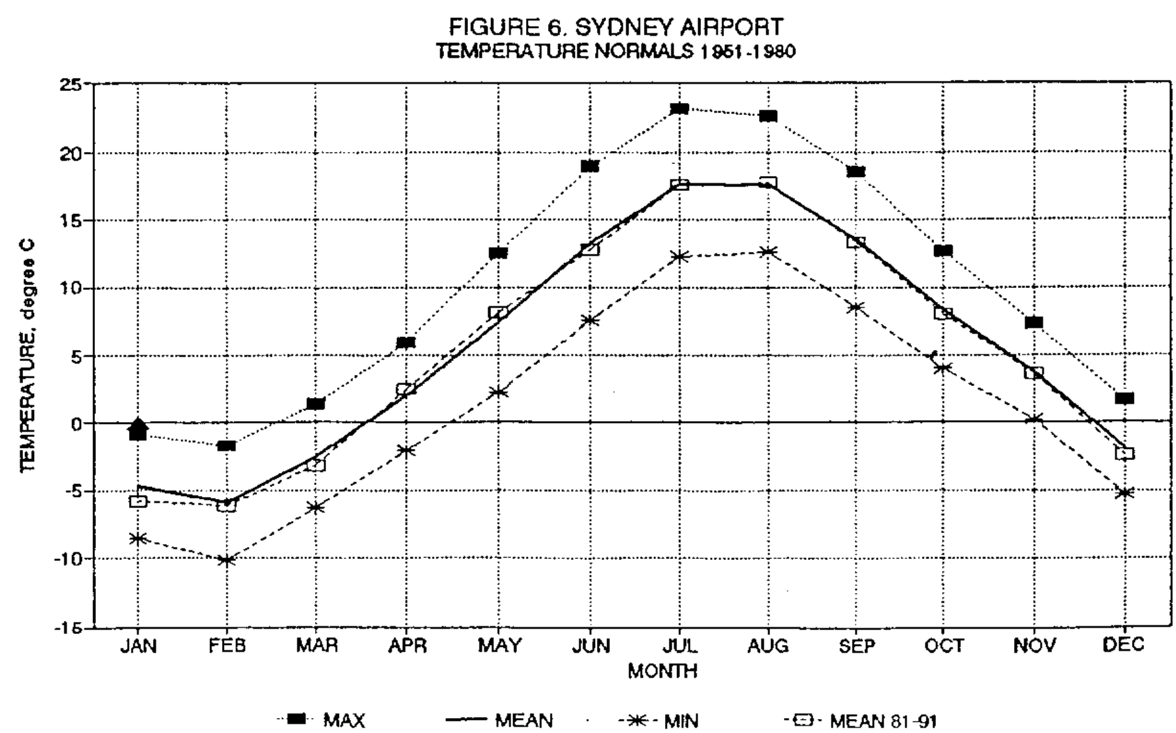


FIGURE 6. SYDNEY AIRPORT
TEMPERATURE NORMALS 1951-1980
TEMPERATURE, degree C
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTH
MAX
MEAN
MIN
MEAN 81-91

Table 2. PRINCE MINE - POINT ACONI, N.S.
A. MINED AREAS from PRODUCTION RECORD

YEAR	PRODUCTION TONNES	ESTIMATED VOLUME cu.ft	AVERAGE THICKNESS ft	AREA sq.ft	CUMULATIVE AREA sq.ft
1975	48,084	849,035	4.92	172,524	172,524
1976	202,293	3,571,955	4.92	725,821	898,345
1977	167,596	2,959,298	4.92	601,329	1,499,675
1978	121,142	2,139,045	4.92	434,654	1,934,329
1979	108,879	1,922,513	4.92	390,655	2,324,983
1980	206,280	3,642,355	4.92	740,126	3,065,110
1981	449,580	7,938,384	4.92	1,613,080	4,678,189
1982	473,707	8,364,402	4.92	1,699,647	6,377,836
1983	735,425	12,985,644	4.92	2,638,683	9,016,519
1984	947,536	16,730,959	4.92	3,399,731	12,416,250
1985	993,758	17,547,116	4.92	3,565,574	15,981,824
1986	1,097,346	19,376,204	4.92	3,937,245	19,919,068
1987	1,189,203	20,998,154	4.92	4,266,825	24,185,893

11-Mar-92

Table 2. PRINCE MINE - POINT ACONI, N.S.
B. "OLD" MINED AREAS from MAPS

	WIDTH ft	LENGTH ft	AREA sq.ft	CUMULATIVE AREA sq.ft	AVERAGE ELEVATION ft	AVERAGE GRND.ELEV. ft
BLOCKS						
A	->	->	212,500	212,500	-40	118
B	->	->	230,000	442,500	-40	105
C	->	->	1,080,000	1,522,500	-75	95
D	->	->	39,375	1,561,875	-115	95
E	->	->	835,000	2,396,875	-120	65
F	->	->	120,000	2,516,875	-220	75
"DEEPS"						
1	20	3250	65,000	65,000	-175	100
2	20	6400	128,000	193,000	-175	100
3	20	6300	126,000	319,000	-175	100
4	20	6150	123,000	442,000	-175	100
5	20	4450	89,000	531,000	-175	100
6	20	2150	43,000	574,000	-175	100
			TOTAL:	3,090,875		

Table 1. PRINCE MINE - POINT ACONI, N.S.
C. DISCHARGE

MINED AREAS

AREA	START DATE	FINISH DATE	WIDTH ft	LENGTH ft	INDIVIDUAL sq.ft	CUMULATIVE sq.ft	ESTIMATED AVG.DEPTH ft a.s.l.	INDIVIDUAL DISCHARGE L/day	CUMULATIVE DISCHARGE L/day
1975	(Ann.Prod.)	75-12-31	(see Table 1A)		172,524	172,524	-158	11,598	11,598
1976	(Ann.Prod.)	76-12-31	(see Table 1A)		725,821	898,345	-145	53,168	64,766
1977	(Ann.Prod.)	77-12-31	(see Table 1A)		601,329	1,499,675	-170	37,571	102,337
1978	(Ann.Prod.)	78-12-31	(see Table 1A)		434,654	1,934,329	-210	21,984	124,321
1979	(Ann.Prod.)	79-12-31	(see Table 1A)		390,655	2,324,983	-185	22,429	146,750
1980	(Ann.Prod.)	80-05-14	(see Table 1A)		330,126	2,655,110	-295	11,886	158,636
SLOPE #1-5	(assumed)	80-06-14	20	62200	1,244,000	3,899,110	-562.5	26,100	184,737
BLOCK 1W	80-05-14	80-08-27	200	2,050	410,000	4,309,110	-520.0	9,305	194,042
BLOCK 1E	80-12-09	81-05-11	200	2,850	570,000	4,879,110	-557.5	12,066	206,108
BLOCK 2E	81-05-25	81-12-17	215	3,000	645,000	5,524,110	-590.0	12,902	219,010
BLOCK 2W	82-02-09	82-09-10	215	3,390	728,850	6,252,960	-575.0	14,959	233,969
BLOCK 3E	82-09-13	83-10-25	290	6,100	1,769,000	8,021,960	-605.0	34,508	268,477
BLOCK 3W	83-08-19	84-02-16	360	2,870	1,033,200	9,055,160	-625.0	19,510	287,987
BLOCK 4E	83-12-01	84-12-07	325	6,760	2,197,000	11,252,160	-637.5	40,672	328,659
BLOCK 5E	84-09-07	85-09-09	360	6,710	2,415,600	13,667,760	-670.0	42,550	371,209
BLOCK 4W	85-08-12	86-04-21	325	4,220	1,371,500	15,039,260	-615.0	26,319	397,528
BLOCK 6E	86-01-27	86-10-03	375	5,260	1,972,500	17,011,760	-697.5	33,375	430,902
BLOCK 5W	86-08-11	87-05-11	320	4,890	1,564,800	18,576,560	-632.5	29,197	460,100
BLOCK 4AW	87-04-24	87-12-11	370	1,880	695,600	19,272,160	-662.5	12,391	472,491
BLOCK 7E	86-11-19	88-06-03	375	4,850	1,818,750	21,090,910	-717.5	29,916	502,407
BLOCK 6W	87-10-05	88-12-19	370	7,370	2,726,900	23,817,810	-672.5	47,854	550,261
BLOCK 8E	?	89-05-19	375	4,140	1,552,500	25,370,310	-742.5	24,676	574,937
BLOCK 7W	88-11-03	89-12-11	370	7,850	2,904,500	28,274,810	-707.5	48,450	623,387
DECLINE #1-3	(assumed)	90-01-01	20	9,300	186,000	28,460,810	-837.5	2,621	626,008
BLOCK 8W	89-10-19	90-06-23	370	7,880	2,915,600	31,376,410	-727.5	47,298	673,306
BLOCK 9W	90-07-03	90-11-21	470	7,775	3,654,250	35,030,660	-760.0	56,745	730,051
AFTER 21 NOV. 1990:		90-11-21							
BLOCK 10W	estimated	91-06-01	475	8,250	3,918,750	38,949,410	-795.0	58,174	788,225
BLOCK 11W	estimated	92-01-01	475	8,330	3,956,750	42,906,160	-835.0	55,924	844,149
BLOCK 12W	estimated	92-06-01	470	7,890	3,708,300	46,614,460	-872.5	50,160	894,309
BLOCK 13W	estimated	93-01-01	470	7,890	3,708,300	50,322,760	-902.5	48,492	942,801
BLOCK 14W	estimated	93-06-01	470	5,530	2,599,100	52,921,860	-940.0	32,632	975,433
BLOCK 15W	estimated	94-01-01	470	7,900	3,713,000	56,634,860	-970.0	45,175	1,020,608
SLOPES:									
S1A	assumed	80-05-01	20	7,400	148,000	148,000	-562.5	3,105	3,105
S1	assumed	80-05-01	20	7,900	158,000	306,000	-562.5	3,315	6,420
S2	assumed	80-05-01	20	11,500	230,000	536,000	-562.5	4,826	11,246
S3	assumed	80-05-01	20	11,500	230,000	766,000	-562.5	4,826	16,071
S4	assumed	80-05-01	20	12,000	240,000	1,006,000	-562.5	5,035	21,107
S5	assumed	80-05-01	20	11,900	238,000	1,244,000	-562.5	4,993	26,100
DECLINES:									
D1	assumed	90-01-01	20	3,100	62,000	62,000	-837.5	874	874
D2	assumed	90-01-01	20	3,100	62,000	124,000	-837.5	874	1,747
D3	assumed	90-01-01	20	3,100	62,000	186,000	-837.5	874	2,621
		GRAND TOTAL:			53,979,750				

MINED AREA		35,030,660 sq.ft
AVERAGE ELEVATION	(calculated)	-509.67 ft a.s.l.
WATER DISCHARGE	1,350,000 USgln/wk =	730,041 L/day
UNIT DISCHARGE for average OVERBURDEN		0.02084 L/sqft/day
UNIT DISCHARGE for 1 ft OVERBURDEN		10.621559 L/sqft/day

FIGURE 7. PRINCE MINE, N.S.
DISCHARGE vs. MINED AREA (Nov '90)

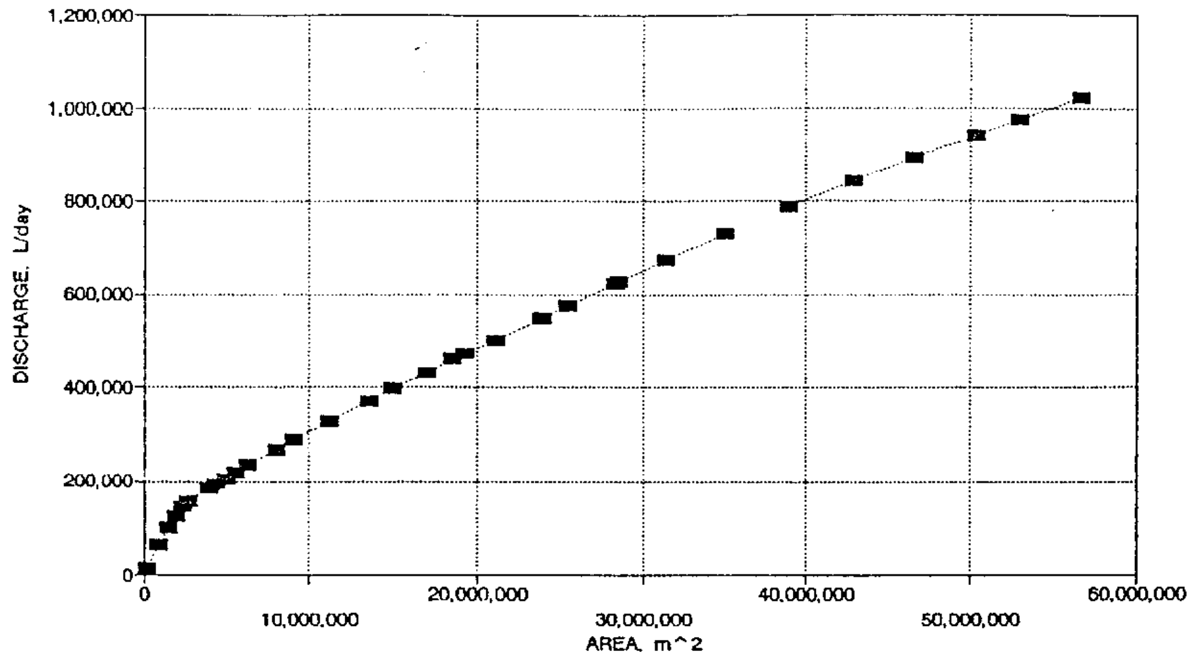
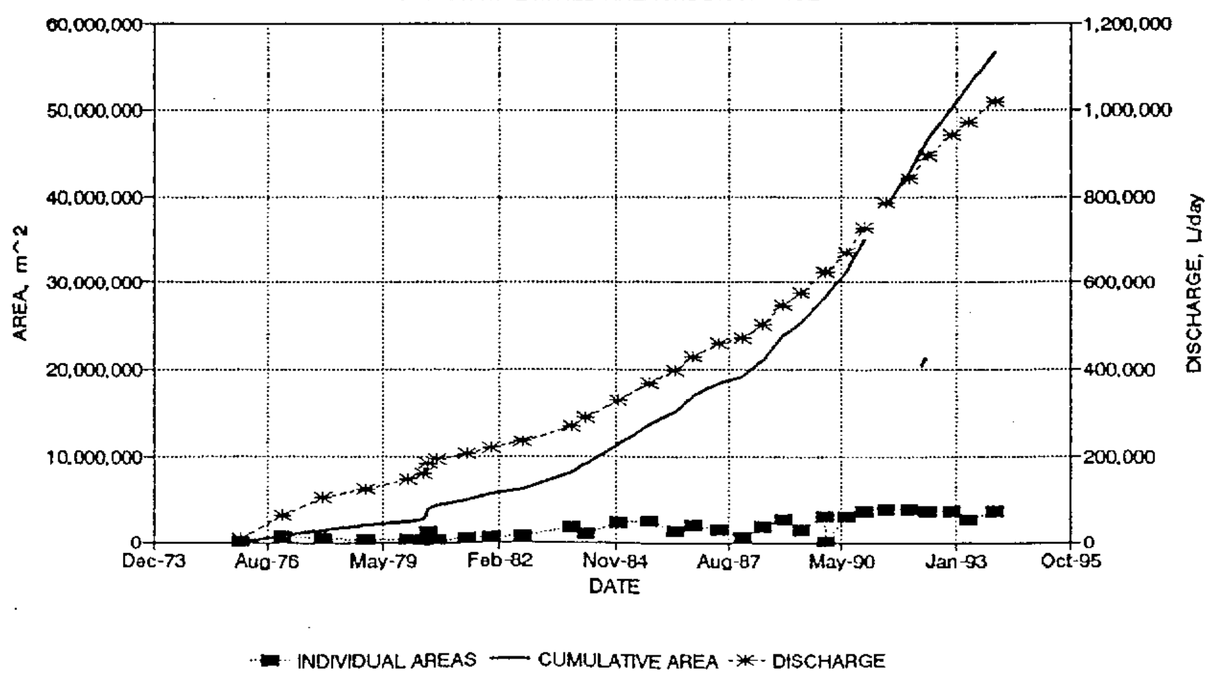


FIGURE 8. PRINCE MINE, N.S.
CUMULATIVE MINED AREA and DISCHARGE



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SAMPLE DATE			21-Sep-89	18-Oct-89	23-Oct-89	15-Nov-89	18-Dec-89	26-Jan-90	26-Feb-90	09-Mar-90
ASSAYERS CODE			?	?	?	?	?	?	?	?
SAMPLING LOCATION		SEAWATER	Prince M. Discharge #1	Prince M. Discharge #1	Prince M. Discharge #1	Prince M. Discharge #1	Prince M. Discharge #1	Prince M. Discharge #1	Prince M. Discharge #1	Prince M. Discharge #1
FLOW, L/min ****										
Temp. (C)										
pH		8.2	2.9	2.9	2.7	2.8	3.1	3.1	2.7	2.7
Cond. (umhos/cm)		40000	37100	41400	27800	40500	41700	49400	46200	43100
Acidity (mg/l)			582	445	530	544	482	480	552	482
Alkalinity (mg/l)										
	At.Wght									
Al	26.9815	0.01	21	18	15.1	25	21	26	29	31
As		0.003								
B		4.6								
Ba		0.03								
Be		6E-07								
Bi										
Ca	40.08	400	1154	1260	1190	1250	1180	1640	1720	1530
Cd		0.00011								
Ce										
Co		0.0005								
Cr		5E-05								
Cu		0.003								
Fe	55.847	0.01	220	120	105	0.5	150	110	167	160
K	39.0983	380	72	50		72	88	95	83	77
La										
Mg	24.305	1350	673	520	465	530	522	618	617	640
Mn	54.938	0.002	39	28.1	21.5	36	32	29	30	41
Na	22.9898	10500	4000	4500	3900	4850	5100	5600	4900	4800
Ni		0.002								
P		0.07								
Pb		3E-05								
S	32.06	see SO4	467.25	530.66	552.36	580.72	630.79	534.00	610.76	614.10
Sb		0.0005								
Si		3								
Sr										
V		0.002								
Y										
Zn	65.38	0.01								
Zr										
Cl	35.453	19000	9600	9830	5170	9490	10100	12600	11200	10300
SO4	96.06	885	1400	1590	1655	1740	1890	1600	1830	1840
NO3/NO2		0.3								
NH4		0.07								
SUM, mmole/L		1,077	523	547	384	553	584	688	623	590
K/Na		0.013	0.006	0.004		0.005	0.006	0.006	0.006	0.006
Na/Cl		1.31	0.99	1.09	1.79	1.22	1.20	1.06	1.04	1.11
Fe/SO4		0.00003	0.46	0.22	0.19	0.0009	0.23	0.20	0.27	0.26
Ca/SO4		2.60	4.73	4.55	4.13	4.13	3.59	5.89	5.40	4.78
Ca/Ca(seawater)		100.0%	288.5%	315.0%	297.5%	312.5%	295.0%	410.0%	430.0%	382.5%
SO4/SO4(seawater)		100.0%	158.2%	179.7%	187.0%	196.6%	213.6%	180.8%	206.8%	207.9%
Cl/Cl(seawater)		100.0%	50.5%	51.7%	27.2%	49.9%	53.2%	66.3%	58.9%	54.2%
Sum/Sum,seawater		100.0%	48.6%	50.8%	35.7%	51.4%	54.2%	63.9%	57.9%	54.7%
Na/Na(seawater)		100.0%	38.1%	42.9%	37.1%	46.2%	48.6%	53.3%	46.7%	45.7%
K/K(seawater)		100.0%	18.9%	13.2%		18.9%	23.2%	25.0%	21.8%	20.3%

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SAMPLE DATE	28-Sep-90	6-Nov-90	5-June-91	4-June-91	20-Aug-91	20-Aug-91	4-June-91	4-June-91
ASSAYERS CODE	?	?	?	?	?	?	?	?
SAMPLING LOCATION	Prince M. Discharge #1	East Tunnel	East Tunnel #2	Rock Dump	PN	PN+O #3	Sewage Lagoon	Brook
FLOW, L/min ****	506.97		39.7					
Temp. (C)								
pH	2.7	2.6	2.6	2.6	3	3	8.5	6.5
Cond. (umhos/cm)	29500	25900	30700	8.97 ??	10400	6310	0.433 ??	0.248 ??
Acidity (mg/l)	512	880	970	8100				6.6
Alkalinity (mg/l)							110	3.6
Al	19.4	54.7	65.46	930	111	71.7	0.01	0.09
As		0.82	1.09	13.57				
B	1.1				0.14	0.1		
Ba	0.18				0.22	0.028		
Be					0.044	0.031		
Bi								
Ca	1160	153.5	227.7	420	239	166	31.05	16.7
Cd		0.03	0.04	0.23				
Ce								
Co		0.25	0.32	6.78				
Cr								
Cu	0.05	0.09	0.03	3.19	0.87	0.5		
Fe	107	265.9	269.9	507.8	208	101	0.33	0.36
K	59				3	2.7		
La								
Mg	550	60.74	85.51	788	164	104	7.88	6.56
Mn	28	20.14	30.34	385.6	87.1	55	0.67	1.91
Na	4520				150	102		
Ni		0.69	0.76	14.24	2.41	1.55		
P						0.06		
Pb		0.22	0.38	3.58				
S	760.95	534.00	647.47	3804.75	881.10	564.04	16.42	20.29
Sb			0.51	4.23				
Si	19				53.5	39.2		
Sr								
V			0.08	0.27	0.06	0.03		
Y								
Zn	3.86	1.84	2.24	36.78	10	5.63		0.01
Zr								
Cl	8340	75	145	45.6	126	86.1	48.6	31
SO4	2280	1600	1940	11400	2640	1690	49.2	60.8
NO3/NO2								
NH4	2.1				0.61	0.62		
SUM, mmole/L	512	32	41	214	60	39	3	2
K/Na	0.005				0.007	0.009		
Na/Cl	1.29				2.83	2.82		
Fe/SO4	0.14	0.49	0.41	0.13	0.23	0.18	0.02	0.02
Ca/SO4	2.92	0.55	0.67	0.21	0.52	0.56	3.63	1.58
Ca/Ca(seawater)	290.0%	38.4%	56.9%	105.0%	59.8%	41.5%	7.8%	4.2%
SO4/SO4(seawater)	257.6%	180.8%	219.2%	1288.1%	298.3%	191.0%	5.6%	6.9%
Cl/Cl(seawater)	43.9%	0.4%	0.8%	0.2%	0.7%	0.5%	0.3%	0.2%
Sum/Sum,seawater	47.5%							
Na/Na(seawater)	43.0%				1.4%	1.0%		
K/K(seawater)	15.5%				0.8%	0.7%		

FIGURE 9. PRINCE MINE, N.S.
MINE WATER - ELEMENT CONCENTRATIONS

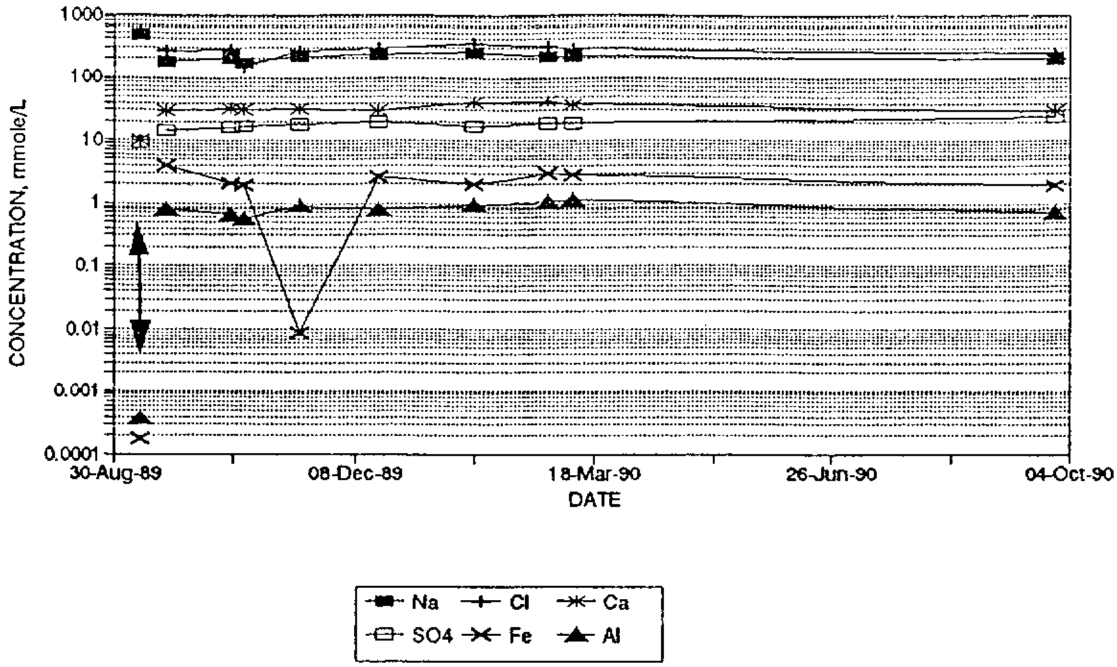

FIGURE 10. PRINCE MINE, N.S.
MINE WATER - ELEMENT RATIOS

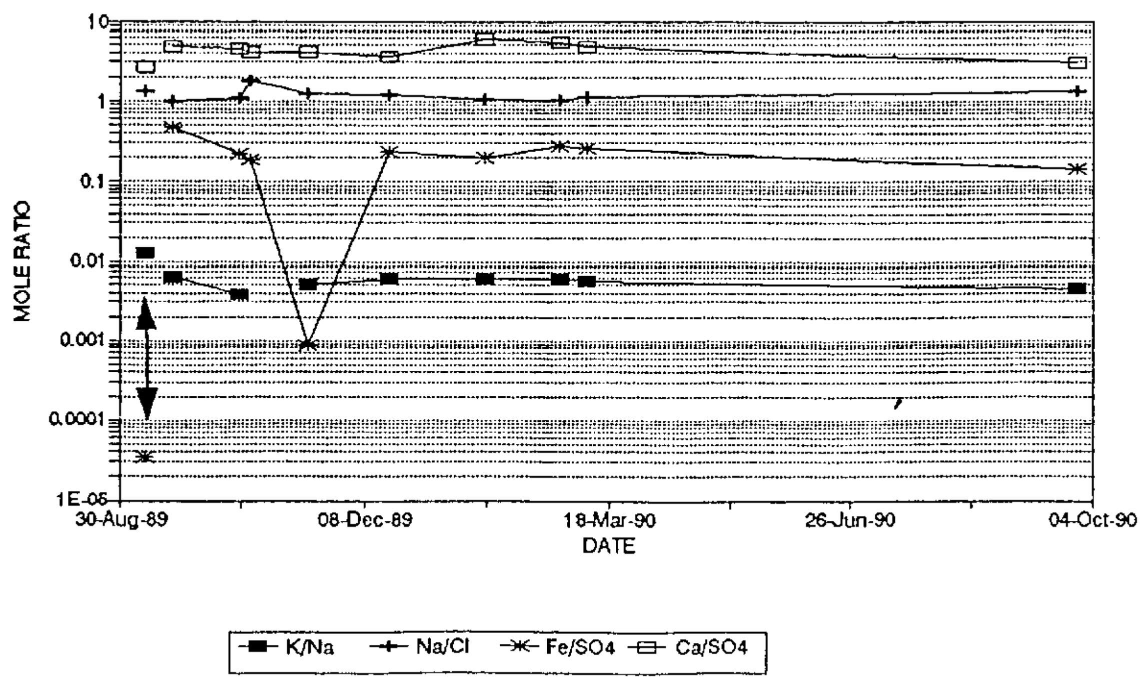

FIGURE 11. PRINCE MINE, N.S.
MINE WATER - SEAWATER COMPARISON

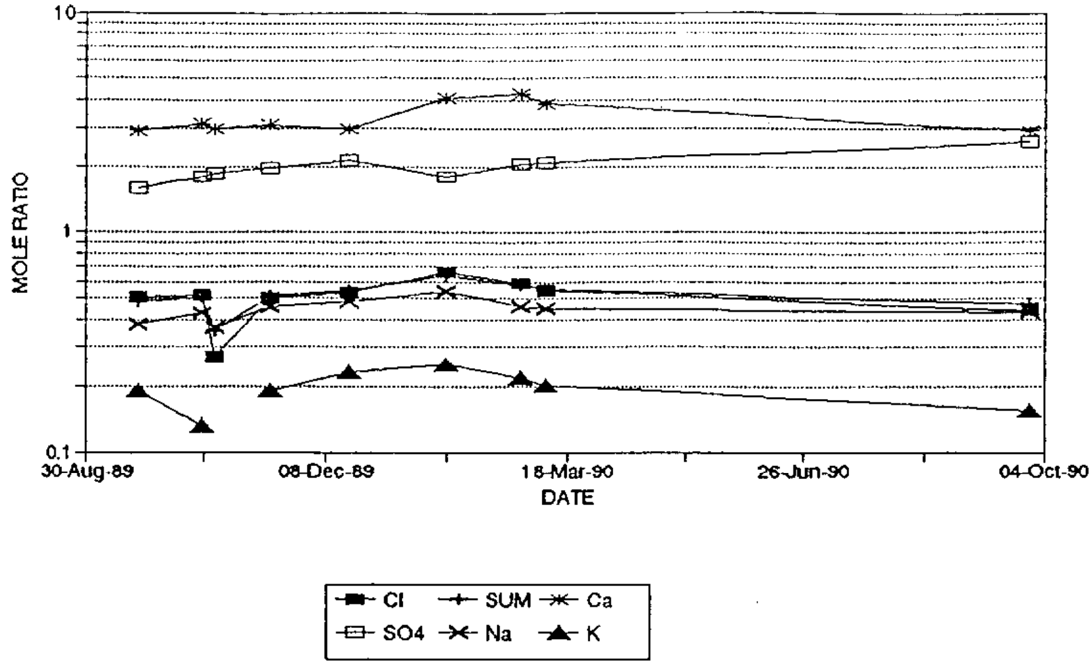

TABLE 4. POTENTIAL ORIGIN OF PRINCE MINE WATER (sample of 28 September 1990)

	MINE WATER	SEA WATER	BROOK WATER	$CaCO_3$	$CaMg(CO_3)$	MnO_2	FeS_2	Na<->Ca	$KFe_3(SO_4)_2$	CaSO4	$KAl(SO_4)_2$
Al	.719	.000	.003	.000	.000	.000	.000	.000	.000	.000	1.000
Ca	28.942	9.980	.417	1.000	1.000	.000	.000	1.000	.000	1.000	.000
Fe	1.916	.000	.006	.000	.000	.000	1.000	.000	3.000	.000	.000
K	1.509	9.719	.000	.000	.000	.000	.000	.000	1.000	.000	1.000
Mg	22.629	55.544	.270	.000	1.000	.000	.000	.000	.000	.000	.000
Mn	.510	.000	.035	.000	.000	1.000	.000	.000	.000	.000	.000
Na	196.610	56.720	.633	.000	.000	.000	.000	-2.000	.000	.000	.000
SO_4	23.735	9.213	.633	.000	.000	.000	2.000	.000	2.000	1.000	2.000
RS	55.278	142.410	3.798	4.000	8.000	4.000	.000	.000	21.000	6.000	12.000
MIX	1.000	1.000	1.000	.000	.000	.000	.000	.000	.000	.000	.000

MIXING RATIO

Seawater fraction : .4604
Freshwater fraction : .5396

MINERAL DISSOLUTION & PRECIPITATION

CALCITE : 21.0449 millimole/L dissolved
DOLOMITE : -3.0898 millimole/L precipitated
PYROLUSITE : .4909 millimole.L dissolved
PYRITE : 12.9607 millimole/L dissolved
ION EXCHANGE : 7.0054 millimole/L Na exchanged for Ca
JAROSITE : -3.6828 millimole/L precipitated
GYPSUM : -.8383 millimole/L precipitated
ALUM : .7170 millimole/L dissolved