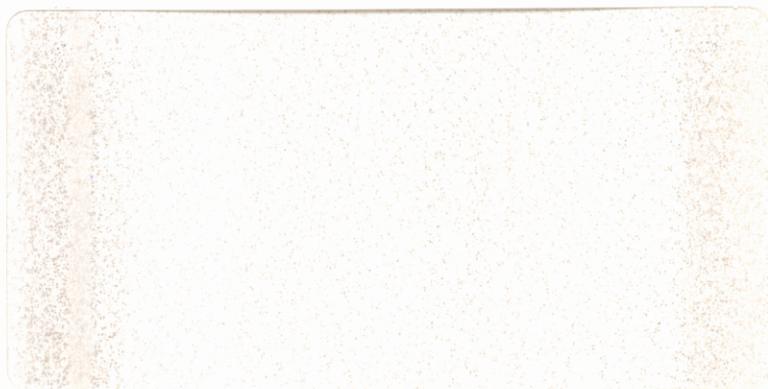


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**REPORT ON
REMEDICATION OF ACIDIC
DRAINAGE PRINCESS
WASTE ROCK SITE, SYDNEY MINES**

File No. 24-3515-004-1

Prepared for:

**ATLANTIC INDUSTRIAL MINERALS
418 Portsway Avenue
Sydport Industrial Park**

BY:

**ADI NOLAN DAVIS
P.O. Box 1688
Sydney, N.S.**

**Project Manager: Fred Baechler
Reviewed by: Lynn Baechler
Date: March 30, 1995**

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EXECUTIVE SUMMARY

The Princess Colliery operated for 100 years (1876 to 1975), producing 30 million tons of coal. The associated coarse waste rock pile covered 54 hectares and contained approximately 1.8 million tons of material. From 1980 to 1989 coal recovery plants operated on the waste site recovering some 300,000 tons of coal. Site contouring and hydro-seeding was subsequently carried out by CBDC.

The objective of this investigation was to assess the potential of utilizing passive treatment technologies to treat the acid drainage still discharging from the site. The May 1994 to March 1995 field program defined the factors governing the formation and transport of acid drainage off site. It documented the history of the site, and prepared topographic mapping. A total of 20 test pits were excavated over the coarse waste pile and 92 auger probes undertaken in Cranberry Bog. A monitoring network consisting of 23 shallow wells and 12 surface water stations were sampled over three seasons for water chemistry, flow and head levels. This was supported by 12 site inspections under different seasonal and weather conditions.

The key point governing the development of a passive remediation plan for the site was the high discharges of highly acidic water from the site. Given the high acidity (3,500 mg/L), high iron and aluminum concentrations (2,000 mg/L and 18 mg/L respectively), as well as high flows (3,000 L/min), the reliance on any one technique (i.e. ALDs, SAPS, wetland) was not considered prudent. The first year work plan recommends minimizing waste-water contact. When groundwater flows become manageable successive passive treatment systems should be considered.

It is recommended that the first year work program reduce the inflow of water to the site by the construction of two stream diversions and one groundwater drain. In addition the drainage density should be increased to enhance storm run-off; thereby reducing infiltration. The key concept in this phase was undertaking a "Natural Forest Soil Transplant". This is an innovative technique but not complex. It is a site specific strategy to re-establish a natural soil ecosystem over initially 7 hectares of coarse waste, which would within two years begin to control infiltrating precipitation.

The implementation of Phase 2 is dependent on the success of Phase 1. If the initial work is successful and groundwater flow rates reduced sufficiently then options put forward for review included increasing the natural forest soil concept to cover the entire site and/or installation of ALDs and SAPS. Throughout this program Edward's Pond will continue to be utilized as an estuarine wetland that serves as the final polishing for discharge from the coarse waste pile.

1.0 INTRODUCTION

1.1 Background

The Princess waste rock disposal area is located in the Town of Sydney Mines (Figure 1-1), Cape Breton. The site lies in close proximity to both the downtown core and residential areas (Figure 1-2).

The Princess Colliery operated for 100 years from 1876 to 1975 producing 30 million tons of coal. In the early 1950's a coal wash plant was established on the site which processed coal until 1983. The associated waste rock pile received wash plant and mine reject material from these operations.

Following closure of the Colliery, a coal recovery operation was set up to recover coal deposited within the waste rock. This operation ceased in 1987 after recovery of just over 300,000 tonnes of saleable coal.

Since that time the site has undergone basic reclamation which included contouring; lime addition; soil amendment(peat) and hydro-seeding. This reshaping resulted in a surface area for the coarse waste pile of about 54 hectares (133 acres). This work was completed in August, 1993.

1.2 Scope of Work

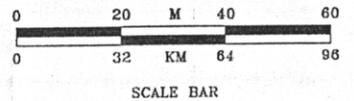
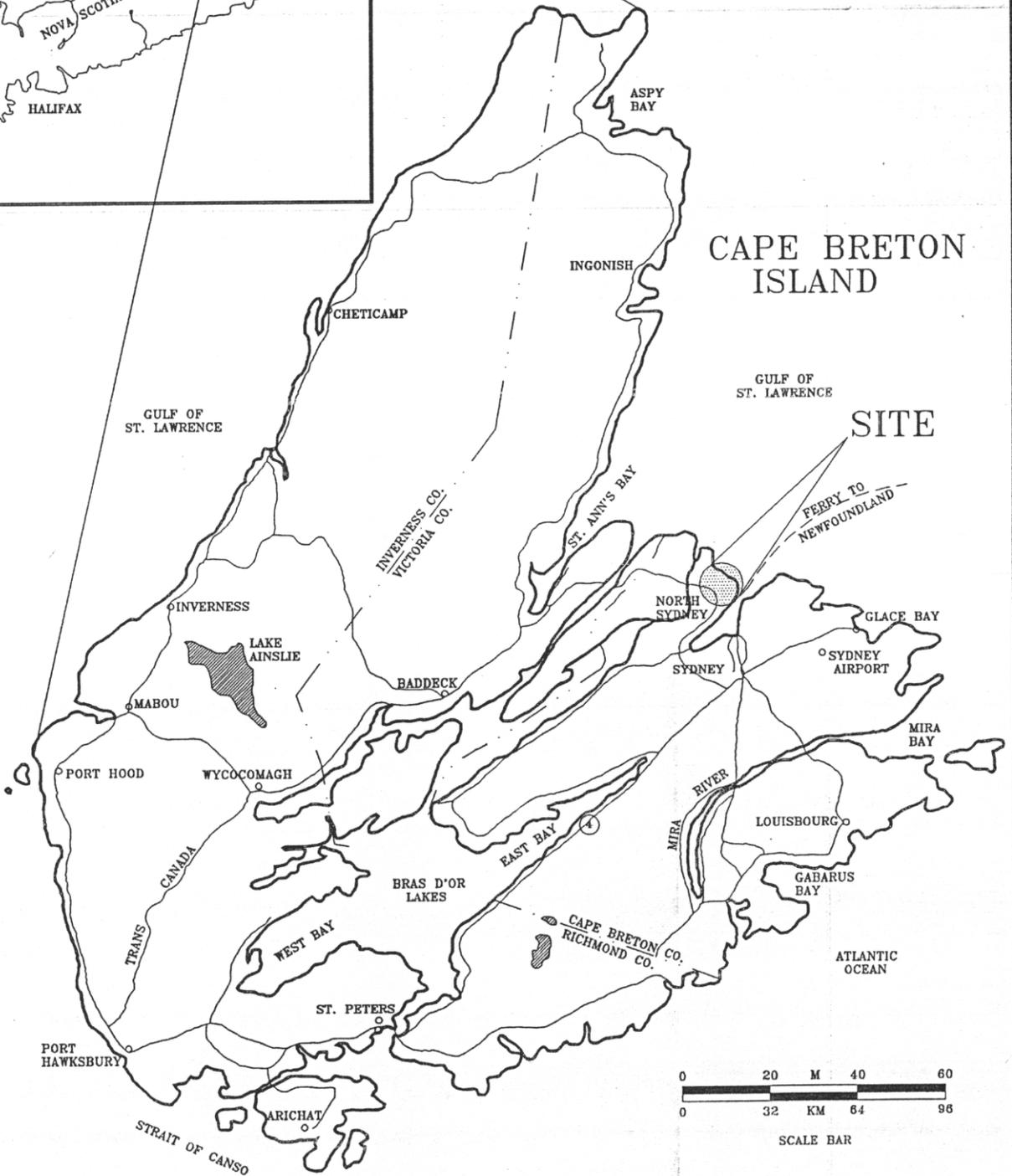
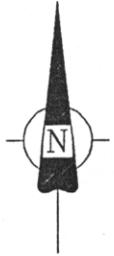
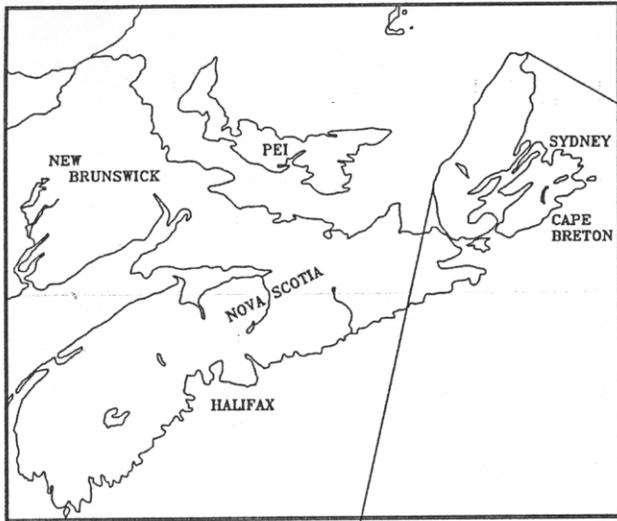
The principle objective of this project has been to investigate the potential of utilizing *passive treatment technologies* to treat the acid drainage discharging from the site.

A proposal to undertake this work was supported by the Cape Breton Development Corporation (CBDC) and submitted to the Nova Scotia Department of Natural Resources for funding in December 1993.

Formal permission to proceed was received on April 13, 1994.

The scope of work outlined for this project was to delineate the ground/surface flow system on site and based upon that information, develop remediation options with associated CLASS D cost estimates.

The physical boundary for this study is outlined on Figure 1-2. Specifically it includes the coarse waste rock site positioned north and west of Pitt Street and Ocean Street. Although there are two other such sites in close proximity, they were not considered part of this study.

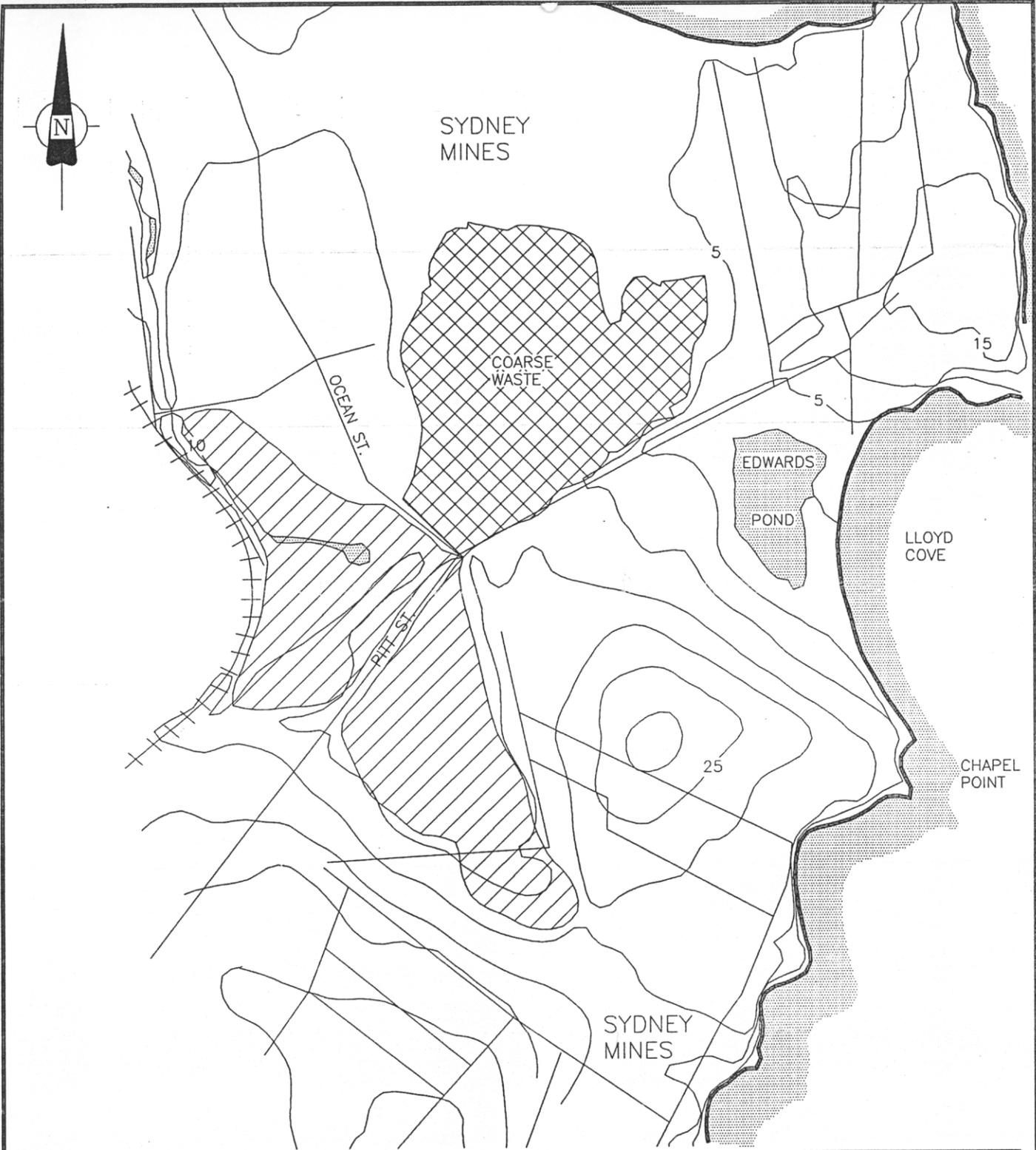


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FIGURE 1-1
REGIONAL LOCATION PLAN
PRINCESS COARSE COAL WASTE DISPOSAL SITE
SYDNEY MINES, NOVA SCOTIA

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STUDY AREA

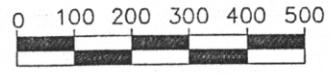


COARSE COAL WASTE ROCK PILES

— 25 — CONTOURS(m)

— / — ROADS/STREETS

+ + + + RAILWAY



SCALE BAR(m)



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FIGURE 1-2
 SITE LOCATION MAP
 PRINCESS COARSE WASTE SITE
 SYDNEY MINES, NOVA SCOTIA

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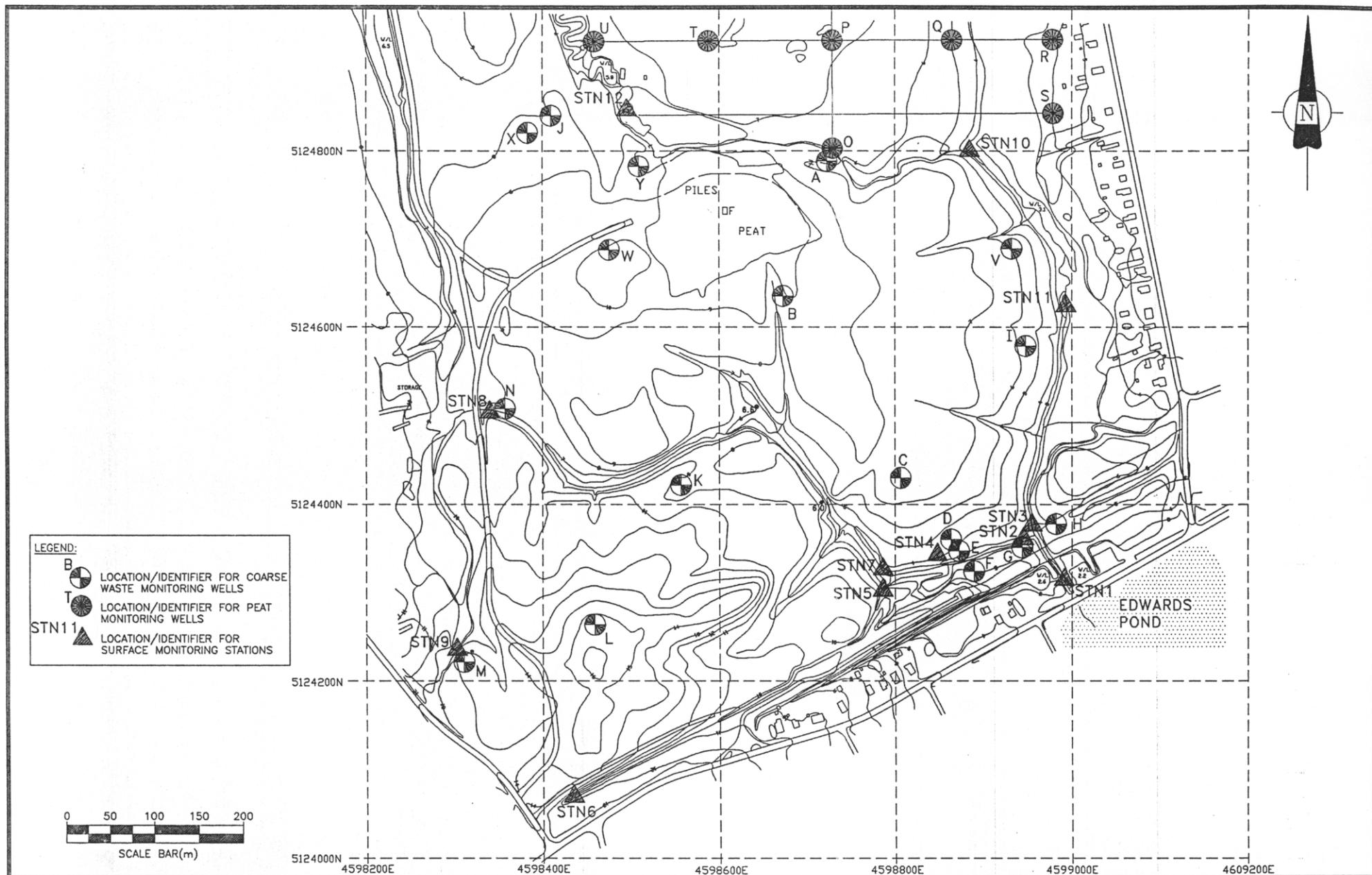
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1.3 Work Programs

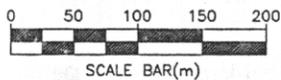
Data acquisition encompassed a total of five (5) tasks as summarized below:

- **Site Mapping:** EASTCAN Ltd of Dartmouth was contracted to develop a topographic map of the site at 1:2,000 with a 1 meter contour interval based on existing air photo coverage flown on June 20, 1993.
- **Site History:** Research was undertaken to document the history of the site, utilizing air photographs; files from regulatory agencies, library and CBDC, as well as discussions with local residents and CBDC staff who had knowledge of the site operations.
- **Site Inspections:** During the course of the field program the site was inspected a total twelve (12) times between May 10, 1994 and March 14, 1995. These took place during differing weather conditions to note how it responded to different seasonal and rainfall events. Photographic coverage was taken during most of these inspections and is available at ADI Nolan Davis's Sydney office for review.
- **Test Pitting and Piezometer Installation:** A total of twenty (20) test pits were excavated over the site to determine geological and groundwater conditions within the coarse waste. In addition, 92 hand probes were undertaken in the bog complex north of the site to determine depth of peat. A total of 16 piezometers were installed in the coarse waste and seven (7) in the bog for long term monitoring. Test pit logs are provided in Appendix A. The locations for these sites is presented in Figure 1-3.
- **Monitoring:** A total of 23 groundwater monitoring wells and 12 surface water stations were monitored between May 31, 1994 and January 9, 1995. After three events; August 16, October 5, 1994 and January 9, 1995, surface water discharge, groundwater head levels and ground/surface water chemistry samples were collected within an eight hour period to obtain a "snapshot" in time of the full range of hydrological conditions. Weather data was provided by Environment Canada staff at the Sydney Airport station, some 15 km southeast of the site. The physical data in terms of groundwater head levels and surface water discharges are presented in Appendix B. Surface and Groundwater Chemistry data is presented in Appendix C.



LEGEND:

-  LOCATION/IDENTIFIER FOR COARSE WASTE MONITORING WELLS
-  LOCATION/IDENTIFIER FOR PEAT MONITORING WELLS
-  LOCATION/IDENTIFIER FOR SURFACE MONITORING STATIONS



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FIGURE 1-3
LOCATION OF SAMPLING STATIONS
PRINCESS COARSE WASTE SITE
SYDNEY MINES, NOVA SCOTIA

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1.4 Study Team

The study team brought together to undertake this project included:

ATLANTIC INDUSTRIAL MINERALS	. Mr. D. MacKenna . Mr. B. Cunningham P. Eng. . Ms. M. MacKenna
ADI NOLAN DAVIS	. Mr. F. Baechler . Mrs. L. Baechler . Dr. J. Foulds . Mr. N. Bach . Mr. O. Roach . Ms B. Penny
SUB-CONSULTANT	. Dr. S. Manley (UCCB)
Representative for CBDC	. Mr. G. Landry P.Eng

2.0 SITE HISTORY

The Princess Coal Colliery was located in the heart of the coastal town of Sydney Mines, Cape Breton. It was the first submarine coal mine in Canada. The Princess mined the Harbour seam and had the distinction of being the largest and most prosperous Nova Scotia mine of the early twentieth century. It opened in 1876 producing 30 million tons of coal before closing in 1975.

In 1900 the Nova Scotia Steel Company purchased the General Mining Association, owner of the Princess Mine. This merger occurred as a result of what was thought to be an abundance of metallurgical coal in the area, a key ingredient in steel production. Over the next few years a coking plant was erected near the site and the steel making operation transferred from New Glasgow to Sydney Mines.

During the next twenty years the steel plant and Princess Colliery produced quality coal and steel. Demand for steel dropped after the end of World War I, contributing to the shut down of the plant in 1921. It was dismantled and integrated with the Dominion Steel Mill in Sydney. Although the closure hurt Sydney Mines economically, the market demand for coal continued, keeping the mine in full production. With growth and expansion, a new coal seam, the Phalen Seam, was worked and the mine output changed from the high quality metallurgical coal to a higher sulphur coal suitable for thermal generation and domestic use.

Prior to the closure of the steel mill, the mining practice involved manual extraction and loading of coal. This system made it possible to assure that a minimum of extraneous materials would be brought to surface with the coal and the product could be well cleaned for the market by screening and hand-picking. This resulted in a low volume of coarse coal waste rock to be disposed of.

With improvements and advances in mining mechanization, hand-loading of coal was virtually eliminated in the 1940's. New methods required large tunnels, reaching beyond the height of the coal seam, which required taking roof shales and sandstone with the extracted coal. This further advancement in methods led to an increase in the volume of coarse waste requiring disposal, which was typically deposited on property adjacent to the mining facilities. The outline of the coarse waste pile as shown in Figure 2-1 reflects this gradual growth in size up to 1950, expanding north from the mining buildings along Pitt Street to Cranberry Bog. In 1950, the dump estimated to be approximately eight hectares in size, contained scrap, waste rocks, coal, and large quantities of sandstone, siltstone and shale.

In the 1950's mechanization further improved coal production techniques. A wash plant, erected on the Princess property in the early 1950's, washed the Princess output as well as coal railed in from Florence #3, Glace Bay #26 Colliery and later Lingan collieries. Washing the mine output separated the coal from the stone waste, thereby increasing the value of saleable coal and the amount of waste.

Washing the coal produced a coarse and fine waste product. The coarse waste contained larger rocks that were directed to a holding bin and then trucked to the Princess Coarse waste site. The fine waste was contained in the wash water which was directed into settling ponds prior to being released to Big Pond.

The Princess coarse waste site received and concentrated the removed inorganic and organic impurities of the washing process as well as the large stone. The dump grew substantially as a result of coal washing (Figure 2-1, outline of waste pile 1969). At the mine's closing in 1975 the waste dump covered an area of 54 hectares, containing an estimated 1.8 million tons of deposited material.

With the explosion of oil prices in the 1980's the demand for thermal coal increased; as well as the desire to rehabilitate abandoned mine dumps and reclaim any remaining coal left in waste piles.

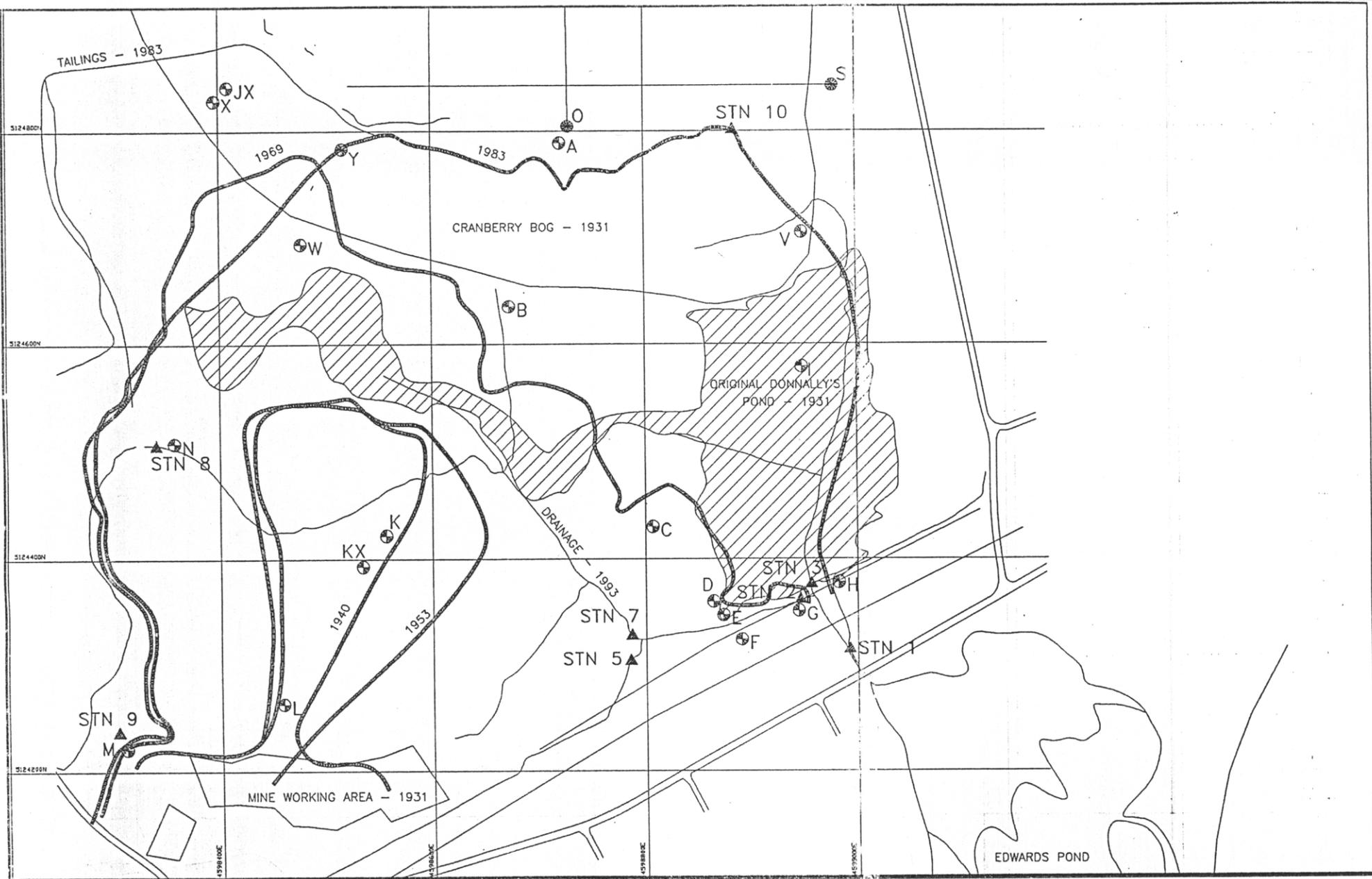


FIGURE 2-1
 EXTENT OF COARSE WASTE WITH TIME
 PRINCESS SITE
 SYDNEY MINES, NOVA SCOTIA



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Montreal based Selco Mining Limited, through its associated company Selminco, expressed interest in the reclamation of coal from waste piles. The Princess mine was identified as the most promising for reclamation. Selminco entered an agreement with the mine's owners, CBDC, to install and operate a wash plant to recover coal; operations commenced in 1980. It was expected that the coal recovered would be low in ash and sulphur, which was subsequently confirmed.

Selminco built a coal recovery plant on site using a wash drum and screens to reclaim the coal. The waste site was reworked, by excavating the stone waste and trucking it to the plant. The material discharged into a drum where lime was added for corrosion protection. The wash drum separated coarse coal from the stone and the stone reject was trucked back to the excavated areas of the stone waste pile. Wash water and fines from the coal recovery plant were piped to a series of settling ponds in the excavated area of the waste site where the solids were settled. Cranberry Bog, located east of Lamond Street was reshaped into several independent interlinked settling ponds with the decanted water discharged to Edward's Pond (Figure 2-2). The reject from the recovery plant was used to construct low profile dikes and cover settled dried ponds. The system of excavation and backfill with coarse waste reject from the plant was arranged to generally contour the site in preparation for grading and revegetation at the end of the coal recovery project.

Selminco completed their recovery in 1987. A local firm, Coastal Construction bought the plant and ran it for a year and a half before dismantling it in 1989. Of the 54 hectares Selminco reworked, 300,000 tons of coal was recovered for a recovery rate of 15%. Under the operation by Coastal Construction 10% coal was recovered from material from other waste sites in the region.

General site contouring was carried out by CBDC in the early 1990's. Limestone and peat moss were applied to the site and it was hydro-seeded in 1993.

3.0 PHYSICAL DESCRIPTION OF THE SITE

A description of the geology, climate and vegetation of the site is provided in Appendix D.

TAILINGS AND DRAINAGE
(as per 1983 air photos)

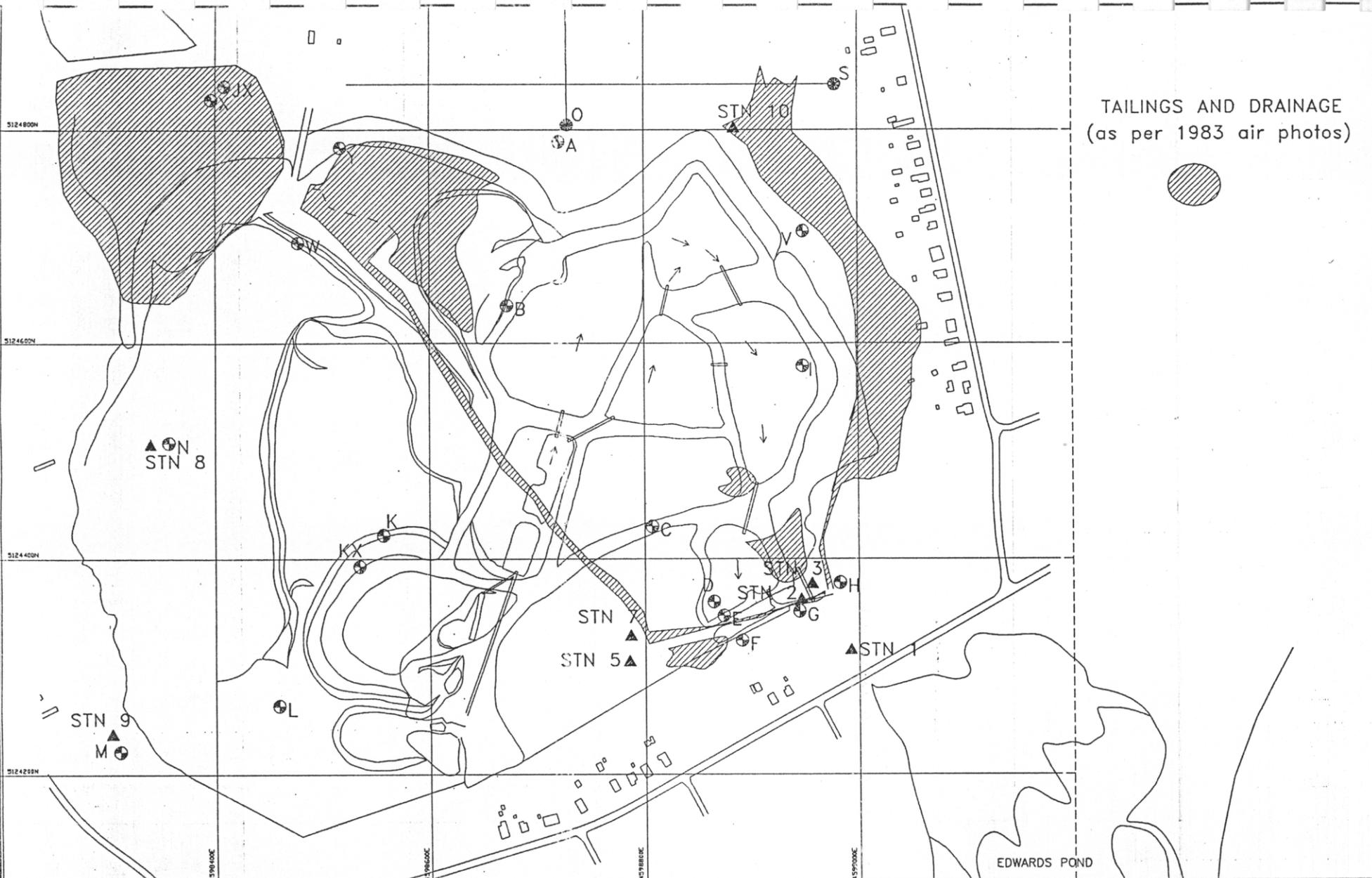


FIGURE 2-2
LOCATION OF SELMINCO TAILINGS BASINS (as per plans 1981-84)
PRINCESS SITE
SYDNEY MINES, NOVA SCOTIA

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4.0 SURFACE WATER HYDROLOGY

4.1 Regional Hydrology

The study area lies within Provincial Watershed No 1FJ-SD59. Within this watershed the two drainages of relevance are the eastward drainage into Edward's Pond and a northward unnamed drainage pattern directly into the sea just west of Cranberry Point. For the purposes of this report the latter will be designated as Black Point Brook.

The watershed of primary concern within this investigation is Edward's Pond. This is the receptor stream for most of the coarse waste site drainage.

4.2 Basin/Channel Morphology

The natural drainage area to Edward's Pond from 1:10,000 mapping is 151 hectares as noted in Figure 4-1. As a result of man-made alterations to the drainage patterns 85 hectares of the Town Brook watershed to the south was added, and in the northwest corner 29 hectares was removed and allowed to drain out Black Point Brook to the north. This resulted in a watershed for Edward's pond of 207 hectares.

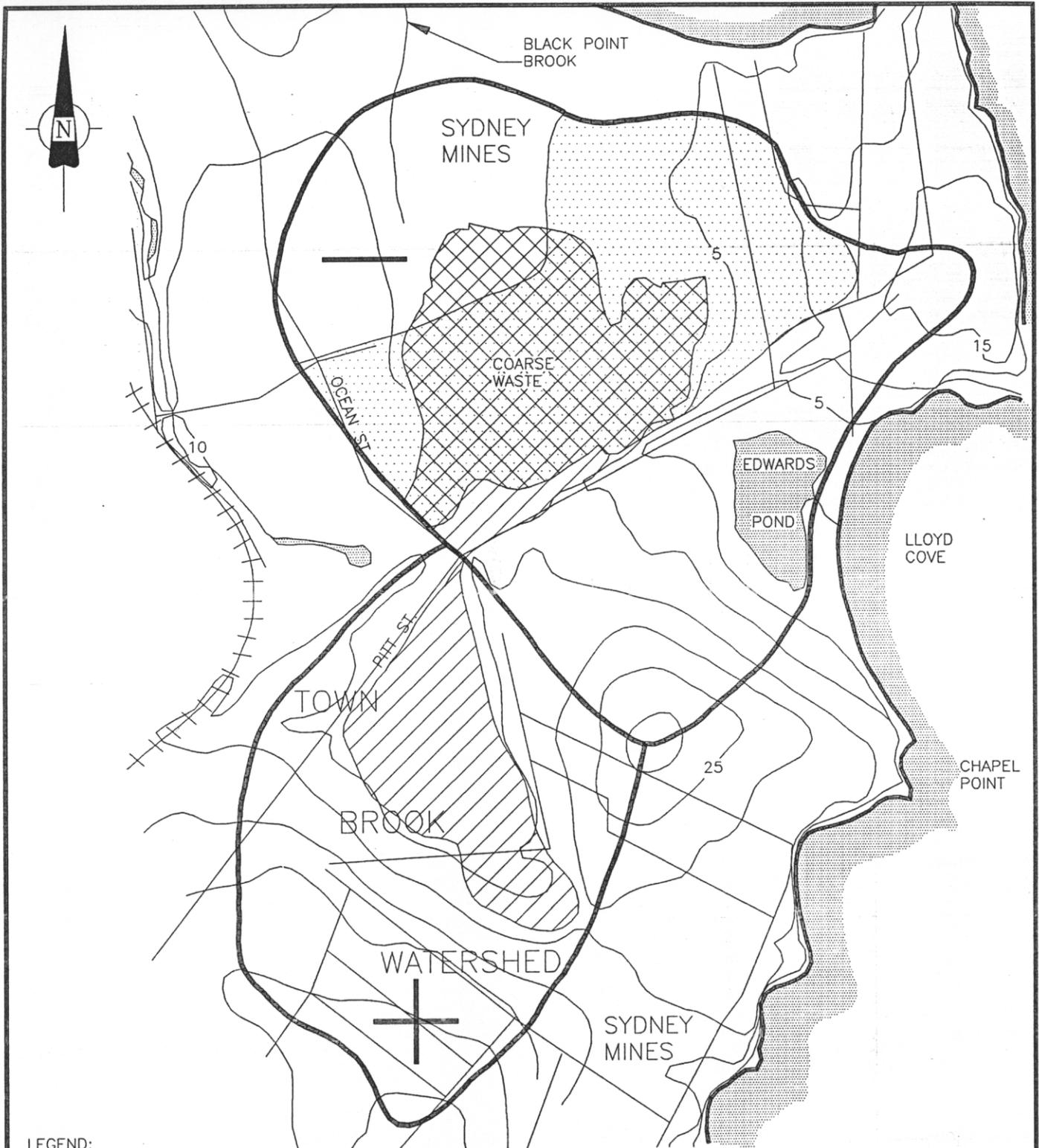
Most of the Town Brook watershed is storm sewered, with run-off waters bypassing Edward's Pond. Only 19 hectares underlain by bog and another coarse waste deposit is not storm sewered and drains by channel flow onto the study site and subsequently into Edward's Pond. Therefore, the Edward's Pond watershed is 141 hectares in size.

The portion of the Edward's Pond watershed directly under investigation in this study encompasses some 63 hectares (Figure 4-1), or 45% of the total.

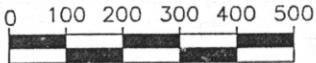
Figure 4-2 defines the major drainage patterns as Swale and Bog Brooks on-site. These have been created primarily by grading procedures during site reclamation.

Grading created two specific types of channels on site:

- The main channels were incised deeply into the topography as exemplified by Swale Brook in which the active channel is present within the confines of a depression 2 - 4 m deep and 3 to 7 m in width. Most of the main channel length is ephemeral (dries up in dry weather), as outlined on Figure 4-3. The perennial reaches for both streams are located at the southern end of the site



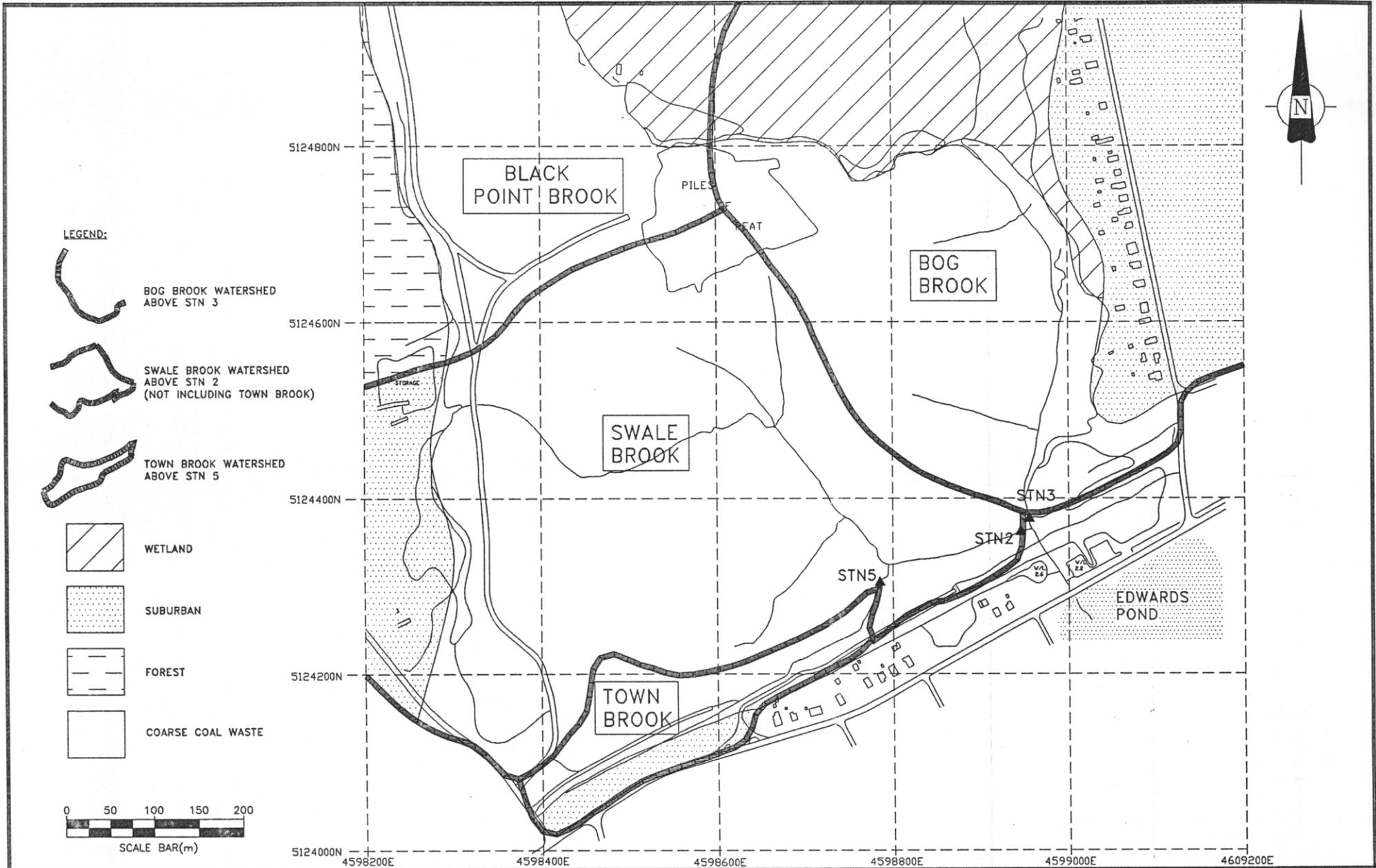
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 MAN-MADE ALTERATIONS	 WATERSHED ABOVE STATION 1 FOR THIS INVESTIGATION	 25 CONTOURS(m)
 INDICATES REMOVED	 NATURAL WATERSHED FOR EDWARDS POND	 ROADS/STREETS
 INDICATES ADDED ON	 RAILWAY	 0 100 200 300 400 500 SCALE BAR(m)
 INDICATES NON-STORM SEWERED AREA		

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FIGURE 4-1
 EDWARDS POND WATERSHED
 PRINCESS COARSE WASTE SITE
 SYDNEY MINES, NOVA SCOTIA

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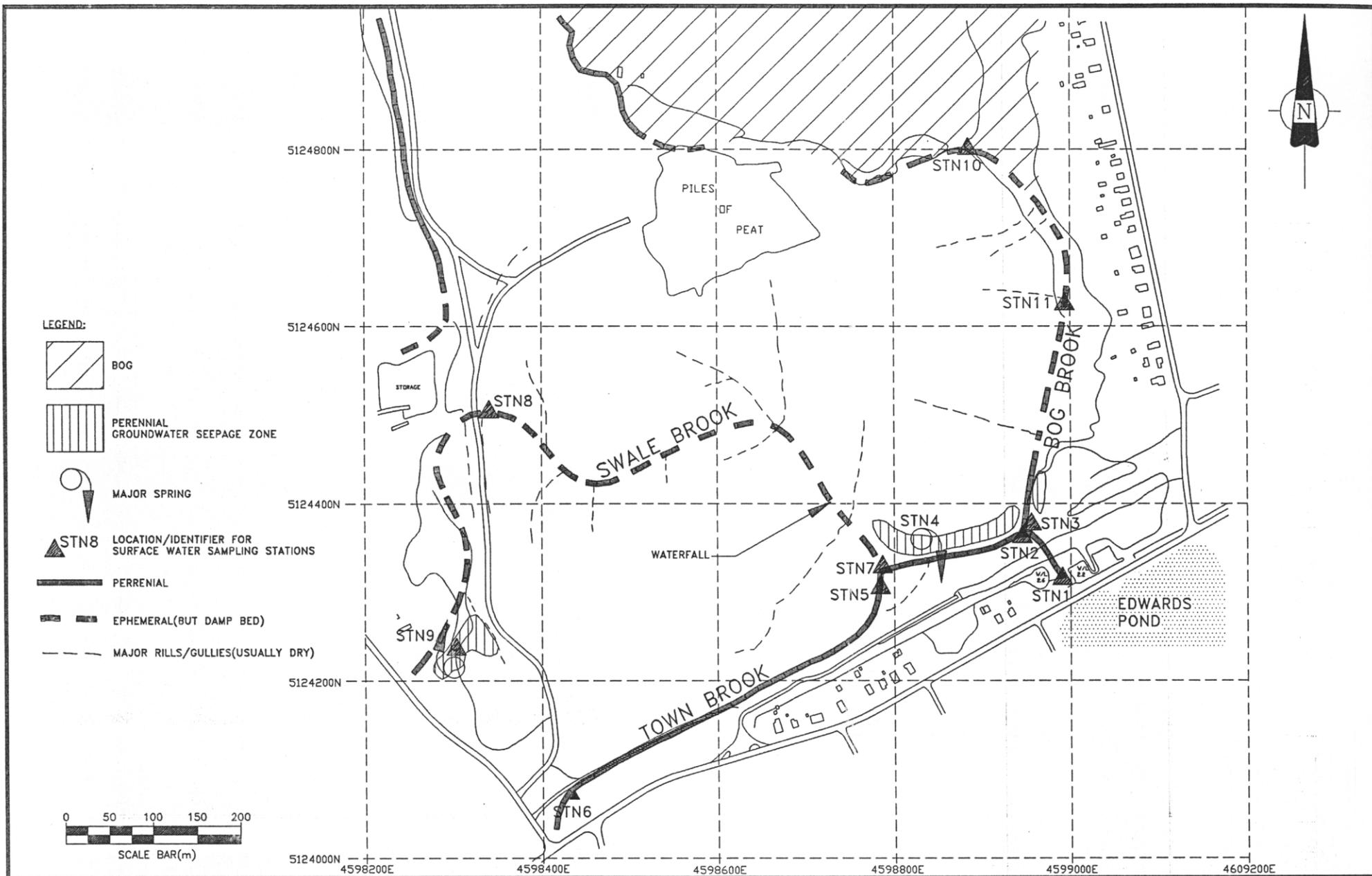


FIGURE 4-3
 SURFACE WATER DRAINAGE FEATURES
 PRINCESS COARSE WASTE SITE
 SYDNEY MINES, NOVA SCOTIA



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below approximately 5 m elevation on Swale Brook and 3 m in Bog Brook. Town Brook on the other hand is perennial, discharging water onto the site all year round.

- A number of rills and gullies are present acting as feeder channels to the main stem. Some apparently were constructed as shallow (<0.5 m), 3 - 10 m wide swales during site grading; others have been created by natural erosion. These features are ephemeral. A brief field survey of the major first order channels indicates a distribution as shown on Figure 4-3.

Within the active groundwater seepage zone present along the northern bank in proximity to stations 2,3, and 4, minor rills were present for 10-15 metres back from the channel; tapering out with the advent of grass cover. These were believed to be created by groundwater seepage forces within the active discharge zone.

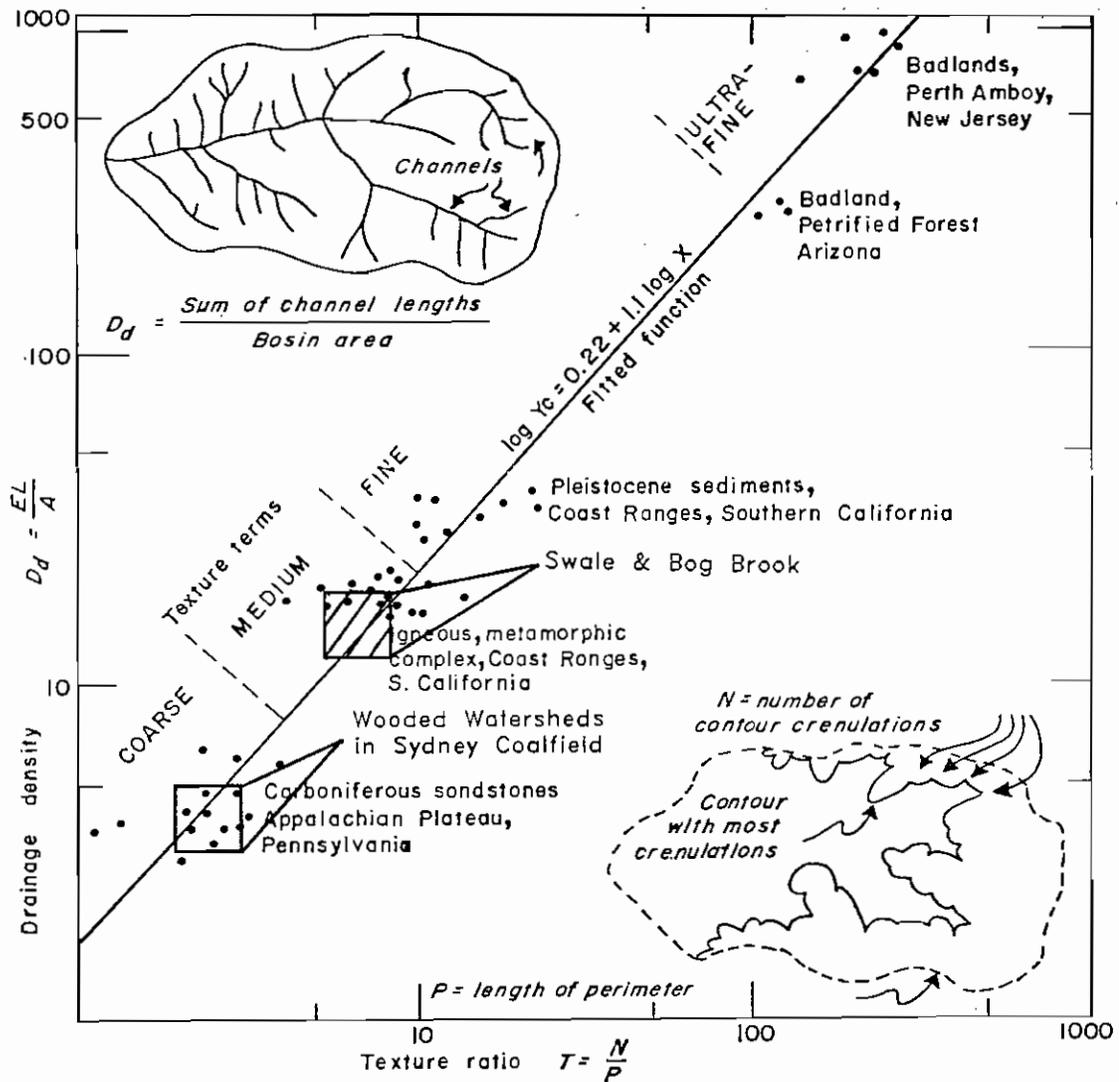
One perennial groundwater seepage zone is present on site in proximity to Swale Brook near the downstream end of the watershed at Station 4 (Figure 4-3). The only other spring zone at the western end of the site near station 9 is ephemeral.

The drainage density over the coarse waste pile for Swale and Bog Brooks was 17 and 13 miles/mile². This, combined with a calculated Texture Ratio of 9.4 for Swale Brook, resulted in a "Medium" textured drainage pattern (Figure 4-4). This is greater than for normal wooded watersheds in the coalfield which have a density of less than 5 mi/mi².

4.3 Basin Land Use

Of the 63 hectares under investigation, the area underlain by coarse waste comprises some 31.7 hectares or 50%. The bog deposit encompasses 16% and the suburban land use to both the east and west 34%.

At present no man-made withdrawals are made from any of the brooks dealt with in this investigation.



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FIGURE 4-4
 DRAINAGE DENSITY VERSUS TEXTURE RATIO
 (AFTER STRAHLER, 1957)
 SYDNEY MINES, NOVA SCOTIA

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4.4 Water Discharge

There had been no monitoring of water discharge within the watersheds. A total of 12 monitoring stations were established for manual monitoring of discharge and water chemistry. The resultant measured flows are presented in Appendix B. The October 5th sampling event was selected as representing the best overall view of fall baseflow conditions (Figure 4-5). In summary the data set indicates:

- Total baseflow discharging off site (Station 1) into Edward's Pond (flows from Swale, Bog and Town Brooks) ranges from approximately 50 to 1100 Lpm (10 to 250 igpm). Measurements taken on January 9, 1995 two days after a 37.4 mm rain/ 15 cm snowmelt event was 3,000 Lpm (660 igpm).
- Approximately 90 to 100 percent of the flow at Station 1 originated from Swale Brook (Station 2). Bog Brook (Station 3) usually provided 1 to 10 %; although on two occasions it ranged as high as 24 to 27%.
- Swale Brook was always perennial below the waterfall, located some 110 m upstream of the confluence with Town Brook. With the exception of one event on July 29, Town Brook always exhibited a higher base flow than Swale Brook at Station 7 by 2 to 10 times. The flow from Town Brook was large enough to provide usually 10 to 20% of the baseflow at Station 1; at times ranging up to 35 to 45%.
- The other source of inflow water to Swale Brook above Station 2 was groundwater seepage discharging out of the northern bank. This was particularly noticeable from the spring at Station 4; but also included the entire active seepage face, which during spring and fall conditions could be up to 200 m long. Due to dispersed flow from the seepage face it was impossible to obtain accurate discharge readings. Major feeder flows were measured to provide the data shown, which ranged under baseflow conditions from 4 to 600 Lpm (approximately 1 to 130 igpm).

Therefore a large portion of the flow discharging off-site during base flow conditions originates from Town Brook.

In an effort to approximate the full range of discharges which could be expected at Stations 1, 3 (Bog Brook), 2 (Swale Brook - without Town Brook) and 5 (Town Brook), theoretical calculations were made by extrapolating data from McAskil Brook via run-off coefficients.

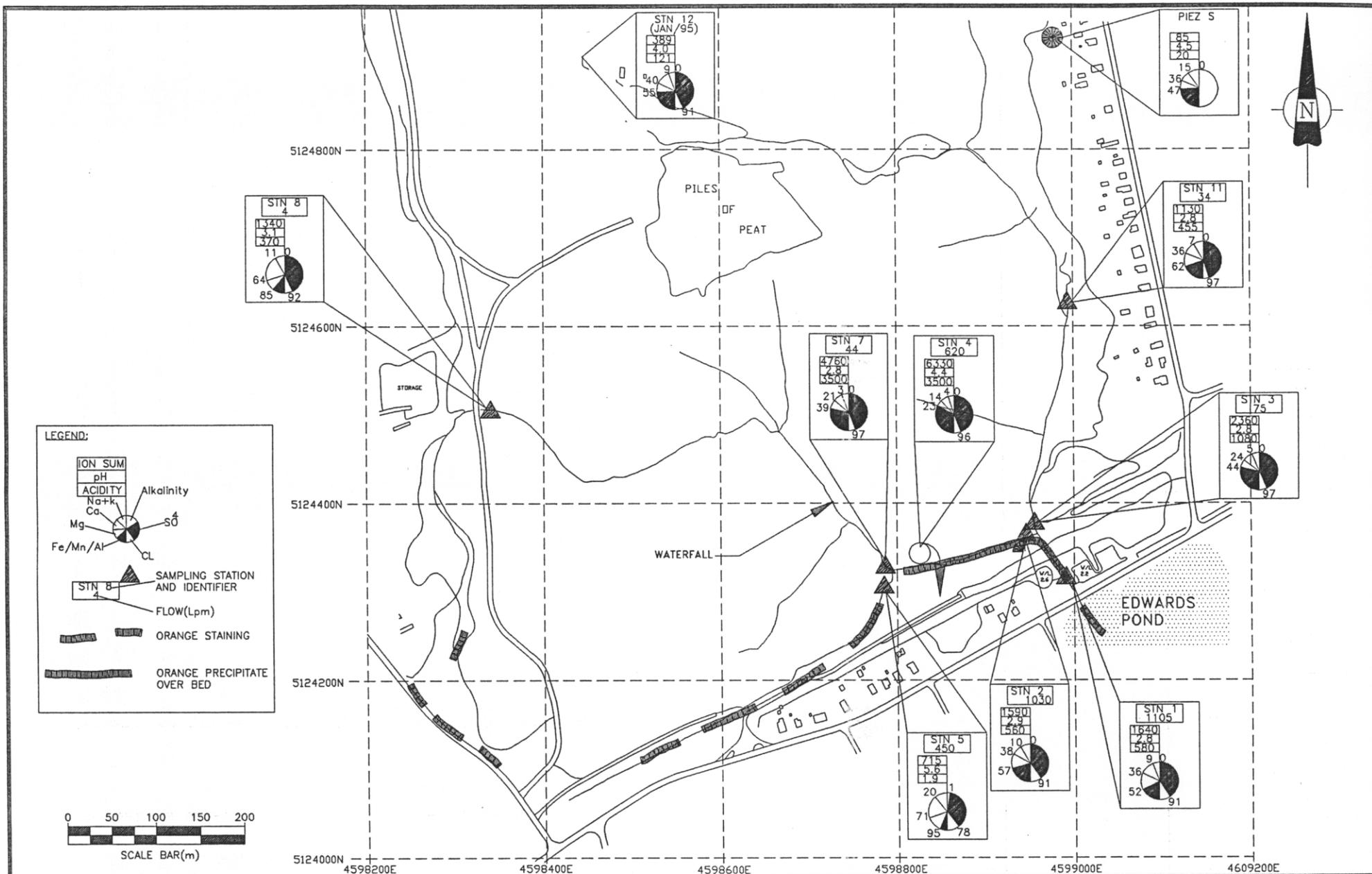


FIGURE 4-5
 OCTOBER 5 MONITORING
 SURFACE WATER DISCHARGE/CHEMISTRY SUMMARY
 SYDNEY MINES, NOVA SCOTIA.



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Since MacAskill's Brook is for the most part under natural conditions extrapolations must be considered approximate at best. The theoretical minimum daily flows correspond closest with the actual flows measured. Mean annual discharges could be up to one to two orders of magnitude larger than that measured.

4.5 Water Chemistry

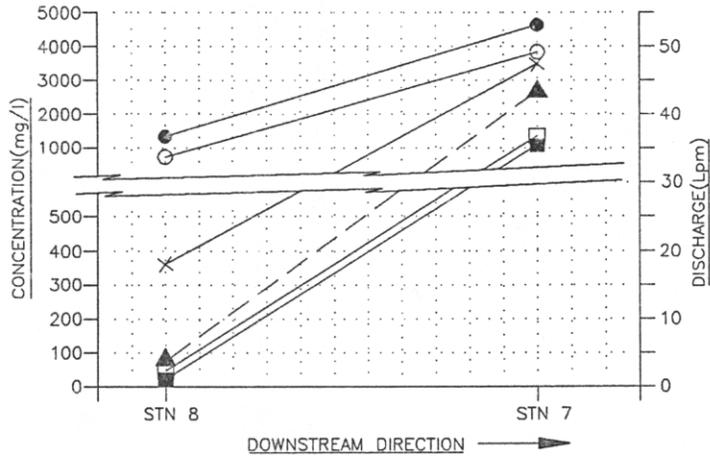
A total of 27 water chemical analyses were undertaken from on-site stations over three different seasons. The data is tabulated in Appendix C and summarized in Figures 4-5, 4-6, and 4-7. The conditions present during the October 5th sampling date were considered a good representation of fall baseflow conditions over the site and were summarized on Figure 4-5. In summary:

- 1) Three major water types were found distributed over the site, namely:
 - The water chemistry in Swale and Bog Brooks (stations 1, 2, 3, 7, 8, and 11) exhibited acidic waters but with a wide range in acidity. The worse case conditions, representative of the coarse waste were taken as Stations 3 and 7. These waters were characterized as a brackish (ion sum 2360 to 4,760 mg/L), very hard (840 - 2210 mg/L), corrosive, highly coloured (530 - 700 TCU), Fe/Mn/Al - SO₄ type water with a low pH of 2.8 to 3.1, and acidities of 1080 - 3500. Nutrients in the form of nitrogen were present as low concentrations of ammonia (0.5 to 1.14 mg/L); phosphorous (ortho was less than 0.01 mg/L); and total organic carbon ranged from 3.0 to 7.0 mg/L. Total metal concentrations ranged from 389 to 1230 mg/L. The same trend in metal concentrations was present at both stations, including in descending order iron (310 - 1040 mg/L), manganese (26.6 - 109 mg/L), aluminum(51 - 75 mg/L), zinc (4.19 - 5.36 mg/L), nickel (0.9 - 1.8 mg/L) and cobalt (0.44 - 0.96 mg/L).

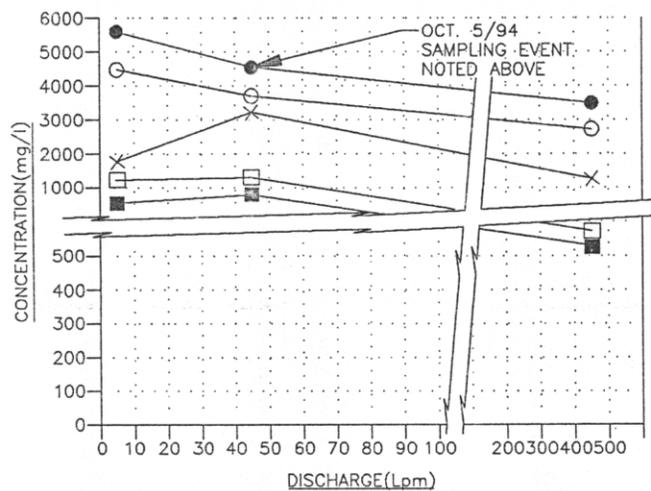
The trend in metal concentrations closely resembled that found at the research coarse waste piles at the Victoria Junction Coal Preparation Plant (Nolan Davis, 1993). Surface water chemistries at the beginning of storm events indicated that the top five metals present were identical to those found at this site. As run-off increased and pH dropped the next three metals to appear where arsenic, copper and cobalt.

SWALE BROOK

RUN-OF-RIVER TRENDS (OCT. 5/94)

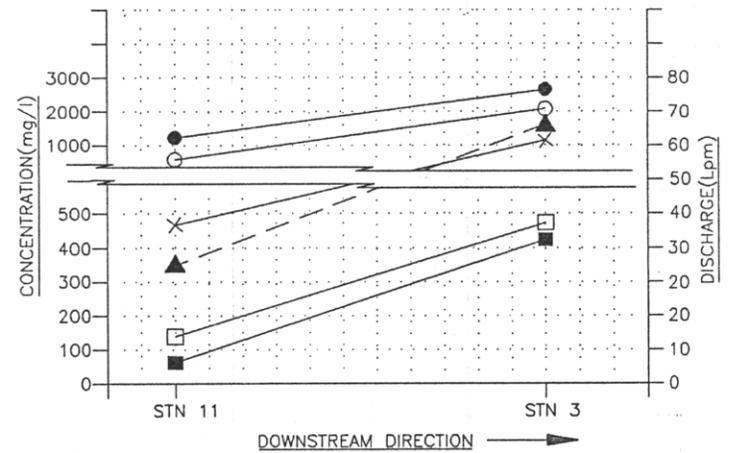


STATION TRENDS WITH FLOW (STN 7)

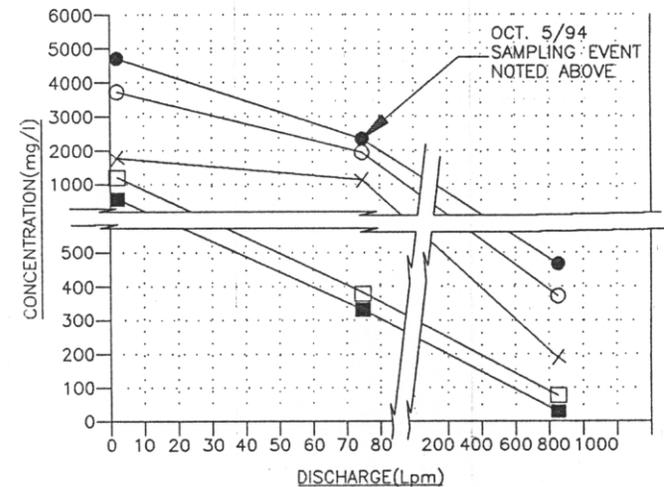


BOG BROOK

RUN-OF-RIVER TRENDS (OCT. 5/94)



STATION TRENDS WITH FLOW (STN 3)



LEGEND:

- ION SUM
- SO₄
- × ACIDITY
- ▲ DISCHARGE
- TOTAL METALS
- Fe

FIGURE 4-6
CHANGES IN SURFACE WATER CHEMISTRY WITH DISCHARGE
AND IN A DOWNSTREAM DIRECTION
FOR SWALE and BOG BROOKS

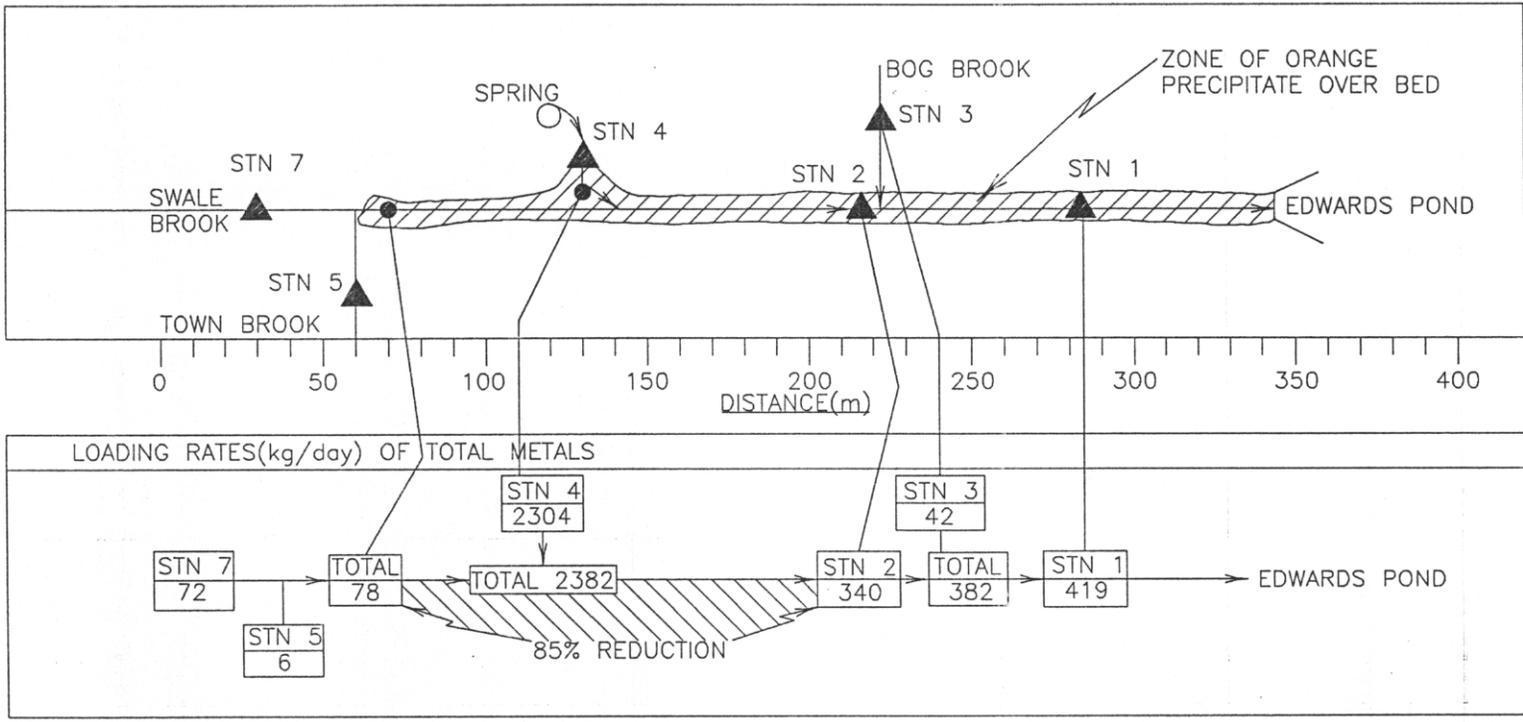


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DISSOLVED METAL CONCENTRATION(mg/l) PROFILE - OCT. 5/94						
	STN 7	STN 5	STN 4	STN 2	STN 3	STN 1
TOTAL METALS	1230	9.0	2579	230	389	264
IRON	1040	0.22	2480	195	310	217
MANGANESE	109	8.9	79.9	23.4	26.6	24.6
ALUMINUM	75	0.31	16	11	51	20
ZINC	4.2	0.06	1.4	1.03	5.4	1.6
NICKEL	1.8	0.14	.4	0.3	0.9	0.4
pH	2.8	5.6	4.4	2.9	2.8	2.8
ACIDITY	3500	19	3500	560	1080	580
COLOUR	700	41	12	140	530	110



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FIGURE 4-7
 CHEMISTRY OF NATURAL REMEDIATION ZONE
 IN SWALE BROOK AS EXEMPLIFIED BY OCT. 5/94 DATA
 SYDNEY MINES, NOVA SCOTIA

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- Town Brook at Station 5 indicated a much different water characterized primarily by its low ion sum (715 mg/L), acidity (19 mg/L), colour (<3 TCU), elevated pH (5.6), and Ca/Mg - SO₄ typing. The total metal concentration was low at 10.5 mg/L, due principally to manganese 8.9 mg/L. This was unexpected, as the recreation area which was constructed from coal waste, also contributes flow to Town Brook.
 - The third water type on site was that associated with the bog deposit, as represented by Piezometer S. This water had a relatively low pH (4.0), and was highly coloured (>1000 mg/L). However, it was distinctive from the acidic waters originating on-site by its low dissolved solids (85 mg/L), acidity (20 mg/L), total metals (although iron is high at 34 mg/L), and dominant chloride anion typing.
- 2) To assess the extent of acid drainage development with time and space, selected parameters were chosen and plotted in Figure 4-6. The changes occurring in water chemistry with travel through the site is shown in the top two diagrams for Swale Brook and Bog Brook. The data on both brooks revealed a similar trend of increasing concentration in the five selected parameters. This occurred even though there was an increase in discharge from 11 to 2 times respectively, which should have resulted in dilution. This suggests a strong input of acidic groundwaters along the stream channel.
- To determine changes at a station over time with alteration in discharge the two lower figures note changes for Swale Brook at Station 7 and Bog Brook at Station 3. Again both revealed a similar trend although this time it is one of decreasing concentration with increasing discharge, due to surface run-offs diluting groundwater inflows.
- 3) One observation in the field was the presence of orange precipitate over the bed of the stream channels in selected reaches (Figure 4-5). The strongest discoloration and continuously thick deposits of precipitate were found over the base of Swale Brook between the confluence with Town Brook and the mouth of Bog Brook. It retained its bright coloration all year round, suggesting a continuous development, rather than association with a first flush event. It commenced immediately upon the mixing of Swale and Town Brook waters, which suggested an association with the addition of the higher pH waters of Town Brook. The iron precipitate is expected to be a function of the continuous introduction of the acidic groundwater seepages entering

from the active seepage zone associated with spring at Station 4. The precipitate continued down past Station 1 and into Edward's pond. Of note was the absence of such precipitate in Swale Brook upstream from Town Brook or in Bog Brook, even though the waters were very acidic, exhibited high total metal concentrations (with the associated very dark reddish brown colour) and were open to oxygen diffusion from the atmosphere.

- 4) To further assess the magnitude of the precipitate phenomenon the changes occurring in the reach between Town Brook and Station 1 were summarized in diagrammatical form in Figure 4-7. In terms of concentrations, the total dissolved metals flowing into the reach was 3818 mg/L from Stations 5, 7 and 4. By the end of the reach at Station 2 this had declined by 94% to 230 mg/L as the metals precipitated into the stream bed. In terms of loading rates, which account for the changes in discharge from each input, there was an 85% reduction in total metal loading rate from 2382 to 340 kg/day. The largest declines in actual concentration, and therefore the chemicals forming up to 95% of the precipitate by weight, were iron, manganese and aluminum. This loss in material from solution may have resulted from precipitation on the bed of the stream, or the material may have moved in colloidal form off-site and into Edward's Pond.

5.0 SITE HYDROGEOLOGY

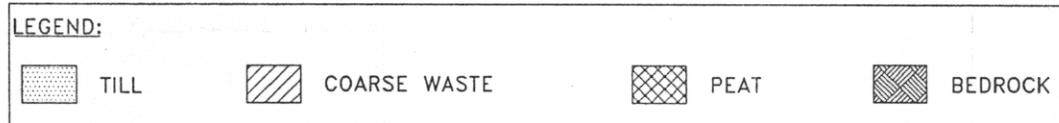
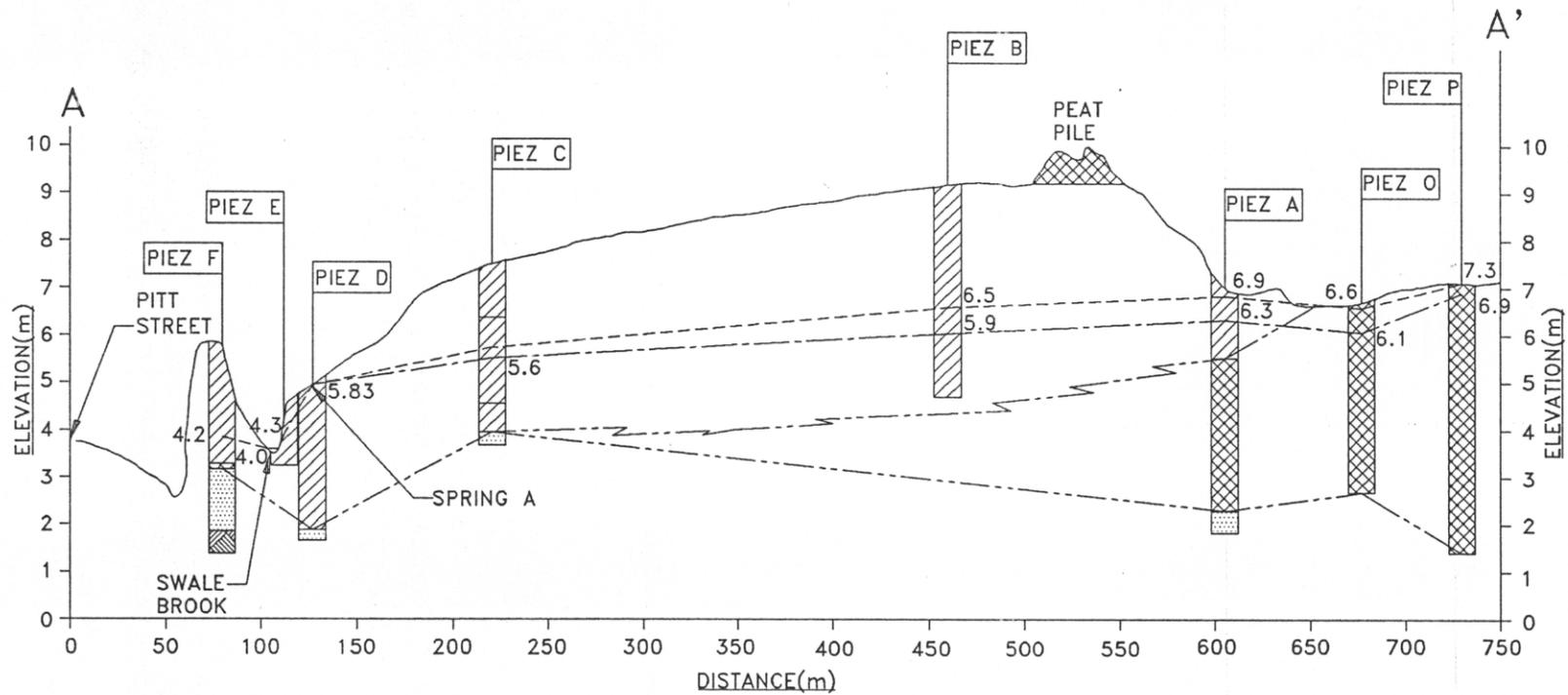
5.1 Hydrostratigraphic Units

A total of three (3) hydrostratigraphic units (HU), or stratigraphic units with similar groundwater properties, were identified on-site including: the Coarse Waste HU, Till HU and Peat HU. A brief description of each is provided below; the aerial extent of these deposits is discussed in Appendix D, Figure D-1. Three hydrogeological cross sections are presented in Figures 5-1, 5-2 and 5-3.

- 1) Coarse Waste HU:

- *Physical Characteristics* -

Investigations into the characteristics of the coarse waste associated with the present preparation plant at Victoria Junction indicated the following characteristics pertinent to groundwater movement within this HU.



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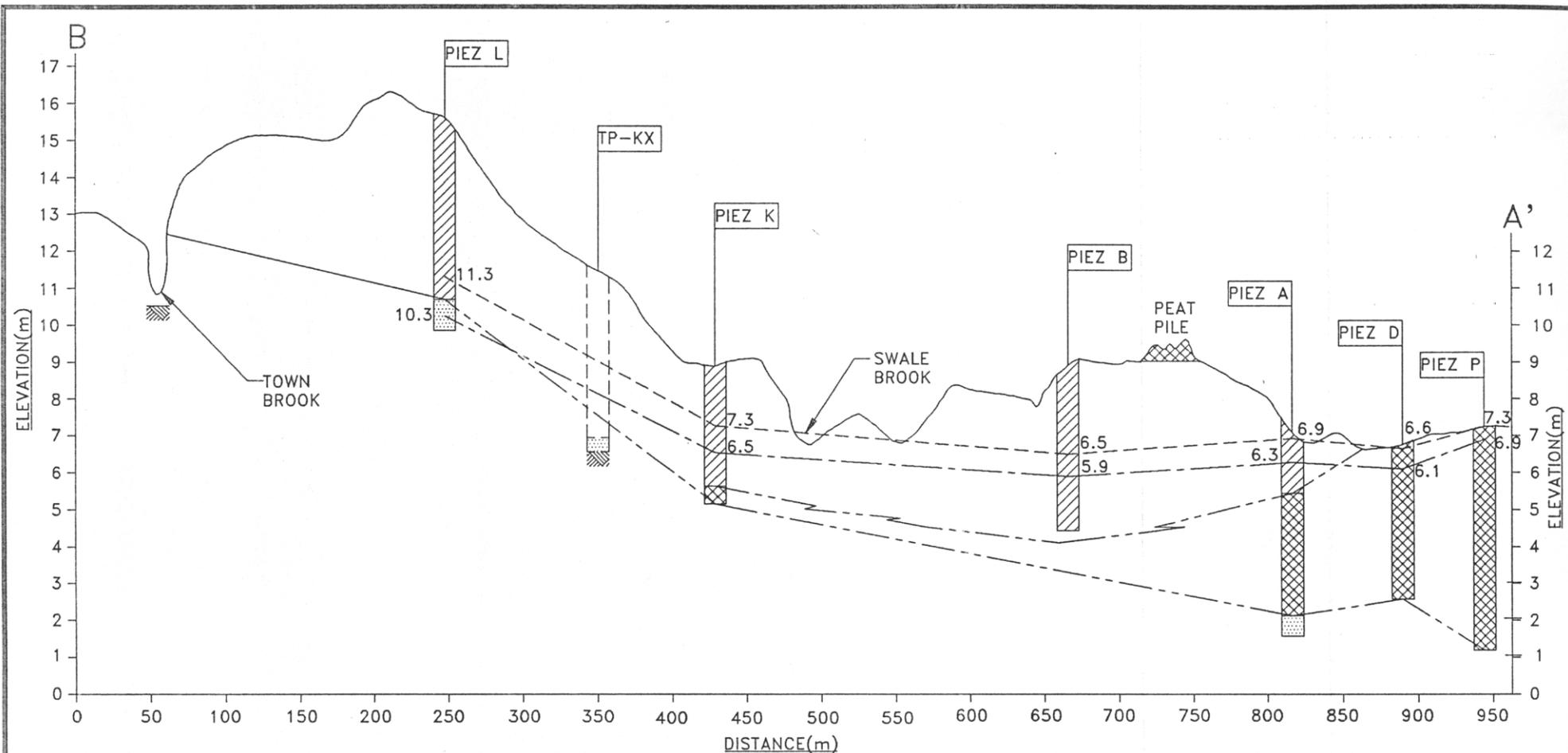
FIGURE 5-1
PRINCESS SITE CROSS SECTION A-A'
LOOKING WEST

DRWN BY: N.B.
 CHKD BY: F.B.

DATE: MARCH, 1995

SCALE: N.T.S.

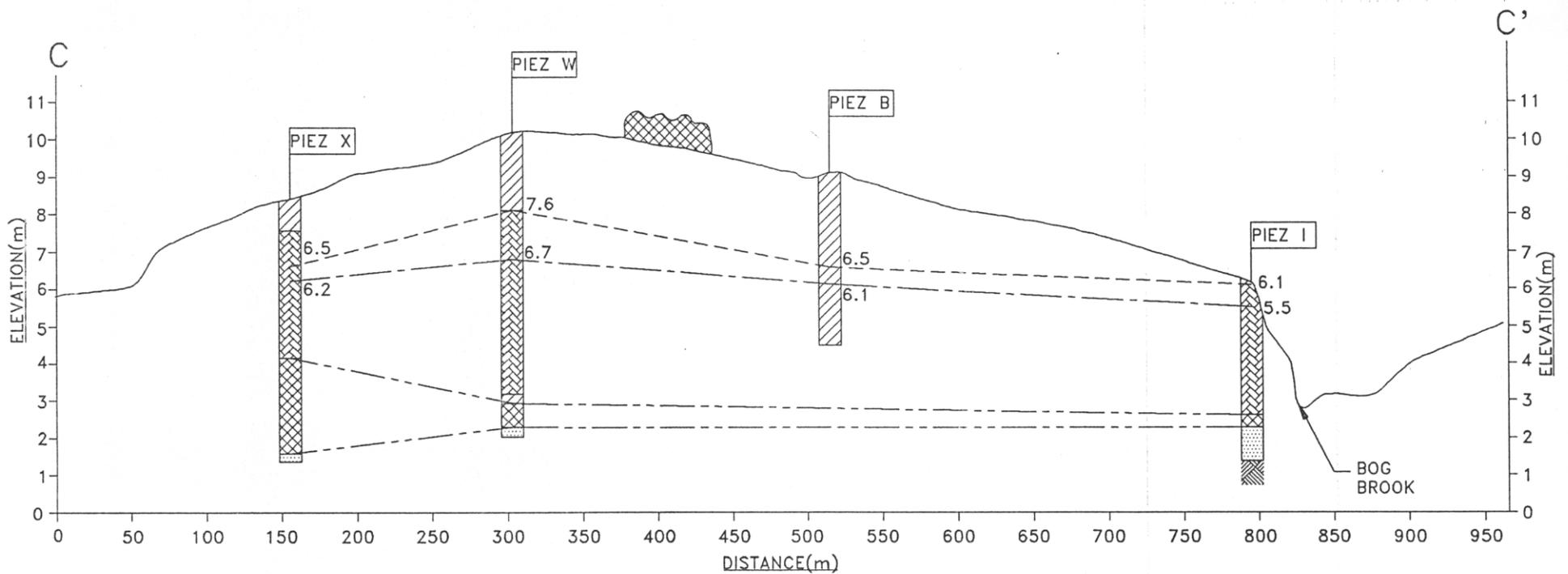
JOB #: 24-3515-004.1



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FIGURE 5-2
PRINCESS SITE CROSS SECTION B-A'
LOOKING WEST

DRWN BY: N.B.	DATE: MARCH, 1995	SCALE: N.T.S.
CHKD BY: F.B.	JOB #: 24-3515-004.1	



GROUNDWATER ELEVATIONS(m)
 --- 7.6 --- MAX. JANUARY/95 — 6.7 — MIN. AUGUST/94

LEGEND:



TILL



COARSE WASTE



PEAT



TAILING BAILINGS



BEDROCK



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FIGURE 5-3
 PRINCESS SITE CROSS SECTION C-C'
 LOOKING NORTH

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DATE: MARCH, 1995

SCALE: N.T.S.

CHKD BY: F.B.

JOB #: 24-3515-004.1

- The lithologic composition of the coarse waste material will generally be composed of mudstones and siltstones with minor sandstone and coal. The high percentage of argillaceous sediments allows the material to breakdown with weathering into finer grain sizes.
- In situ permeability testing using VJ coarse wastes, indicated values in the range of 1×10^{-1} to 1×10^{-2} cm/s. Once compacted and weathered, in situ testing indicated a similar range to the JWA values of 10^{-5} to 10^{-7} cm/s.

The test pitting indicated a wide range in grain sizes including the fine laminated sediments associated with the old tailings ponds. It was therefore difficult to arrive at an accurate range of hydraulic conductivity to represent this unit. However, by utilizing the flow rates from the active seepage face around Station 4, knowing the water table gradient from the piezometers and assuming a porosity of 0.2 to 0.4 resulted in a bulk hydraulic conductivity of 10^{-3} cm/s. This value will be assumed to be relevant for most of this unit except in those areas where the old tailings were found. Those areas will be designated with a hydraulic conductivity of 10^{-5} to 10^{-7} cm/s range.

From our experience at this site, and at the Summit coarse waste site in New Waterford, we believe the process of waste rock deposition (rear end dumping), resulted in a layer of relatively coarse material just over the top of native soil conditions which in both cases was a bog/swamp peat deposit. Permeabilities, therefore seem to be highest at the bottom of the sequence. The point to be kept in mind is, that the material forming this unit has been reprocessed and reshaped in recent years. Surface weathering and settling of the material to a final value is probably still in a state of flux.

In hydrogeological terms the unit can be classified physically on a macro-scale as a heterogeneous, anisotropic, porous, non-fractured, unconsolidated media, with flow being controlled by primary permeability.

- Chemical Characteristics -

Whole rock analyses of sandstone and shale roof material which could be incorporated into a coarse waste dump were reported by CBDC from samples associated with the Phalen Seam. Barium, arsenic, and strontium were present at values greater than 45 mg/L. Zinc, vanadium, tin, boron, copper, chromium, nickel, beryllium, cobalt, lead were found in the 2 to 20 mg/L range. Uranium, mercury were present at less than 1 mg/L.

Static testing of acid producing/consuming potential of coarse waste rock at the VJ plant site indicate a range of acid producing potential from 24 to 125 lb/t, while the acid consuming potential ranged from only 6 to 23 lb/t. Total sulphur values were in the 0.4 to 3.1% range. It is expected this information approximates the conditions at the Princess site.

2) Till HU:

From other investigations throughout the Sydney Coalfield a bulk permeability range of 1×10^{-4} to 1×10^{-6} cm/s will be taken as being representative of this HU within the study area. Matrix porosities for this unit have been calculated to range from 0.30 to 0.35.

In hydrogeological terms the unit can be classified physically on a macro scale as a heterogeneous (clasts), isotropic, porous, non-fractured, semi-consolidated medium, with flow being controlled by primary permeability.

3) Peat HU:

The literature suggests the upper fibrous zone of the peat deposit should exhibit hydraulic conductivities of 10^{-2} to 10^{-3} cm/s, usually within the top 0.5 m. At depth the decomposed peat within the Sapric zone can exhibit declining values to 10^{-5} to 10^{-6} cm/s. On the Princess site these values may be lower where the peat has been compacted by the overlying coarse waste.

Hydrogeologically, this unit can be classified physically on a macro-scale as a heterogeneous (layered), isotropic, porous, non to semi consolidated, non-fractured media, with flow being controlled by primary permeability.

5.2 Groundwater Flow System

Complete monitoring of all groundwater head levels within four hours, was undertaken three times during the project, simultaneously with surface water and chemical sampling programs to provide a "snapshot" of hydrogeologic conditions. The October data was selected to best represent a plan view of the water table within the coarse waste (Figure 5-4). Data from the other two events concurred.

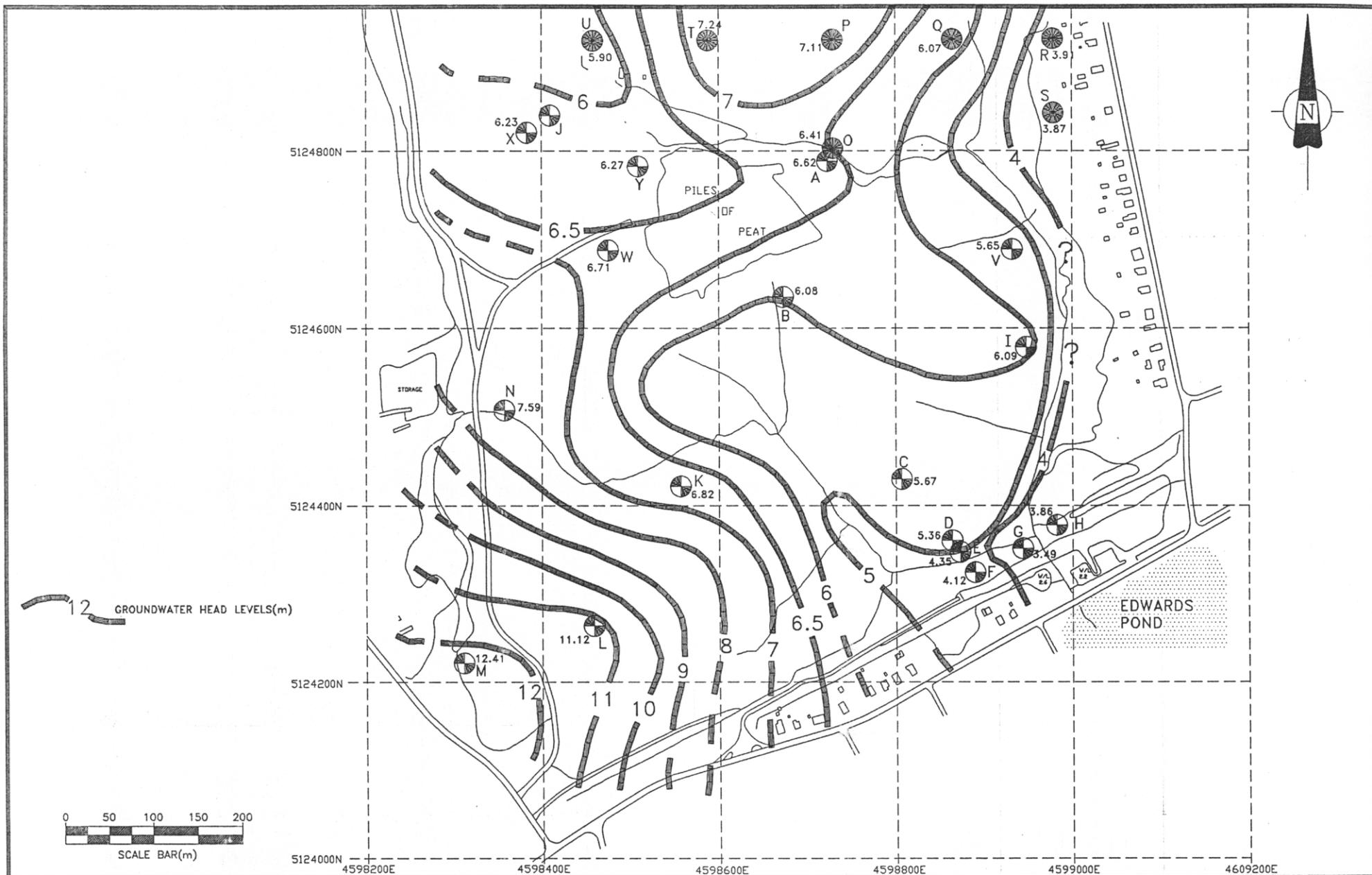


FIGURE 5-4
 GROUNDWATER TABLE HEAD LEVELS - OCT.6/94
 PRINCESS COARSE WASTE SITE
 SYDNEY MINES, NOVA SCOTIA



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The monitoring indicated the water table was developed within the Coarse Waste HU. The groundwater divide separating flow to the north into the Black Brook watershed from flow to the south into Edward's Pond roughly followed the surface water watershed divide which is positioned under the topographic high at the north end of the site, i.e. Piezometer W. However, the site topographic high in the southwest corner of the site, i.e. Piezometer L, records transmission flow from a higher area along Ocean Street.

The water table map indicates the potential for flow from Cranberry Bog to move southward and under the site. All southward directed flow is controlled by the configuration of the main surface channels on-site which flow toward the southeast corner of the site to exit the site into Edward's Pond.

The three hydrogeological profiles presented in Figures 5-1, 5-2, and 5-3 indicate:

- Figure 5-1 indicates the potential for water within the peat to move onto the site; although there was a slight depression in the water table at piezometer-O. The water table sloped southward across the site at 0.2% until close to Swale Brook. At this point it was 1.5 meters above the base of the brook, creating the active seepage face noted in this area and in particular the spring monitored at Station 4. Piezometer F indicated there was a rise in the water table south of Swale Brook sufficient to ensure no direct groundwater flow under the road bed and directly into Edward's Pond.
- Figure 5-2 indicates the topographic high in the southwest corner of the site at piezometer L had a very low water table positioned in close proximity to the interface between the Coarse Waste and Till HUs. This suggested at this higher elevation, the groundwater flow system may be controlled by the slope of the top of the Till HU. Flow was directed down gradient toward Swale brook. However, no active seepage faces were present in the brook.
- Figure 5-3 records the association of the highest water table elevation coincident with the topographic high and Piezometer W. This may be a function of the presence of the low permeability fine tailings in this area. The water table at Piezometer I adjacent to Bog Brook was also high, 2.5 meters higher than the base of the brook, however no active seepage faces were present in this area, probably due to the presence of the low permeability tailings.

Seasonal fluctuations in the water table from the one year of monitoring were relatively small. The topographic high areas recorded the largest fluctuations, but even here they were usually less than 0.5 m; with the largest recorded (0.9 m) at Piezometer W.

Theoretical, apparent, horizontal groundwater flow velocities within the Coarse Waste HU were generated utilizing a bulk permeability range of 1 to 9×10^{-3} cm/s, porosities of 0.2 to 0.4 and the gradients established from the monitoring wells. In the central portion of the site between Piezometers B and D flow velocities toward Swale Brook were in the range of 1 to 70 m/yr. In the southwest corner of the site from Piezometers L to K this range increased to between 15 and 300 m/yr.

The water table configuration resulted in a relatively thick (2 to 5 m) unsaturated zone over most of the site. This is critical in terms of the increased depth of oxygen diffusion into the coarse waste and therefore the development of acidic products which are flushed into the water table with rainfall events.

5.3 Hydrogeochemistry

The construction of test pits and installation of piezometers at the Princess Waste site showed the acid drainage being generated by the coarse waste varied significantly under the site. Generally, the water was found to be highly acidic (acidities:2500 - 5000 mg/l) with iron concentrations ranging from 250 - 5000 mg/L and pH's ranging from 2.8 - 4.5 units. Manganese ranged from 50 - 150 mg/L and aluminum from 10 - 500 mg/L. Nickel and cobalt were the trace metals having the highest concentrations in solution; up to 7.5 and 3.6 mg/L respectively. A summary of groundwater chemistries found during the October 5, 1994 event is presented in diagrammatical form in Figure 5-5.

5.3.1 Water Chemistry as a Reflection of Depositional Material

The initial sampling indicated pockets of water high in conductivity and iron concentrations (Piezometers I and V). From the test pit logs these correlated with areas of fine laminated tailings associated with the Selminco coal recovery project in the 1980's. When the sample at Piezometer I was field filtered, the water had a yellowish tinge, indicating there was a significant concentration of ferric iron in the sample. The anomalies in the water chemistry may be accounted for by either of the following:

- Permeabilities would be relatively low in the tailings, restricting groundwater flow and resulting in longer contact time with the sediments. There were oxidized zones in the tailings indicating preferential paths of groundwater flow within the sediment.

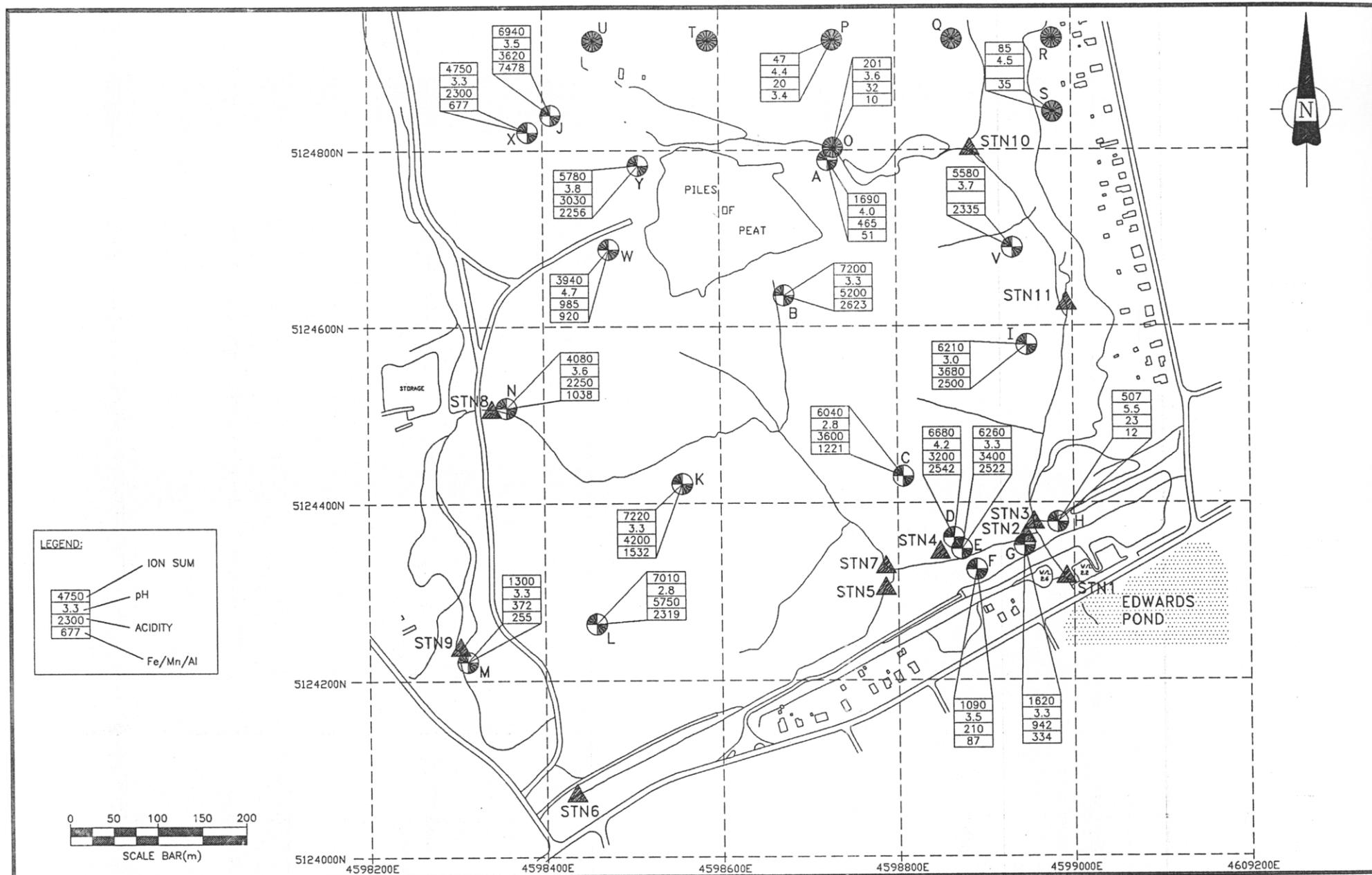


FIGURE 5-5
SUMMARY OF GROUNDWATER CHEMISTRY - OCT.5/94
PRINCESS COARSE WASTE SITE
SYDNEY MINES, NOVA SCOTIA



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- The coal washing recovery process may have concentrated the sulfide minerals in the tailings.

Under topographic highs (Piezometers B and L) where the thickness of unsaturated material was the greatest, the groundwater chemistry was typically high in dissolved solids, especially iron and sulphate, and reported calcium/magnesium ratios nearly 1:1. Acidity values at Piezometers B and L were 5300 and 9300 mg/l respectively. The construction of both test pits indicated highly oxidized material within the zone where the water table was expected to fluctuate.

5.3.2 Evolution of Chemistry with Recharge

The water collected at the time of construction (July and September) is considered to be representative of actual in situ water, without the influence of dilution by precipitation. These waters were generally calcium sulphate type waters; however, magnesium often supplemented the dominant cation especially in recharge areas. Subsequent sampling in October and January indicated significant evolution of the chemistry within each sampling station. At that time the ratio of calcium magnesium was seen to decrease, with magnesium frequently becoming the dominant cation. There was little or no change in the dominance of the anions by sulphate.

The water chemistry changes from one sampling date to the next reflected the impact of recharge on the chemistry on the coarse waste pile waters. Each piezometer was seen to respond differently to the recharge flux, as summarized below:

- Cross Section A-A' -

The following summarizes seasonal water chemistry changes along the section A-A' (Figure 5-1). The section represents the range of conditions from recharge at Piezometer A, to discharge at Spring #4.

- At Piezometer A, located near the bog, the iron and calcium concentrations decreased, while magnesium, ammonia, aluminum, cobalt, nickel, and strontium concentrations increased. There was a slight increase in the ion sum with fall recharge.
- At Piezometer B there was a slight dilution of dissolved ions in October as reflected in the ion sum. However, although there was a drop in iron, sulphate and other major ions, there was a significant increase in copper,

zinc, aluminum, beryllium, cobalt, lead, uranium and vanadium with fall recharge. Sampled again in January, the trends in constituent concentrations remained consistent, resulting in the highest concentrations of these metals measured over the entire site with the exception of Piezometer L.

- At Piezometer C, fall recharge diluted the water with respect to iron, sodium and potassium and chloride. There was a significant increase in magnesium, as it became the dominant cation. Manganese, copper, zinc, aluminum, cobalt, nickel and uranium all increased significantly.
- At Piezometer D, further along the flow path, water chemistries were observed to have a slight increase in iron, sulphate, and ion sum. The remaining metal concentrations decreased slightly.
- *At Piezometer E and Spring #4 the water chemistries were essentially the same and represented the discharge portion of the groundwater flow system. Over the three sampling events the water chemistry was found to be relatively stable with sulphate approximately 5500 mg/l, chloride 145 mg/l, iron 2000 - 2500 mg/l, and ion sum (6000 mg/l). Aluminum was reported between 12 - 18 mg/l with the exception of the October chemistry at Piezometer E which recorded 35 mg/l aluminum. The water was a calcium/magnesium sulphate type water with a calcium : magnesium ratio approximately 1:1.*
- The water chemistries at Piezometers F and G located south of Swale Brook at the southern end of the cross section were unique to the water chemistries at the Princess waste site. They had a relatively low ion sum (1000 mg/l), low iron concentrations (<50 mg/l) and a calcium magnesium ratio of 2:1. Fall recharge at Piezometer G resulted in significantly increased calcium and magnesium and chloride and a dramatic drop in silica. At the present time these chemical changes suggest that during high flow, the water at Piezometer G may be influenced by the water chemistry from the main waste pile (Spring #4).
- Piezometer H, constructed on the east side of the brook draining the waste site, was positioned to represent background chemistry. The test pit encountered 1.2 metres of coarse waste over red till. The water sampled during the construction was collected from a permeable zone in the till and was represented by a calcium sulphate water. It initially had a high pH (7.4) and low ion sum (<500 mg/l), relatively low iron (3 mg/l) and aluminum. Between the time of construction and the fall sampling, magnesium increased

relative to calcium, the pH dropped to 5.5, alkalinity dropped to <1, and the aluminum increased an order of magnitude. It seems the water in the test pit was affected by the recharge through the thin coarse waste which is mixing with the interstitial water in the till.

- West Side of Site -

The water chemistries at Piezometers M and N positioned on the west side of the site are similar in that they are calcium : sulphate type waters, with calcium : magnesium ratios greater than 3:1 and ion sums less than 1500 mg/l. When Piezometer N was sampled at the time of construction, the water reported a pH of 5.8 and an alkalinity of 32 mg/l. These anomalies in the water chemistry reflected the effect of buried garbage at this location. During recharge in October, magnesium increased relative to calcium; and sulphate, iron, manganese, zinc, aluminum, chromium, cadmium, cobalt, lead nickel and uranium rose significantly. These increases may reflect the effect of acid drainage on the buried garbage (car bodies, sofas, refrigerators, etc.) or comparing the water chemistry from the October sample at Piezometer L (discussed below), the metal concentrations may indicate a portion of groundwater flow was from the high area at piezometer L toward Piezometer N.

- Cross Section B-A' -

A second cross section through the groundwater flow system was investigated from Piezometer L (recharge area) to Piezometer K (discharge area) near Swale Brook. Unfortunately no sample was collected at TP-L; at the time of construction as there was essentially no water in the test pit.

- The October sampling at Piezometer L reported the worst groundwater quality recorded to date at the site. Sulphate 12700 mg/l, iron 4300 mg/l, and acidity at 9350 mg/l, were associated with very high copper (5 mg/l), zinc (19 mg/l), aluminum 580 mg/l, cadmium (80 ug/l), chromium (620 ug/l), cobalt (3600 ug/l), nickel (7500 ug/l), uranium (80 ug/l) and vanadium (470 ug/l). The January sampling at TP-L showed significant dilution of the water chemistry (approximately by 50%).
- The sample from Piezometer K, collected during fall recharge indicated a concentration of chemical parameters including iron, sulphate and aluminum and metals such as chromium, cobalt, nickel and uranium. The chemical

evolution at this station was well correlated with the water chemistry at TP-L indicating groundwater flow from Piezometer L toward Piezometer K, as supported by head measurements.

- Eastern Portion of the Site -

The water chemistry along the eastern portion of the site was characterized by Piezometers I and V. The water sample from Piezometer I along the eastern boundary of the site, although highest in sodium, calcium, sulphate, iron, and ion sum, reported relatively low concentrations of aluminum and other metals at its time of construction. Fall recharge resulted in a significant dilution of the major ions (approximately 50%) with the exception of magnesium. Along with the dilution of major ions, aluminum, cobalt, chromium, lead, nickel, selenium and uranium increased significantly.

Both water samples collected from Piezometer V, not far from Piezometer-I indicated major ion water chemistry very similar to the October Piezometer-I chemistry. Metal concentrations however, with the exception of arsenic were lower at Piezometer V.

- Northwest Corner of the Site -

Varying water chemistries were recorded in the three piezometers installed at in the northwest section of the waste pile in September. The water at Piezometers X and W reported moderate ion sums (4000 mg/l), iron (1000 mg/l) and acidity (1000 mg/l). Aluminum contributed to the high acidity at Piezometer X. Metal concentrations were also elevated at Piezometer X due to the influence of the fine tailings on the water chemistry.

Piezometer Y at the north of the site, near the bog showed a greater influence of acid generation than Piezometer A, with iron, sulphate and acidities elevated to levels over the remainder of the site.

- Bog -

Piezometers O, P and S were installed in the bog. The location of Piezometer P and its water chemistry assumes it represents background conditions in the bog. The sample collected during fall recharge shows dilution of the major ions with the exception of sulphate, as well as dilution of the metals. Piezometer O showed the influence of acid drainage in that calcium, magnesium, sulphate, and metals such as cadmium, cobalt and nickel were elevated above background. The sample from Piezometer S indicated elevated potassium, sodium, chloride which may be indicative of septic systems or residential run-off into the wetland in this area.

5.4 Ground/Surface Water Interaction

The interaction of the ground and surface water flow fields was investigated at six different sites.

Commencing in the upstream reaches of Swale Brook (surface water Station 8) the groundwater levels (Figure 5-6) for all monitoring events showed the base of the stream channel was always higher than the water table. This resulted in streamflow infiltrating into and recharging the groundwater flow system. This would account for the upper reaches of the stream being ephemeral. Similar conditions existed within Swale Brook downstream for some 500 m to the base of the waterfall as supported by comparison of water levels at Piezometers at K and B (cross section B-A'- Figure 5-2), as well as K and C. Once below the water fall, the base of the stream channel was below the water table and groundwater inflow commences, as exemplified by the cross section at surface water station 2 with Piezometer data at D, E, and F (Figure 5-6). This explained the perennial conditions present in the channel below the waterfall.

In Bog Brook, cross section C-C' (Figure 5-3) the water table was located well above the stream bed indicating groundwater seepage into the channel. However, the lower permeabilities associated with the tailings in this area, significantly reduce the inflow rate.

5.5 Existing Users

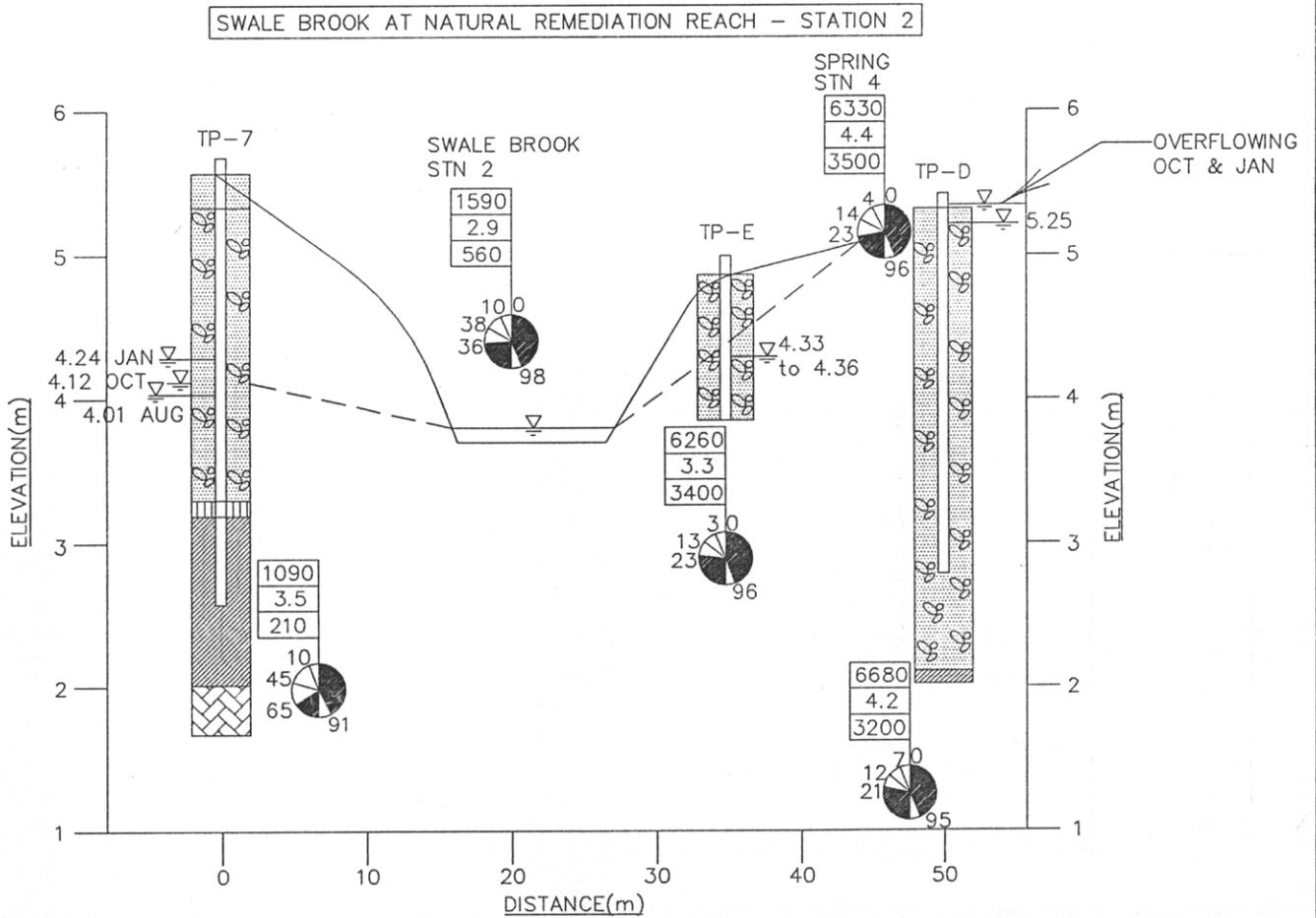
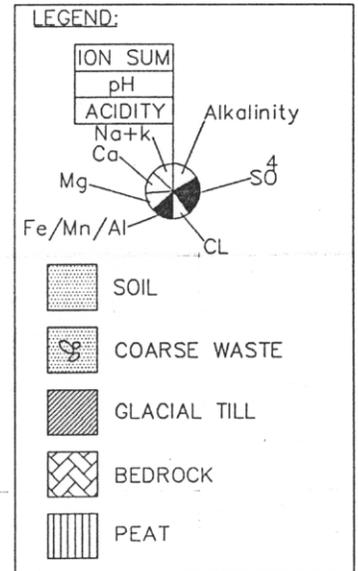
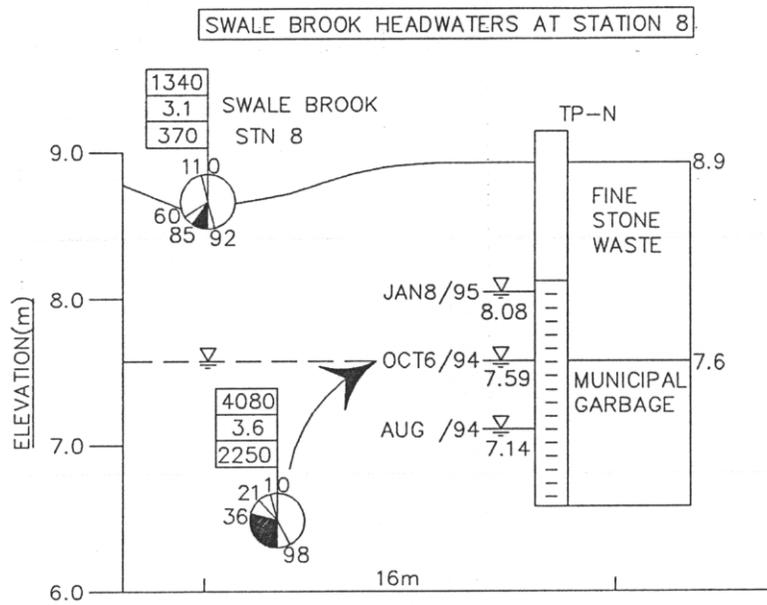
At present there are no groundwater withdrawals in close proximity to the site, given that the area is fully serviced by a central surface water supply some distance from the site.

6.0 REMEDIATION

The following remediation options were considered for the Princess waste site:

- active treatment
- passive treatment
- do nothing

Active chemical treatment was rejected for this site due to the long term treatment required, high maintenance and operational costs. The "do nothing" option was rejected because of the high visibility of the site within the Town of Sydney Mines. Area residents would like to see positive action taken for stewardship of the property and adjacent lands, specifically Edward's Pond.



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FIGURE 5-6
 GROUND-SURFACE WATER INTERACTIONS
 EXEMPLIFIED BY OCT. 5/94 DATA
 SYDNEY MINES, NOVA SCOTIA

DRWN BY: N.B.	DATE: MARCH, 1995
CHKD BY: F.B.	JOB #: 24-3515-004.1

Given the high acidity (3500 mg/l), iron and aluminum concentrations (2000 mg/l and 18 mg/l respectively) of the acid drainage, and the high flows (measured up to 3000 L/min) at this site the reliance on any *single* passive technique (i.e. drainage diversions, anoxic limestone drains (ALD's), successive alkalinity producing systems (SAPS), wetlands, and vegetative cover) is not considered prudent.

The following discussion will set out in some detail the various aspects of a passive treatment plan for the Princess coarse waste site.

6.1 Discussion: Passive Treatment Options

The success of any acid drainage remediation plan for this site is dependent upon minimizing infiltration, and diverting surface drainage/groundwater inflow away from the source material (waste pile).

6.1.1 Infiltration Reduction

- Enhance Surface Run-off -

The existing drainage network (described in Section 3.1), was found to have a higher drainage network than normal wooded terrain in this area. However, site inspections revealed a number of localized areas where water was still ponding. This was apparently due to a combination of low slopes, slight depressions and the absence of proper drainage channels. These areas were in nearly every instance characterized by the absence of grass growth. The retention of water in these areas would act to reduce run-off, enhance infiltration and inhibit revegetation.

The four major areas where ponding was noted are shown in Figure 6-1. A proposed augmented drainage system, also shown on that figure, would require construction of 2700 m of swales. This would increase the drainage density by a factor of 1.4 to 2.3. Where gradients exceed 3% the drainage swales will require erosion protection.

Considering most of this channel length will be positioned above the groundwater table, efforts should be made to minimize infiltration from the base of the channel during storm water transit. The channels beds should be lined with a low permeability liner, although the cost effectiveness of this approach has not been determined.

- Natural Forest Soil Transplant -

Experts in environmental assessment maintain that restoration of lands affected by mine spoils, so called derelict lands, is limited not by knowledge, but by lack of funding. Reclamation is also highly site specific, so it is difficult to follow exactly the procedures set up elsewhere. The success of restoration depends upon average precipitation, slope of the land, and how the need for reclamation might be affected by the existing legislation.

Technologically, the Princess coarse waste site is considered to be in the category of manageable or restorable given the high rainfall (and snowfall) and topography. Controlling the contaminated acid surface drainage of mine spoils by re-establishing vegetation has been actively pursued in mining areas of North America, particularly the southwestern USA since the 1930's, with essentially disastrous results. Vegetation eventually died. (Raven, P. et al, 1993). Newer techniques had to be developed in these mining areas, which were site specific. The site specific amendments involved utilizing time released fertilizers and specialized seed application. The specific techniques do not apply to the spoils in Cape Breton, but the principle of focusing on modifying the composition of the parent material, or regolith, so that plants can become established is a prudent one to follow.

Over large areas of the US the site specific treatments encourage plant growth, not just for aesthetic purposes, or for maintenance of local animal and plant populations, but also to control or manage the surface drainage through the development of an intact ecosystem which by definition, controls and utilizes the incoming precipitation.

The use of existing coarse waste at the Princess site is unsuitable for anything but very long term succession. This long term succession cannot be expected to significantly control infiltration for hundreds of years. However, using a recommended natural forest soil transplant, vegetation can be expected to significantly reduce infiltration within two years.

Theoretically, reclamation should be easier in Cape Breton because of higher rainfall, even though higher rainfall contributes to greater acid mine drainage. Hence, using reclamation as a site specific strategy in an area of high rainfall and flat topography can be both a technologically and ecologically sound method of managing the surface drainage. Landscaping to control the amount of water infiltrating into the coarse waste, and other passive treatment systems will be combined with natural forest soil transplant as strategy for the Princess site.

The appropriate topsoil could not be purchased from a sand and gravel company. Site specific requirements would require that the soil mass applied be suited for a stable secondary succession of plants and animals. Essentially, a forest soil from a deforested site would be excavated and re-deposited over the coarse waste site. The transplanting would be undertaken without devastating the donor property.

Typical soil profiles and structures in northern temperature climates are maintained by surface organic horizons with long standing populations of fungi, bacteria and plant remains in complex symbiotic association. To a great extent, the excavation and transportation must preserve intact the complex system of organisms that constitute the soil structure. This is innovative but not complex. Soil would not be graded or compacted, but left as placed, providing an average depth of 0.7 metres. This is not a proposal to develop a farm field or a range land type habitat. This is a site specific strategy to re-establish a natural soil ecosystem over the spoils using the principle that the natural ecosystems would then, to a great extent, interact with the climate to control incoming precipitation.

- Impermeable Capping -

The concept of installing a less permeable cover over the site was considered as an option for reducing infiltration over the site. Asphalt, clay, plastic, fine limestone, and CFB ash were considered. Costs for installing the first four options were not considered economically viable. The use of CFB ash from NSPI at Point Aconi is a possibility; however, research is required to determine the impact this material would have on future vegetation options and the contribution, if any to the dissolved metal loads to be treated. The long term durability of all of these materials will also have to be considered.

6.1.2 Groundwater Diversions

Section 4 suggests flow from the bog could be a source of groundwater flux under the coarse waste site. It will therefore, be necessary to construct a diversion channel to divert this water northwestward into the Black Point Brook watershed (Figure 6-2). This would require a 220 m open ditch 3 metres deep to be constructed from piezometer A to exit at an elevation of 93.27 m at the barrier dam to the north (the barrier dam will have to be lowered 2 metres to result in any significant drainage from the area).

6.1.3 Surface Water Diversions

Based upon the assessment of surface water hydrology (Section 4) and ground/surface water interactions (Section 5) there are three locations where surface waters could be diverted away from the site: Town Brook, Swale Brook and drainage from Lamond Street (Figure 6-2).

- Town Brook Diversion -

Because flows from Town Brook have contributed up to 45% of the water leaving the Princess site, Town Brook will have to be diverted away from its present water course, in the southeastern portion of the site, where the area has been designated for passive treatment systems (Figure 6-3). The flow will continue to enter Edward's Pond prior to entering the ocean. This diversion will not be undertaken until passive treatment is in place; otherwise the iron which currently precipitates downstream from the confluence of Town Brook and Swale Brook, will take place at the entrance to or in Edward's Pond.

- Swale Brook -

Divert the upper reaches of Swale Brook to the west side of Cranberry Bog, to drain northward into Black Point Brook. This diversion will necessitate constructing a new channel approximately 250 metres long by 1.0 metres deep.

- Lamond Street Drainage -

Divert surface drainage from Lamond Street which now flows into Bog Brook, by constructing a ditch along the street to the south, bypassing the waste site. This diversion requires approximately 125 metres of ditching.

No material will be removed from the site during the site and/or drainage manipulation. The material will be relocated close to its source to modify topography.

6.1.4 Control Subsurface Seepage

Construct a barrier wall as a trench, excavated down to the original till and backfilled with peat muck (Sapric Zone), to the current high water table level. Construct an infiltration gallery up-gradient of the barrier wall to collect the water and allow it to move to a point discharge, where it would be piped through the barrier wall and into the treatment system (described below). The infiltration gallery could be constructed to serve a dual purpose by

using coarse limestone as the drainage medium and widening the gallery at the discharge end to provide sufficient time to raise the pH of the water. This would in fact become an Anoxic Limestone Drain (ALD), the first step in the passive treatment process (see Figure 6-3).

6.1.4 Anoxic Limestone Drains

Initially, acidic groundwater seepage which is low in dissolved oxygen, will be directed by a barrier wall(s) into one or more anoxic limestone drains (ALD's), where alkalinity will be added to the water by contact with the limestone, Ph will rise, and aluminum will precipitate. This partially treated water will exit into an aeration ditch and settling pond where metals will precipitate and the pH will drop again.

From our experience at another coarse waste site in the area we believe the success of an ALD is dependent on the contact time of the water with the limestone. Therefore, the prevention of seepage into the ALD, through the sidewalls, especially near the exit of the ALD, is critical. Restriction of flow into the ALD will be difficult to achieve unless the barrier wall is constructed and groundwater flow is directed to the inlet of the ALD.

6.1.5 Successive Alkalinity Producing Systems

Because the acidity and metal concentrations are very high, one treatment step with limestone will not be enough to remediate the water chemistry. Therefore, the water discharging from the ALD settling pond will be channelled into successive alkalinity producing systems (SAPS) and settling ponds. The SAPS are ponds where vertical flow is controlled by subsurface drains, through a layer of organic material (which removes oxygen), and a layer of limestone, to exit with the addition of alkalinity and pH and the loss of some metal concentration and acidity. Directed into an aeration ditch and another settling pond, additional metal concentration and acidity will be lost. Designed in sequence, this method of treatment will remediate the water discharging from the site.

Remediation of the acidic water, prior to discharge into surface water courses, will be optimized if the ALD and SAPS are placed in the southeastern portion of the site before leaving the property and flowing into Edward's Pond. The water quality requiring treatment is characterized by the chemical data at Spring #4; high dissolved solids (6000 mg/l), iron (2000 mg/l), aluminum (15 mg/l), pH (3.8-4.4) and acidities (3500 mg/l). The present water quantity and quality is borderline for successful treatment by (ALD's and SAPS), however, it is expected previously discussed techniques for reducing the contact between the waste pile and water (infiltration and groundwater flux) will also have a positive impact on the water quality.

Following the installation of the techniques designed to reduce infiltration and groundwater flux through the pile, the site discharge which requires treatment is expected to be approximately 180 l/min.

It is expected six SAPS over a 1 - 2 hectare area will be required to effectively treat the discharge from this site.

6.1.6 Edward's Pond - Final Polishing Pond

Edward's Pond, although off-site, cannot be ignored throughout the remediation process. It will continue to be utilized as an estuarine wetland that serves as the final polishing for the discharge from the coarse waste pile. Natural biological communities will be allowed/encouraged to re-establish themselves along the shoreline of this tidal pond. This process will be facilitated by the passive treatment technologies upstream from the pond. The resulting increase in vegetation will restore the pond to a more natural habitat and will enhance the physical stability of the sediments.

6.2 Recommendations - Passive Treatment Options

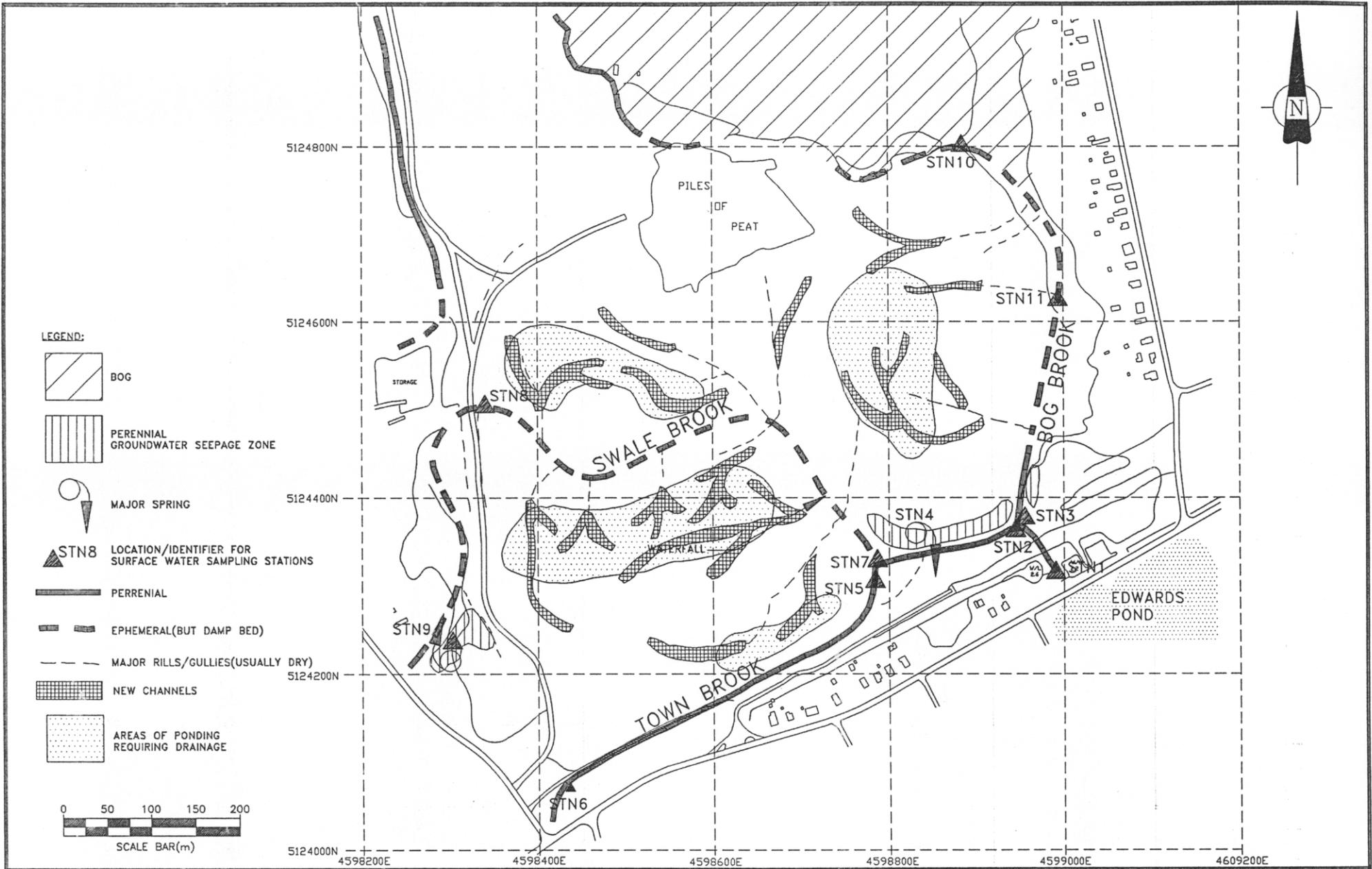
Based on the understanding of the factors governing acid drainage at the Princess Site (Sections 4, 5 and APPENDIX E), *the interaction of the solid material in the waste pile, and water (infiltration and groundwater) must be minimized before subsurface passive treatment (limestone amendments, settling ponds) is initiated.*

Therefore, the following combination of passive treatment options are recommended for Phase 1, Phase 2 and subsequent years, for remediation of acidic discharges at the Princess Waste Site. Class D costs for these options are included in Section 7.0.

- Phase 1 -

Year 1:

- Reduce infiltration over the entire Princess Waste Site by *enhancing surface run-off* with additional swales and channels (Figure 6-1).
- Divert *Swale Brook* and the *Lamond Street Drainage* (Figure 6-2).



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FIGURE 6-1
 PROPOSED ENHANCED DRAINAGE PATTERN
 PRINCESS COARSE WASTE SITE
 SYDNEY MINES, NOVA SCOTIA

DRWN BY: N.B.
 CHKD BY: F.B.

DATE: MARCH, 1995
 JOB #: 24-3515-004.1

- Install the interceptor ditch between Cranberry Bog and the Princess Waste Site (Figure 6-2).
- Reduce infiltration by placing six (6) hectares of the site marked on (Figure 6-3) under *Natural Forest Soil Transplant*. This area was chosen because of its position as a recharge area for the groundwater seepage zone at/near Spring #4, and because of the frequency of monitoring stations already established, which will be used to monitor the success of the implementation.
- Edward's pond - encourage plant communities to grow at the shoreline. **The sediment in Edward's Pond should not be removed.** Disturbance of the material may re-mobilize metals presently held up in the silts and clays.

Year 2:

- Continue to reduce site infiltration by *Natural Forest Soil Transplant* expansion near the initial site and in the recharge area of Piezometer - L.
- Edward's pond - encourage plant communities to grow at the shoreline.

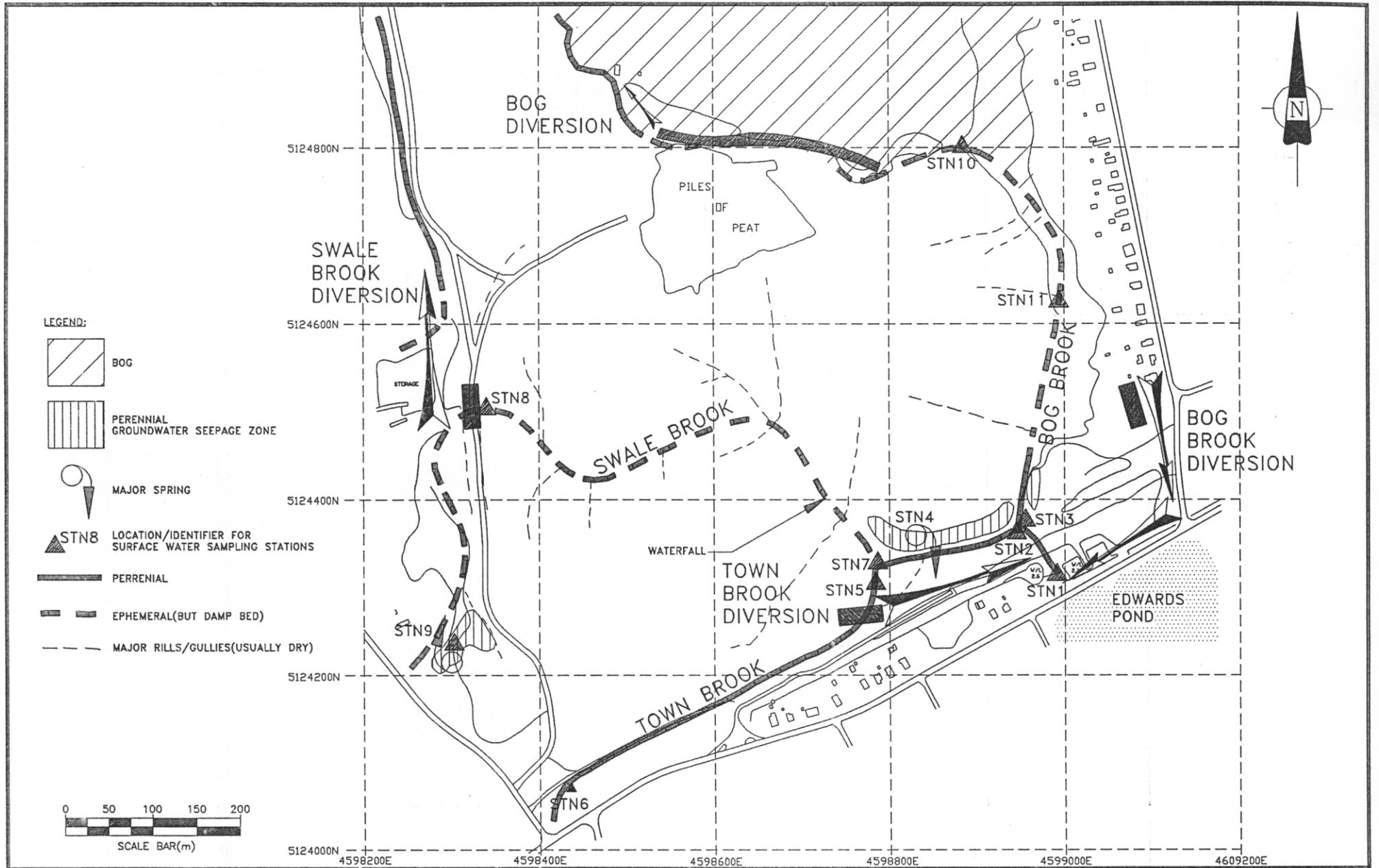
During Phase 1 water chemistry, head levels and surface water discharge measurements will be monitored on a regular basis. This monitoring will permit the assessment of the success of the options implemented and will provide additional data to refine future design options. A measure of the success will be the amount and quality of acidic groundwater leaving the site.

Concepts and resulting Class D cost estimates for the continued amelioration of acid generation at the site are presented to provide a range of options available.

- Phase 2 -

Year 1:

- Continue to reduce site infiltration by *Natural Forest Soil Transplant*.
- Control subsurface seepage by the installation of the *barrier wall and infiltration gallery* (Figure 6-3).



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FIGURE 6-2
 GROUND/SURFACE WATER DRAINAGE DIVERSIONS
 PRINCESS COARSE WASTE SITE
 SYDNEY MINES, NOVA SCOTIA

DRWN BY: N.B.
 CHKD BY: F.B.

DATE: MARCH, 1995
 JOB #: 24-3515-004.1

- Install *anoxic limestone drain(s), successive alkalinity producing systems* and settling ponds in the area marked on Figure 6-3)
- If required, divert *Town Brook*

Subsequent Years:

- Continue to reduce site infiltration by *Natural Forest Soil Transplant* expansion adjacent to established sites, until the entire site is under *Natural Forest Soil Transplant*.

7.0 COST SUMMARY - CLASS D COSTS

	DESCRIPTION	COSTS
PHASE 1 - YEAR 1	Design	\$ 10,000
	Re-shaping existing swales and regrading the land to produce positive drainage from all parts of the site	\$ 50,000
PHASE	Divert flows entering the site away from the site	\$ 30,000
	Natural forest soil transplant (6 hectares @ \$40,000/hectare)	\$240,000
	Monitoring	\$ 20,000
YEAR 2	Natural forest soil transplant (@ \$40,000/hectare)	
	Monitoring	\$ 20,000
PHASE 2 - YEAR 1	Design	\$ 15,000
	Natural forest soil transplant (@ \$40,000/hectare)	
	Barrier Wall	\$ 80,000
	Infiltration gallery and ALD	\$170,000
	Town Brook Diversion	\$ 5,000
	6-SAPS	\$270,000
	Monitoring	\$ 20,000
Subsequent Years	Natural forest soil transplant (@ \$40,000/hectare)	

APPENDIX A
TEST PIT LOGS

TEST PIT SUMMARY

LOCATION: Princess Coal Dump, North Sydney

PROJECT: 35-15004

DATE: July 12-14, 1994

ID	Surveyed Elevation (m)	Total Depth (m)	Water @ (m)	Bedrock @ (m)	Static Water Level (m) July 14/94	Piezometer Installed (m)	Field Chemistry	Lithology (m)	Water Sample
TP-A	7.15	5.5	damp @ 1 m @ 1.5, 4.3	nil	0.61	@ 5.5	cond=1890 pH=5.67 (top of peat)	0-1.7 coarse waste, 1.7-5.1 peat, 5.1-5.5 grey and red mottled till, sandy, pebbly.	FF 2:50 pm (hard to filter)
TP-B	9.6	5	@ 1.1	nil	3.3	@ 5.0	cond=7850 pH=4.28	0-1.3 fine waste, 1.3-2.1 coarse waste, 2.1- fine waste 2.1-5.0 fine waste (caving 4-5 m) coarse zone highly oxidized	FF 4:00 pm
TP-C	8.17	4.4	pouring in @ 3.4	nil	1.58	@ 4.4	cond=3950 pH=4.0	0-2.2 fine waste, 2.2-3.4 laminated silt and clay (settling pond material?) 3.4-4.1 coarse waste, 4.1-4.2 peat, 4.1-4.4 till, sandy, red, pebbly (photo, teeth marks in silt + clay)	FF 10:20 am
TP-D	5.32	2.5 (caving)	@ 1.6 pouring in @ 2.0 hydrocarbons	nil	0.05	@ 2.5	cond=5250 pH=4.5	0-3.2 coarse waste + garbage bags 3.2 or greater, red sandy till. Protector angled. (piez. construction dries up Spr #4)	FF 12:20 pm
TP-E	4.86	1.5	from brook 1 m	nil	0.72	@ 1.5	cond=5560 pH=4.41	0-1.5 coarse waste	FF 12:40 pm
TP-F	5.59	3.9	pouring in @ 1 m clear water pouring in @ 1.85 m	3.5	1.49	@ 3.0	cond=1470 pH=2.6 clear water pouring in @ 1.85 m	0-0.3 soil zone, 0.3-1.0 coal, 1.0-2.2 coarse waste, @ 2.2 thin peat (0.05 m), 2.2-2.4 oxidized till silty, clay till, compact), 2.4-3.5 reddish brown till, 3.5-3.9 broken, oxidized, siltstone	FF 8:30 am
TP-G	4.76	3.9 (caving)	damp @ 1.6 H2O @ 1.8 hydrocarbons o H2O, up from bottom	nil	1.33	@ 3.0	cond=1000 pH=3.8	0-4 coal, .4-2.8 ash (S. side of hole), 2.8-3.2 fine sand c coal + rock frags (mine waste), 3.2-3.5 peat c roots, fine grey silt below peat, 3.5-3.9 grey, sandy, silt till. Vertical piling NE. edge of hole, caving badly, horizontal beam N side of hole II t old track. North side of hole no ash, yellowish brown and gre fill. No similarity from one side of hole to the other.	FF 10:20 am
TP-H	5.19	3.1	damp @ 1.0 H2O @ 2.3	3.1	2.07	@ 3.0	cond=615 pH=6.42	0-1.2 coarse waste, 1.2-1.6 peat, 1.6-3.1 till, red, stoney, 3.1 fine weathered sandstone	FF 11:45 am
TP-I	6.27	4.9	damp @ 1.6 H2O @ 1.75	4.9	missed	@ 3.0	cond=12000 pH=5.44	0-1.75 fine, compact waste, 1.75-3.6 laminated silt + clay, (oxidized zones @ 2.3 and 3.4 m), 3.6-3.95 highly compress peat, 3.95-4.9 reddish brown sandy till, 4.9 bdrk (unidentified)	FF 2:00 pm filtered yellowish

TEST PIT SUMMARY

LOCATION: Princess Coal Dump, North Sydney

PROJECT: 35-15004

DATE: July 12-14, 1994

ID	Surveyed Elevation (m)	Total Depth (m)	Water @ (m)	Bedrock @ (m)	Static Water Level (m) July 14/94	Piezometer Installed (m)	Field Chemistry	Lithology (m)	Water Sample
TP-J	8.38	4.9	little water @ 2.85	nil	1.1	@ 4.9		0-0.8 fine waste, 0.8-2.85 fine laminated silt + clay 2.85-3.15 peat, 3.15-3.75 fine laminated silt + clay 3.75-4.4 peat, 4.4-4.9 red brown till mottled c grey, compact	
TP-JX		6	none			none installed		0-1.2 coarse waste, 1.2-4.1 laminated silt + clay, red hematite band @ 2.9, 4.1-6.0 peat c old tree roots. peat reddish, darker near bottom, (laminations strike 140/35	
TP-K	9.59		damp @ 2.7 @ 3.0	nil	2.67	@ 4.4	cond=4440 pH=3.93	0-1.4 fine waste, 1.4-3.95 coarse waste, 3.95-4.3 peat, 4.3-4.4 sandy, brown till	FF 9:20 am (hard to filter)
TP-KX		4.9	nil	4.8		none installed		0-1.7 fine compact waste, 1.7-4.7 coarse waste, 4.7-4.8 till, sandy, greyish brown 4.8-4.9 sandstone, fine grey	
TP-L	15.66	5.7	seep @ 5.1	nil	4.95	@ 5.7		0-4.5 coal waste, 4.5-5.1 oxidized waste, 5.1-5.7 red till	
TP-M	12.97	2.4	0.9, 1.35	nil	0.57	@ 2.4	cond=1230 pH=4.58	0-1.35 grey clay, 1.35-1.7 fine waste, 1.7-2.4 peat 2.4 till, brown, silty	FF 11:00 am
TP-N	8.89	2.3	@ 1.5 hydrocarbons	nil	1.57	@ 2.3	cond=1870 pH=6.31	0-1.25 fine waste, 1.25-2.3 garbage inc. hydrocarbons water black, terrible smell	FF 12:15 pm
P-O	8.55	4.1						PEAT	
P-P	7.23	6.0						PEAT	
P-Q	8.2	2.6						PEAT	
P-R	4.06							PEAT	
P-S	3.73							PEAT	
P-T	7.58	5.8						PEAT	
P-U	6.38							PEAT	
TP-V		3.5	2.7 on top of peat					0-0.8 fine waste, 0.8-1.3 very coarse waste, highly oxidized, 1.3-2.0 oxidized waste, 2.0-2.7 coal waste, 2.7-2.9 peat, 2.9-3.2 grey till, 3.2-3.5 red sandy till	
TP-W		6.2	6.9 on top of peat					0-2.3 ash and coarse waste, 2.3-7.0 laminated sand, silt, 7.0-7.3 coarse waste and wood, 7.3-7.9 peat, 7.9-8.1 grey sand c shells, 8.1-8.2 red till	
TP-X (near JX)		7.0	seeping in @ 3.2 m					0-1.2 fine coal waste, 1.2-4.4 laminated sand and silt (tailings), 4.4-7.0 peat/roots, 7.0 till (red, pebble) water on top of till	
TP-Y		6.5	seeping in on top of peat					0-0.8 fill and coarse waste, 0.8-2.0 fine coal waste, 2.0-4.0 coarse waste, highly oxidized @ 2.0 m, 4.0-6.1 m peat, 6.1-6.5 till (red, silty clay)	

APPENDIX B
PHYSICAL MONITORING DATA

**PRINCESS SITE
FIELD DISCHARGES (Litres per minute)**

STN #	MAY 31	JUNE 16	JULY 5	JULY 29	AUG 16	OCT 5	JAN 9
STN 1	1042	226+	208+	293	59+	1105+	3012
STN 2	918	219	204	241	59	1030	2203
STN 3	115	7.0	4.0	71	<0.5	75	809
STN 4 (Spring)	54*	34*	78*	83*	4*	619*	1193+
STN 5							
STN 6	474●	414●	30	29●	21●	450●	530●
STN 7	130	35	13	38	7	44	480*
STN 8	DRY	DRY	DRY	DRY	DRY	4	105*
STN 9	8	<1	DRY	DRY	DRY	DRY	<1
STN 10	19	DRY	DRY	DRY	DRY	DRY	138*
STN 11	NM	NM	NM	NM	NM	34	NM



MAJOR WATER
CHEMISTRY SAMPLING
DATES

●

MEASURED BY
FILLING CONTAINER
REMAINDER OF
MEASUREMENTS BY
(surface velocity x 0.9)
(area)

NM

NOT MEASURED

+

ADDITION OF STATION
2+3

▲

MEASURED BY
FLOWMETER

++

STATION 2-(STN 5 & 7)

*

APPROXIMATE DUE TO
ICE CONDITIONS OR
DISPERSED FLOW

**MEASURED AND THEORETICAL DISCHARGES
FOR SWALE, BOG AND TOWN BROOK**

from McAskill Brook (1980 - 89 Av.) missing 1985					
	R Coef.	Total Watershed STN 1	Bog Brook STN 3	Swale Brook (without town Brook) STN 6	Town Brook STN 5
Mean Annual	Av. (10 yr.) 0.688m ³ /sec/Km ² range 0.469 0.864	0.433m ³ /sec. 0.295 0.544	0.241m ³ /sec. 0.164 0.302	0.193m ³ /sec. 0.131 0.242	0.151m ³ /sec. 0.103 0.190
Minimum Daily Flows	Av. 0.020m ³ /sec. Range 0.010 0.030	0.013 0.006 0.019	0.007 0.004 0.011	0.006 0.003 0.008	0.004 0.002 0.007
Maximum Daily Flows	Av. 11.3 Range 5.34 17.3	7.12 3.36 10.90	3.96 1.87 6.06	3.16 1.50 4.84	2.49 1.18 3.81
May 31		0.017	0.002	0.015	0.008
June 16		0.004	<0.001	0.004	0.007
July 5		0.003	<0.001	0.003	0.001
July 29		0.005	0.001	0.004	0.001
Aug 16		0.001	<0.001	0.001	<0.001
Oct 5		0.018	0.001	0.017	0.008
Jan 9		0.050	0.013	0.037	0.009

APPENDIX B: PHYSICAL MONITORING DATA

**ADI NOLAN DAVIS
PRINCESS WASTE ROCK SITE
JOB # 3515.004.1**

GROUNDWATER HEAD LEVELS

Location	Monitoring Point Elevation (m)	August 16, 1994		October 6, 1994		January 8, 1995	
		Water Level (m)	Elevation (m)	Water Level (m)	Elevation (m)	Water Level (m)	Elevation (m)
Piez.- A	7.00	0.73	6.27	0.39	6.62	0.14	6.86
Piez.- B	9.37	3.44	5.93	3.29	6.08	2.88	6.49
Piez.- C	8.17	2.61	5.56	2.50	5.67	flooded	
Piez.- D	5.32	0.07	5.25	+0.04	5.36	overflowing	+5.32
Piez.- E	5.01	0.68	4.33	0.67	4.35	0.65	4.36
Piez.- F	5.59	1.58	4.01	1.47	4.12	1.35	4.24
Piez.- G	4.76	1.39	3.37	1.27	3.49	1.02	3.74
Piez.- H	5.19	1.79	3.40	1.33	3.86	1.17	4.02
Piez.- I	6.27	1.27	5.00	0.19	6.09	0.80	5.47
Piez.- K	9.69	3.23	6.46	2.87	6.82	2.40	7.29
Piez.- L	15.71	5.37	10.34	4.59	11.10	4.42	11.29
Piez.- M	12.97	0.81	12.16	0.57	12.40	0.19	12.78
Piez.- N	8.89	1.75	7.14	1.30	7.59	0.81	8.08
Piez.- O	7.40	1.32	6.09	0.99	6.41	0.83	6.57
Piez.- P	8.18	1.28	6.91	1.08	7.11	0.90	7.28
Piez.- Q	7.10	1.35	5.76	1.04	6.07	0.90	6.20
Piez.- R	4.77	1.20	3.58	0.86	3.91	0.73	4.05
Piez.- S	4.73	1.06	3.68	0.87	3.87	0.75	3.98
Piez.- T	8.41	1.38	7.04	1.18	7.24	0.98	7.43
Piez.- U	7.23	1.52	5.72	1.33	5.90	1.12	6.11
Piez.- V	6.32			0.67	5.65	0.60	5.72
Piez.- W	10.37			3.67	6.71	2.79	7.58
Piez.- X	8.75			2.52	6.23	2.23	6.52
Piez.- Y	7.70			1.43	6.27	0.95	6.75

APPENDIX C
WATER CHEMISTRY DATA

APPENDIX D
PHYSICAL DESCRIPTION OF SITE

APPENDIX D - PHYSICAL DESCRIPTION OF THE SITE

D-1.0 Geology

A plan view of site geology is presented in Figure D-1. Three geological cross sections are presented in Figures 5-1, 5-2, and 5-3; with locations noted in Figure 3-1.

D-1.1 Bedrock Geology

The site is located geologically within the Sydney Carboniferous Coalfield. Specifically the site is totally underlain by the Sydney Mines Formation of the Morien Group. It is comprised of primarily argillaceous sedimentary rock types including mudstone, shale, siltstone, with minor sandstones and thick economical coal seams. The bedrock strikes northwest - southeast under the site with dips to the north of up to 10 degrees (Boehner et al, 1986).

Bedrock outcrops within the study area at only one spot, associated with the bed of Town Brook along the southern perimeter of the site (Figure D-1).

The test pit program was designed to key in on primarily the overburden but did encounter bedrock at test pits KX,I,F and H. The lithology consisted of siltstones and sandstones.

D-1.2 Surficial Geology

- Glacial Till -

The bedrock in the area is directly overlain by a stony, sandy silt to silty sand basal glacial till (Baechler, 1985). General thicknesses in the area range from 3 - 7 m. Where full thickness was encountered on-site thicknesses ranged from 1 to 2.5 m.

Within the study area the till is exposed under the soil horizon on the east, west and south boundaries. All test pits reaching the base of the coarse waste encountered till (i.e. test pits M,L,J,A,KX,K,C,D,I,F,G, and H). It is therefore assumed that it is continuous under the site and has been drawn as such on the cross sectional diagrams. The cross sections indicate the surface of the till is sloped northward under the site at 0.5 to 0.8%; although in the southwest corner it slopes northward at 3.1%. One localized important exception is the depression under Swale Brook (Figure 5-1). The east-west cross section (Figure 5-3) indicates that the elevation of the till is relatively uniform along this orientation.

- Peat -

Immediately overlying the glacial till is a peat deposit. Prior to disposal activities the site was covered by a bog, which was subsequently partially infilled. Locally the bog has a number of names; for the purposes of this report it will be referred to as Cranberry

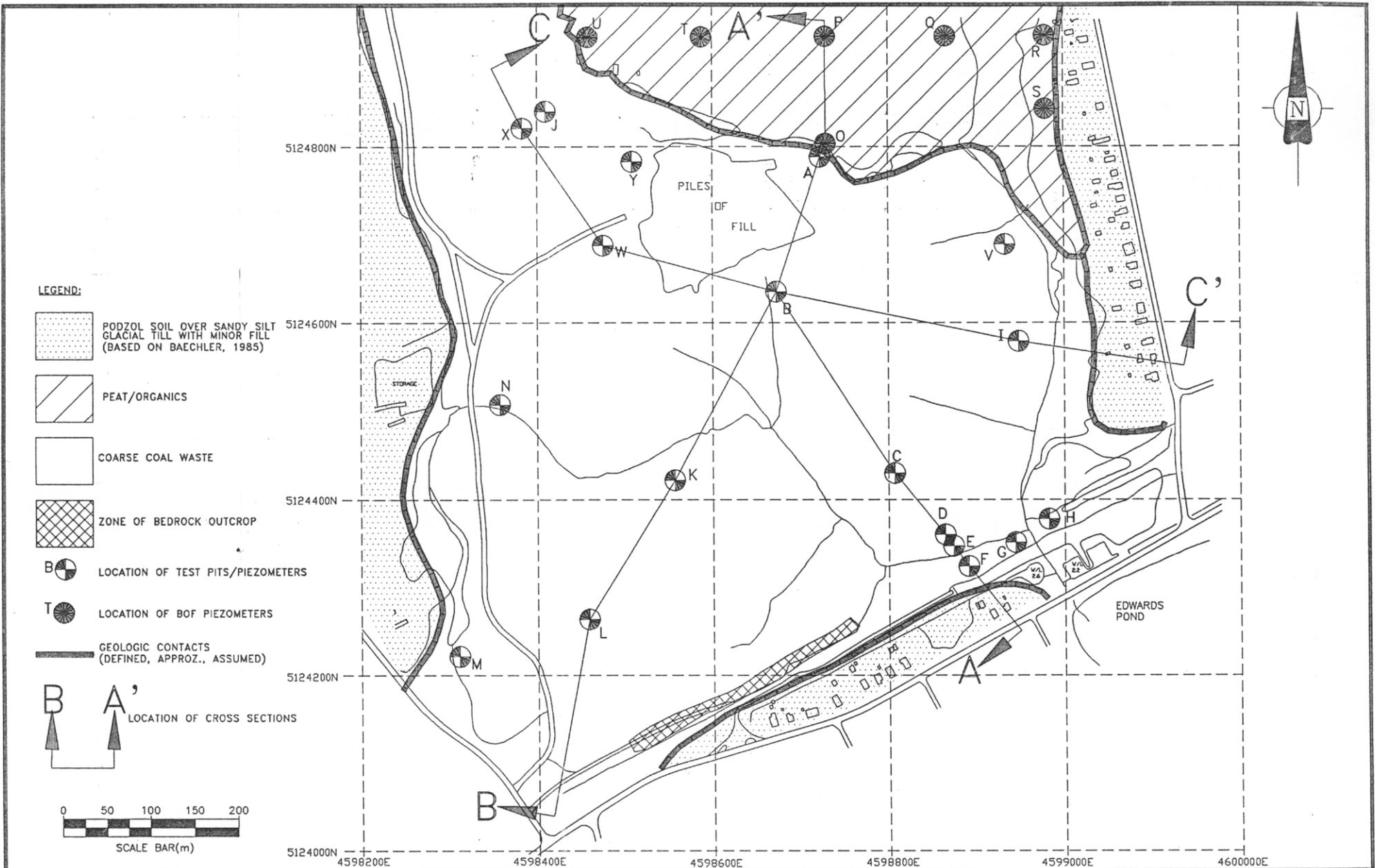


FIGURE D-1
SUMMARY OF SURFICIAL GEOLOGY
PRINCESS COARSE WASTE SITE
SYDNEY MINES, NOVA SCOTIA



ADI NOLAN DAVIS INC.
Engineering and
Environmental Management
Sydney, Nova Scotia

DRWN BY: N.B.
CHKD BY: F.B.

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Bog. The untouched remains of the bog is present along the northern perimeter of the site. The north-south cross section A-A' (Figure 5-1) indicates probing within the bog revealed depths ranging up to 7 m. The unit is also present in compressed form under the coarse waste material, decreasing in thickness to the south. At all test pits which excavated to the base of the coarse waste, peat was found, with the exception of the southwest corner of the site at Test Pit L.

- Coarse Waste -

Overlying the peat is the coarse coal rock waste. The test pits indicate an average thickness of 3 to 5 meters, with maximum values under the topographic highs at Test pit L and W of 6 to 7 meters.

Test pit excavations indicated that the waste could be classified into three distinct lithological types including coarse and fine waste and laminated tailings.

D-1.3 Topography

Site grading activities resulted in a gently rolling topography with relief ranging from 2 m at the southeast corner near the outflow to Edward's Pond to a maximum of 16.3 m at a knoll in the southwest corner of the site. Most of the surface area of the site ranges between 4 to 10 m geodetic.

D-2.0 Climate

The general Sydney area exhibits a humid, continental climate. Climatic and weather information, considered to be representative of the study area, was extracted from the nearly 50 years of records accumulated at Environment Canada's, Atmospheric Environment Service (AES) "Sydney A" station. The 1951 - 80 Normals of pertinent parameters are presented in Table D-1.

The mean total annual precipitation is 1399.9 mm. It is well distributed seasonally, with minimum values from May through September. Maximum precipitation occurs during the fall rains, peaking in November and December.

The mean annual air temperature is 5.7 °C, with a minimum monthly mean in February (-5.9 °C) and a maximum monthly mean in both July and August (17.7 °C).

In relation to the 30 Year Normals the weather conditions occurring during the study period approximated Normal conditions with the exceptions of April, June, July, October, November and December which could be characterized as Warm and dry.

The water balance diagram characterizing the study area utilizing the 1951 - 80 Normals

TABLE D-1

PERTINENT CLIMATIC NORMALS AT SYDNEY A (1951 - 1980 PERIOD)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR	CODE
SYDNEY A														
46° 10'N 60° 3'W 62 m														
Daily Maximum Temperature	-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	1
Daily Minimum Temperature	-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	1
Daily Temperature	-4.7	-5.9	-2.5	2.0	7.4	13.2	17.7	17.8	13.5	8.4	3.8	-1.8	5.7	1
Standard Deviation, Daily Temperature	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	1
Extreme Maximum Temperature	14.4	12.8	17.8	27.2	31.1	34.4	33.9	35.0	32.2	25.0	22.2	16.7	35.0	
Years of Record	39	39	39	40	40	40	40	40	40	40	40	40	40	
Extreme Minimum Temperature	-23.3	-25.6	-23.9	-13.3	-7.8	-3.9	2.2	2.8	-1.7	-5.6	-11.1	-18.9	-25.6	
Years of Record	39	39	39	40	40	40	40	40	40	40	40	40	40	
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	1
Snowfall	74.5	68.6	63.9	25.4	5.3	T	0.0	0.0	T	2.6	12.0	65.6	317.9	1
Total Precipitation	149.0	123.6	131.4	102.0	95.2	82.1	81.4	101.3	87.2	122.7	160.4	163.8	1399.9	1
Standard Deviation, Total Precipitation	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	1
Greatest Rainfall in 24 hours	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	
Years of Record	39	39	39	40	40	40	40	40	40	40	40	40	40	
Greatest Snowfall in 24 hours	44.5	45.2	37.3	29.2	24.9	1.0	0.0	0.0	T	15.7	21.6	58.7	58.7	
Years of Record	39	39	39	40	40	40	40	40	40	40	40	40	40	
Greatest Precipitation in 24 hours	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	
Years of Record	39	39	39	40	40	40	40	40	40	40	40	40	40	
Days with Rain	8	6	8	10	13	13	12	13	12	14	15	11	135	1
Days with Snow	16	14	13	7	1		0	0	0	1	5	16	73	1
Days with Precipitation	20	16	17	14	14	13	12	13	12	15	18	22	168	1

data courtesy Environment Canada
(Atmospheric Environment Service)

is presented in Figure D-2. It indicates that the two major groundwater recharge periods occur associated with the fall rains (October, November, December) and spring rain/melt events (March, April, May).

D-3.0 Vegetation

Over the course of several years CBDC undertook re-vegetation of the site which was completed in 1993.

The reclamation of the Princess Waste site following coal recovery operations, was completed in three stages. These included :1) contouring to final grade;) testing of reclamation procedures; and 3) establishing a vegetative cover.

The contouring was undertaken according to a plan that would result in filling of the tailings ponds and levelling the high areas (stone piles). It also allowed for controlled drainage of surface run-off by constructing swales that would direct water towards the southeast where it exited the site.

Testing of reclamation procedures was done by establishing test plots of varying soil amendments, fertilizer rates and seed mixes. Final reclamation specifications were based on these results.

The vegetative cover was applied to the site in three stages:

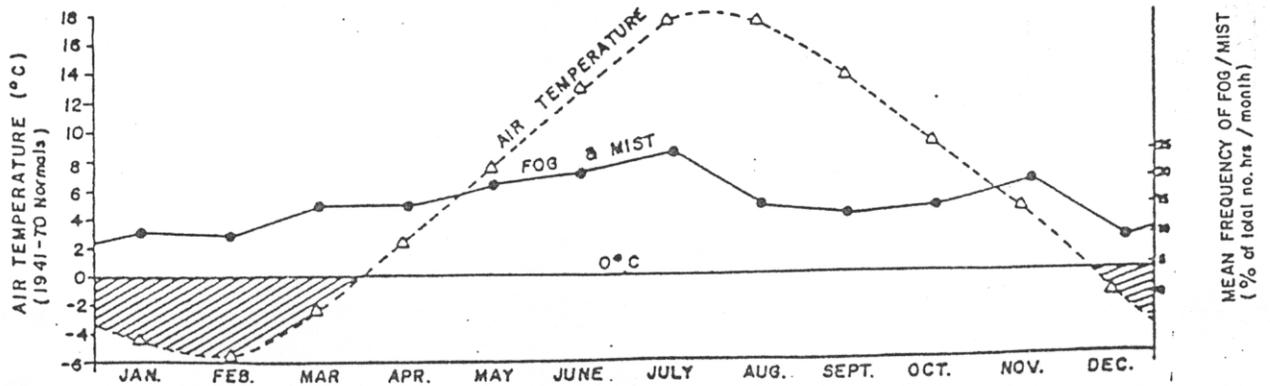
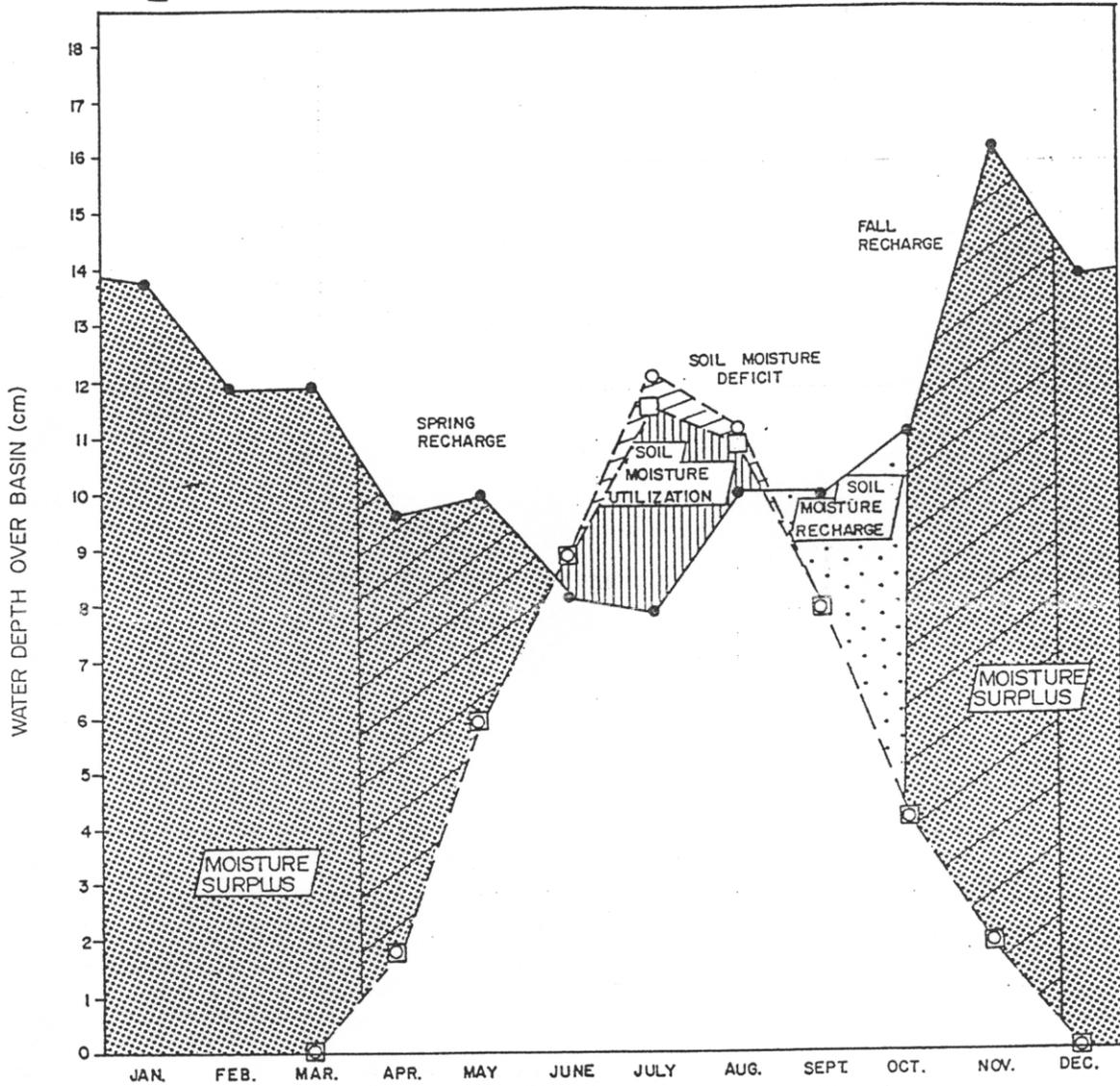
- agricultural limestone was spread over the surface at 50 tonnes/hectare;
- peat was spread over the surface at a nominal 50 mm cover and then tilled into the top 100 mm of ground;
- hydraulic seeding was done with a slurry mix that would cover at the following rates:

grass seed mix	- 112 kg/hectare
mulch	- 1100 kg/hectare
fertilizer	- 443 kg/hectare

The resultant grass cover presently established on-site (summer of 1994) was visually broken down into three types for the purpose of this investigation, including : good, scattered and no growth. The aerial extent of this coverage is noted in Figure D-3. The extent of good growth is present primarily over the topographic high areas; where as the no growth zones dominate the lower elevations in proximity to the main drainage channels.

LEGEND

- Precipitation
- Potential evapotranspiration 1941-70 Normals utilizing Sydney Airport data.
- Actual evapotranspiration



**NOLAN, DAVIS
& ASSOCIATES**

FIGURE D-2
WATER BALANCE DIAGRAM



FIGURE D-3
 VEGETATION COVER 1994
 PRINCESS COARSE WASTE SITE
 SYDNEY MINES, NOVA SCOTIA



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APPENDIX E

SEEPAGE FACE CONTRIBUTION TO SITE RUNOFF

APPENDIX E - SEEPAGE FACE CONTRIBUTION TO SITE Run-off

- Dilution Effects -

The surface water chemistry, generated by the combination of run-off from the site and baseflow, without the influence of Town Brook, has been characterized by the water chemistry collected at Stations 7 and 3. The chemistries are variable depending on the amount of run-off diluting the groundwater contribution (base flow) to each water course. During the summer when run-off was minimal, the water chemistry from Station 7 and 3 (tabulated in Appendix 1) could be described as a magnesium/calcium : sulphate water, high in dissolved solids (5700, 4700 respectively), very acidic (2.8-2.4) with moderate iron (800-900 mg/L), manganese (125 mg/l) and aluminum (Sta-3 40 mg/l, Sta-7 160 mg/l). Associated with the highest aluminum (Sta-7) was elevated nickel (1.9 mg/l), cobalt (1.1 mg/l). Early fall recharge at TP-7 caused a slight dilution (15%) of major ions and a significant increase in metal concentrations such as arsenic, chromium, and uranium. At Sta-3 the early fall recharge resulted in a significant dilution of major ions (60%), with increases in aluminum, cobalt, nickel, and uranium.

By January 8th, after a rainfall and snow melt event on January 7th, Sta-7 was 60% diluted with respect to summer concentrations, Sta-3 was diluted by 90%. The high dilution at Sta-3 can be accounted for because 77% of the drainage area of Bog Brook is off the Princess Waste Site.

Table 4-1 shows the discharge measurements at surface water stations on the site. Total discharge from the site as measured at Station #1 included contributions from Town Brook, the upper reaches of Swale Brook and the Bog as measured at Station #10. Peak flow at Station 1 was measured at 3000 l/min. Eliminating the contributions from Town Brook, Upper Swale Brook and the influence of the Bog on Bog Brook cut the flow to approximately 2200 l/min (480 igpm).

- Seepage Face -

Table 4-1 shows the discharge along the 200 metre seepage face in the vicinity of Spring #4. It should be noted that of the entire drainage at Station #2, the seepage face contributed approximately 50% of the flow except during periods of low flow (72%) and during spring run-off (34%). If the run-off from Town Brook was eliminated from the flow at Station #2, then the seepage face contributed to 70-90 % of the surface flow leaving the western portion of the site. At Station #1, where the total water leaving the site is measured, the seepage face was found to contribute from 50-80 % of the flow leaving the site (the contribution from Town Brook was eliminated from these calculations).

These percentages indicate that under the present site conditions infiltration accounts for a large part of the water balance.

TABLE E-1

DATE	SEEPAGE FACE l/min	% SEEPAGE FACE OF STN-2	% SEEPAGE FACE OF STN-2 - STN-6	% SEEPAGE OF STN 1 - STN 6
May 31	314	34	71	55
July 29	174	72	82	66
August 16	31	52	82	82
October 5	536	52	92	82
Jan 9	1193	54	72	48

At peak flow approximately 1000 l/min was contributed to the site discharge by groundwater seepage along a 200 metre seepage face in the vicinity of Spring #4. Calculations indicated a permeability of 2.8×10^{-3} cm/sec for the material in this area of the waste site. Groundwater velocities of 100 m/year were calculated using this permeability and assuming a porosity of 0.4.