CAPE BRETON DEVELOPMENT CORPORATION
PROPOSED CLOSE-OUT
VICTORIA JUNCTION TAILINGS BASIN
VICTORIA JUNCTION, NOVA SCOTIA

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CAPE BRETON DEVELOPMENT CORPORATION
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PROJECT NO. 8996

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REPORT TO

CAPE BRETON DEVELOPMENT CORPORATION

ON

PROPOSED CLOSE-OUT
VICTORIA JUNCTION TAILINGS BASIN
VICTORIA JUNCTION, NOVA SCOTIA

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EXECUTIVE SUMMARY

1. Jacques, Whitford and Associates Limited has been retained by the Cape Breton Development Corporation, under the terms of the "Agreement for Consulting Services" dated June 25, 1993, and CBDC's Purchase Order No. 14010-JAW01 dated July 15, 1993, to develop a decommissioning plan for the Victoria Junction Tailing Basin.

2. CBDC's coal preparation facility at Victoria Junction includes a coal wash plant and processed coal stock pile area, a coarse waste disposal area, and a tailings basin which is used for disposal of fine tailings. The tailings are pumped to the basin in slurry form, with the slurry water including process water and run-off from the wash plant site.

3. CBDC requires a plan for the close-out of the Tailings Basin in an environmentally-sound manner. The tailings contain pyrite, and the requirement is to ensure that potential pyrite oxidation does not result in acid generation and the release of toxic heavy metals to the receiving groundwater and surface waters. The approach selected by CBDC to prevent the onset of acid generation is to reduce the oxidation process by permanent subaqueous storage, such that the oxygen necessary for the chemical reactions is prevented from reaching the tailings.

4. The decommissioning plan will provide permanent sub-aqueous storage of the tailings within the present basin, utilizing the existing dam, decant, spillway and settling pond.

5. The present sub-aerial tailings - that portion which is exposed to the atmosphere in the western portion of the basin - will be cut down, and redeposited in the present pond area in the eastern portion of the basin. The lowest elevation to which the tailings can be cut down is to el. 130 feet; the redeposited tailings would lie below el. 128 feet. The total volume would be about 640,000 cubic yards.

6. To reduce the volume of tailings to be moved, the sub-aerial tailings can be cut down to a higher elevation. Various aspects considered in this study indicate that the maximum elevation would be about 134 feet. For this elevation, the redeposited tailings will lie below el. 124 feet, and the volume would be about 282,000 cubic yards.

7. The normal operating pond level will be 4 feet above the highest tailings (i.e., the cut-down tailings pile). Water depths at the east end of the basin would then be at least 6 feet.

8. The catchment area provides enough runoff to maintain submergence in all years including drought years. For the most extreme drought event analyzed, the water cover should not be less than about 1.7 feet.

9. For a design pond level at el. 134 feet, the freeboard provided by the existing dam will be adequate. For a pond level at el. 138 feet, the dam will have to be raised.

10. The decant system can be operated with fixed weir elevations, to reduce operating costs. In this case, pond levels associated with various mean flows will range between +1.2 feet and -2.3 feet of the normal level. Closer regulation of pond levels can be achieved using the installed gate valves.

11. The 100-year 24-hour rainfall will cause a temporary rise in pond level of 1.1 to 1.4 feet, depending on the pond level at the onset of the storm.

12. The tailings will be moved by methods which minimize exposure to oxidizing conditions, and which control sediment loadings in discharges to the receiving waters during the operation. A number of methods are briefly described, which indicate that dredging is the most suitable and cost-effective method.

13. Potential environmental concerns related to surface water and groundwater resources, aquatic and terrestrial habitat, and wild life have been identified and reviewed. The chosen method of sub-aqueous disposal, and available mitigative technologies, are sufficient to reduce the net release of acidity and dissolved solids to surface waters and groundwater and will result in a positive impact.

14. Effects of the redistribution activities on aquatic and terrestrial habitats and wildlife will be temporary. The project is in itself a mitigation measure, and, if developed with the mitigation measures identified, should result in an overall positive effect on the environment and the valued ecosystem components.

15. Therefore, under the terms of the Environmental Assessment and Review Process Guidelines, it is recommended that the project proceed, with implementation of the mitigative and monitoring measures described in this report.

16. The major cost component of the decommissioning plan is moving the tailings. Class "C" estimates for a plan with the tailings cut down to el. 130 feet is $1,949,000. For a plan with a cut-down elevation of 134 feet, the estimate is $1,276,000.

1.0 INTRODUCTION

Jacques, Whitford and Associates Limited has been retained by the Cape Breton Development Corporation (CBDC), under the terms of the "Agreement for Consulting Services" dated June 25, 1993, and CBDC's Purchase Order No. 14010-JAW01 dated July 15, 1993, to develop a decommissioning plan for the Victoria Junction Tailings Basin.

The CBDC requires a plan for the close-out of the Tailings Basin in an environmentally-sound manner. The tailings contain pyrite, and the requirement is to ensure that potential pyrite oxidation does not result in acid generation and the release of toxic heavy metals to the receiving groundwater and surface waters. The approach selected by CBDC to prevent the onset of acid generation is to reduce the oxidation process by permanent subaqueous storage, such that the oxygen necessary for the chemical reactions is prevented from reaching the tailings.

The submergence technique has been under study in Canada for several years by the Mine Environmental Neutral Drainage (MEND) Program, and is now accepted as a sound solution.

This report contains the results of engineering and scientific studies performed to develop the plan, in accordance with CBDC's requirements which are summarized below:

1. Redistribution of accumulated tailings and prevention of acid generation.

2. Inducement of flood water and maintenance of water cover.

3. An Initial Environmental Assessment, per Environmental Assessment and Review Process Guidelines.

4. Class "C" estimate of the costs of implementing the Plan.

In accordance with the principal system of units used heretofore by CBDC and their consultants, this report has been prepared using Imperial units of measurement, with SI units being provided in brackets where source data were in those units.

This report supersedes an interim report which was submitted on August 6, 1993.

2.0 BACKGROUND

CBDC's coal preparation facility at Victoria Junction includes a coal wash plant and processed coal stock pile area, a coarse waste disposal area, and a tailings basin which is used for disposal of fine tailings. The tailings are pumped to the basin in slurry form, with the slurry water including process water and run-off from the wash plant site. The basin, located about two miles (3 km) northwest of the plant, was constructed by building an earth fill dam across a low valley draining to the east, as shown on Figure 2.1. Kilkenny Lake, a secondary water source for the Town of New Waterford, lies about 1500 feet north of the basin on the other side of a low ridge. Water discharged from the tailings basin enters Kehoe Brook.

The coal preparation plant processes about 3.3 million tons (3 million tonnes) of raw coal per year, of which about four or five percent (120 000 - 150 000 tonnes) ends up as fine coal waste. The present basin was designed to handle an annual average production of 160,000 tons (145 000 tonnes) of fine coal waste tailings over a period of 20 years.

The tailings retention dam was constructed during the summer of 1982, and following the installation of groundwater monitoring wells, a pipeline, and a pumping station at the preparation plant, intermittent pumping of tailings commenced in December, 1984. Continuous pumping began in June, 1985. Process water and surface water from the plant site were used as transport water, and after September, 1987, surface drainage from the coarse waste pile was also pumped with the tailings slurry.

In 1990, surface water sampling revealed elevated levels of sulphates and chlorides in Kilkenny Lake, and studies were undertaken to determine the source, and whether remedial measures were required. One direct outcome was the decision to lower the operating level of the tailings pond to reduce the amount of groundwater seepage from the basin to Kilkenny Lake, and since that time the pond level has fluctuated between about el. 136 feet and about el. 126 feet.

Ultimately, CBDC decided that the most certain way of protecting the water supply in Kilkenny Lake was to cease operating the tailings basin.

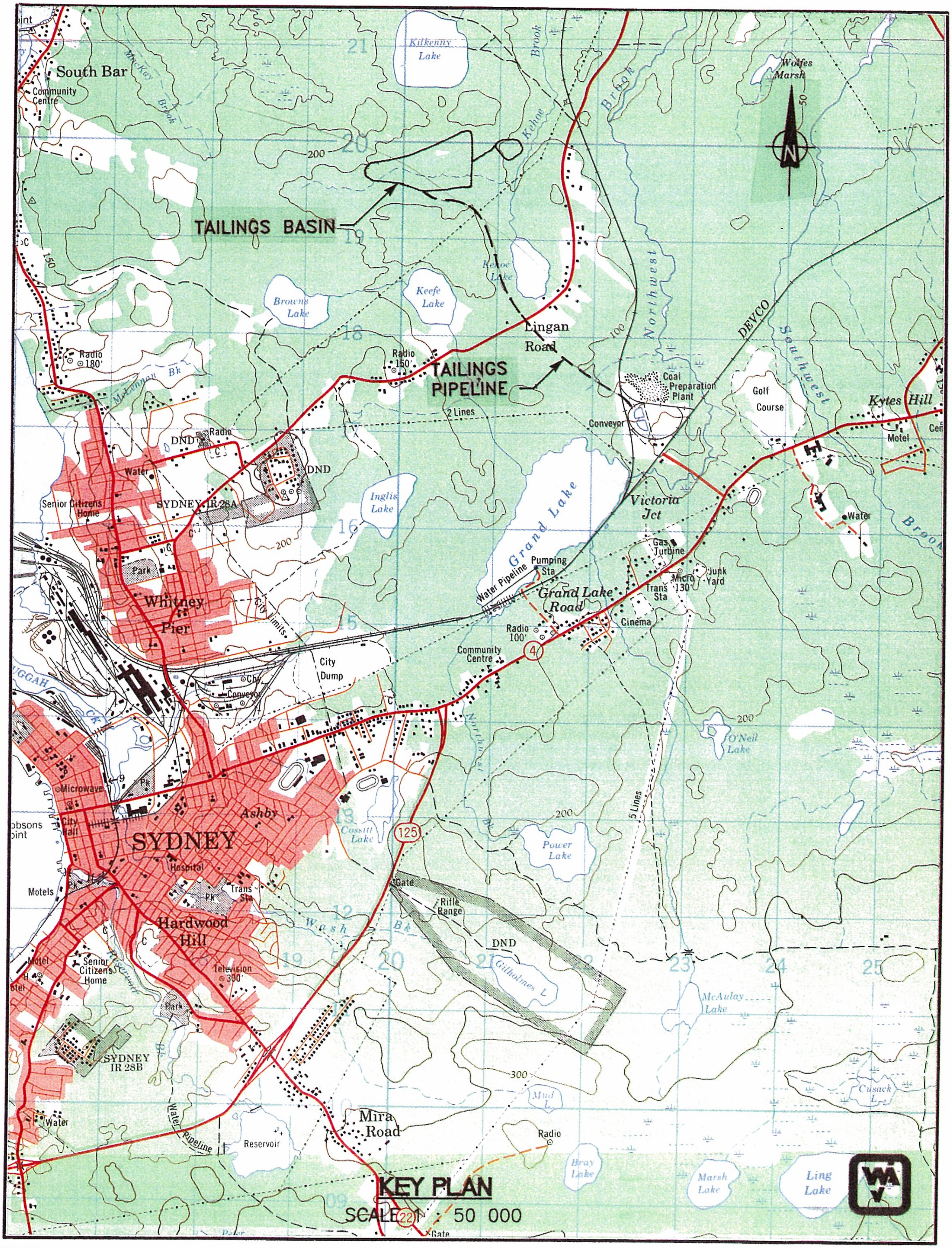

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FIGURE 2.1

3.0 REVIEW OF PREVIOUS STUDIES

The initial geotechnical, hydrological and design studies were performed by Geocon between 1978 and 1983. The results of groundwater monitoring and related aspects were reviewed in a series of reports by Geocon and Nolan Davis between 1987 and 1991 which concluded that seepage was occurring through a pervious zone of the bedrock underlying the ridge between the tailings basin and Kilkenny Lake. Subsequently Geocon studied possible remediation alternatives during 1991 - 1992.

Reports resulting from their studies, which were reviewed by JWA, are included in the References, Appendix 1. Geocon (1992a) studied several options to reduce the seepage between the tailings basin and Kilkenny Lake. Their analyses were summarized as follows:

1. Tailings Seal. A seal of fine tailings deposited on the bottom of the pond would not be effective. A reduction in seepage of less than 10 percent would be achieved for high water level in the pond.

2. Grout Curtain. Cement grouting of the sandstone bedrock would result in a seepage reduction of only about one-third for a high water level in the tailings pond. Furthermore, the grout option was not considered reliable.

3. Low Pond Level. Seepage could be reduced by lowering the tailings pond. The quantity of seepage at a pond elevation of 125 feet would be about 50 IGPM compared to 125 IGPM at a pond elevation of 135 feet.

Geocon (1992a) also addressed closure concepts at the end of the design operating period (about AD 2005). The concept envisaged permanent submergence of the tailings, together with provision of adequate flood routing and adequate measures for long term stability of the dams. CBDC's decision to close the tailings in the near future does not alter the principles put forward by Geocon, but it radically alters the details, since the tailings volume will be much smaller.

4.0 ORGANIZATION OF THIS REPORT

The concept of permanent submergence of the tailings has found wide acceptance (MEND 1989), and has been adopted by CBDC as the most appropriate solution, and is reflected in the scope of work (Section 1.0 of this report). This report addresses the work scope in the Sections which follow. Sections 5 and 6 describe the tailings redistribution plan and the associated hydraulic considerations of permanent water cover, flood routing, and wave action. An initial environmental assessment of the proposed Plan follows in Sections 7 to 9. Finally, cost estimates for the closure plan are presented in Section 10.

5.0 TAILINGS REDISTRIBUTION PLAN

5.1 General

The aim of the redistribution is to achieve total submergence, so as to reduce or eliminate acid generation within the tailings. Both environmental and economic considerations call for this to be done with a minimum of disruption to the existing facilities; thus the redistribution should be achieved while retaining the present dam, decant system, spillway and settling pond. All of the latter structures, whether modified or not, would be required to permit control of water levels in the basin and to ensure that discharges to receiving surface waters meet environmental standards.

The simplest way to achieve all the above objectives would be to cut down the present subaerial tailings pile - that portion exposed to the atmosphere in the west end of the basin, - and place it in the existing pond area at the east end of the basin. This section examines the material balances and pond levels involved in achieving this, and examines methods for moving the materials.

5.2 Present Tailings Pile

The tailings have been discharged essentially from a single point on the south side of the basin since inception. In 1992, the end of the discharge pipe was lengthened 200 feet out into the basin. Thus the tailings form a flat cone above the pond level, as shown in Drawing No. 8996-1 (updated to July, 1993). Deposition slopes range from about 4 percent near the discharge point to about 1 percent farthest from this point. Underwater slopes are indicated by recent soundings to be about 2.5 percent to 3 percent. The small pond at the west end of the basin discharges into a small stream which runs easterly along the north side of the pile. In places the stream has cut a channel through the tailings.

5.3 Physical Properties Review

Physical properties were reported by Geocon (1992a). The tailings consist of sand and silt sizes, with a general trend of decreasing mean grain size with increasing distance from the point of discharge; up to 30 percent clay sizes were found in tailings deposited underwater farthest from the pipe.

Other physical properties are summarized below (Geocon 1992a)

Vane (undrained) shear strength	45 to 900 psf
- finer tailings range	50 to 150 psf
- coarser tailings range	100 to 400 psf
Moisture content	10 to 40 percent
Specific gravity	1.5 to 3
Coefficient of permeability (typical)	2×10^{-7} to 2×10^{-8} m/s
Dry unit weight	70 pcf

Tailings above the water table are found to be well drained and capable of standing at near vertical slopes in test pits. In contrast, near the edge of the pond and wherever the water table is near the surface, the tailings will just bear a person's weight.

5.4 Material Balance

The variables to be examined are the final level to which the tailings are cut down, and the corresponding final pond level. The final tailings cut-down level will define the volume of tailings to be moved, which in turn may affect the methods used for excavation, transport, and redeposition, as well as the timetable. The final pond level will define any requirements for changes to the dam, decant system and spillway, as well as defining the zones of alteration of the aquatic and terrestrial habitats.

The quantity of tailings in the basin has been computed from the 1993 survey update of the tailings surface, and the original topography (Geocon 1983), using the software package Microlynx. The amount of tailings to be produced up to mid-year 1994 has been added to the totals, using an average annual production of 106 000 tonnes, based on the actual total tonnage placed during the past 8 years. These quantities have been compared to figures presented by Geocon (1992a). The results are presented in Table 5.1a. The dry unit weights given in the table have been computed from the measured volumes and tonnages; it can be seen that Geocon's measurements yield an average dry unit weight of 70 pcf, and our computations give 62.8 pcf. Calculations based on specific gravity of the particles (Geocon 1983) projected dry unit weights in the range 50 pcf to 70 pcf; thus both values computed from field data are reasonable. As a result, it is estimated that the total volume in mid-1994 will be 30.1 to 33.5 million cubic feet, as shown in the Table.

Estimated volumes of tailings above various elevations, extrapolated to mid-1994, are shown in Table 5.1b. The volume of the basin, below various elevations, has also been computed using the original topography (Table 5.1c).

Table 5.1 MATERIAL QUANTITY BALANCE

(a.) TAILINGS VOLUMES				
Reference Date	Tailings Volume $feet^3 \times 10^6$	Tailings Quantity tons	(tonnes)	Dry Unit Weight 7p.c.f.
June 1991	20.0[1]	702,000	(636 000)[2]	70.0[6]
July 1993	29.8[3]	937,000	(850 000)[4]	62.8[6]
July 1994	33.5[5] 30.1[5]	1,053,000	(956 000)	62.8 70.0

1. *Geocon 1992 measured*
2. *Geocon 1992 computed*
3. *JWA 1993 measured*
4. *CBDC 1993*
5. *Projected*
6. *Computed from volume and tonnage*

(b.) CUMULATIVE TAILINGS VOLUME VERSUS ELEVATION		
Elevation Feet	Tailings Volume above this Elevation $feet^3 \times 10^6$	(cubic yards)
126	29.1	(1,077,000)
128	22.8	(844,000)
130	17.3	(640,000)
132	12.1	(448,000)
134	7.6	(282,000)
136	4.9	(182,000)
138	3.2	(118,000)

(c.) QUANTITY BALANCE	
Elevation feet	Basin Storage Capacity $feet^3 \times 10^6$
126.0	21.9
127.0	25.8
128.0	30.4
129.0	34.9
130.0	39.6

5.4.1 Minimum Tailings Elevations

A comparison of the maximum estimated 1994 tailings volume (33.5 million cubic feet) and the basin storage volume shows that all the tailings could be stored below el. 129 feet, if the tailings surface were to be struck dead level, and if the dry unit weight of the redeposited tailings is in the range 63 to 70 pcf. With respect to the latter, the density of tailings redeposited below water is likely to be at the lower end of the range, and a dry unit weight of 63 pcf is considered to be appropriate. In our opinion, a margin of conservatism is applicable to quantity calculations, and this can be provided by setting the nominal excavation depth at el. 130 feet. The total volume of tailings to be moved will be 640,000 cubic yards.

The nominal calculated fill level in the tailings pond then becomes el. 128 feet, which allows some excess capacity in the fill area, should it be required. This also allows for deeper water cover near the decant location, the advantages of which are discussed in Section 6.4.

The proposed plan is illustrated by Drawing 8996-2. All boundaries shown are approximate, being based on interpreted survey information collected at different times; however, the general layout is sufficiently precise for purposes of the plan. To provide a nominal 4-foot water cover, the proposed normal pond level has been set at el. 134 feet; discussion supporting this selection is presented in Section 6. Sections A-A and B-B indicate the cut and fill aspects of the operation. The limit of the tailings after redistribution is shown, and it can be seen that there will be areas from which the tailings are completely removed. In Area A, the original ground surface will be exposed to form the bottom of the pond. In Area B, the original ground surface will be exposed above the pond level.

Generally, around the perimeter of the pond, the pond bottom at the shoreline will be natural ground, with locally some tailings residue. The east side, abutting the dam, is obviously not included in this characterization. It is noted that no tailings will be placed in the small pond at the west end of the site, and that the new shoreline will extend beyond the presently-mapped limit in this area.

5.4.2 Alternative Tailings Elevations

Examination of Table 5.1b shows how the selection of a higher final tailings cut-down elevation will reduce the volume of tailings to be moved. This has an obvious impact on costs. There will also be obvious impacts on the pond level and pond surface area and, as a result, on environmental and other features of the site. In principle, any elevation above the minimum could be considered. For illustration purposes and to keep this report focused, we have selected only one alternative tailings cut-down elevation; it should be possible to conveniently consider other elevations, by comparing them with the two cases which are continued forward through this report.

For example, the selection of el. 134 feet will reduce this volume by about 358,000 cubic yards as compared to el. 130 feet. The nominal calculated fill level in the pond will then become el. 124 feet. Details of this alternative are shown on Drawing 8896-3. The proposed normal pond level would be el. 138 feet, to provide a nominal 4 feet of cover over the cut-down tailings area. In the partially filled-in present pond, the water depth would be about 14 feet.

Sections A-A and B-B indicate the cut and fill aspects of the operation. The excavated tailings would be placed in the deep portion of the pond, towards the dam. The limit of the tailings after redistribution is shown, and it can be seen that there will be areas from which the tailings are completely removed. In Area A, the original ground surface will be exposed to form the bottom of the pond. In Area B, the original ground surface will be exposed above the pond level.

Generally the reconfigured basin will be similar to that of the minimum tailings elevation case. Around the perimeter of the pond, the pond bottom at the shoreline will be natural ground, with locally some tailings residue. The east side, abutting the dam, is obviously not included in this characterization. Again, no tailings will be placed in the small pond at the west end of the site, and the new shoreline will extend beyond the presently cleared limit in this area.

The selection of cut-down elevations other than 130 feet and 134 feet would result in final pond details similar to those represented on Drawings 8896-2 and 8896-3.

5.5 Methods to Redistribute Tailings

5.5.1 General

Typical methods that may be used to move the tailings fall into four categories:

1. Dredging.
2. Sluicing. —?
3. Dragline and related tracked earthmoving equipment.
4. Combinations of the above.

For maximum cost effectiveness, the method would be left to the contractor under the terms of a performance specification: one in which he must meet the objectives by whatever equipment and method he chooses. These objectives include the following:

1. Exposure of tailings to oxidizing conditions during operations to be minimized.
2. Existing dam, decant and spillway structure to be maintained.
3. Acceptable discharge water quality to be maintained.

With regard to item 3, it is noted that daily operation of the present system introduces large quantities of suspended solids into the pond, which are now being adequately handled through the decant and settling pond system; these features will be utilized during tailings moving operations.

5.5.2 Equipment

Dredges. Small floating dredges with a draft of the order of 3 feet, capable of being mobilized to this site, are available. They are of the cutter-suction type, which use a pipe fitted with a cutter head and suction pump to dredge the material, and discharge it through a floating pipeline up to 1000 feet long. In operation, the dredge can maintain its own working pond, and the discharge point can be fitted with spreaders and moved as required to control the placement of the dredged material.

The chief advantages of a dredge operation are that (i) aerial exposure of the tailings is minimized, and (ii) deposition can be controlled quite well. The chief disadvantage is that it would not be able to work the high tailings of Area B.

Sluicing. In a sluicing operation, high pressure hoses are used to excavate the material, which is carried away by the sluicing water. The resulting slurry flow has characteristics similar to the present discharge. Recirculated pond water would be used. What equipment req'd?

The chief advantage of sluicing is relatively low cost. Disadvantages are (i) no local experience with large-scale operations, and (ii) poor control over deposition locations.

Draglines, etc. A dragline operation using large units would work from stable platforms. The dragline bucket excavates the material and casts it to the disposal area. Since the area exceeds the dragline reach, particularly as it concerns casting, it must be mobile. As a land operation, there are limits to its effective operation and it would require supporting equipment: for instance, bulldozers which would push the material to the dragline, and barges into which excavated material would be dumped for disposal outside the reach of the dragline. Excavation in Area B would pose no problem for this equipment. Mounting the dragline on a barge would increase its mobility and would reduce, although not eliminate, the double handling of the land operation.

A barge-mounted dragline shares the operating advantages of a dredge, but is probably less cost-effective.

5.5.3 Timetable

The total amount of tailings to be moved will depend on the selected cut-down elevation. It is desirable to complete operations within a short time frame, during the summer when precipitation levels are lowest, to minimize the potential problems of oxidation and surface water quality. Using a number of units, it is feasible to move 10,000 cubic yards per day, resulting in a moving operation of 70 days duration at full production for the minimum tailings elevation option, and less for higher elevations.

Hydrological data presented in Section 6 and summarized in Figures 6.3 and 6.4 show that there is normally a period in August when there is no discharge from the pond. [In drought years this period can extend over three or four months]. Advantage can be taken of this natural phenomenon to conduct at least part of the tailings moving operations without having to release dirty water downstream. It is also possible to store about 40 days runoff in the pond, between el. 125 feet and el. 135 feet, which is deemed to be a practical interval. This would further assist the contractor in conducting operations without release downstream.

Following redistribution, the pond level may have to be raised to achieve the intended water cover. The data presented in Figures 6.3 and 6.4 show that there is normally a net inflow from mid-September on, but during drought years it could be November before there is a strong inflow.

While climate is obviously not predictable for a given year, these considerations indicate that the period July-September is the best for the tailings moving operation.

5.5.4 Related Mitigation Activities

The methods for moving the tailings will incorporate features designed to offset unfavourable climatic conditions and mitigate environmental effects. If conditions are wetter than normal, it is likely that pond levels can not be controlled as indicated above and there will be fairly constant discharge. To reduce the particulate loading in the discharge, a silt curtain will be installed around the decant tower, and provision will be made for batch treatment in the settling pond if required. Make-up water can also be delivered to the pond from the tailings discharge pipeline, to mitigate drought effects and reduce the time in which the tailings are exposed. Other mitigation measures are discussed in Section 8.

5.6 Effects of Tailings Levels on Existing Structures

The decant tower is understood to have been designed for a final tailings storage level of 135 feet, although the anticipated maximum tailings level was not expected to exceed el. 129 feet. The projected tailings level at the decant under all of the redistribution options will be at or below about el. 128 feet, thus being within the original design criteria and not calling for any modifications on this account. Likewise, the final tailings level will not impinge on the stability of the dam.

6.0 HYDRAULIC ASPECTS OF PERMANENT SUBMERGENCE

From a hydraulic perspective, the close-out scheme must ensure that the following criteria are met:

1. The tailings do not become exposed particularly during a drought period.
2. The hydraulic structures are capable of discharging flood waters from storm events without overtopping the dam.
3. The effects of wave scour are minimized.

Various analyses to meet these objectives have been carried out and these include:

1. Annual water balance, for average and drought years.
2. Routing of storm events through the pond.
3. Examination of the mechanisms and effects of waves and associated bottom scour.

6.1 Decant Tower and Discharge System Characteristics

The decant tower is located 70 feet upstream of the centreline of the dam, as shown on Drawing 8996-1. It is a reinforced concrete structure founded on natural ground at el. 115.0 feet, with the top deck at el. 140 feet. It contains two separate decant compartments: one designed to decant water to the treatment plant during normal operations, the other designed to decant water to a discharge pipe and open channel during periods of extreme runoff.

The decant system to the treatment plant incorporates a 4-foot wide inlet weir, with a sill at el. 125 feet and provision for stoplogs, leading to a well which discharges to a 14-inch diameter concrete pipe (invert el. 118.0 feet). This pipe reduces to 10-inch diameter, and carries water to the treatment plant, where the outlet is fitted with a valve. The discharge capacity of this system has been established by Geocon (1983b): it is noted that the capacity is governed by the outlet valve. Flows from the treatment plant empty into the settling pond. It is understood that operation of the treatment plant has not been required to date.

The decant system to the overflow line has been modified since the initial construction. The 6-foot wide inlet weir now has a concrete sill at el. 135 feet, but incorporates a pair of 16-inch gate valves (invert el. 125 feet) through which flow can be regulated into a 30-inch diameter concrete pipe (invert el. 117.0 feet). The pipe runs under the dam and discharges into the channel and thence into the original creek, which empties into Kehoe Brook about 1600 feet downstream of the dam. The discharge capacity of this system is now probably governed by the capacity of the gate valves; this has not been investigated in detail since the decommissioning plan envisages a passive decant system where the valves do not have to be operated, and flow to the overflow line will be established by head versus discharge characteristics of the weir and pipe system, as originally determined by Geocon (1983b).

6.2 Annual Water Balance

The components of the annual water balance include the following:

1. Inflows from catchment runoff and direct precipitation on the pond area minus evaporation from the pond.

2. Out-flows due to discharge by the decant system and seepage losses.

After a review of hydrological data, we selected three annual situations for water balance analyses: (i) average annual flows consisting of a succession of average monthly flows; (ii) a "dry summer"; and (iii) two "dry years."

6.2.1 Watershed Runoff

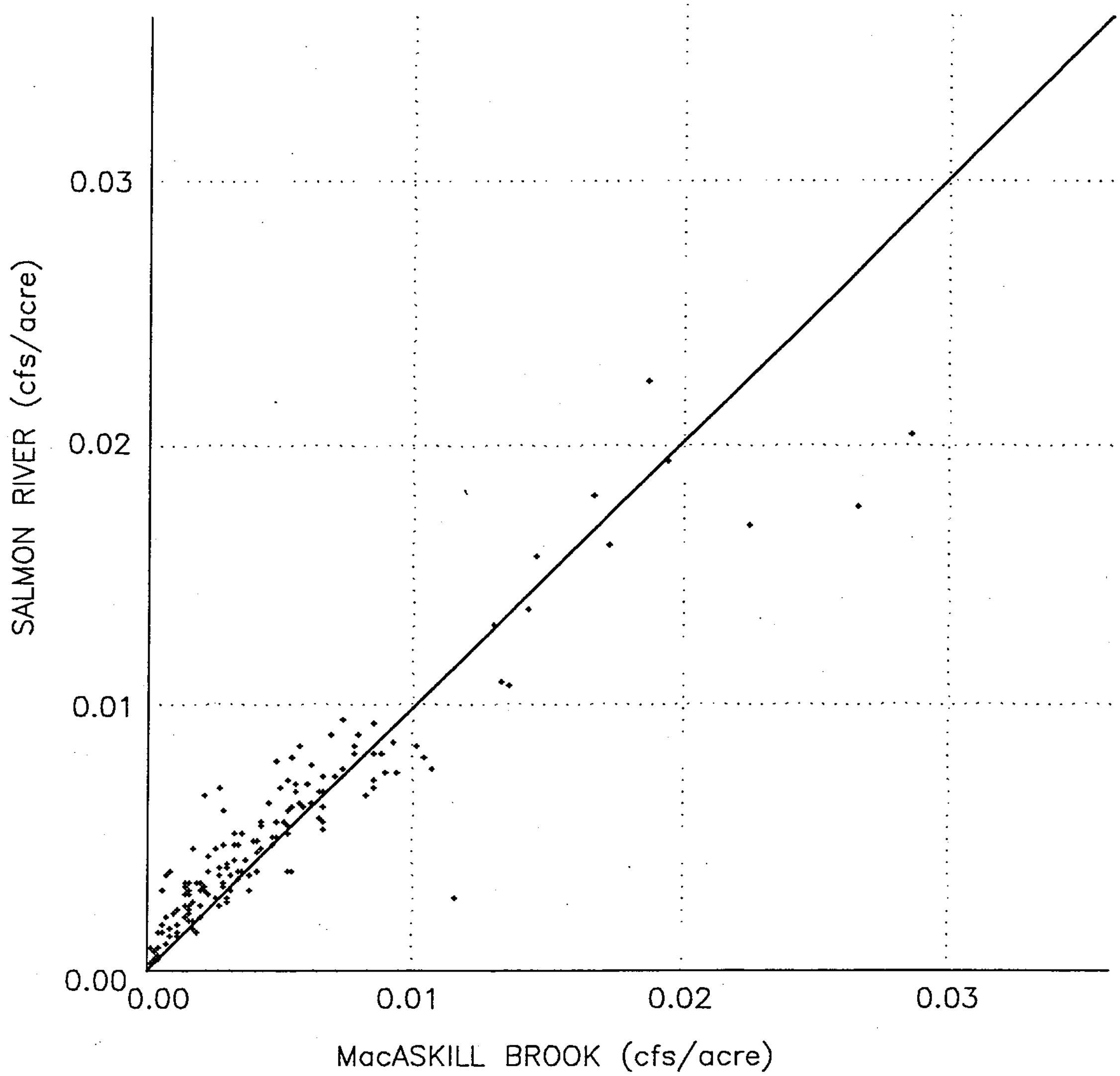
Two gauged watersheds (Environment Canada 1991) in the area were used to estimate runoff from the 636 acre (2.6 km^2) tailings basin. The first is a 4,250 acre (17.2 km^2) watershed located about 6 mi (10 km) southeast of the tailings site, identified as MacAskill's Brook near Birch Grove (Station No. 01FJ002). The second, identified as Salmon River at Salmon River Bridge (Station No. 01FJ001) covers an area of about 49,000 acres (199 km^2) and is located about 20 mi (30 km) southwest of the site. Salmon River, with records from 1966 was used to supplement the data from the closer MacAskill's Brook with records since only 1978. Both watersheds are unregulated (i.e. natural flow).

In order to confirm the validity of the more distant Salmon River data, the monthly data from both watersheds were normalized by area. The data for corresponding months were then plotted as shown on Figure 6.1. The figure indicates that an approximate 1:1 relationship exists for flows from the two watersheds. The use of Salmon River data between 1966 and 1978 is therefore considered valid.

Runoff data to be used in water balance computations consisted of the following:

1. Average annual flows consisting of a succession of average monthly flows were evaluated.

2. A "dry summer" was examined. By inspection of the historical data, the summer of 1975, as gauged at Salmon River, was one of the driest summers for the period of record.



COMPARISON OF NORMALIZED MONTHLY FLOWS

3. Two "dry years" were analyzed. Again, by inspection of the historical data, both 1985 and 1989 were years of relatively low annual flow. The flows used for 1985 are a combination of MacAskill Brook and Salmon River data, while the 1989 flows are from MacAskill Brook.

Table 6.1 shows these flows. It is noted that because of the relatively short period of record (26 years), the flows used for analysis of the "dry summer" of 1975 were modified to produce less flow than was actually recorded. Although not shown in Table 6.1, the modified flows used in the analysis are 80 percent of those measured. The maximum and minimum recorded flows are also presented, for comparison.

Table 6.1 WATERSHED RUNOFF (cfs/acre) x 100

	Mean	Min	Max.	1975	1985	1989
January	0.586	0.143	1.359	0.286	0.257	0.529
February	0.458	0.043	1.330	0.114	0.286	0.229
March	0.686	0.157	1.416	0.758	0.529	0.157
April	1.172	0.529	2.831	1.487	0.715	1.444
May	0.543	0.229	2.360	0.987	0.686	0.300
June	0.257	0.029	1.201	0.257	0.701	0.172
July	0.172	0.014	0.644	0.014	0.200	0.072
August	0.157	0.014	0.715	0.014	0.043	0.029
September	0.243	0.014	0.887	0.014	0.086	0.143
October	0.501	0.143	1.001	0.787	0.200	0.558
November	0.744	0.143	2.074	0.787	0.558	0.772
December	0.701	0.200	1.873	1.873	0.358	0.300
Year	0.515	0.386	0.729	0.615	0.386	0.386

Source: Environment Canada, Historical Stream Flow Summary, Atlantic Provinces, to 1990

1. *MacAskill's Brook near Birch Grove - Station No. 01FJ002 (Area= 17.2 km²) 6.6 sq. miles)*
2. *Salmon River at Salmon River Bridge - Station No. 01FJ001 (Area = 199 km²) 78.8 sq. miles)*

The total catchment of the tailings basin is about 636 acres (2.57 km^2). Of this area, the pond area receiving direct precipitation is about 144 acres (0.58 km^2) at an operating level of 134 feet, while the watershed comprises the remaining 492 acres (1.99 km^2).

6.2.2 Precipitation and Evaporation

The precipitation data used in the water balance analyses were derived from data provided by the Atmospheric Environment Service for Sydney A, and cover the period 1942 to 1991. The data are shown in Table 6.2 and are "total" precipitation. The data are tabulated in a form similar to that for flows described in the previous paragraphs. Mean monthly precipitation was used in conjunction with the average annual flows, while the monthly precipitation data for specific years was used with flows for the corresponding years (1975, 1985, 1989). Maximum and minimum recorded data are also shown for comparison. The monthly precipitation values have been applied directly to the pond area of 144 acres. It is noted that for modelling of the "dry summer" water balance, monthly precipitation for 1975 was modified by a factor of 80 percent, as discussed above.

Evapotranspiration from the 492 acre watershed contributing runoff to the pond has been indirectly accounted for by using the normalized flows, as described in the preceding Section. However, evaporation from the 144 acre pond must be subtracted from the direct precipitation to the pond. No monthly evaporation data have been found and for the purposes of our analyses, potential evapotranspiration data for Halifax (Phillips 1976) were used. These are also shown in Table 6.2. The mean annual value of 21.9 inches corresponds with that provided for Halifax in the Hydrologic Atlas of Canada (1978), which also indicates that annual lake evaporation is 21.7 inches for the Sydney area. Based on this, the monthly pond evaporation rates are assumed to be reasonably similar to the potential evapotranspiration rates given in the Table. For the case of modelling the "dry summer" of 1975, the evaporation rates have been increased by a factor of 1.25.

6.2.3 Seepage Losses

Seepage losses from the tailings pond towards Kilkenny Lake to the north have been previously estimated at 125 IGPM (0.33 cfs) with a pond level at el. 135 feet to a minimum of 50 IGPM (0.13 cfs) with a pond level at el. 125 feet (Geocon 1992a). Geocon also concluded that a tailings seal on the bottom of the pond would not be very effective, and we have chosen to ignore any small reduction in seepage which might result from tailings redistribution in the present pond. In our analyses, we have used a greater seepage loss to account for potential seepage in other directions and through and beneath the dam, and to provide a margin of safety in the drought year analysis. Potential seepage losses have been set at 360 IGPM (0.96 cfs) for the pond at el. 136 feet, linearly decreasing to 165 IGPM (0.44 cfs) at an elevation of 130 feet. These losses have been incorporated into the stage-discharge relationship for the decant system in our water balance analyses.

Table 6.2 SYDNEY TOTAL PRECIPITATION (1942-1991) (inches)

	Mean	Min	Max.	1975	1985	1989	Evaporation Mean
January	5.69	1.85	9.75	7.80	4.07	4.89	0
February	4.80	1.70	8.53	1.95	4.51	5.88	0
March	4.90	1.52	9.28	5.75	4.64	5.33	0
April	4.43	0.94	10.52	5.55	2.55	3.87	1.0
May	3.90	0.89	9.24	3.41	4.61	0.89	2.3
June	3.47	0.93	7.20	2.95	7.20	3.91	3.5
July	3.13	0.70	8.58	1.06	3.11	1.68	4.7
August	3.88	0.70	8.57	2.27	3.76	2.41	4.3
September	4.13	1.37	10.11	2.90	1.67	4.71	3.1
October	4.97	1.41	9.97	7.37	3.81	5.29	2.0
November	6.20	1.58	13.14	3.94	4.16	8.16	0.90
December	6.01	2.15	12.39	10.18	5.89	2.31	0
Year	55.33	40.26	77.70	Σ55.14	Σ49.97	Σ49.33	Σ21.9

Sources: *Precipitation data from Environment Canada,*
Atmospheric Environment Service (AES)
Station data for Sydney A., received July; 1993
Evaporation data from D.W. Phillips, AES 1976.

6.2.4 Stage-Storage-Discharge Relationships

Figure 6.2 shows the stage-storage-discharge relationships applicable to the present pond and decant system. The stage-area and stage-volume relationships have been established by assuming the tailings elevations discussed in Section 5, which effectively results in the original topography above el. 130 feet. Therefore, for the purposes of this study, the predevelopment contours above el. 130 feet have been used.

The decant stage-discharge relationship has been taken from Geocon (1983b), since the decant system currently proposed for close-out will operate under these approximate relationships. For the minimum tailings elevation, the nominal pond level will be established at el. 134 feet by setting the treatment weir at this elevation This is shown on Figure 6.2, where the "treatment" weir is set at el. 134 feet and the "overflow" weir is set one foot higher, at el. 135 feet. For the optional higher pond levels, the weirs would be set correspondingly higher, and the stage-discharge curve would predict the same discharge for the same head at the weirs.

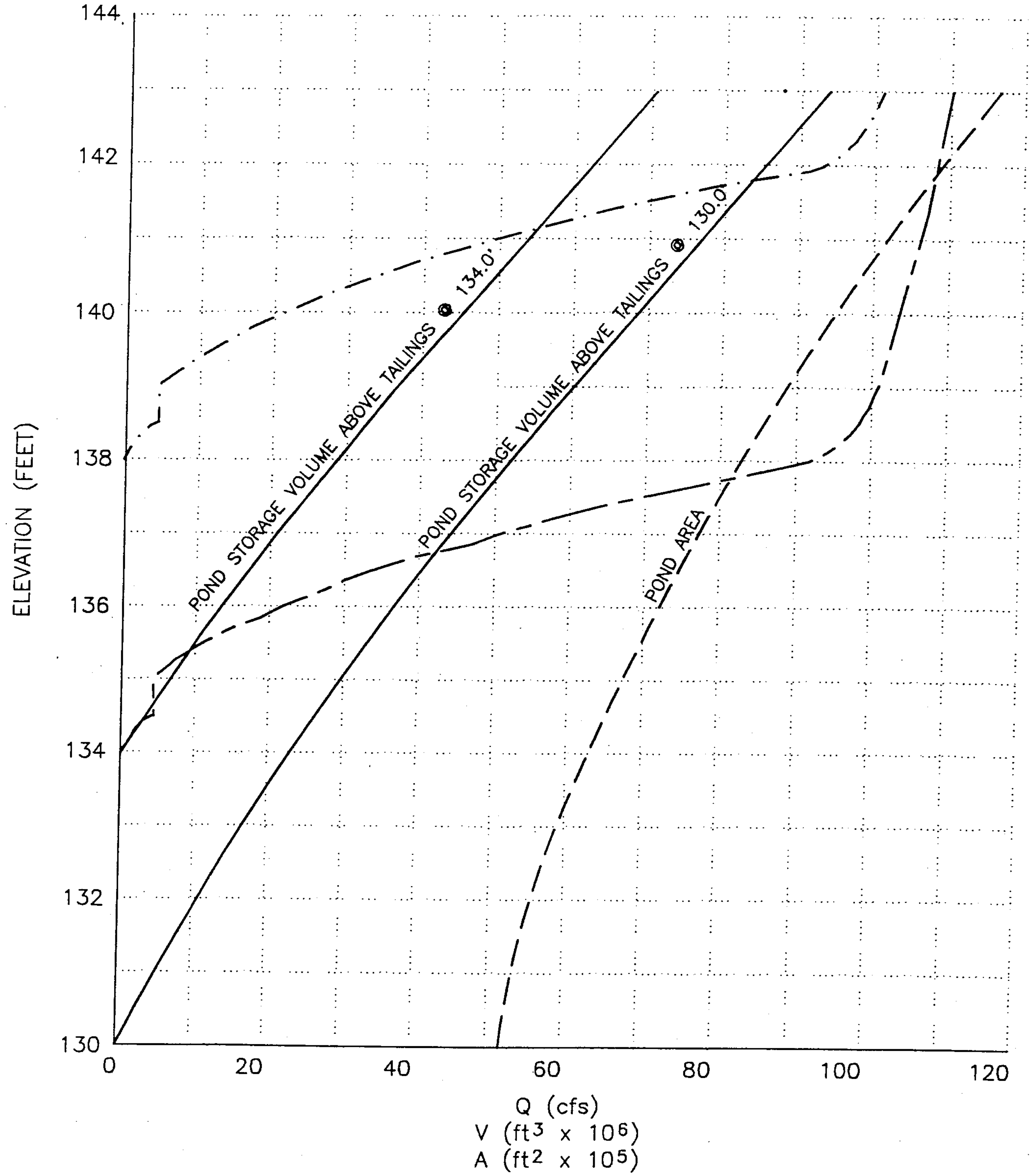
The combined stage-storage-discharge relationship has been used to route the monthly flows through the pond for the water balance analyses. The same relationship has been used for routing of storm events, as discussed in the next section.

6.2.5 Water Balance Results: Pond at El. 134.0 Feet

The various elements (watershed runoff, direct precipitation, evaporation) were routed through the pond using an initial elevation of 134 feet, and a time step of 15 days. This time step is considered acceptable for the level of accuracy required of this analysis. The results are presented graphically as pond level over a 12 month period on Figure 6.3.

Average Year. The figure shows that for an average year, the pond level can be expected to rise to an elevation of about 135.2 feet by the end of April, declining to a level of about 133.9 ft by mid to late August, such that there is no flow over the weir, and rising again to a level of about 135 feet by the end of December. For an average year the pond level can be expected to fluctuate by about 1.4 ft, resulting in a temporary minimum water cover over the tailings of about 3.9 feet.

Drought Year. The analysis of the "dry summer" year of 1975 results in a pond fluctuation of about 2.9 feet, as shown on Figure 6.3. The pond level remains above elevation 134 feet until July, at which time it is expected to fall to a level of about 132.4 ft by late September, resulting in a water cover of about 2.4 feet over the tailings. As discussed previously, the inflows (runoff and direct precipitation) and evaporation have been modified in order to more conservatively simulate a drier period than that provided by the short period of record.



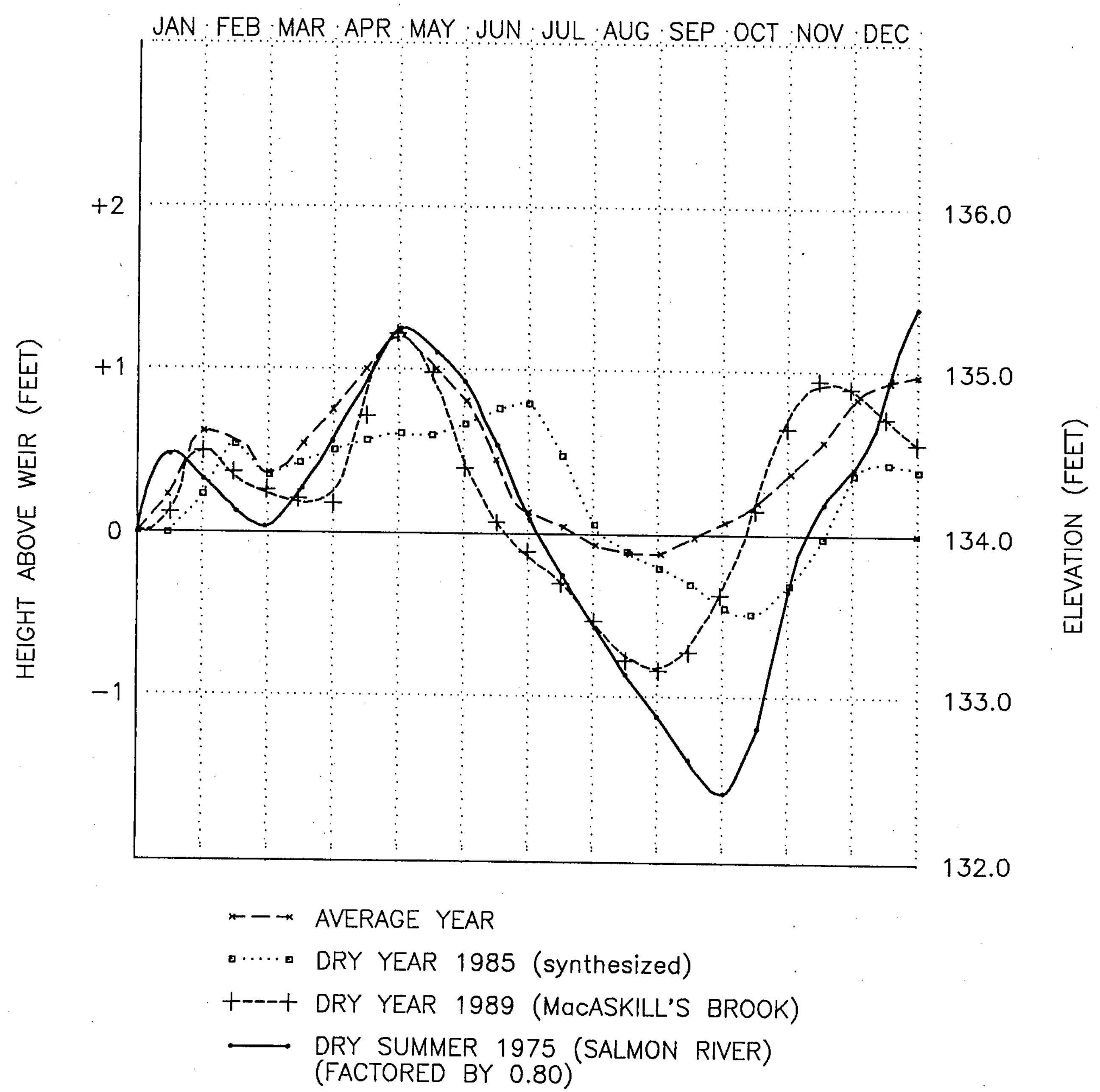
—LEGEND—

— · — · —	QUANTITY WITH TREATMENT WEIR AT 138.0' OVER-FLOW WEIR AT 139.0'
—— — ——	QUANTITY WITH TREATMENT WEIR AT 134.0', OVER-FLOW WEIR AT 135.0'

STAGE – STORAGE – DISCHARGE RELATIONSHIPS

8996 FIG6-2 93/09/10

8996 FIG6-3 93/09/10

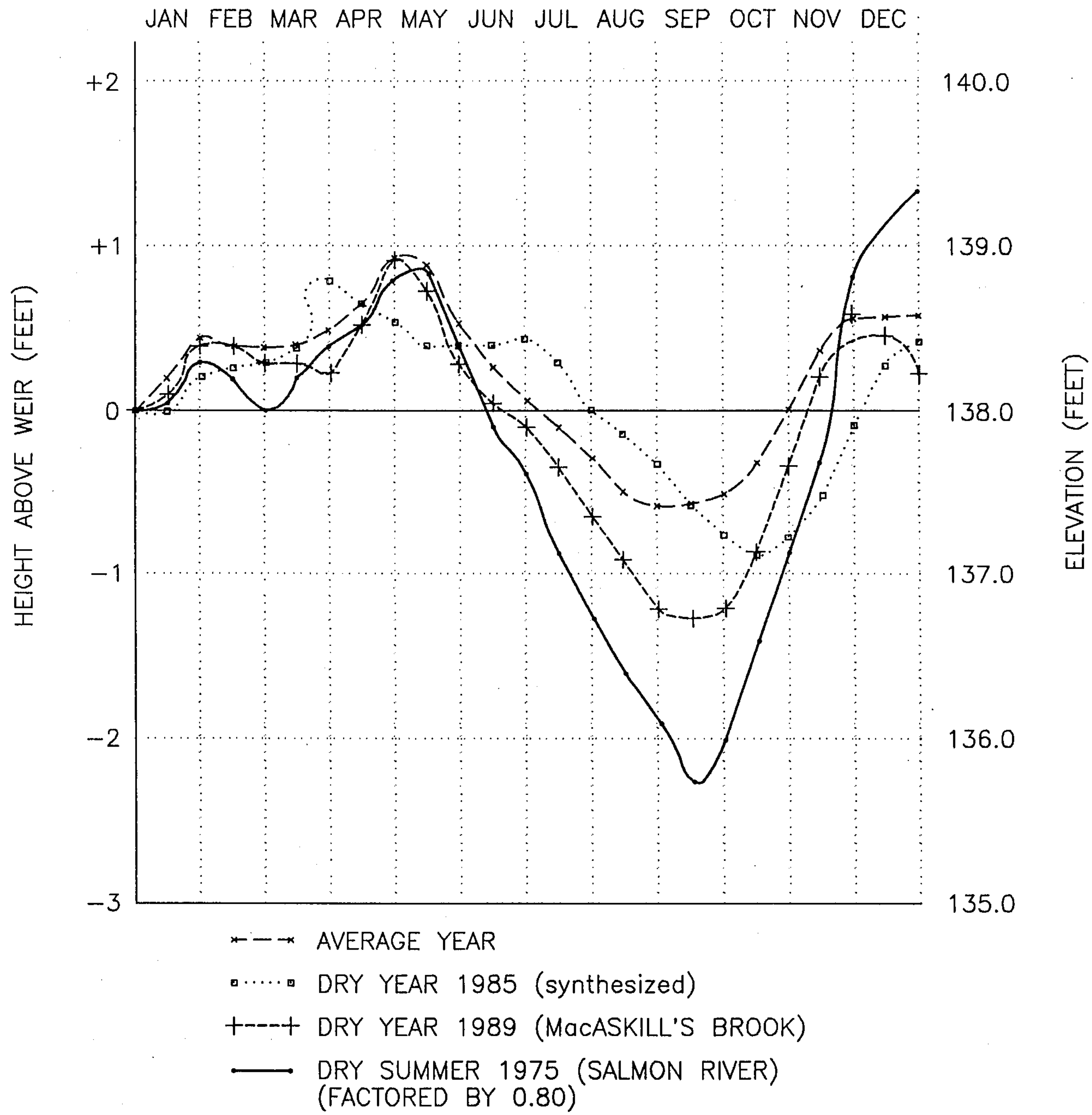


ANNUAL WATER BALANCE – NOMINAL POND LEVEL 134.0 FT

8996

FIGURE 6.3

8996 FIG8-3 93/09/10



ANNUAL WATER BALANCE — NOMINAL POND LEVEL 138.0 FT

FIGURE 6.4

Typical "Dry" Years. The results of the two typical "dry" years analyzed are also presented on Figure 6.3. The minimum water levels were calculated to be about elevation 133.5 and 133.2 feet, for the conditions of 1985 and 1989, respectively.

The conclusion that can be drawn from these analyses is that, while there may be a pond level fluctuation of up to 2.5 to 3 feet, sufficient safety remains to maintain submergence of the tailings. It is recommended, however, that monitoring of pond levels and record keeping be incorporated into the operation for an extended period of time in order to provide data that will validate these predictions.

6.2.6 Water Balance Results: Pond at El. 138.0 Feet

The same analysis was performed for an elevation of 138 feet, and the results are presented in Figure 6.4.

Average Year. The figure shows that for an average year, the pond level can be expected to rise to an elevation of about 138.9 feet by the end of April, declining to a level of about 137.4 ft by late August, such that there is no flow over the weir, and rising again to a level of about 138.6 feet by the end of December. For an average year the pond level can be expected to fluctuate by about 1.5 ft, resulting in a temporary minimum water cover over the tailings of about 3.4 feet.

Drought Year. The analysis of the "dry summer" year of 1975 results in a pond fluctuation of about 4.2 feet, as shown on Figure 6.3. The pond level remains above elevation 138 feet until July, at which time it is expected to fall to a level of about 135.7 feet by early September, resulting in a water cover of about 1.7 feet over the tailings. As discussed previously, the inflows (runoff and direct precipitation) and evaporation have been modified in order to more conservatively simulate a drier period than that provided by the short period of record.

Typical "Dry" Years. The minimum water levels were calculated to be about el. 137.1 and el. 136.7 feet, for the conditions of 1985 and 1989, respectively.

The conclusion that can be drawn from these analyses is that, for pond level fluctuations of up to 2.5 to 3 feet, sufficient safety remains to maintain submergence of the tailings; however, the dam provides insufficient freeboard. Required alterations to the dam and appurtenant structures are discussed in Section 6.5.

6.3 Storm Flood Routing and Resulting Pond Level

In order to ensure that flood flows can be safely accommodated and passed by the existing decant structure, design storms were analyzed for the final configuration. The response time of the catchment is estimated to be in the order of two hours; however, because of the attenuation which will be provided by the large pond area and volume, the 24 hour storm more closely represents the maximum flows that would have to be accommodated by the system. Therefore, the 24 hour precipitation events were used in our analyses.

Table 6.3 shows the data used for analyses of storm events for nominal pond levels at el. 134 feet and el. 138 feet. For each case, two initial pond levels were assumed to exist prior to the onset of the storm, depending on the time of year as shown in the previous section on water balance. At the onset of a storm during the summer months, the pond would tend to be at the nominal design level, while at other times of the year the pond level may initially be about one foot higher.

Table 6.3 STORM PRECIPITATION AND RESULTS

Return Period (years)	24 Hour Precipitation (inches)	Probability of Exceedence in 20 Years (percent)	Maximum Pond Elevation (ft)			
			Initial Pond at 134 feet	Initial Pond at 135 feet	Initial Pond at 138 feet	Initial Pond at 139 feet
1,000	8.40	2	135.9	136.6	139.6	140.5
100	6.43	18	135.4	136.2	139.2	140.1
50	5.76	33	135.2	136.0	139.0	139.9
25	5.20	56	135.1	135.9	138.9	139.8
10	4.54	88	134.9	135.8	138.8	139.7
5	3.87	99	134.7	135.6	138.6	139.5
2	3.02	100	134.5	135.4	138.5	139.4

6.3.1 Pond at El. 134 Feet

Based on a design life of 20 years for the existing decant, a storm with a return period of 100 years will (statistically) have an 18 percent probability of being exceeded at least once during the 20 year life. This is typically regarded as a high probability for a dam and reservoir of this size, however, our analysis indicates that the maximum pond level for such an event would be about elevation 136.2 feet, leaving a freeboard of almost 4 feet. In fact, the 1000 year storm, which has an acceptable probability of exceedence of 2 percent, would result in a pond rise to a maximum of about 136.6 feet, leaving almost 3.5 feet of freeboard. Therefore, the pond system as proposed will adequately accommodate severe storms, without over topping of the dam, provided that the decant system is properly maintained.

6.3.2 Pond at El. 138 Feet

For the same storms, our analysis indicates that the maximum pond level for the 100 year storm would be about elevation 140.1 feet, theoretically overtopping the dam. The 1000 year storm would result in a pond rise to a maximum of about 140.5 feet, again exceeding the present dam crest. Therefore, the pond system as proposed will require that the dam be raised sufficiently to provide adequate freeboard. This is discussed in Section 6.5.

It is noted that the emergency spillway has not been included in these calculations, since its function is to come into play only if the decant system fails to function because of accidental blockage.

6.3.3 Abandonment Spillway

It is common to use the Probable Maximum Precipitation (PMP), or some fraction, as the design storm for abandonment purposes. The PMP is estimated as 26.5 inches of rainfall over 24 hours, compared to the 100 year, 24 hour storm of about 6.4 inches. The analysis using this event indicates that the decant system is not adequate to pass the resulting probable maximum flood (PMF).

We have reviewed the capacity of the existing emergency spillway to determine whether it can safely discharge the PMF. Based on simplifying assumptions regarding the existing emergency spillway which has an invert elevation of 137 feet, our calculations show that it will accommodate the PMF with an initial pond level of 134 feet; however, the present dam would likely be over-topped if the pond level is initially at el. 135 feet or higher.

For a pond level at el. 138 feet, and a revised dam crest at el. 143 feet, similar considerations would apply.

Accordingly, to function as an abandonment spillway, the existing spillway should be redesigned bas on the selected operating pond level, so that the invert is at the pond level, and that it has a slop downstream of the invert of one percent. The channel will require appropriate rip-rap protection to prevent erosion of the channel and dam. The details of this design and specific location can be established at the design stage of the final abandonment plan.

6.4 Water Depth and Wave Action

The selection of an appropriate water depth for permanent subaqueous storage requires that fluctuation of pond levels be accommodated, as discussed in the preceding sections, and that the effects of wave action be taken into account. Concerns related to wave action centre on tailings particles being stirred up off the bottom and entering the water column: first, it affects the amount of suspended solids in water discharged from the pond; secondly, these conditions lead to potential oxidation and related chemical effects in the surface water.

The effect of waves is to cause water particles below the surface to oscillate about a mean position, which results in both horizontal and vertical water particle velocities. The horizontal velocities at the mudline have the potential to erode bottom particles, which then enter the water column. For purely orbital water motion, the soil particles do not have a net forward motion, and they will settle out again due to gravitational forces after the wind velocity decreases sufficiently; however, they could be transported by any currents until they settle out again.

Wind records for Sydney shown in Table 6.4 show that maximum hourly velocities in the range 38 to 60 mph can occur from most directions of the compass. The most severe conditions for wave development are easterly winds with a velocity of 60 mph, since the maximum fetch coincides with the east-west direction.

Table 6.4 WIND DATA FOR SYDNEY, 1941 TO 1990

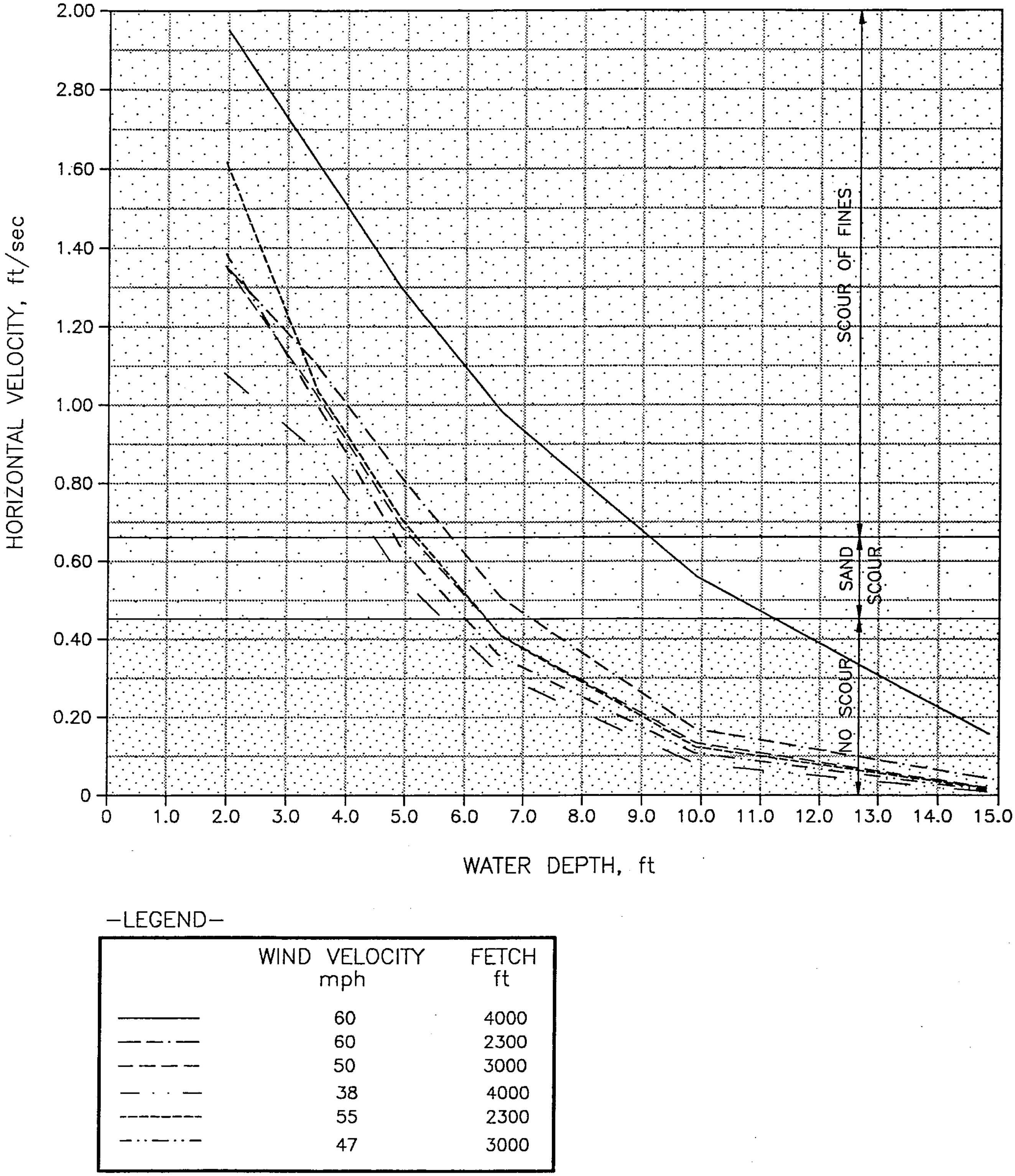
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Speed (mph)	23	22	22	21	20	18	17	17	17	20	21	22	20
Most Frequent Direction	W	W	W	N	SW	SW	SW	SW	SW	SW	W	W	SW
Maximum Hourly Speed (mph)	55	55	60	50	50	47	45	38	55	60	53	60	
Direction	E	SE	E	SW	SE	NE	S	W	NW	SE	S	S	
Maximum Gust Speed (mph)	75	77	80	71	68	71	54	55	80	86	80	100	
Direction	SE	SW	SE	S	W	N	W	W	N	S	S	S	

Predictions of wave generation have been made for the final pond, using maximum hourly wind speed data for Sydney (AES, 1993), fetches for all compass directions, and various water depths, using US Army Corps of Engineers (1984) prediction models. The resulting wave heights and periods are presented in Table 6.5. From various wave theories used to determine the shape and other characteristics of waves, we have selected Stokes' "second order" theory to predict wave length, celerity, and horizontal velocity at the mudline (i.e., potential scour velocity). The results are also shown in Table 6.5 and in Figure 6.5. It can be seen from the table and figure that bottom velocities

Table 6. 5 WAVE AND WATER PARTICLE VELOCITY PREDICTIONS

Wind Velocity (mile/hr)	Fetch (ft)	Water Depth (ft)	Wave Height (ft)	Period (sec.)	Wave Celerity (ft/s)	Wave Length (ft)	(d/L)	Horiz. (1) Velocity (ft/s)	Horiz. (2) Velocity (ft/s)
60	4000	14.8	2.20	2.20	11.27	24.79	0.60	0.08	0.16
60	2300	14.8	1.90	1.90	9.73	18.49	0.80	0.02	0.04
50	3000	14.8	1.54	1.85	9.48	17.53	0.84	0.01	0.03
38	4000	14.8	1.31	1.80	9.22	16.60	0.89	0.01	0.02
55	2300	14.8	1.57	1.85	9.48	17.53	0.84	0.01	0.03
47	3000	14.8	1.48	1.80	9.22	16.60	0.89	0.01	0.02
60	4000	9.8	3.12	2.15	11.01	23.68	0.42	0.33	0.67
60	2300	9.8	1.74	1.85	9.48	17.53	0.56	0.09	0.17
50	3000	9.8	1.41	1.82	9.32	16.97	0.58	0.06	0.13
38	4000	9.8	1.21	1.75	8.96	15.69	0.63	0.04	0.08
55	2300	9.8	1.51	1.80	9.22	16.60	0.59	0.06	0.13
47	3000	9.8	1.38	1.78	9.12	16.23	0.61	0.05	0.11
60	4000	6.6	1.97	2.12	10.33	22.39	0.29	0.93	0.98
60	2300	6.6	1.67	1.82	9.18	16.84	0.39	0.50	0.50
50	3000	6.6	1.38	1.81	9.14	16.66	0.39	0.40	0.41
38	4000	6.6	1.21	1.75	8.87	15.61	0.42	0.31	0.31
55	2300	6.6	1.54	1.77	8.96	15.95	0.41	0.41	0.41
47	3000	6.6	1.38	1.76	8.92	15.78	0.42	0.36	0.36
60	4000	4.9	1.80	2.10	9.66	21.17	0.23	1.27	1.30
60	2300	4.9	1.57	1.80	8.82	16.20	0.30	0.82	0.82
50	3000	4.9	1.31	1.80	8.82	16.20	0.30	0.68	0.68
38	4000	4.9	1.15	1.75	8.65	15.39	0.32	0.55	0.56
55	2300	4.9	1.48	1.75	8.65	15.39	0.32	0.71	0.72
47	3000	4.9	1.31	1.75	8.65	15.39	0.32	0.63	0.64
60	4000	3.3	1.41	2.10	8.51	19.20	0.17	1.52	1.64
60	2300	3.3	1.23	1.80	8.06	15.27	0.21	1.13	1.17
50	3000	3.3	1.08	1.80	8.06	15.27	0.21	1.00	1.03
38	4000	3.3	0.98	1.75	7.96	14.59	0.22	0.87	0.89
55	2300	3.3	1.25	1.75	7.96	14.59	0.22	1.11	1.14
47	3000	3.3	1.12	1.75	7.96	14.59	0.22	0.99	1.02
60	4000	2.0	0.98	2.10	6.99	15.95	0.12	1.58	1.95
60	2300	2.0	0.82	1.80	6.77	13.20	0.15	1.22	1.37
50	3000	2.0	0.82	1.80	6.77	13.20	0.15	1.22	1.37
38	4000	2.0	0.69	1.75	6.72	12.72	0.15	1.01	1.10
55	2300	2.0	0.98	1.75	6.72	12.72	0.15	1.44	1.62
47	3000	2.0	0.85	1.75	6.72	12.72	0.15	1.25	1.39

1. Linear Wave theory
2. Stokes' 2nd Order Wave theory.



RELATIONSHIPS BETWEEN PREDICTED SCOUR VELOCITIES AND WATER DEPTH

8996 FIG6-5 93/09/10

of about 0.45 to 2.0 feet/s can develop in water less than 6 feet deep for various wind conditions, and very low velocities (<0.16 feet/s) are associated with water depths of 15 feet or more.

For comparison, minimum water velocities for sediment erosion, transportation and deposition are shown in Figure 6.6 (Herbich 1981). The broad band separating "erosion" and "separation" covers the results of a number of mathematical and physical models. The particle sizes of the tailings are of interest in the context of this figure. Mean grain size diameters (D_{50} size) reported by Geocon range from 0.005 mm to 0.3 mm. Examination of the erosion curve shows that, for the velocity range 0.45 to 2.0 feet/s (15 to 60 cm/s), some of these particles would be eroded. Sand particles (>0.08 mm) would roll on the bottom or settle out very quickly. Silt and clay (<0.08 mm) would be likely to enter the water column, and thus the velocity causing turbidity would be in the range 0.6 to 2.0 feet/s (20 to 60 cm/s).

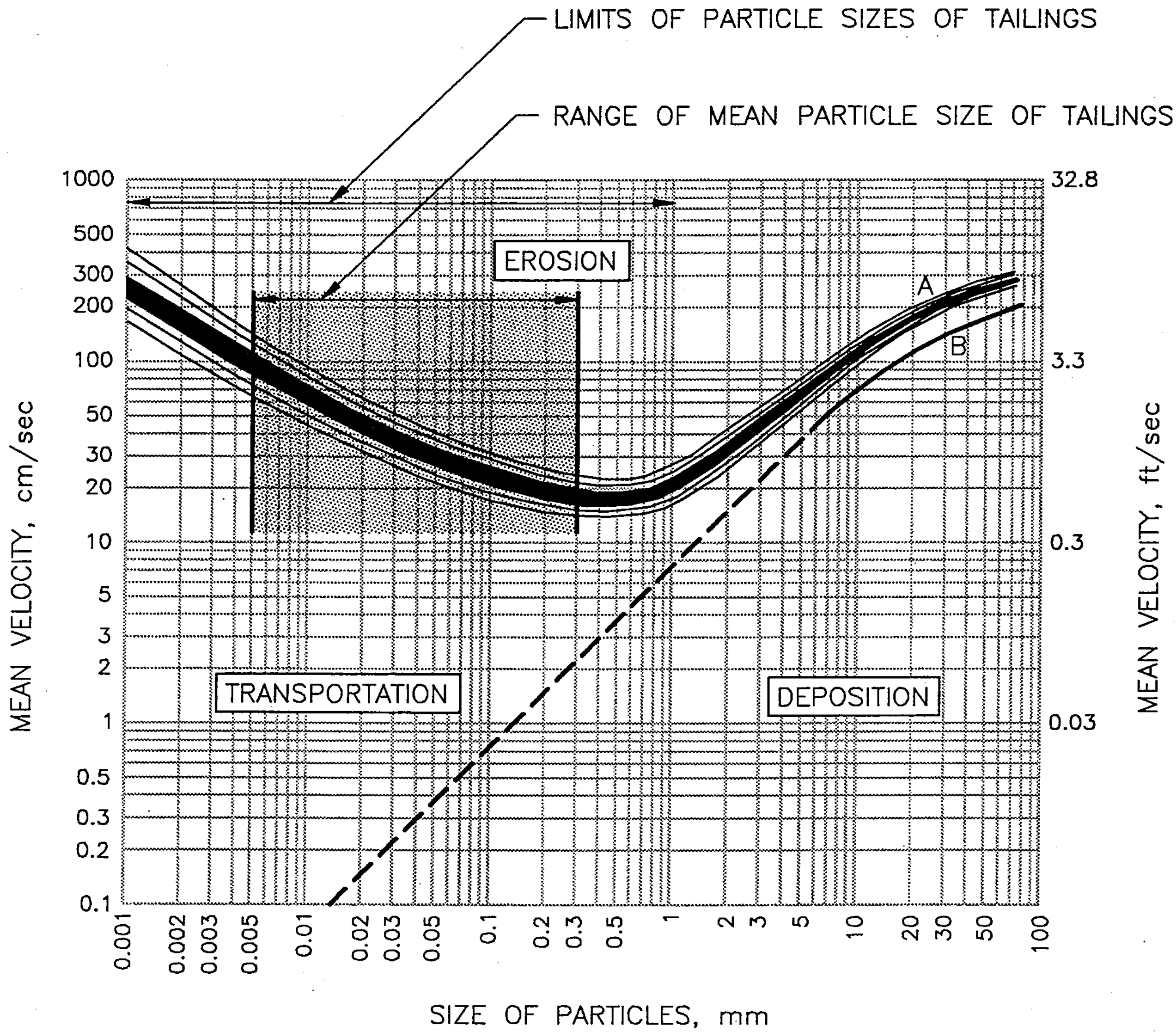
Some predictions may be made by comparing Figures 6.5 and 6.6. For water depths greater than 6 feet, velocities will be less than 0.6 feet/s and water column turbidity will not occur, for all wind conditions <u>except the maximum easterly wind</u> shown by the solid line in Figure 6.5. For water depths greater than 9 feet, velocities will be less than 0.6 feet/s and turbidity will not occur, <u>for all wind conditions</u>. Scour of the very fine material at velocities greater than 2.0 feet/s (60 cm/s) will only occur if the water is less than 2.0 feet deep. Thus, it is concluded that pond waters will become more-or-less turbid only during periods of maximum easterly winds, for depths less than about 6 feet.

Likely chemical reactions are discussed in Section 8. Suspended solids are discussed further below.

Sediment settling velocities computed by Stokes' law indicate that particles within the D_{50} size range given above will settle within a few hours under still water conditions, such that the surface waters would likely be quite clear above the decant level. However, experience indicates that it is difficult to predict settling times for very small particles under real operating conditions. It is also not possible to relate particle sizes to the quantity of suspended solids likely to be present in discharged waters.

The possible option of eliminating the deleterious effects of bottom scour by selecting a minimum water depth greater than 9 feet would impact significantly on tailings levels and flood routing, and exceeds water depths currently being used or considered within the industry. Since total elimination of turbidity is not required, it is proposed to select a nominal minimum water depth of 4 feet. For the minimum tailings elevation option (Section 5.4.1), this would result in a pond elevation of 134 feet, and cover between 4 feet and 6 feet. For tailings to el. 134 feet (Section 5.4.2), this would result in a pond elevation of 138 feet, and cover between 4 feet and 14 feet.

Around the perimeter of the pond, the bottom will be mainly natural ground, covered by the plant habitats described in Section 7.4, or else a stripped, disturbed natural ground surface where tailings have been removed. The natural ground is a silty sand and gravel till. Within the wave zone, the vegetation



8996 FIG6-6 93/10/19

MINIMUM VELOCITIES FOR SEDIMENT EROSION AND DEPOSITION

layer will effectively mitigate against erosion; in other areas exposed fines in the till will be eroded until an armour of coarse sand and gravel has developed. The overall impact is seen to be slight.

6.5 Effects on Existing Structures

6.5.1 Pond El. 134 Feet

This pond level is the same as the "maximum operating water level" used by Geocon in the design of the dam. As described in Sections 6.2 and 6.3, the crest elevation will provide adequate storage of the 100-year, 24-hour rainfall, and the emergency spillway has adequate capacity. Thus, no modifications to the dam and spillway geometry are required.

Some change in the operation of the decant system is proposed, but no significant structural modifications to the tower and downstream structures are required.

6.5.2 Pond El. 138 Feet

For this pond level, the dam will not provide enough freeboard, and the crest will have to be raised. Computed maximum pond levels are as high as el. 140 feet, and to provide for wave action a freeboard allowance of 3 feet is called for, giving a crest elevation of 143 feet.

The dam is a homogeneous earthfill structure, built of glacial till, with rip rap on the upstream slope, and a drainage blanket below the downstream toe. Similar till would be used to raise the crest, maintaining the same crest width. The upstream slope line would be maintained, and the downstream slope would shift accordingly. The upstream rip rap would be extended to the crest, and the drainage blanket would be extended to the new downstream toe. The overall volume of new construction would be about 27,000 cubic yards.

Again, some change in the operation of the decant system is proposed, but no significant structural modifications to the tower and downstream structures are required.

The emergency spillway invert would be raised to el. 140 feet under this option.

6.6 Abandonment

The decommissioning plan presented in this report will provide a stable, long-term storage facility for the tailings. Ultimately, however, the facility should be capable of being sustained without active management or maintenance. At that time, the decant tower and discharge pipes should be taken out of service, and all flows routed through a permanent abandonment spillway, with appropriate rip-rap protection to prevent erosion. The present emergency spillway may be modified in line with the recommendations discussed in Section 6.4. Alternatively, the abandonment spillway may be developed at the location shown on Drawing 8996-2. This location has the advantage that flows would be routed through the settling pond and it would be maintained as a wildlife habitat. An abandonment spillway would also be required for the settling pond.

Abandonment procedures would also require an evaluation of the stability of the dam.

7.0 EXISTING ENVIRONMENT

The geology and hydrogeology of the tailings basin facility and the surrounding area have been extensively investigated in earlier reports (Geocon 1983b, 1991, 1992a; Nolan Davis 1990a). This report supports most of the earlier work and draws upon it in the discussion of the existing geological and hydrogeological environment.

A site visit was made on July 16, 1993 at which time surveys were conducted to characterize the aquatic and terrestrial habitats surrounding the existing tailings disposal area. Habitat and wildlife surveys were generally restricted to areas within the presently-cleared limits where possible disturbance associated with the flooding of the tailings was expected to occur.

7.1 Geology and Hydrogeology

The tailings facility is intermittently underlain by deposits of peat which are typically less than 2 feet thick and which occur in formerly low lying areas throughout the basin. Peat up to 20 feet thick occurs in the centre of the buried swamp upon which the facility is located.

Underlying the peat and directly underlying the tailings in most areas is a silty sand and gravel till which varies in thickness from approximately 8 to 14 feet. It is reported that, throughout the region, local granular outwash deposits occur, although none have been reported in the tailings basin area.

The surficial deposits overly Carboniferous clastic rocks of the Morien Group. This group consists of sandstones, mudstones, conglomerates and coal measures. The coarse clastic units (sandstone, conglomerate) are well fractured and can exhibit extremely high secondary permeabilities which results in the Lower Morien Group being one of the most productive aquifers in Nova Scotia.

The hydraulic conductivity of the till reportedly ranges between 10^{-8} and 10^{-7} m/s and no measurements have been reported for the organics. The sandstone bedrock was packer-tested and pump-tested during previous work and the results indicate horizontal hydraulic conductivities generally between 10^{-7} and 10^{-5} m/s but ranging as high as 10^{-4} m/s.

A conceptual, pre-development groundwater flow model at this site involves the following components:

1. Abundant rainfall resulting in high recharge potential.

2. Relatively active local flow systems recharging in high areas and discharging into lower swamps or lakes.

3. Despite high hydraulic conductivity in bedrock, regional groundwater flow is limited by low gradients and to a lesser extent, by locally low hydraulic conductivity of the overburden materials (till, organics).

The result of this type of flow system is a landscape dominated by numerous lakes and swamps. Each surface water body is at a slightly lower or higher elevation than the adjacent body. The groundwater flows between them, and in some respect their surface elevations, are controlled by the regional hydraulic gradient. The addition of the tailings facility, operating at water levels at least 10 feet higher than the original swamp, has changed this natural balance by increasing hydraulic gradients; most importantly, between the tailings pond and Kilkenny Lake.

These increased hydraulic gradients have resulted in high groundwater velocities (possibly in excess of 3000 feet per year). This is consistent with arrival times of chloride and sulphate in monitoring wells shortly after the tailings facility began operation. Pre-development groundwater velocities have not been calculated but it is likely that the facility has greatly increased them (See Section 8.3).

7.2 Hydrochemical Environment

The existing hydrogeochemical environment in the pond and downstream / downgradient is dominated by (1) the process water in the slurry discharge and (2) the geochemical processes which occur in both the pond water and the groundwater environment.

7.2.1 Slurry Process Water

The process water contains a high dissolved solids load, the bulk of which is sulphate, chloride, calcium, and sodium. Typical ranges of the important parameters are as follows (B. Clyburn, pers. comm., August 31, 1993):

Sulphate	600 - 1300 mg/L
Chloride	700 - 1200 mg/L
Hardness	1050 - 1750 mg/L
Alkalinity	1 - 130 mg/L
DOC	(high)
pH (pH Units)	6.9 - 7.1

The elevated DOC (dissolved organic carbon) results from the presence of a polymeric thickening agent in the slurry.

The dilution of the process water with the pond water results in lower concentrations of dissolved solids. The resultant concentrations at the final point of discharge from the settling pond (Station KL-1) are generally between one half and one third of those of the process water. The available ranges of concentration (1993 data) are as follows:

Sulphate	140 - 505 mg/L	(mean = 310 mg/L)
Chloride	208 - 640 mg/L	(mean = 425 mg/L)
pH	6.5 - 7.3	(mean = 7.0)

The process water therefore controls the geochemistry of the pond water and this is of concern because a subsurface hydraulic connection has been inferred to exist between the tailings pond and Kilkenny Lake. A study by Geocon (1991) documented a three to six-fold increase in chlorides and a two to three-fold increase in sulphates in the lake water after the tailings base opened. Chemical relationships were used to estimate the total flux from the pond to the lake of approximately 150 IGPM, [Later revised to 125 IGPM (Geocon 1992a)].

7.2.2 Geochemical Processes

At this site, the primary geochemical process which causes concern with respect to both surface water and groundwater quality is the oxidation of pyrite as represented by the following equation:

$$4FeS_2 + 15O_2 + 14H_2O <=> 4Fe(OH)_3 + 8SO_4^{2-} + 16H^+ \qquad (7.1)^1$$

This oxidation can occur in both the pond by oxidation of suspended matter or substrate materials and in the subsurface. If the oxidation occurs in the unsaturated tailings pile, the products can discharge into the pond. This can, in turn, infiltrate into the groundwater environment and ultimately discharge into Kilkenny Lake.

The well-documented impacts on water resources from pyrite oxidation include a decrease in pH, an increase in dissolved metals (iron, manganese, aluminum and heavy metals), and an increase in total dissolved solids (TDS), particulary sulphate.

When tailings, waste rock or naturally pyritiferous rock oxidizes, there is a potential for neutralization of the resulting acidic solutions by the same material. Two broad types of tests are conducted to determine whether a material is likely to be acid generating (i.e. if there are insufficient neutralizing

[1] This reaction occurs at higher pH through a number of intermediate steps. If more acidic conditions form, ferric hydroxide will not precipitate and the ferric ion will itself oxidize pyrite. At pH values low enough to support that reaction, bacterially mediated oxidation also occurs, causing an exponential increase in amount of acid produced.

materials in the matrix to consume all the acid which may be produced). The first is known as "static testing" and involves an analysis of the material and a comparison (in equivalence units) of the proportion of neutralizing minerals to acid generating minerals. This type of test is inherently flawed because its use requires the assumption that all acid generating and neutralizing materials in the rock are available to react and this is rarely the case. A far more comprehensive way of determining the acid production potential is known as "kinetic testing". This group of tests involves an attempt to duplicate field conditions in the laboratory and periodic measurement of the chemical products for many months to determine if acid is being produced and if neutralizing minerals are being consumed.

Both static and kinetic testing have been carried out on the Victoria Junction tailings and the results have all shown that net acidity is likely to be predominate in future if the processes which generate acid are allowed to continue unchecked. Key word!

Prior to initiation of this study there had been no direct evidence that oxidation was occurring in the tailings pile even although the pile has been exposed above the pond level for a number of years. Theoretically, unsaturated conditions should result in the oxidation process beginning fairly quickly (certainly within weeks). As a result of this concern, four small monitoring wells were installed in the exposed tailings at the locations shown on Drawing 8996-1. They consisted of two-inch diameter PVC pipe, slotted at the bottom and driven into the tailings to a depth of approximately 6 feet. They were sampled using an inertial pumping system and the samples were submitted to the lab within 6 hours for filtration and preservation. The analytical results are provided in Table 7.1.

Table 7.1 ANALYTICAL RESULTS - SHALLOW MONITORING WELL SAMPLING PROGRAM

ESL-9877 Filtered Determination	Unit	Sample A	Sample B	Sample C	Sample D
Sodium	mg/L	501.00	585.00	124.00	553.00
Potassium	mg/L	7.95	6.26	4.34	7.91
Calcium	mg/L	479.00	139.00	216.00	165.00
Magnesium	mg/L	160.00	43.00	41.00	100.00
Hardness	mg/L	1854.94	524.16	708.19	823.81
Alkalinity ($CaCO_3$)	mg/L	331.90	248.10	396.20	479.50
Bicarbonate ($CaCO_3$)	mg/L	331.90	247.96	396.17	479.17
Carbonate ($CaCO_3$)	mg/L	0.00	0.14	0.03	0.33
Sulfate	mg/L	2020.00	4.00	303.70	11.80
Chloride	mg/L	36.76	989.50	165.80	1102.50
Silica	mg/L	5.94	5.59	7.05	4.84
Ortho Phosphorus	mg/L	0.02	0.12	0.01	0.06
Nitrate-Nitrite (N)	mg/L	0.01	0.01	0.01	0.13
Ammonia (N)	mg/L	0.05	0.38	0.01	1.65
Iron	mg/L	4.90	0.03	21.60	0.09
Manganese	mg/L	14.50	0.22	11.60	0.05
Copper	mg/L	0.02		0.04	0.01
Zinc	mg/L	0.06		0.02	0.01
Total Organic Carbon	mg/L	4.00	37.10	33.60	72.20
Color	TUC	11	5	12	5
Turbidity	NTU	64.00	0.82	84.00	0.81
Conductivity	umhos/cm	4690.00	3870.00	1953.00	4500.00
pH	units	6.5	7.4	6.7	7.5
pH (filtered)	units	7.9	8.0	7.8	7.7
Cation Sum		59.07 meg/L	36.10 meg/L	19.66 meg/L	40.81 meg/L
Anion Sum		48.53 meg/L	32.07 meg/L	17.49 meg/L	39.22 meg/L
Percent Difference		9.79	5.92	5.83	1.99

Samples taken August 17, 1993

The recent sampling has indicated that in the upper, unsaturated portion of the existing tailings pile (the vadose zone), sulphide oxidation is occurring. Samples A and C were taken from small monitoring wells installed 400 feet east and 600 feet west of the tailings discharge pipe respectively (see Drawing 8996-1). Sample A and, to a lesser extent, Sample C exhibit elevated sulphate and/or metals. The relatively high ratio of sulphate to chlorides suggests that the majority of the sulphate in the sample could not have resulted from discharge from the inlet pipe. The pH in both is only slightly acidic and a measurable alkalinity is also present. This indicates that insitu buffering is occurring as a result of the intrinsic neutralization potential of the tailings. This buffering provides an example of why it is difficult to determine the onset of sulphide oxidation using pH as an indicator. During neutralization, hydrogen ions are replaced by calcium as carbonate minerals are dissolved. Very high total dissolved solids (TDS) concentrations can occur, consisting largely of calcium and sulphate ions, if the process of acid generation and neutralization is extensive. This process is exemplified by the high hardness and sulphate concentrations in samples A and C.

Samples B and D exhibit chemistry which suggest an opposite process is occurring to that which is occurring at the other two monitoring well locations. Both B and D have very low sulphate concentrations and chlorides which are so high that it suggests no dilution of the tailings discharge water has occurred. Both are located in braided stream portions of the tailings outwash fan and, although tailings was not being discharged at the time of sampling, it is likely that the interstitial waters at these points are recharged directly by the tailings water. Despite this, however, the concentrations of sulphates in these waters is less than 5 percent of that expected in the tailings water. This suggests that sulphate is being reduced to sulphide in a partial reversal of the reaction represented by Equation 7.1. The most likely reason for this is that the high TOC in the discharge water and the polymeric thickener in the tailings are biodegrading. This will consume all the available oxygen and then begin to consume sulphate as an oxidizing agent. The result is that no oxygen will be available for oxidation of the tailings and acid already produced will be consumed by the reduction of sulphate. This is supported by the inverse correlation between TOC and sulphate concentrations in the four samples.

The net result of this latter process may be that the oxidation of tailings in the vadose zone is being delayed. This can only be considered good because it has reduced the consumption of neutralizing materials in the tailings. It may also explain the lack of increased acidity and sulphates in the pond water despite the fact that a portion of the tailings has been unsaturated for a number of years.

The presence of relatively minor alkalinity in the slurry water may also be helping to neutralize the pH resulting from sulphide oxidation reactions in both the unsaturated tailings pile and the pond itself. However, an alkalinity of less that 150 mg/l is not high and its contribution to neutralization compared with minerals in the solid phase is low. It is likely that the neutralizing capacity of minerals in the tailings itself is a much more important factor in maintaining neutral pH conditions in the pond water.

Oxidation in the submerged tailings (the phreatic zone) can, and likely does, occur on this site but it is limited by the solubility of oxygen. The phreatic zone is normally considered closed to the input of oxygen and therefore the maximum amount of oxygen available to react in the phreatic zone is equal to the solubility of oxygen in the recharge water (~ 12 mg/l). According to Equation 7.1, this results in a minimum pH of 3.4 and a maximum sulphate concentration of approximately 19 mg/l. In practice, the pH resulting from phreatic zone oxidation is never as low as 3.7 because of buffering by other minerals and because the infiltrating surface waters are not always saturated with respect to oxygen.

7.3 Aquatic Habitat

Three ponds are present within the study area. The largest is the tailings pond. The water in the tailings pond is highly turbid as a result of suspended tailings particles. It is unlikely that light penetrates more than a few centimetres into the water column; consequently, aquatic vegetation is probably absent and aquatic fauna, if present, may be expected to be depauperate both in species richness and biomass.

The smallest water body is a shallow pond located at the western end of the tailings disposal area. This pond receives water from the small stream which originally traversed the tailings pond. This stream has been impounded by the mounding of tailings near the tailings discharge pipe to form the pond. Tailings intrude into the pond on the eastern shore. The extent of this intrusion is not known. This pond supports at least two species of aquatic macrophytes including pondweed (*Potamogeton epihydrus*) and *P. berchtoldi*). Other aquatic macrophyte species may occur in the pond but the soft bottom permitted examination of only the edge of the pond. Aquatic insects were abundant in the pond. There was no evidence to suggest that fish are present in this pond.

The third water body observed during the site visit was the settling pond for the tailings disposal area. This pond was notable for the clarity of water in it. It was possible to see to a depth of two to three metres on the day of the survey. This pond supports a lush growth of aquatic macrophytes, particularly musk-grass (*Chara* sp.) which appears to form a continuous carpet on the bottom of the pond. Pondweed (*Potamogeton epihydrus*) and bur-reed (*Sparganium* sp.) were also found growing on the bottom of the pond and a large bed of emergent broad-leaved cat-tail (*Typha latifolia*) was found at the western end of the pond. Large numbers of banded-killifish (*Fundulus diaphanous*) were observed in the pond. Several local people were observed fishing on the pond. They reported that brook trout (*Salvelinus fontinalis*) are regularly caught in the pond.

7.4 Terrestrial Habitats

Nine terrestrial habitats are found in the vicinity of the tailings disposal area, each of which is discussed below. No rare species as defined by Maher et al. (1978) or Argus and Pryer (1990) were observed in any of these habitats.

Tall Emergent-Dominated Shore Marsh: This habitat was found around the margin of the pond at the western end of the tailings pond. It is associated with standing water, generally, less than 50 cm deep. The dominant species include three species of emergent plant, broad-leaved cat-tail (*Typha latifolia)*, rattle-snake grass (*Glyceria canadensis*), soft rush (*Juncus effusus*); and two species of pondweed (*Potamogeton epihydrus* and *P. berchtoldi*).

Graminoid-Dominated Shore Marsh: This habitat type occurs on wet sites which are free of standing water. Sedge (*Carex canescens*[2]) and broad-leaved cat-tail are the dominant species. Other common species include sphagnum moss (*Sphagnum* spp.), St. John's-wort (*Hypericum virginicum*), violet (*Viola* sp.), rush (*Juncus militaris*), and bulrush (*Scirpus atrocinctus*). A sparse shrub overstory is present which is composed of speckled alder (*Alnus rugosa*) and willow (*Salix pyrifolia*).

Moss-Dominated Shore Marsh: Two distinct subunits of this habitat type were present around the margins of the tailings pond. In low lying areas where organic matter from wetlands predating the tailings pond was present, a virtually continuous mat of sphagnum moss punctuated by sedge (*Carex canescens*), soft rush, bulrush and violet was present along with scattered willow (*Salix pyrifolia*). At higher elevations where wave action has exposed mineral soil and where soil drainage is less impeded, the sphagnum moss cover is replaced by hair-cap moss (*Polytrichum commune* and *P. juniperinum*) along with bulrush, grass-leaved goldenrod (*Solidago graminifolia*), and pitcher plant (*Sarracena purpurea*). The shrub overstory is somewhat denser than on the wetter sites and is composed of willow, speckled alder and mountain white birch (*Betula cordifolia*).

Tall Shrub-Dominated Shore Swamp: This habitat type is found at the western end of the tailings basin on sites which do not appear to have been affected by fluctuations in water levels. This stability has permitted the survival of a well developed shrub overstory dominated by speckled alder. Other species comprising the shrub layer of this habitat include mountain white birch, willow (*Salix pyrifolia*), black spruce (*Picea mariana*), and lambkill (*Kalmia angustifolia*). The ground vegetation layer consists of an extensive cover of sphagnum moss along with patches of calla lily (*Calla palustris*), St. John'-wort, sedge (*Carex canescens*), and blue joint (*Calamagrostis canadensis*).

Meadow: Meadow habitat fringes the eastern half of the tailings pond. It has developed in areas which were previously cleared and flooded by the operation of the tailings pond. Fluctuations in pond water level combined with wave action have resulted in the loss of approximately 20 cm of top soil. The remaining soil is moderately well drained so wetland plant communities have not developed. Instead an open grassland dominated by tickle-grass (*Agrostis scabra*), soft rush and grass-leaved goldenrod

[2] Latin binomials are used when there are more than one species associated with the common name; (i.e., there are approximately 100 species of sedge in Nova Scotia so the binomials are used wherever the sedge is mentioned.)

(*Solidago graminifolia*) has formed. Other common ground vegetation species include bulrush, broad-leaved cat-tail and sedge (*Carex scoparia*). At lower elevations near the present water level, a thin layer of coal tailings has been deposited on the surface of the soil. The vegetation here is somewhat different from that found at higher elevations possibly due to different drainage and soil chemistry regimes associated with the presence of the tailings. The dominant species here are marsh cress (*Rorippa islandica*), knotweed (*Polygonum* sp.) and tickle-grass. Small quantities of grass-leaved goldenrod and fox-tail barley (*Hordeum jubatum*) are also present. All of the dominant species of this habitat are ruderal species which are characteristically found on highly disturbed areas such as roadside ditches.

Tailings: Most of the area covered by tailings is devoid of vegetation, probably as a result of nutrient deficiencies, problems with soil water availability and instability of the substrate. Around the fringes of the tailings pond where less than approximately 25 cm of tailings are present and plant roots are able to penetrate into the underlying soil, plant cover increases considerably. The most abundant species on these shallow tailings are bulrush, common beggar-ticks (*Bidens frondosa*), broad-leaved cat-tail, soft rush, and puccinellia (*Puccinellia distans*).

Immature Hardwood Forest: This habitat type forms a distinct band which surrounds much of the tailings disposal area. It has developed following the clearing of mature hardwood forest during the construction of the tailings pond in 1982. These stands support a variety of tree and shrub species which form a dense canopy. White birch (*Betula papyrifera*), red maple (*Acer rubrum*) and trembling aspen (*Populus tremuloides*) are the dominant species of the canopy. American beech (*Fagus grandifolia*), yellow birch (*Betula allegheniensis*), mountain-ash (*Sorbus americana*), and red-berried elder (*Sambucus pubens*) are also relatively common. The ground vegetation layer is composed mainly of bracken fern (*Peridium aquilinum*), bunchberry (*Cornus canadensis*), wild sarsaparilla (*Aralia nudicaulis*), yellow clintonia (*Clintonia borealis*), and rough goldenrod (*Solidago rugosa*).

Mature Softwood Forest: Mature softwood forest is restricted to imperfectly drained areas near the western end of the coal tailings disposal area. The tree canopy is very dense and is dominated by black spruce. Balsam fir (*Abies balsamea*), tamarack (*Larix laricina*) and red maple also form part of the canopy. Shrub-sized woody vegetation is very sparse and consists of witherod (*Viburnum cassinoides*) and advanced regeneration of balsam fir. The ground vegetation layer is also poorly developed and consists mainly of sphagnum moss and sedge (*Carex trisperma*).

Mature Hardwood Forest: Most of the undisturbed area surrounding the tailings disposal area is occupied by this habitat type. It is typically associated with moderately well drained to well drained sites. American beech and red maple are the dominant tree species in much of this forest along with lesser quantities of white birch, yellow birch, hop-hornbeam (*Ostrya virginiana*), and sugar maple (*Acer saccharum*). The shrub layer is composed largely of advanced regeneration of tree species such as

American beech, yellow birch, red maple, and balsam fir. Wood fern (*Dryopteris spinulosa*), wild sarsaparilla, bunchberry, wild lily-of-the-valley (*Maianthemum canadense*), and yellow clintonia are the dominant ground vegetation species.

7.5 Animal Wild Life

All species of bird, mammal, reptile, and amphibian observed within the habitats bordering the coal tailings disposal area were recorded. These inventories are not complete due to time limitations but provide a good indication of the species which are most abundant in these habitats.

7.5.1 Birds

Table 7.2 lists the bird species which were observed in the vicinity of the tailings disposal area and the habitats in which they were observed. None of the species observed is considered to be rare in Nova Scotia (Tufts 1986) or Canada (COSEWIC 1992). Bird observations were restricted to the areas surrounding the tailings basin which will be subject to flooding and/or disturbance associated with the subaqueous disposal of the tailings. Birds found in this area were classified into four habitat groups based on the habitats where they were found including birds associated with open water, birds associated with wetlands and meadows, birds associated with immature hardwood forest, and birds observed flying over the site. Each of these groups is discussed in the following text.

Table 7.2 BIRD SPECIES NOTED IN HABITATS ADJACENT TO THE TAILINGS DISPOSAL AREA

Species	Common Name	Habitats
Ardea herodias	Great Blue Heron	FO
Accipiter gentilis	Northern Goshawk	FO
Actitis macularia	Spotted Sandpiper	OW,WM
Larus argentatus	Herring Gull	FO
Sterna hirundo	Common Tern	OW
Empidonax alnorum	Alder Flycatcher	IH
Tachycineta bicolor	Tree Swallow	FO
Cyanocitta cristata	Blue Jay	FO
Corvus corax	Common Raven	FO
Corvus brachyrhynchos	Common Crow	FO
Turdus migratorius	American Robin	IH
Catharus guttatus	Hermit Thrush	IH
Bombycilla cedrorum	Cedar Waxwing	IH
Vireo olivaceus	Red-eyed Vireo	IH
Dendroica petechia	Yellow Warbler	IH
Dendroica coronata	Yellow-rumped Warbler	IH
Dendroica virens	Black-throated Green Warbler	IH
Seiurus aurocapillus	Ovenbird	IH
Geothlypis trichas	Common Yellowthroat	IH
Setophaga ruticilla	American Redstart	IH
Quiscalus quiscula	Common Grackle	WM, IH
Carduelis tristis	American Goldfinch	IH, FO
Passerculus sandwichensis	Savannah Sparrow	WM
Junco hyemalis	Dark-eyed Junco	IH
Zonotrichia albicollis	White-throated Sparrow	IH
Melospiza georgiana	Swamp sparrow	WM
Melospiza melodia	Song Sparrow	WM, IH

OW - Open Water WM - Wetlands and Meadow IH - Immature Hardwood Forest FO - Flying Over

Open Water: Common Tern and Spotted Sandpiper were the only birds which appeared to utilize open water habitat in the study area. Two terns utilized a partially sunken log in the tailings pond as a resting site and several Spotted Sandpipers foraged around the edge of the tailings pond at the time of the survey.

Wetlands and Meadow: Six species of bird were associated with this group of habitats including Spotted Sandpiper, Savannah Sparrow, Common Yellowthroat, Swamp Sparrow, Common Grackle and Yellow Warbler. Evidence suggests that Spotted Sandpiper and Savannah Sparrow nest in the meadow habitat, Swamp Sparrows breed in the various marsh habitats and Common Yellowthroats and Yellow Warblers breed in the tall shrub dominated shore swamp. Song Sparrows may be expected to nest in both the meadow habitat and in the immature hardwood forest bordering the meadow habitat. Those which establish nests after leaf-out may be expected to place them in the immature hardwood forest bordering the meadow. Grackles were observed in the cat-tail dominated marsh. They may be expected to feed in the wetlands and meadows but probably breed in nearby woodlands. The meadow and drier portions of the marsh habitats appear to provide good feeding habitat for all of the sparrow species.

Immature Hardwood Forest: Sixteen species of bird were observed in the immature hardwood stands surrounding the tailings disposal area (Table 7.2) including Hermit Thrush, American Robin, Red-eyed Vireo, Alder Flycatcher, American Goldfinch, Cedar Waxwing, Common Grackle, Dark-eyed Junco, Song Sparrow, and six species of warbler including Yellow Warbler, Yellow-rumped Warbler, Black-throated Green Warbler, Overbird, Common Yellowthroat, and American Redstart. All of these species may be expected to breed in this habitat or the mature hardwood stands bordering this habitat type. Some species such as Song Sparrow, Dark-eyed Junco, American Robin, Common Grackle, Common Yellowthroat, and Yellow Warbler can be expected to forage in the wetland and meadow habitats as well as the woodlands.

Flying Over: Seven species were observed flying over the tailings disposal area (Table 7.2). There is no evidence to indicate that these species interact with the habitats surrounding the tailings area although it is highly likely that some of them do on occasion. American Crow, Common Raven, Northern Goshawk, Blue Jay, and Tree Swallow probably nest in the mature woodlands surrounding the study area. American Crow and Common Raven may be expected to feed in the wetlands and meadow habitats and Blue Jays probably forage in the immature hardwood forest. Tree Swallows may be attracted to the settling pond and shallow pond at the western end of the tailings disposal area by hatches of aquatic insects. Northern Goshawk may occasionally hunt for birds and small mammals along the edge of the immature hardwood forest. The nearest Great Blue Heron rookery is located near Lingan. Some Great Blue Herons may forage for small fish and frogs in ponds on the site; however, these ponds provide relatively poor feeding habitat compared to nearby coastal habitats.

7.5.2 Mammals

observed or evidence??

Only five mammals were noted in the vicinity of the tailings disposal area, none of which are rare in Nova Scotia (Isnor 1981) or Canada (COSEWIC 1992). These included white-tailed deer (*Odocoileus virginanus*), coyote (*Canis latraus*), red fox (*Vulpes*), beaver (*Castor canadensis*), and varying hare (*Lepus americanus*). The terrestrial species may be expected to feed in the habitats surrounding the disposal area and use the various ponds as a source of water. Beaver appear to be restricted to the settling pond where a lodge was found.

7.5.3 Herpetofauna

Three species of frog and three species of snake were noted during the site visit. Frogs were encountered most frequently in and around the shallow pond at the western end of the tailings disposal area. Green frogs (*Rana clamitaus melanota*) were frequently heard in this pond while leopard frogs (*Rana pipiens*) were observed on a number of occasions in the surrounding marsh habitat. Pickerel frogs (*Rana palustris*) were found around the margin of the settling pond. Green snake (*Opheodrys vernalis*), garter snake (*Thamnophis sirtalis pallidula*) and northern redbelly snake (*Storeria occipitomaculata*) were observed in the meadow habitat. None of the reptiles and amphibians noted in the area are considered to be rare in Nova Scotia (Gilhen and Scott 1981) or Canada (COSEWIC 1992).

8.0 POTENTIAL ENVIRONMENTAL EFFECTS OF THE PROJECT AND PROPOSED MITIGATION

8.1 Valued Ecosystem Components

Based on the results of the site visit and review of the existing literature, four Valued Ecosystem Components (VECs) (Beanlands and Duinker 1983) have been identified in the study area: groundwater, surface water, habitats, and animal wild life. Groundwater and surface water quality concerns are the driving force behind the construction of the subaqueous tailings disposal area and as such their inclusion in the screening level assessment is warranted. Construction of the facility will affect terrestrial and aquatic habitats surrounding the existing tailings disposal area and species of animal wild life which live in them. A method incorporating the use of screening matrices assisted with identification of interactions of project related activities with the VEC's. The matrix is shown in Table 8.1, and the interactions are discussed in the following text.

Table 8.1 INTERACTION MATRIX OF PROJECT ACTIVITIES AND VALUED ECOSYSTEM COMPONENTS

Activities	Valued Ecosystem Components				
	Groundwater	Surface Water	Aquatic Habitats	Terrestrial Habitats	Animal Wildlife
Excavating and Redepositing Tailings	☐	⊠	⊠	☐	⊠
Vehicle Movement	☐	⊠	⊠	☐	⊠
Water Level Alterations	⊠	⊠	⊠	⊠	⊠
Refuelling	⊠	⊠	⊠	⊠	⊠

☐ *no impact*
◘ *unknown impact*
⊠ *impact - mitigatable*
■ *impact - nonmitigatable*

8.2 Surface Water

Surface water subject to direct contamination is limited to the pond itself, and Kehoe Brook. Indirectly, Kilkenny Lake will be affected by seepage of pond waters as groundwater flow.

Two surface water contamination scenarios which could potentially occur at this site are discussed below: pyrite oxidation in the pond itself; and pyrite oxidation in the unsaturated tailings pile (vadose zone) before close-out.

8.2.1 Pyrite Oxidation in the Pond

Pyrite oxidation in the pond results from oxidation of bottom sediments and suspended sediments in the water column. The reaction represented by Equation 7.1 is limited by the availability of oxygen and availability of unreacted sulphides. The maximum solubility of oxygen in cold water is about 12 mg/l but in shallow, unstratified pond water, there is a constant input as a result of diffusion from the atmosphere enhanced by agitation of the bottom sediments by wave action. The limited availability of oxygen in the water column results in slower oxidation of sulphides than could occur under moist, unsaturated conditions. As long as reactive sulphides are available, the oxidation process will not stop but the process will be slow enough that dilution by precipitation will likely attenuate any impacts as discussed further below.

The factor which will most limit sulphide oxidation in the pond is the availability of reactive sediments and this is related to the surface area of sediments exposed. If the bottom sediments remained undisturbed, sulphides in the upper few millimetres of sediments will rapidly become exhausted and the amount of oxidation will drop off. However, due to the shallow nature of this pond, it is likely that wave action will disturb the sediments.

Calculations carried out as part of this investigation (Section 6.4) suggest that, based on prevailing wind patterns, design water depth and tailings grain size, there is likely to be some erosion of bottom sediments by wave action. The thickness of sediment that will be disturbed is unknown but it is known that wave induced currents are oscillatory and therefore will not result in net transport except by suspension and redeposition of the finer sediments. This means that it will be the same upper layer of sediment which is disturbed by periodic high winds and this sediment is likely to become fully oxidized with time.

With the removal of tailings water as a source of dissolved solids, there will be a sharp drop in the concentration of both sulphate and chlorides along with many other parameters in the pond water. Some oxidation of tailings on the pond bottom and the suspended tailings is expected for the first few years but the very high rate of dilution from precipitation is expected to largely mitigate the effects.

8.2.2 Pyrite Oxidation in the Tailings Vadose Zone Before Close-out

Prior to decommissioning, pyrite oxidation can occur in the unsaturated tailings pile. From an environmental standpoint, this is by far the most serious process which could occur on potential acid rock drainage sites. During vadose zone oxidation, both pyrite and oxygen are available to react in almost limitless quantities and the result is often a highly acidic, metalliferous leachate which can discharge into surface water. This process is of concern only before decommissioning because the planned subaqueous disposal will eliminate the vadose zone.

The kinetic testing described in Section 7.2 is an attempt to simulate vadose zone oxidation. As has been mentioned, the laboratory testing has indicated the likelihood that net acidic conditions will eventually occur in the tailings if vadose zone oxidation continues. In addition, the results of the monitoring well sampling described in Section 7.2 indicate that vadose zone sulphide oxidation is now occurring although this is in conjunction with simultaneous neutralization. However, this is not immediately obvious from the concentrations observed at the outfall which are consistent with dilution of the tailings process water by precipitation.

8.2.3 Mitigation

The chosen method at this site for mitigation of potential acid rock drainage impact on groundwater and surface water is subaqueous disposal. Abundant evidence now exists (MEND 1989; MEND 1990a, 1990b, 1990c, 1990d, and others) which indicates that subaqueous disposal is the most effective method for permanently reducing sulphide oxidation in reactive sulphide-rich wastes.

As stated at the beginning of this Section, the main concern with respect to the potential short-term degradation of pond water quality as a result of oxidation of available reactive sediments relates to effects on Kehoe Brook. The length of time that the process of bottom sediment and suspended sediment oxidation is expected to operate will likely be short and the effects minor. It is unlikely that significant degradation of water quality in the pond will occur during this period. However, if it does, it would be feasible to use the existing treatment plant to mitigate downstream impacts.

The proposed close-out plan requires excavation of part of the tailings pile and redeposition in the pond. There may be increased oxidation of suspended sulphides as a result of the increased turbidity in the pond but common sense would suggest that the effects will not be severe. This is based on the fact that agitation and suspension has been occurring throughout the life of the facility and there has been little or no discernable increase in sulphate concentrations at the pond outfall which can be attributed to oxidation.

Any increase in sulphate concentration as a result of oxidation during redistribution of the tailings will certainly be exceeded by a drop in concentration as a result of the tailings process water ceasing to discharge into the pond. It is unlikely that pH will drop considerably during this period but if the pond water does becomes degraded seriously (i.e. less than pH 4.0) then the potential for contamination of Kilkenny Lake must be addressed. If this occurs, liming of the pond could be considered. Approximately 1.6 tons of lime would be required to raise the pH of the entire pond from 4.0 to 7.0.

Somewhat decreased pH may also occur in the first several years (i.e. prior to consumption of available sulphides in the pond) during periods of dry weather when the dilution effect is eliminated or during periods of sustained high winds when bottom sediments would be most disturbed. Liming could also be carried out in this event.

It should be noted that some of the existing problems with the tailings facility will end upon closure. Sulphates from that source and from ongoing vadose-zone oxidations will be eliminated and this is expected to offset any increases due to oxidation of suspended matter in the pond. Chlorides will drop off almost completely because the tailings discharge is the only major source of chlorides in the basin. Other parameters such as metals and organic carbon associated with the tailings discharge will also drop off.

The net alkalinity in the tailings water is not likely to be a major factor contributing to the current neutral pH conditions in the pond and therefore, its elimination is not expected to cause a major decrease in the overall neutralizing capacity.

In conclusion, the chosen method of subaqueous disposal, and available mitigative technology, are sufficient to reduce surface water quality concerns to an acceptable level.

8.3 Groundwater

When the tailings facility was built, it greatly increased hydraulic gradients in the underlying ground and resulted in strongly effluent conditions, i.e. it resulted in a net loss of water due to exfiltration from the pond. As previous studies have indicated, this has resulted in downward flow into the highly transmissive bedrock, rapid lateral flow northward (downgradient) through bedrock and then contribution to the baseflow into Kilkenny Lake.

Geocon (1992a) estimated the average seepage rate from the pond into Kilkenny Lake to be approximately 132 IGPM at a pond elevation of 136 feet. For the proposed pond level between el. 134 feet and el. 138 feet, this rate is not expected to decline after close-out, and would be about 120 to 150 IGPM. The relatively small difference in predicted rate is not considered to be a determinant in the final selection of a pond level. The important factor is that the quality of the seepage water entering Kilkenny Lake will reflect the quality of the pond water, plus geochemical changes which will occur in the subsurface as a result of the close-out strategy.

As mentioned above, vadose zone oxidation of sulphides is likely occurring now, and will continue until the tailings are submerged. However, the near neutral pH values indicate that the intrinsic buffering capacity of the tailings is resulting in insitu neutralization of the acid produced. The reversal of the oxidation process may also be occurring as a result of biodegradation of organic matter. These processes maintain low metals concentrations and near neutral pH values and may respectively result in both high and low sulphates in the resulting groundwaters.

Previous kinetic and static testing of the tailings (Geocon 1992a) has revealed a net positive acid generating potential. Therefore, if vadose zone oxidation were allowed to continue, the insitu buffering process would continue until all the buffering material along a given flowpath was exhausted and "breakthrough" of acidic water would occur.

After closeout, oxidation in the (then) larger volume of submerged tailings (the phreatic zone) will continue to occur but it will be limited by the solubility of oxygen, as discussed in Section 7.2. This process is not, therefore, directly impacted by the proposed tailings redistribution.

8.3.1 Mitigation

After the facility has been redesigned and subaqueous conditions achieved, vadose zone oxidation of sulphides will end and the (much less severe) process of phreatic zone oxidation of sulphides will continue. This process is naturally limited by the lack of availability of oxygen in the subsurface and the relatively minor amounts of acid produced will probably be attenuated by buffering in the tailings and further along the flowpath. This buffering process could potentially occur for very long periods of time considering the low levels of acidity produced by phreatic zone oxidation. However, it is important to ensure that the buffering capacity of tailings and natural strata is not exhausted prior to complete decommissioning. This could occur by allowing the pond to become too acidic during the redistribution process and/or the first several years after closure. It could also occur if vadose zone oxidation in the tailings, which is now occurring, is allowed to continue.

Groundwaters which have been impacted by reactions in the phreatic zone will consume far lower quantities of buffering materials than those impacted in the vadose zone. Waters with a pH of 2.0 will consume 100 times ~~more buffering material than~~ waters with a pH of 4.0. Put another way, a flowpath which would buffer phreatic zone oxidation for 500 years would likely buffer vadose zone oxidation for only 5 years.

→ depends on acidity as well as pH (i.e. metal conc. etc.)

For this reason it is important to complete the re-design quickly (i.e. in no more than two years). It should be reiterated that all the buffering materials in the tailings do not have to be consumed to have acid breakthrough. Only those along a given (perhaps preferential) pathway need be consumed to have the potential for breakthrough of acidic conditions into surface waters with associated heavy metal loadings.

Some mitigation by natural processes is also likely to occur. Attenuation of metals by adsorption to clay minerals and thick organics below the pond will likely occur to some extent. Long-term build up of organic materials on the bottom of the pond may result in consumption of oxygen and a reduction in oxidation of pyrite. Percolation of fine sediments into the upper tailings from upstream sources may reduce permeability. These processes are all possible but need not be relied upon.

In conclusion, the combined effects of engineered and naturally-occurring mitigative processes will reduce the net release of acidity and dissolved solids from the tailings basin to groundwater and will result in a positive impact on water quality conditions for the foreseeable future.

8.4 Habitats

8.4.1 Aquatic Habitats

All of the ponds found in the existing tailings disposal area will be affected by the redistribution of the tailings. The tailings pond will be completely reconfigured and will be amalgamated with the shallow pond at the western end of the tailings disposal area. The tailings pond supports little if any aquatic life so its alteration is of little consequence. The shallow western pond supports a small but relatively productive aquatic habitat which would be adversely affected through smothering if tailings or turbid water are permitted to enter it. The settling pond also supports a productive aquatic habitat which includes the presence of brook trout and other fishes. The tailings redistribution operations, and wave action, will produce suspended solids which will be decanted into the settling pond. The settling pond has been accepting suspended solids from the tailings pond for a number of years but has been able to maintain a suitable environment for salmonids throughout this period. If there are not large unanticipated inputs of turbidity and fine tailings particles, it is expected that it will continue to do so during the period of reconfiguration, and later.

Accidental spills of fuel, hydraulic fluid, lubricants and coolants could occur during routine equipment maintenance activities. Such spills into aquatic habitats could cause mortality or morbidity of plants and animals.

8.4.1.1 Mitigation

Control of turbidity during tailings moving operations should be the main focus of mitigation for aquatic habitats affected by the project. Silt curtains deployed around the decant structure and management of pond levels to increase retention time will reduce the amount of suspended solids discharged into the settling pond. The implementation of these mitigative measures should control the negative effects associated with the project. In fact, the cessation of inputs of tailings and the establishment of a relevantly stable wetland on the site will enhance the availability of aquatic habitats.

Where feasible, refuelling and other maintenance activities should be conducted at designated locations away from aquatic habitats. Refuelling of floating equipment will necessarily occur on the water. It is recommended that oil sorbent booms be placed around the dredges or barges during refuelling operations to contain any spilled fuel. At all refuelling and maintenance sites, appropriate cleanup equipment should be available and personnel should be trained in its use.

8.4.2 Terrestrial Habitats

Project activities will affect six of the nine habitats found in the vicinity of the existing tailings disposal area. The effects will be of two types: (i) temporary changes in water level during tailings-moving operations, and (ii) permanent changes in pond level.

Tall Emergent-Dominated Shore Marsh habitat would be temporarily flooded when tailings redistribution occurs if water levels are raised to assist in controlling discharge water quality or to provide adequate water depth for operation of the suction dredges. This area is likely to be affected by turbidity which could cause some mortality of submerged aquatic plants. Any effect resulting from the loss of plants would be temporary until the vegetation becomes reestablished, probably after several growing seasons.

Graminoid-Dominated Shore Marsh and Moss-Dominated Shore Marsh can be expected to be affected by temporary flooding of much of this habitat, but more importantly, permanent flooding of much of these habitats by pond levels between el. 134 feet and el. 138 feet. Temporary flooding would result in some mortality of vegetation particularly if it occurs during the growing season. Permanent flooding will result in loss of this habitat and its replacement by a wetter habitat type.

The redistribution of the tailings below el. 130 feet would eliminate the extremely sparse plant cover which occurs around the margins of the tailings. The loss of this vegetation is of little consequence when weighed against the benefits of prevention of acid mine drainage, and the likelihood of development of a more-desirable wetland vegetation.

Meadow habitat will be affected by permanent flooding during the redistribution of the tailings resulting in the loss of much of this habitat. This highly disturbed early successional habitat will be lost but will be replaced by a more-desirable wetland habitat.

Project activities are not expected to interact with the Tall Shrub Dominated Stream Swamp, Mature Softwood Forest or Mature Hardwood habitats for the minimum tailings elevation option (pond at el. 134 feet). However, for pond levels higher than this, there will be progressive flooding of these habitats at the west end of the pond.

Accidental fuel spills could potentially affect large areas of wetland habitat should the fuel enter the tailings pond. The Tall Emergent-dominated Shore Marsh would be most susceptible since it is inundated for much of the year.

8.4.2.1 Mitigation

Effects of the project on terrestrial habitats can be reduced in several ways. During tailings moving operations the water level in the tailings pond should be raised only to the minimum required for operations, and these operations should proceed as quickly as possible to minimize the time that plant communities are inundated. Area B, which will be above the final pond level, should be hydroseeded to stabilize the surface against erosion until natural species take over. Areas of Mature Forest habitat which will be permanently flooded should be cleared beforehand. Refuelling precautions would be the same as described in Section 8.4.1.1.

Wetland habitat will replace all of the habitat lost or altered during the construction of the subaqueous tailings containment area. The replacement wetland habitats represent habitat types which are relatively uncommon in Nova Scotia and which are declining in abundance. In this respect, the project will enhance the existing environment resulting in a net positive effect.

8.5 Animal Wild Life

Animal wild life will be affected by displacement and disturbance. For a pond level at el. 134 feet, the degree of displacement is expected to be minimal since little habitat will be lost and the bulk of the habitat which will be affected supports relatively few species. For higher pond levels, there will be more habitat loss at the west end of the pond.

Disturbance associated with reconfiguration operations may cause small numbers of animals to temporarily abandon suitable habitat in the vicinity of the existing tailings pond. No particularly sensitive species of wild life were observed using the habitats adjacent to the tailings disposal area so disturbance is not expected to cause wild life to move more than a few hundred feet from the source of disturbance.

8.5.1 Mitigation

Due to the small numbers of wildlife species potentially affected, no site specific mitigation measures are proposed. The duration of the reconfiguration operation should be as short as possible and unnecessary habitat damage should be avoided. The creation of additional wetland will provide valuable wild life habitat. As such, the project is expected to benefit wetland wild life overall.

8.6 Monitoring

A monitoring program to determine the effectiveness of the proposed mitigation measures will be required. As a precautionary measure, the existing monitoring wells outside the limits of the tailings basin should be monitored closely during and after the basin close-out operation. A long-term monitoring program should also be set up which would be designed to measure the success of mitigative measures for years to come.

The existing monitoring wells between the pond and Kilkenny Lake should be supplemented by four or five bi-level monitoring wells along the edge of the tailings facility. The purpose of these wells would be to monitor for early indications of acid breakthrough in the bedrock and overburden aquifers. The monitoring wells should be sampled two to four times a year for the first five years and analyzed for the major ions (calcium, magnesium, sodium, potassium, chloride, sulphate and alkalinity), pH, temperature, iron, manganese and aluminum as a minimum. The frequency of sampling and number of monitoring wells could be reduced after five years pending the outcome of the sampling but the monitoring should be continued in the long term.

Early signs of acid breakthrough may include an increase in sulphate followed by an increase in metals concentration followed finally by a decrease in pH. Once the slurry water ceases and the process of vadose zone oxidation of sulphides is cut off, the trend should be downward in all parameters (except pH which will likely not change). A long-term concentration of sulphate of less than 50 mg/l in groundwater is expected if complete subaqueous disposal is achieved.

No biological monitoring program has been identified because active mitigation measures are not called for.

Predicted water level fluctuations associated with the nominal 4 feet of water cover indicate that the tailings will always remain submerged; however, pond levels should be monitored at monthly intervals for the initial ten years in order to provide data to validate these predictions. The need for continued monitoring beyond five years should be assessed at the appropriate time.

9.0 RECOMMENDATION REGARDING THE INITIAL ASSESSMENT DECISION

9.1 Possible Decisions

Environmental screening involves the evaluation of potential environmental effects of a proposed undertaking. The screening identifies possible adverse effects, the need for modifications to the project as proposed to minimize or avoid those effects, and the need for further investigation. The results of an environmental screening allow the proponent or initiating agency under the EARP, in this case, CBDC, to reach one of nine possible decisions respecting the requirement for further assessment of the project (Duffy 1986):

1. Automatic exclusion, based on lists defined on a program-by-program basis. The project proceeds.

2. No significant adverse effects. The project proceeds.

3. Effects can be mitigated with known technology, environmental design, and conformance to legislation and regulations. The project proceeds with mitigation and monitoring measures identified and recorded.

4. Potentially adverse effects are unknown. The proposal is given further study until a decision can be made.

5. Ability to mitigate effects is unknown. The proposal is given further study until a decision can be made.

6. Where potentially adverse effects are significant, according to criteria developed by FEARO and the initiating department, then the proposal is referred to the Minister of the Environment for a public review by a Panel.

7. Where there is public concern about potential environmental effects, such that a public review is desirable, then the proposal is referred to the Minister of the Environment for a public review by a Panel.

8. Automatic referral based on lists defined on a program-by-program basis. The project is referred for public review by a Panel.

9. Potential adverse environmental effects are unacceptable, in which the proposal must be modified and then re-screened or be abandoned.

9.2 Conclusion and Recommendation

Potential environmental concerns relating to surficial and groundwater resources, aquatic and terrestrial habitat and wildlife were identified and reviewed. Recommended and available mitigative measures are considered sufficient to eliminate or reduce the identified environmental concerns to an acceptable level. It is therefore recommended that the project proceed with implementation of the mitigative measures and monitoring program described herein. The nature of this project (i.e. remediation of a tailing pond) is in itself a mitigation measure and, if developed with the mitigation measures identified, should result in an overall positive effect on the environment and the valued ecosystem components.

10.0 COST ESTIMATES

Quantity and cost estimates for the close-out plan are presented in the following tables. We have presented estimates for the dredging option only, since we believe that it is the preferred method in terms of both feasibility and price.

Table 10.1 QUANTITY AND COST ESTIMATES: POND EL. 134 FEET

Item	Unit	Quantity	Unit Cost	Amount
1. Moving tailings	yd^3	640,000	$3.00	$1,920,000.00
2. Decant Modifications	LS	1	$2,000.00	$2,000.00
3. Silt Curtain	LS	1	$4,000.00	$4,000.00
4. Batch Treatment	LS	1	$5,000.00	$5,000.00
5. Hydroseeding, Area B	yd^2	20,000	$0.40	$8,000.00
6. Short Term Monitoring Program	LS	1	$10,000.00	$10,000.00
			TOTAL	**$1,949,000.00**

Table 10.2 QUANTITY AND COST ESTIMATES: POND EL. 138 FEET

Item	Unit	Quantity	Unit Cost	Amount
1. Moving tailings	yd^3	282,000	$3.50	$ 987,000.00
2. Decant Modifications	LS	1	$3,000.00	$3,000.00
3. Dam Modifications	LS	1	$210,000.00	$210,000.00
4. Silt Curtain	LS	1	$4,000.00	$4,000.00
5. Batch Treatment	LS	1	$5,000.00	$5,000.00
6. Clearing	acre	27	$2,000 00	$54,000.00
7. Hydroseeding, Area B	yd^2	7,000	$0.40	$3,000.00
8. Short Term Monitoring Program	LS	1	$10,000.00	$10,000.00
			TOTAL	**$1,276,000.00**

Note:
1. *All unit costs in 1993 dollars.*
2. *Applicable GST and PST not included.*
3. *Final design and preparation costs of tender packages are not included.*
4. *LS = lump sum.*

11.0 CLOSING COMMENTS

Environmental components of this report have been prepared by Michael Crowell, Stewart Hamilton and Earle Hickey, assisted by Prof. Bill Freedman. Engineering aspects have been prepared by Demetri Georgiou, P. Eng. and John Brown, P. Eng. assisted by Paul Graham, P. Eng. The assistance provided by CBDC staff is acknowledged with thanks.

Respectfully submitted,

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