ENGINEERING DESIGN AND CONSTRUCTION REPORT PHASE IV - COMPOSITE SOIL COYER ACID WASTE ROCK STUDY HEATH STEELE MINES

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REPORT FOR

ENGINEERING DESIGN AND CONSTRUCTION
PHASE IV - COMPOSITE SOIL COVER
ACID WASTE ROCK STUDY
HEATH STEELE MINES

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Submitted to:

Heath Steele Mines
P.O. Box 400
Newcastle, N.B.
ElV 3M5

by:

AD1 Nolan Davis
1133 Regent Street, Suite 407
P.O. Box 44, Station "A"
Fredericton, N.B.
E3B 4Y2

Project Manager: Michael D. Riley
Reviewed By: Alan Bell
Date: November 15.1994

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Executive Summary

A 130 cm thick composite soil cover was constructed on an experimental waste-rock pile at the Heath Steele Mines site near Newcastle, New Brunswick. The cover consists of a 30 cm thick sand base, a 60 cm thick compacted glacial till, a 30 cm thick granular layer, and a final 10 cm thick gravel layer for erosion protection. The till was compacted on the sand base in three finished lifts each of 20 cm thickness. Results of a preconstructed pad test indicated six passes of a 5 tonne vibratory compactor were required to attain the design specifications of 95 percent of the Modified Proctor maximum dry density at a moulding water content of 2-3 percent wet of the optimum. These compaction specifications also ensure that the till has a degree of water saturation of at least 95 percent, which is required to reduce oxygen and acid fluxes in the underlying pile. Quality control measures were taken during the construction to ensure the specifications were followed. Monitoring instrumentation was installed during the construction of the cover.

Results indicate a reduction in gaseous oxygen concentrations in the pile from 20 percent before cover to about 1 percent after cover placement. The decreased oxygen penetration implies reduced oxygen flux and acid production. Volumetric water-contents averaged about 32 percent in the till immediately following cover installation and 7 months later. The water-content data are corroborated by soil suction measurements. Temperatures in the pile have decreased following cover installation but appear to be more influenced by climatic variability than by a decrease in heat production and hence sulphide mineral oxidation. Observed discharge from two lysimeters, installed below the cover indicate infiltration of 2 percent of precipitation during a 55-day period when rainfall was heavy. The volume of the seepage has been reduced but the quality from the pile has not changed since cover installation. Further monitoring will be required to confirm the reduction in acid production.

Sommaire

Une couverture de sol composite de 130 cm d'epaisseur a été construit sur une pile expérimentale de stériles sur le site de la mine Heath Steele près de Newcastle au Nouveau-Brunswick. La couverture consiste d'une couche de fondation de sable de 30 cm d'epaisseur, un till glaciaire compacté de 60 cm, un sol granulaire de 30 cm, et finalement une couche de gravier de 10 cm d'epaisseur comme protection contre l'érosion. Le till a éte mis en place sur la fondation de sable en trois couches compactées de 20 cm d'epaisseur. Les résultats d'une surface d'essai avant la construction ont indique que six passes au compacteur vibrateur de 5 tonnes étaient nécessaires pour atteindre les devis de compactage, ce qui correspond à 95 pourcent de la densité sèche maximale du Proctor modifié et à une teneur en eau de mise en place de 2-3 pourcent du côté humide de l'optimum. Ces critères assurent également que le till ait un degré de saturation en eau d'au moins 95 pourcent, requis pour réduire les flux d'oxygene et d'acide dans la pile sous-jacente. Des mesures de contrôle de qualite ont été prises au cours de la construction afin d'assurer le respect des plans et devis. Des instruments de mesures ont aussi été installés durant la construction de la couverture.

Les résultats indiquent une reduction des concentrations d'oxygene gazeux dans les stériles, passant de 20 pourcent avant la mise en place de la couverture à 1 pourcent après la mise en place de la couverture. La diminution de la penetration d'oxygene indique implicitement une reduction du flux d'oxygène et de la production d'acide. Les teneurs en eau volumétriques étaient en moyenne de 32 pourcent dans le till, immédiatement après la mise en place de la couverture ainsi que 7 mois plus tard. Les données de teneur en eau concordent avec les mesures de succion dans le sol. Les temperatures dans l'halde ont diminué suite à l'installation de la couverture, mais semblent être plus intluencées par les variations climatiques que par la diminution de la production de chaleur pouvant provenir de l'oxydation du soufre present dans les stériles miniers. Les debits observes dans deux lysimbtres installés sous la couverture indiquent un taux d'infiltration d'environ 2 pourcent de la precipitation au cours d'une période de 55 jours durant laquelle la pluie a été abondante. Le volume d'infiltration a été réduit et la qualité du lixiviat après l'installation de la couverture n'a pas change. 11 est necessaires que le suivi de la couverture soit prolongé afin de confirmer la reduction d'acide.

1.0 INTRODUCTION

Sulphide ore mining in Northeast New Brunswick has produced waste rock piles containing acid generating pyritic rock. The Heath Steele Mines (HSM) property located in this region was developed in the late 1950's before the implications of acid mine drainage (AMD) were fully appreciated. The property presently contains in excess of 20 acid generating waste rock piles. Since this region of New Brunswick is famous for salmon runs and sports fishing, the presence of acid generating waste rock within the watersheds is a major concern. Under the Clean Environment Act., (NB Regulation 87-83) regulatory agencies and mine operators require a practical, economical solution to the waste rock problem.

The "Heath Steele Waste Rock Study," which is registered within the national MEND Program, has been in progress since 1988. The objectives of the project, which is currently funded by Brunswick Mining and Smelting Corporation (BMS) and both the governments of New Brunswick and Canada, are to evaluate the performance of a soil cover placed over an existing acid waste rock pile at HSM, and to assess the cover's effectiveness as a method for long term management of acid generating waste rock. The study was developed in four phases with funding for the first three phases approved on December 16, 1988. The four phases of the overall project are as follows:

Phase	I	-	Selection of four waste rock piles for monitoring and evaluation
Phase	II	-	Installation of monitoring equipment in the four piles identified in Phase I to define waste rock characteristics and background data
Phase	III	-	Geotechnical and column testing to evaluate the performance characteristics of potential covers
Phase	IV	-	Placement of soil cover and performance monitoring

Phase I was completed in the summer of 1988 with Phases II and III completed at the end of 1990. The final report (MEND Project 2.3 1. la) containing Phases I to III is available from MEND.

On February 28, 1991, a proposal was submitted by HSM for Phase IV of the study for which funding was approved on July 4, 1991. The following report, which documents the results of the project to the end of October, 1993, specifically addresses the engineering design and construction of the composite soil cover placed on waste rock Pile 7/12 in August and September 1991. It also presents the subsequent two years of performance monitoring data, including reference Pile 18.

2.0 BACKGROUND

2.1 General

In Phases I and II of the "Heath Steele Waste Rock Study", four selected waste rock piles, identified as Pile 1 8A, 18B, 17 and 7/12, were instrumented and monitored to define the background conditions related to the acid generation process. The instrument clusters to measure both temperature and oxygen concentrations in each of the four selected waste rock piles were installed at nominal l-2 metre depth intervals, The temperature and oxygen concentrations were measured in waste rock Piles 1 8A, 18B and 17 from November 1988 and Pile 7/12 from June 1989 on a monthly basis to September 199 1.

It is recognized that oxygen transport is the dominant rate-controlling mechanism in most acid generating waste rock piles and that the major oxygen transport mechanism is gas transfer through the pore spaces of the pile. Gas transfer is by a combination of diffusion, convection and advection, with the inter-relationships between these mechanisms dependent on factors such as pile geometry, pile composition, pile placement technique and pile history. A key finding of Phase II of the study was that the depth profiles of oxygen and temperature for each of the four piles monitored differed significantly from pile to pile yet were reasonably consistent within a given pile. It is apparent that the manner in which gas transfer occurs within each of the HSM waste rock piles is different despite many similar characteristics and geographic proximity.

The waste rock piles at the HSM site have already oxidized and presumably contain large volumes of stored acidity. Furthermore, a substantial amount of unoxidized sulphide minerals is present within the HSM waste rock piles, as shown in the mineralogical data (Nolan Davis, 1990). This unoxidized material will oxidize upon contact with oxygen and water. Therefore, a management system for the acid generating waste rock at HSM must not only contain the stored acidity but also inhibit the oxidation process and thus reduce the volume of generated mine AMD. An effective cover system will control both the water and the rate of oxygen infiltration into the waste rock pile.

The design of a saturated soil cover required the development of methodologies for predicting its long term hydraulic and diffusive behaviour. Phase III of the "Heath Steele Waste Rock Study", carried out by Noranda Technology Centre (NTC), involved the development of an appropriate soil cover design based on the performance characteristics of natural soils in the vicinity of HSM. The NTC studies indicated that a three layer composite soil cover, consisting of a fine grained saturated glacial till sandwiched between two coarse-grained granular layers would be an effective management approach. Glacial till, when compacted at a water content slightly more wet than the optimum, has a low hydraulic conductivity and will also provide an effective oxygen barrier. The coarse-grained granular layers above and below the glacial till will help prevent it from drying out.

2.2 Waste Rock Pile 7/12

Waste rock Pile 7/12 is located approximately 1 km from the HSM mill complex off the main Haul Road. The pile was moved to this site in June 1989 as part of the ongoing monitoring program at HSM.

Pile 7/12 was moved to an engineered base consisting of an impermeable Fabrene membrane placed on a sand base and then covered by a protective layer of 150 cm sand. The pile contains approximately 14,000 tonnes of pyritic waste rock with a maximum depth of 5.0 m. The pile is instrumented with seven sets of thermocouples and six sets of pore gas clusters. Perimeter ditching and membrane placement was completed to allow for separate collection of surface runoff and underdrain flow. Pile 7/12, is the only pile at HSM for which a water and contaminant balance can be determined and was selected as the pile upon which the composite soil cover would be tested.

A site plan of the HSM property showing the location of the study piles is shown in Figure 2-1.

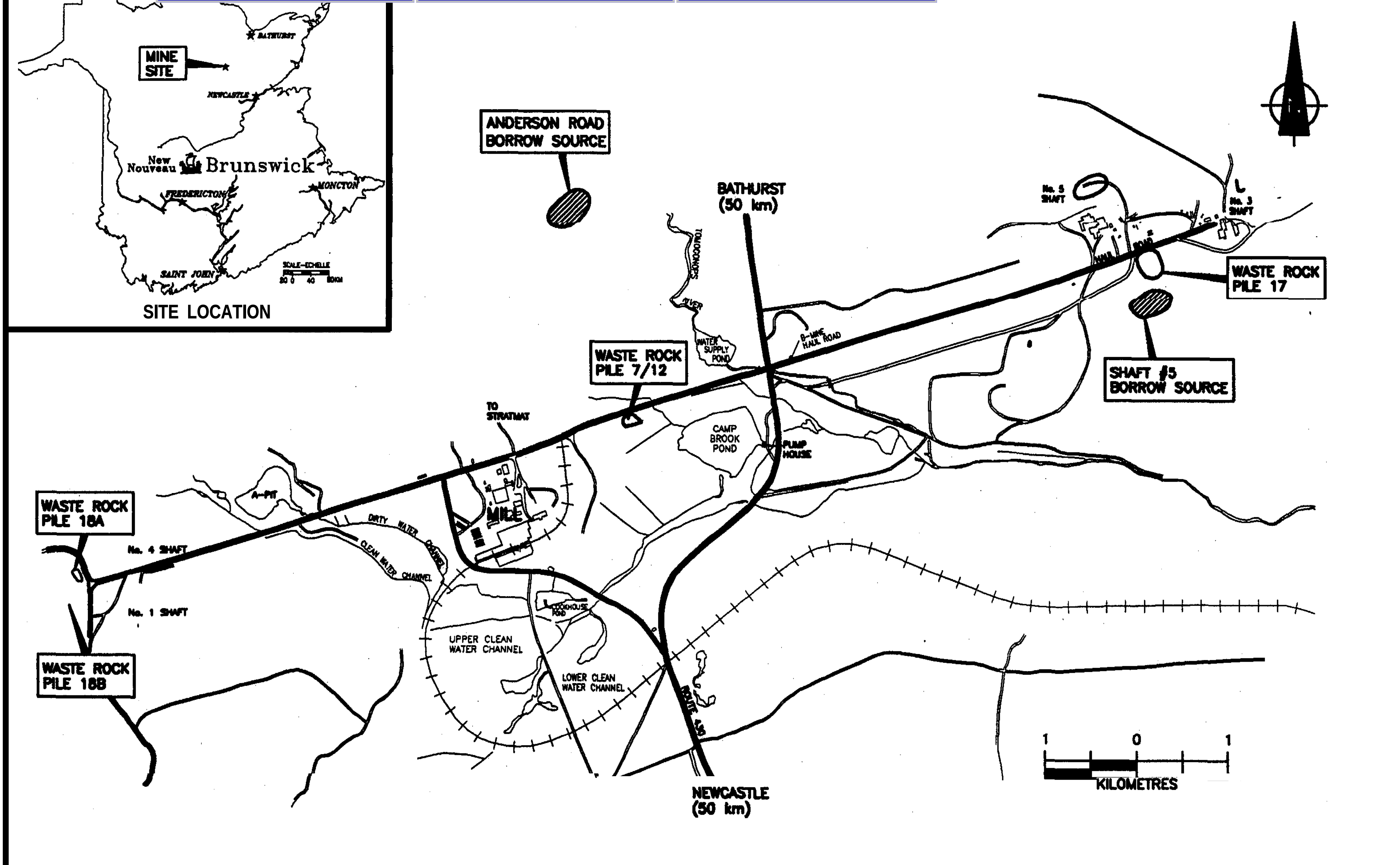

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FIGURE 2-1

SITE PLAN – HEATH STEELE MINES

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3.0 COVER DESIGN

3.1 Design Rationale

NTC evaluated a number of soil cover designs for placement over Pile **7/12**. Studies indicated that an initially saturated single soil layer placed on a waste rock pile will ultimately desaturate by drainage and moisture losses due to evaporation. The **diffusion** coefficient of oxygen for such a system, although initially low, will increase with time, resulting in increased oxygen diffision into the pile. Furthermore, a cover with only one soil layer could potentially dry out and crack over time, especially if the soil has a high clay content.

For Pile **7/12,** NTC proposed a composite soil cover consisting of a fine **grained** saturated glacial till sandwiched between two coarse **grained** granular layers as an effective oxygen barrier based on the following rationale:

i) The base granular material will drain to residual saturation before the till. At residual saturation, the granular layer is unsaturated, thus minimizing the hydraulic conductivity and maintaining saturation of the till during dry periods.

ii) The fine **grained** glacial till compacted at a moisture content slightly wet of optimum can be expected to have a low hydraulic conductivity while acting as an effective moisture and oxygen barrier.

iii) The overlying coarse **grained** granular layer is required to prevent the till layer from **drying** out at the surface as well as acting as a recharge layer to the underlying till.

A **surficial** coarse-grained granular layer for erosion protection was also included in the design.

The NTC designed composite soil cover adopted for the Phase IV Study requires a 30 cm base granular layer, a 60 cm saturated glacial till, a 30 cm overlying coarse-grained granular layer and a 10 cm thick erosion protection layer. The thickness of the different layers are designed to maintain the glacial till saturated for a minimum of 50 days without precipitation.

3.2 Engineering Design

3.2.1 Engineering Drawings

The engineering design involved the preparation of engineering drawings and project specifications required for the actual construction of the cover based on the design criteria provided by NTC. During the summer of 1991, a total of three engineering drawings plus project specifications were completed by AD1 Nolan Davis Inc., formerly Nolan Davis and Associates (NB) Ltd.

The AD1 Nolan Davis' Drawing Nos F91-057-1, F91-057-2, and F91-057-3 were produced as part of the engineering design. The first drawing, F91-057-1, presents the results of the site surveys carried out on July 12, 1991. AD1 Nolan Davis' Drawings Nos F91-057-2 and F91-057-3, show construction and instrumentation details respectively. The final slope of the completed pile cover is 3: 1 (Horizontal: Vertical) with the layer thickness as previously noted. Special attention was also given to sealing the glacial till to the existing Fabrene membrane. The three drawings were included as part of the tender package provided to local contractors during tendering and these were used as engineering construction drawings during the subsequent cover placement. Reduced scale reproductions of the drawings are appended at the end of this report.

3.2.2 Project Specifications

The project specifications prepared by AD1 Nolan Davis defined the specific requirements for each of the following identified work items:

Borrow Source;
Surface Preparation;
Sand Base;
Impermeable Cover;
Granular Cover;
Erosion Protection; and
Leachate Collection.

A copy of the project specifications is provided in Appendix I.

The following sections provide additional details on the specific project requirements for the work items noted above.

Borrow Source

The construction of the cover required that a source of glacial till be found for the impermeable cover. The selected borrow source was identified by HSM.

Surface Preparation

The initial task in the placement of the composite soil cover was the surface preparation of waste rock Pile 7/12. This included filling all depressions and large voids on the side slopes and top of the pile while removing any high points by grading. Depressions and large voids were infilled with crushed rock or waste rock from other areas of the pile. The crushed rock for infilling was specified as crushed rock meeting New Brunswick Department of Transportation specifications for minus 37.5 mm crushed rock for both gradation and quality.

Sand Base

The sand base was specified to have a minimum thickness of 30 cm over the entire waste rock pile meeting the following gradation requirements:

60% ranging between 0.5 and 4.0 mm diameter
D_{10} ranging between 0.35 and 0.40 mm diameter

Specifications required that the sand base be placed and compacted to 92 percent Modified Proctor density (ASTM D 1557) with the final finished surface to be flat with surface irregularities within ±25 mm average grade.

Impermeable Cover

The impermeable cover was specified as a local glacial till soil meeting the following specifications:

- **Grain Size (ASTM D 422)**
  Maximum particle size of 30 mm
  Minimum percent finer than 0.075 mm particle size of 40% by dry weight
  Minimum percent finer than 0.002 mm particle size of 10% by dry weight
  D_{10} ranging between 0.001 and 0.003 mm particle size

- **Moisture Content (ASTM D 2216)**
  -2 to +4% of optimum moisture content

- **Atterberg Limits (ASTM D 4318)**
  Liquid Limit > 30 and Plasticity Index > 15

- **Moisture Density Relations (ASTM D 1557)**
  Soil compacted to 95% of maximum dry Modified Proctor density at a moisture content of -2 to +4% of optimum.

- **Hydraulic Conductivity (ASTM D 2434)**
  Coefficient of permeability (k) 1 x 10^{-7} cm/sec or less,

Specifications required that the glacial till cover be placed in maximum 20 cm thick lifts and compacted to 95% of its Modified Proctor density with the final compacted surface of the glacial till to be flat with surface irregularities within ± 25 mm of average grade.

A tight seal between the existing base Fabrene membrane and glacial till cover was also specified (AD1 Nolan Davis' Drawing No. F91-057-2).

Granular Cover

The 30 cm thick granular cover was specified as a well graded pit run sand and gravel or equivalent crushed rock meeting the following requirements:

Maximum particle size of 50 mm
Maximum percent finer than 0.075 mm size of 8% by weight

Specifications required the granular cover to be placed in 15 cm thick lifts and compacted to 92 percent of its Modified Proctor density (ASTM 1557).

Erosion Protection

Erosion protection to be placed over the complete soil cover was specified as a minimum 10 cm thick layer of coarse gravel or crushed rock having a maximum particle size of 75 mm and 15 percent by weight finer than 4.75 mm.

Leachate Collection

Final design required that the leachate collected from within the pile and cover seepage from the two installed lysimeters be directed via installed piping to an outfall structure located at the base of Pile 7/12 on the north face. Water samples are collected from the outfall structure which drains to Camp Brook Pond via a 100 mm PVC pipe.

3.3 Construction Materials

3.3.1 Granular *Soils*

Contractors intending to submit a proposal for construction of the composite soil cover were required to submit samples of granular materials they proposed to use. The samples were forwarded to NTC for acid generating potential testing. A total of 9 samples from various sources were tested by NTC and the test results indicated that the granular materials were not acid generating material.

The granular soils used for sand base, granular cover and erosion protection were all screened aggregates from the Shaddick Lake deposit located 15 km from the site.

3.3.2 Glacial Till

In the summer of 1988, glacial till samples were collected from five different sites in the vicinity of HSM by NTC and tested for use in a composite soil cover. The results of this testing and analysis are presented in MEND Project Report 2.3 1. la. Of the five samples tested, the recommended till source was from the Stratmat CNE Extension site. However, it was concluded that the deposit was uneconomical because of the haul distance (20 km) and poor condition of the access road.

In late July early August 1991, HSM carried out an extensive survey of the mine property in the vicinity of Pile 7/12 for alternative source of glacial till. The field surveys, carried out using a pionjar drill, identified the Anderson Road Borrow Pit as a possible source, at a haul distance of approximately 3.2 km from the site (see Figure 2-l). Cost proposals from the contractors for construction of the composite cover on Pile 7/12 were based on using glacial till from this source.

A third source of glacial till, located 2.5 km east of Pile 7/12, was identified by HSM prior to the start of construction. Testing carried out by NTC found this source, referred to as the Shaft No. 5 Borrow Source, suitable for use in cover construction, This glacial till source was ultimately selected for use. Its location is shown on Figure 2-1.

4.0 COVER CONSTRUCTION

4.1 Contractor Selection

Eight contractors from the Newcastle-Bathurst area were invited to submit proposals for the construction of the cover. At an August 12, 1991 site meeting, the project requirements were presented to the contractors. Four proposals were received with the proposal submitted by ATCO Construction of Newcastle selected on the basis of both price and experience.

4.2 Construction Quality Control

The composite soil cover was placed on Pile 7/12 during the period August 28 to September 19, 1991. The work was carried out under the full time supervision of AD1 Nolan Davis personnel who maintained daily records of site activities, inspected each of the placed soil layers and carried out in situ density testing and laboratory testing as required.

The quality control procedures implemented by AD1 Nolan Davis during construction to ensure project specifications were achieved. This included:

i) Laboratory testing was carried out at an on-site temporary laboratory to ensure that the soils provided met project requirements for gradation. The glacial till was also tested on site for moisture content and Atterburg limits.

ii) Moisture density relations tests were conducted prior to the placement of each of the soils to determine the soil's maximum dry density and optimum moisture content. In the case of the glacial till, a second test was carried out during construction.

iii) On-site stockpiles of each material to be placed were visually inspected on a regular basis for consistency of quality.

iv) The thickness of each placed layer was regularly measured prior to placement of the next layer using survey level equipment.

v) The compaction of each layer was monitored to ensure the minimum number of passes of the vibratory compactor were completed.

vi) In-situ density testing utilizing a nuclear density gauge were conducted during the placing operations to ensure that all soils were properly compacted at the specified moisture contents and required density.

vii) The calibration of the nuclear density gauge was checked daily prior to usage.

The results of the laboratory testing are summarized in the following sections and are included in Appendix II. In situ density test results are presented in Appendix III.

4.3 Construction Activities

4.3.1 Surface Preparation

The initial task for the cover placement was the preparation of the surface of Pile 7/12. For the pile shaping, a Caterpillar 215 hydraulic excavator, working from the top of the pile was used to remove the high points on the side slopes while infilling surface voids and depressions. The top of the pile was levelled with the hydraulic excavator and a small Caterpillar D3 tractor. Two holes, each measuring about 3.5 x 2 x 1.2 m were excavated at the top of the pile for the placement of two lysiieters. The excavated material was utilized for infilling the voids around the lysimeters. About 50 tonnes of crushed rock were used to fill voids and depressions in some areas of the surface.

The project specifications required that a Fabrene membrane liner be placed at the base of the pile to have a tight seal between the Fabrene liner and the glacial till. As part of the surface preparation, sand and gravel around the perimeter of the pile was excavated manually to expose approximately 0.3 m of membrane at the base of the pile. A double-layered 6 mil polyethylene was placed over the exposed Fabrene membrane and keyed into the glacial till core of the composite soil cover, as indicated on Figure 4-l. The polyethylene was put as an additional measure to improve the seal between the composite soil cover and the Fabrene membrane.

The final prepared surfaces of Pile 7/12 were relatively flat with all major voids infilled and high points removed. No new waste rock was added to the pile during surface preparation.

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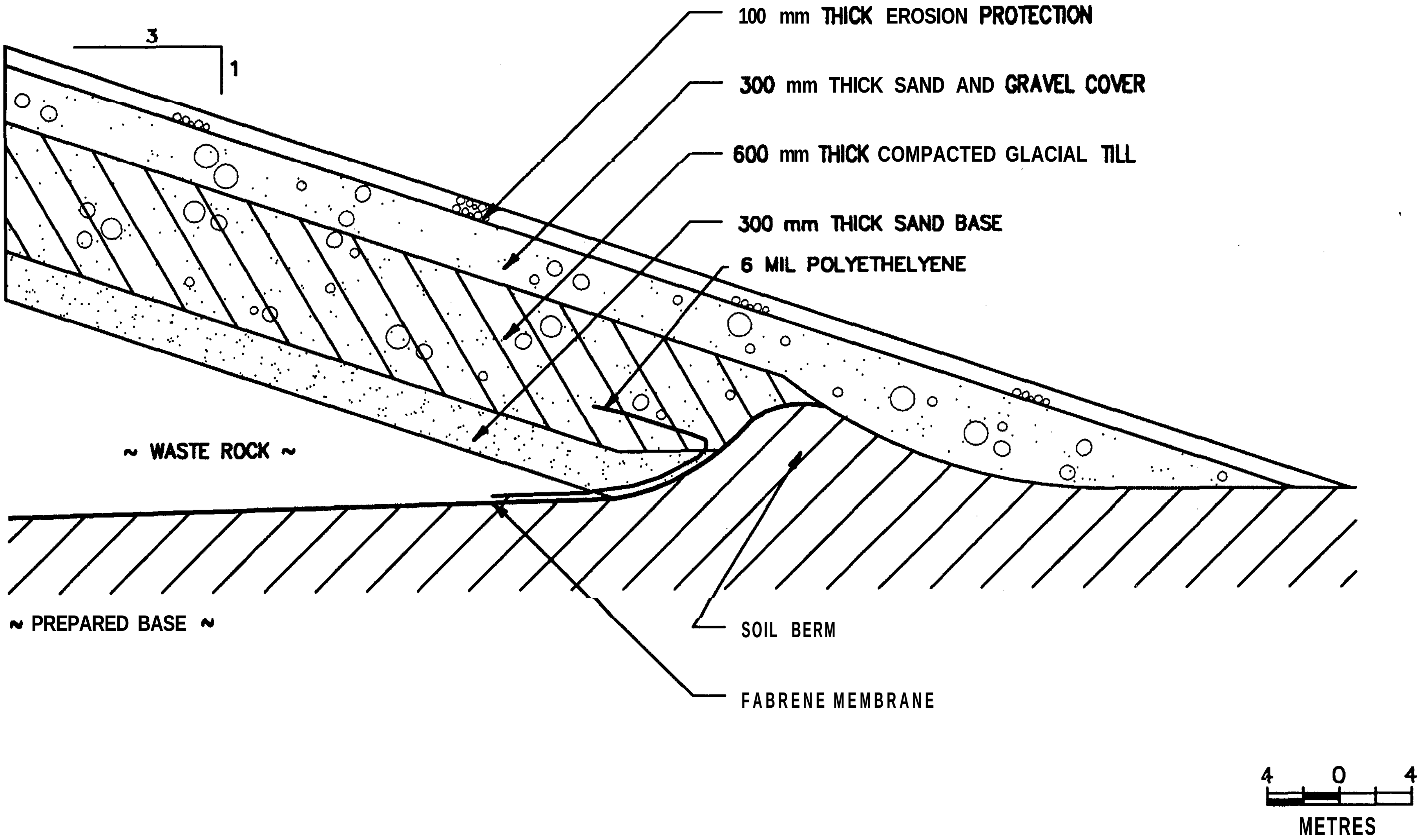

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FIGURE 4-1

COVER CONSTRUCTION DETAIL

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4.3.2 Sand Base

The prepared surface of Pile 7/12 was covered with a minimum 30 cm thick layer of medium to coarse sand from the Shaddick Lake deposit. The sand was placed with a front end loader, spread with a small Case 3 10 tractor, and compacted with a 5 tonne vibratory compactor. A minimum of four passes was used to compact the sand base with water applied to assist in the compaction to the required density.

The final side slope of the sand base was graded to 3H: 1V slope as required in the design. In areas near the outer edges of the pile, a layer of greater than 30 cm thickness was provided to maintain the required grades.

The results of one grain size analysis carried out on the sand base material, shown on Figure II-l of Appendix II, shows that the sand is comprised of 4 percent gravel particles, 90 percent sand particles, and 6 percent silt and clay size particles.

The compacted sand base met the design criteria as specified by NTC for gradation and was compacted to the specified in-situ density.

4.3.3 Composite Cover

4.3.3.1 Borrow Source

The borrow source for the glacial till was located approximately 2.5 km east of Pile 7/12 and to the immediate south of waste rock Pile 17. Seven test pits or trenches were completed in the deposit by HSM using a track mounted hydraulic excavator to delineate the extent of the deposit. Visual and tactile inspection of the till deposit indicated that the deposit was sand and gravel within a clayey silt matrix typical of glacial deposits in this area. Cobbles and boulders up to 1 m in diameter were noted throughout the deposit. Representative samples of glacial till from the test pits were forwarded to NTC for analysis. The results of four grain size analyses conducted on these samples, shown in Figure II-2 of Appendix II, indicated the tii to comprise of 10-28 percent gravel, 10-29 percent sand, 39-48 percent silt and 5-18 percent clay size particles. The natural moisture content of the test samples ranged from 15.8-24.8 percent. On the basis of this testing, the soil was approved for use by NTC. Based on observations during the field investigation, the amount of the glacial till available was judged to be sufficient (1500 m^3) for the construction of the composite soil cover.

During placement of the glacial till, representative samples were recovered daily for subsequent laboratory analysis. The results of seven grain size analyses carried out on these samples, shown on Figures II-3 and II-4 of Appendix II, indicated that the glacial till was comprised of 13-37 percent gravel, 25-35 percent sand, 25-43 percent silt and 7-14 percent clay size particles. Most cobbles and boulders found in the till were removed by the contractor prior to placement and compacting.

The results of two Moisture Density Relations (ASTM D1557) tests carried out on representative samples of the glacial till are presented in Figure II-5 of Appendix II. The optimum moisture content was determined to be 13.5 percent with a maximum dry density of 1965 kg/m^3.

The results of three Atterburg limit tests carried out on the glacial till samples indicate the soil to have a liquid limit of 27-28 and a plasticity index of 5-6.

The glacial till met the design criteria as specified by NTC for Atterburg limits and generally, NTC gradation requirements. Three of the samples tested had a percentage material finer than 0.002 mm particle size (clay size) less than the specified 10 percent while exceeding the minimum 40 percent specified minimum total tines (silt and clay size particles) content. With the high percentage of total fines, the low percentage clay size particles it is not expected to impact on the long term cover performance.

4.3.3.2 Placement

Prior to placement of glacial till on the Pile 7/12, a field test strip measuring approximately 5 x 10 m in plan was constructed at the southwest comer of Pile 7/12 to test the method of placement and compaction technique. Glacial till was placed over the test strip in maximum 20 cm thick lifts and compacted with the 5 tonne vibratory compactor with in-situ density testing carried out after each pass of the compactor. A total of three layers of till, equalling approximately 60 cm in thickness were placed and compacted. The results of the in situ density tests indicated that a minimum of six passes of the 5 tonne vibratory compactor would be required to achieve the specified Modified Proctor density.

On September 3, 1993, the contractor cleared and grubbed the borrow source area and-started excavating the glacial till. The material was trucked to Pile 7/12 where it was stockpiled at the base of the pile. The moisture content of the glacial till at the source was found to be 5% or more above the optimum. Consequently, the glacial till was allowed to dry in the stockpile prior to placement. From the stockpile, the dried glacial till was transported to Pile 7/12 with a Hough payloader and spread with a small bulldozer. Cobbles and boulders in the glacial till were removed manually, both from the stockpiled area and as the till was being placed. The glacial till was placed in maximum 20 cm lifts and compacted with the 5 tonne vibratory compactor.

Approximately 1500 m^3 of glacial till was placed and compacted on Pile 7/12 from September 4 to September 14, 1991. The weather during the period from September 3 to 10 was generally sunny with moderate temperatures, allowing for placement of the glacial till on the west, south and east slopes of the pile, and the initial top layer of the pile. However a major rainstorm on September 10, 1991 resulted in excess moisture in this top layer. Subsequent vibratory movement during glacial till placement caused this excess moisture to "pump up" through the till, causing the soil to be very soft and spongy in places. The soil as placed was deemed unacceptable by AD1 Nolan Davis site personnel. As a result, the glacial till on the top of the pile was removed on September 14, allowed to dry, and then, replaced and compacted. The north slope was completed last.

Ninety-four in-situ tests were carried out on the compacted glacial till. The results of this testing, provided in Appendix III, indicate the degree of compaction to range from 93 to 101 percent of the Modified Proctor density at moisture contents ranging from 14.5 percent to 20.3 percent and averaging 17.0 percent. Over several areas where low density tests were measured, additional compaction effort was applied prior to placement of the next layer.

Based on the results of quality control testing, plus observations by on-site AD1 Nolan Davis personnel during construction, the compacted glacial till was accepted by AD1 Nolan Davis as meeting the project specification requirements. While it was not possible to remove 100 percent of the oversize material, the small amount of oversize material that was not removed from the glacial till is not expected to significantly impact the long term performance of the cover.

4.3.4 Granular Cover and Erosion Protection

A granular cover consisting of clean sand and gravel was placed over the entire pile. Grain size analysis, shown on Figure II-6 of Appendix II, indicate the sand and gravel to comprise of 60 percent gravel, 38 percent sand and 2 percent silt and clay sii particles. The results of one Moisture Density Relation Test (ASTM D 1557) shown in Figure II-7 of Appendix II indicate the sand and gravel to have a maximum dry density of 2245 kg/m^3 at an optimum moisture content of 6.6 percent.

The sand and gravel was placed in 15-20 cm thick lifts and compacted to a minimum 92 percent of its maximum dry Modified Proctor density. This sand and gravel arrived on site in a dry condition, making it necessary to add moisture during placement to achieve the specified in situ density. Sixteen in situ density tests were conducted on the compacted sand and gravel. The results of this testing provided in Appendix III indicate degree of compaction ranging from 91 to 95 percent, averaging 93.2 percent of Modified Proctor density at moisture contents ranging from 3.0 to 6.4 percent, averaging 5.5 percent.

A final 100 mm erosion protection layer, consisting of a well graded gravel having a maximum particle size of 75 mm, was placed over the pile and compacted with several passes of the vibratory roller.

Upon completion of the cover, the entire test site was graded, with all debris, roots, branches and other deleterious materials removed and appropriately disposed off-site.

On October 23, 1991, Pile 7/12 was surveyed using standard survey techniques and the same baseline and elevation datums as the initial site survey. The results of this survey are shown on attached AD1 Nolan Davis Drawing No. F91-057-1.

4.4 Lysimeter Installation

Prior to placement of the sand base, two lysimeters constructed of half sections of two metre diameter High Pressure pipe were installed in excavations on the top of Pile 7/12 at the northeast and northwest corners. The lysimeters, each measuring 2.0 x 3.1 m in plan with the longer dimension orientated in the north-south direction, were sloped downward at a 2 percent gradient to promote drainage to the outfall structure at the north side of the pile. The lysimeter excavations were lined with sand to protect the lysimeters. The interior of the lysimeter located in the northeast comer of the pile was backfilled with sand while the lysimeter in the northwest comer was backfilled with a clean crushed stone. Material in both lysimeters was saturated before the sand base was placed overtop. Piping from both lysimeters was trenched into the sand base layer to the base of Pile 7/12 for connection to the outfall structure.

4.5 Outfall Structure

A fabricated steel outfall structure was installed at the base of the pile on the north side to which four collection pipes from within the pile were connected. The four 50 mm diameter collection pipes include two draining the lysimeters, one from the perimeter ditch at the base of the pile and one from the centre of the pile. Traps and a PVC gate valve were installed on each of the collection pipes at the entrance of the outfall structure to ensure oxygen free condition for collected samples.

The outfall structure, with overall dimensions of 1.8 x 1.0 x 0.7 m high, has four internal compartments, each approximately 0.2 x 0.3 x 0.3 m, into which the pipes drain. The cover of the outfall structure is insulated with 50 mm styrofoam while all internal exposed surfaces are covered with fibreglass epoxy. A sketch of the outfall structure is shown on Figure 4-2. The separate chambers in the outfall structure enables the discharge and chemistry from each pipe to be monitored individually. Overflow from the outfall structure is collected and gravity fed to the Camp Brook Pond via a 100 mm diameter drainage pipe.

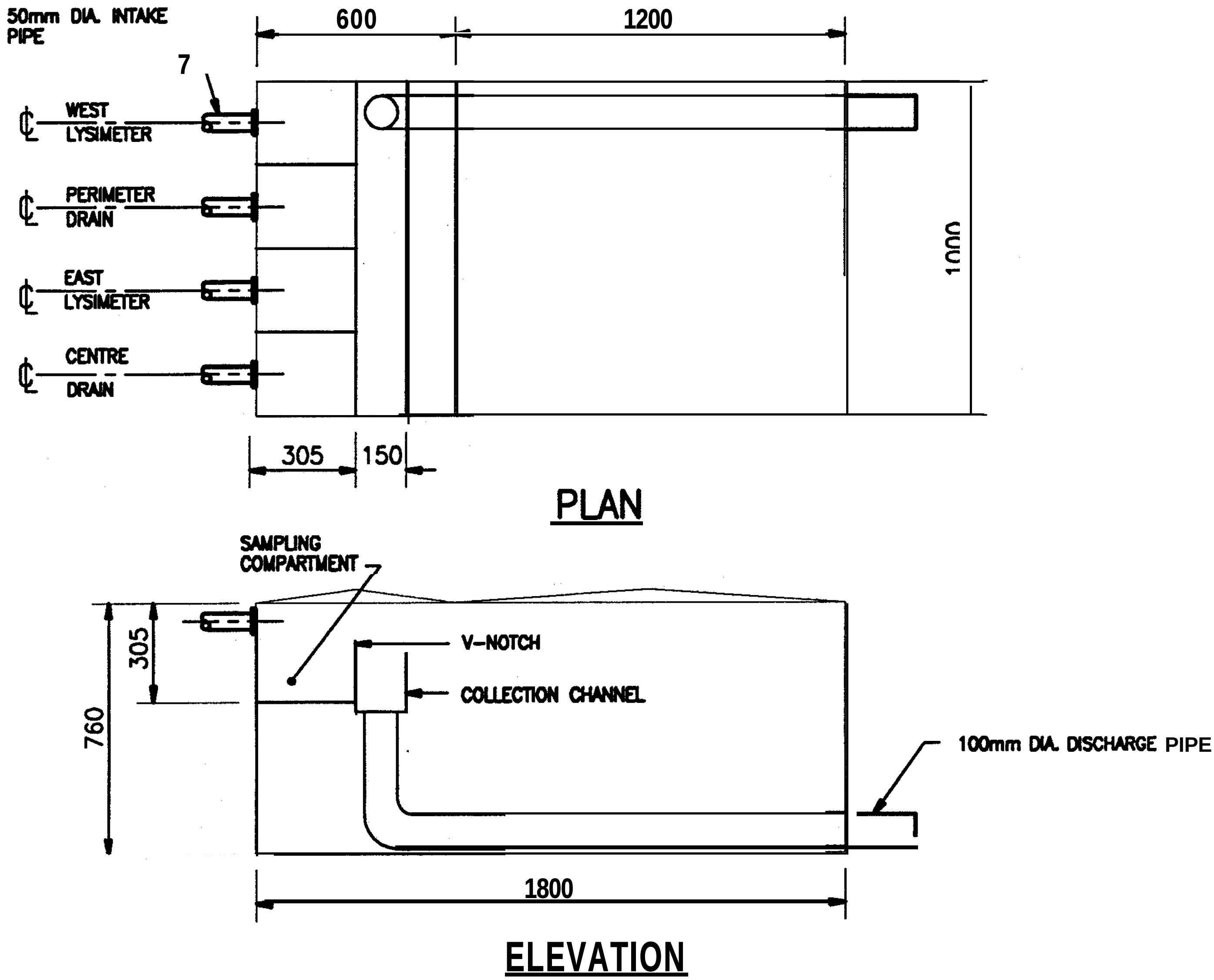
4.6 In Situ Permeability Testing

Three in situ permeability tests were carried out on the compacted glacial till by NTC during the period of September 13 to 15, 1991. The testing was carried out with an Air Entry Permeameter (AEP).

The initial permeability test on the glacial till on top of Pile 7/12 was terminated due to excessive water loss. The loss cf water is presumed to be caused by the presence of gravel in the till within the excavation ring for the AEP which presumably caused quick channelling of the water. The area tested was subsequently re-excavated, allowed to dry, and then recompacted.

Two successful AEP tests were conducted on top of Pile 7/12 in material similar to the initial unsuccessful test. Positive seating of the AEP was obtained for these two tests although the presence of gravel was also noted. The results indicated average hydraulic conductivity values of 9 x 10^{-8} and 2 x 10^{-8} cm/sec which is considered typical of the glacial till material placed.

The measured in-situ hydraulic conductivity are both below the maximum (1 x 10” cm/sec) as specified in the NTC design.



NOTE :
1. ALL DIMESIONS ARE IN MILLIMETERS
2. ALL INTERIOR SURFACES COVERED WITH FIBERGLASS EPOXY.

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FIGURE 4-2

OUTFALL STRUCTURE

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4.7 Summary of Cover Construction

The composite soil cover as designed by NTC was placed over Pile 7/12 at HSM during the period August 28-September 19, 1991 by Atco Construction of Newcastle, N.B. A summary of construction activities is as follows:

- The surface of Pile 7/12 was graded with mostly waste rock from the pile to fill depressions while flattening high points. A total of 50 tonnes of non-acid generating minus 37.5 mm minus crushed rock was also used in the surface preparation.

- A well graded sand meeting project specifications for gradation was placed and compacted to minimum 92 percent Modified Proctor density over the pile. Minimum thickness of the sand was 30 cm.

- Glacial till from a borrow source 2.5 km from Pile 7/12 was placed over the waste rock pile in maximum 20 cm lifts and compacted to an average of 96 percent Modified Proctor density at moisture contents ranging between 1 and 4 percent above optimum.

- Grain size analyses of the glacial till found the material to generally meet project specifications for gradation with the exception of several samples which had less than the minimum percentage of clay size particles. These samples however, had above the minimum special total silt and clay size content.

- The contractor removed most of the oversize material in the glacial till prior to placement. Because the material was placed in three separate layers, any oversize material which was not removed by the contractor is not expected to impact on the overall cover performance.

- Granular soils provided for both the granular cover and erosion protection met project specifications for gradation and were placed and compacted to the specified layer thickness and in situ densities.

The results of site quality control testing, plus observations made during construction, indicate that the composite soil cover had been constructed in accordance with project specifications.

5.0 MONITORING INSTRUMENTATION

5.1 Project Requirements

The objective of the monitoring program was to evaluate the rate of oxygen ingress into the cover and moisture infiltration through the cover and to continue monitoring the acid generating reaction processes within the pile by measuring temperature and oxygen concentrations. The monitoring program measured and evaluated the following parameters:

- Local precipitation and air temperatures
- Moisture, temperature and soil suction levels within the composite soil cover
- Oxygen levels within the pile
- Temperatures within the pile
- Volume of seepage through the composite soil cover
- Volume of leachate from the pile
- Chemistry of leachate from the pile

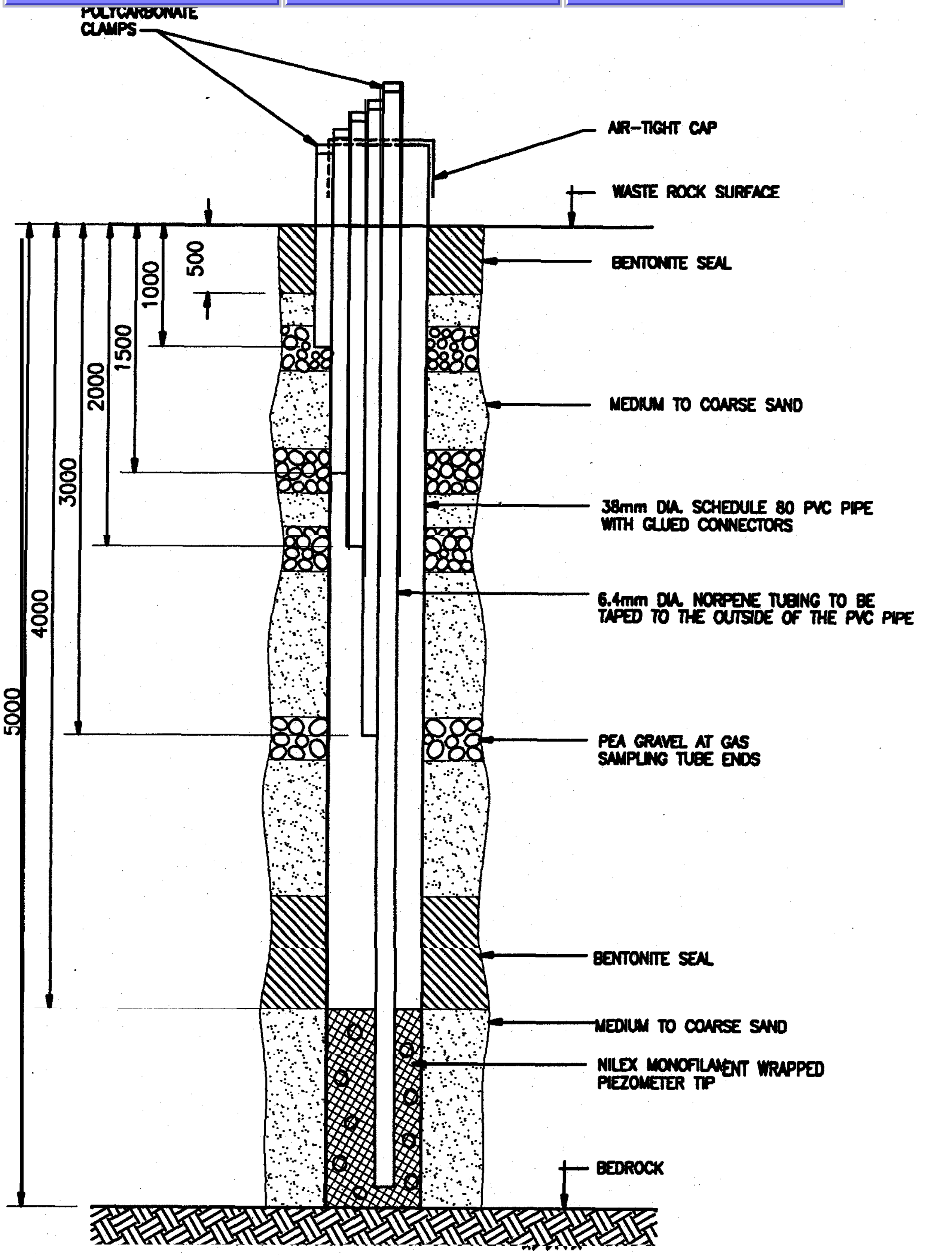
The following sections provide additional detail on the instrumentation and monitoring of Pile 7/12. Pile 18B was also monitored as a reference pile in conjunction with Pile 7/12.

5.2 Waste Rock Pile

5.2.1 Instrumentation Clusters

As part of Phase II of the Heath Steele Study, a number of instrumentation clusters were installed in selected waste rock piles to measure both pore gas and temperature along vertical profiles. The typical instrumentation clusters placed in 1989 at each sampling location in Pile 7/12 consisted of a 38 mm diameter PVC piping piezometer installed to 6.3 m depth with a series of neoprene pore gas monitoring tubes and temperature probes attached along the exterior perimeter of the piezometer (see Figure 5-l).

The thickness of the composite soil cover required extension of each piezometer and attached neoprene tubing, and thermocouples which was carried out by AD1 Nolan Davis personnel during cover placement. Bentonite pellets were placed around the PVC extensions which extended through the compacted glacial till to insure a seal between the cover and piezometer. The specific details of both the pore gas and temperature installations are described below.



NOT TO SCALE

ALL DIMENSIONS ARE IN MILLIMETRES UNLESS INDICATED OTHERWISE

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FIGURE 5-1

TYPICAL INSTRUMENTATION CLUSTER

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5.2.2 Pore Gas Measurement

A series of flexible non-collapsing neoprene rubber tubes attached to the outer circumference of the PVC piezometer are 'used to measure pore gas. Sampling ports are located at depths of approximately 2.3, 2.8, 3.3, 4.3, 5.3 and 6.3 m below the cover surface. The ends of the neoprene tubing extending above the cover are clamped closed at all times except during sampling events. The gaseous oxygen and CO, present in the pore gases are measured using low-volume portable analyzers (Teledyne Model 320A). During each monitoring event, the instrument is connected to the neoprene tubing and the tube clamp released. The instrument draws air through the tubing to the sensors located within the analyzer which. measure the percentage of oxygen within the pore gas. The gaseous oxygen is measured using a Teledyne Model 320A while the CO, is measured with a Telaire CO_2 meter.

5.2.3 Temperature Measurement

To monitor temperature within the waste rock, type K thermocouples were attached to the PVC piezometers at depths of approximately 1.6, 2.8, and 5.9 m below the cover surface. The type K thermocouples are fabricated to meet specific requirements for acid resistance and are certified as long-lasting for burial in contact with water. The type K thermocouples are well-suited to operate within the temperature conditions expected at the site. The thermocouples are calibrated for direct temperature reading in °C when connected to a Donnitor 90 digital thermometer.

5.3 Composite Soil Cover

During construction, sensors were installed by NTC within the composite soil cover to measure soil moisture content, temperature and matric potential (soil suction). The instrumentation was installed in the till layer, the granular cover and the sand base at two locations on top of the waste rock pile. A summary of the sensors and depth location below the surface of the composite soil cover is provided in Table 5-1.

TABLE 5-1
Monitoring Sensors, Pile 7/12

MONITORING SENSOR	PARAMETER MONITORED	LAYER	DEPTH BELOW COVER SURFACE (m)
TDR	Moisture Content	Granular Cover	0.1 to 0.4
		Glacial Till	0.4 to 0.6
		Glacial Till	0.8 to 1.0
		Base Sand	1.0 to 1.3
Thermocouples	Temperature	Glacial Till	0.4
		Glacial Till	0.7
		Glacial Till	0.9
		Base Sand/Waste Rock Interface	1.3
Heat Dissipation (Agwa Blocks)	Soil Suction	Granular Cover	0.3
		Glacial Till	0.6
		Glacial Till	0.9
		Base Sand	1.2
Gypsum Block	Soil Suction	Granular cover	0.3
		Glacial Till	0.4
		Glacial Till	0.6
		Glacial Till	0.9
		Base Sand	1.0
		Base Sand/Waste Rock Interface	1.3

5.3.1 Soil Moisture Content

The soil moisture content of the glacial till cover is measured using Time-Domain Reflectometry (TDR). TDR is a radar technique in which a fast rise time voltage pulse is propagated through the soil and its reflection measured. The pulse is guided through the soil by stainless-steel rods of known dimensions. The measurement of travel time (At) yields an estimate of "apparent" dielectric constant (K,) of the soil. The volumetric soil-moisture content (θ_v) is then calculated using a relation developed by Topp et al. (1980), or other soil-specific relations. The TDR transmission lines were fabricated by NTC, based on a three-rod design. The rods were 30 cm long in the sand layers and 20 cm long in the till. The probes were placed in each layer horizontally as the cover was being constructed. The application of the voltage pulse and measurement of At were performed with a Tektronix 1502B TDR metallic cable tester.

The moisture sensors were calibrated by NTC during installation. As an additional calibration check the field moisture content results were compared to the in-situ moisture content measurements as determined by AD1 Nolan Davis with a nuclear density gauge and found to be in agreement.

5.3.2 Temperature

Thermocouples, similar to the type K previously placed in the waste rock, were also installed throughout the cover to measure the temperature in each of the cover materials.

5.3.3 Soil Suction

Soil suction is measured by heat dissipation and electrical resistance, with both methods measuring a specific physical property of an absorbent or a porous block in equilibrium with the soil of interest. From these measurements, matric (or pressure) potential produced from the soil-water capillary forces is determined. Soil suction, being the negative of matric potential, is defined in terms of the soil phase and is therefore a positive number. It is generally expressed as pressure (kPa or bars) or hydraulic head (metres of water or pF).

A heat-dissipation sensor measures the rate at which heat dissipates in a porous ceramic block. The development of the sensor is presented in Rahardjo et al. (1989). A sensor based on a design developed by Phene et al. (1971), which consists of a miniature heater and a thermocouple encased in a porous ceramic block, was adapted for the soil cover. The thermal conductivity of the ceramic block is sensitive to its water content and can be related to soil suction. The temperature of the block is measured before and after a known quantity of heat is delivered to the block. More heat will dissipate through the block at higher water contents, resulting in a smaller increase in temperature (AT). If the soil loses water and the suction increases, then the water content of the sensor decreases and AT increases. Consequently, AT is proportional to the soil suction. Where each sensor is unique in its relation to soil suction, calibration is required prior to installation. Calibration procedures similar to those presented Fredlund and Wong (1989) were followed.

An electrical-resistance sensor, commonly composed of gypsum (Bouyoucous and Mick 1940), measures the electrical resistance of an absorbent block, . Resistance is sensitive to the water content of the block; high water contents yield low resistance. When the block is in contact with soil, the electrical resistance varies inversely with soil suction. Electrical resistance, however, also varies with pore water chemistry. Gypsum is used for two reasons: (i) its relatively low solubility contributes to the longevity of the sensors, and (ii) a saturated solution containing Ca^{2+} and SO_4^{2-} ions provides effective buffering at low pH. As a result, the variance of the resistance of a gypsum block, resulting from the small changes in soil chemistry, has less significance than that of a block composed of an inert material. In general, individual gypsum blocks have similar response to soil suction; therefore a generalized calibration provided by the manufacturer was used.

Four heat-dissipation sensors were installed at each monitoring station, one in each sand layer and two in the till; and six gypsum blocks were installed, one in each sand-till contact. All sensors were installed as each lift was placed. Following compaction, a small-diameter (25mm) hole was augered, the sensor installed in a soil slurry, and the hole backfilled and sealed to the surface with bentonite.

5.4 Meteorological Data

A fully operational meteorological station was established on Pile 7/12 in June 1992. The station records rainfall, evaporation, temperature, relative humidity and wind on a continuous basis.

5.5 Automated Monitoring System

An automated monitoring system was installed on Pile 7/12 to collect and store the large volumes of data generated by the sensors. The system consists of two Campbell Scientific data loggers, Model CR10, with three Campbell Scientific multiplexers. The three multiplexers consists of two AM416's for soil suction and thermocouple sensors and one SDMX50 for TDR probes. The data acquisition system was programmed to record data from the sensors at regular time intervals, varying from hourly to daily readings.

Meteorological data from the weather station is also recorded and stored in the dataloggers.

5.6 Collection System - Seepage Through Cover

Two lysimeters, which were installed directly beneath the composite soil cover, collected the seepage through the cover above the lysimeters. The water collected was then drained to the base of the pile and into a dedicated coilection chamber inside the outfall structure. This connection was made via a 50 mm PVC pipe installed underneath the composite soil cover along the north face of the pile.

A drain was installed in the center of the pile at the base. The water reaching the perimeter ditch which is located at the intersection of the composite soil cover with the Fabrene membrane at the base of the pile, is directed to a collecting drain connected to the outfall structure.

5.7 Instrumentation Monitoring Equipment Summary

A summary of the instrumentation either installed in waste rock Pile 7/12 or used to monitor performance is summarized in Table 5-2.

Additional details on instrumentation and monitoring of waste rock piles is presented in the Field Procedures Manual prepared as part of MEND project 1.22.1 a.

TABLE 5-2
Instrumentation, Pile 7/12

	METHOD
Cover and Pile Parameters	
Soil suction	(1) Heatdissipation sensors
	(2) Electrical-resistance sensors (gypsum blocks)
Moisture content	Time-domain reflectometty (TDR)
Gaseous oxygen and CO_2	Portable oxygen and CO, meters in conjunction with permanently emplaced sampling tubes
Temperature	Thermocouple sensors
Seepage through cover	Two collection-basin lysimeters, each 2.0 x 3.1 m, 6.2 m^2 surface area, 9.8 m^3 volume, semicylindrical, acid-resistant, high-density polyethylene
Water Quality	Outflow collection and laboratory analysis:
	(i) Lysimeters (seepage through the cover)
	(ii) Pile perimeter dram (pile runoff, through the cover's granular base above the waste rock)
	(iii) Pile base (seepage through the cover and the pile)
Meteorological Parameters	
Rainfall	Tipping-bucket rain gauge
Evaporation	U.S. Class A evaporation pan
Air temperature	Thermistor sensors
Relative humidity	Surface resistivity (of impervious solid) sensor
Wind speed	Three-cup anemometer
Automated monitoring system	
Parameters measured	Soil suction, moisture content, soil and air temperature, relative humidity, wind, rainfall, and pan evaporation
Data acquisition	Two Campbell Scientific, model CR10 dataloggers
	Three Campbell Scientific multiplexers: AM4 16 multiplexer for soil suction sensors, AM416 multiplexer for thermocouple sensors, and SDMXSO multiplexer for TDR probes
TDR measurement	Tektronix 1502B TDR metallic cable tester
Data retrieval	Computer modem or direct connection
Power	12 V dc (110 V ac source)

6.0 MONITORING RESULTS

The performance of the composite soil cover on Pile **7/12** was monitored on a continuous basis since September 1991. Pile **18B,** the control pile, was also monitored over the same period in conjunction with Pile **7/12**.

The monitoring results, to October 1993 and prehminary interpretation are presented in the following sections. Additional monitoring details are presented in Appendix IV.

6.1 Gaseous Oxygen

The oxygen concentrations measure& since 1991 for Piles **7/12** and 18B are summarized in Tables IV-1 and IV-2 respectively of Appendix **IV** and shown graphically over time in Figures IV-1 to IV-12 for each of the monitoring stations. The results of oxygen concentration measurements to October 1993 indicate that:

- Prior to placement of the cover, oxygen concentrations in Pile **7/12** ranged from 3.2 to 20.8 percent.
- Oxygen levels near the surface of the pile are particularly influenced by the weather (decreasing in the winter).
- In the summer as temperatures in the pile increase, thermal convection of oxygen into the pile causes oxygen levels to increase.
- After cover placement in September 1991, there was a dramatic decrease in oxygen concentrations throughout Pile **7/12**.
- Oxygen concentrations within the pile as of October 1993 were measured at less than 1 percent.

The magnitude of the change in oxygen concentration before and after the placement of the cover is illustrated on Figures 6-l and 6-2, where the range of oxygen concentrations within the pile has been plotted from May 1989 to October 1993. It is apparent from Figures 6-1 and 6-2 that the most significant decrease in oxygen occurred within several months after cover placement.

The oxygen concentrations measured in Pile 18B exhibit a cycle that is mainly dependent of the climatic conditions, and to a lesser extent, the oxidation rate of the waste rock.

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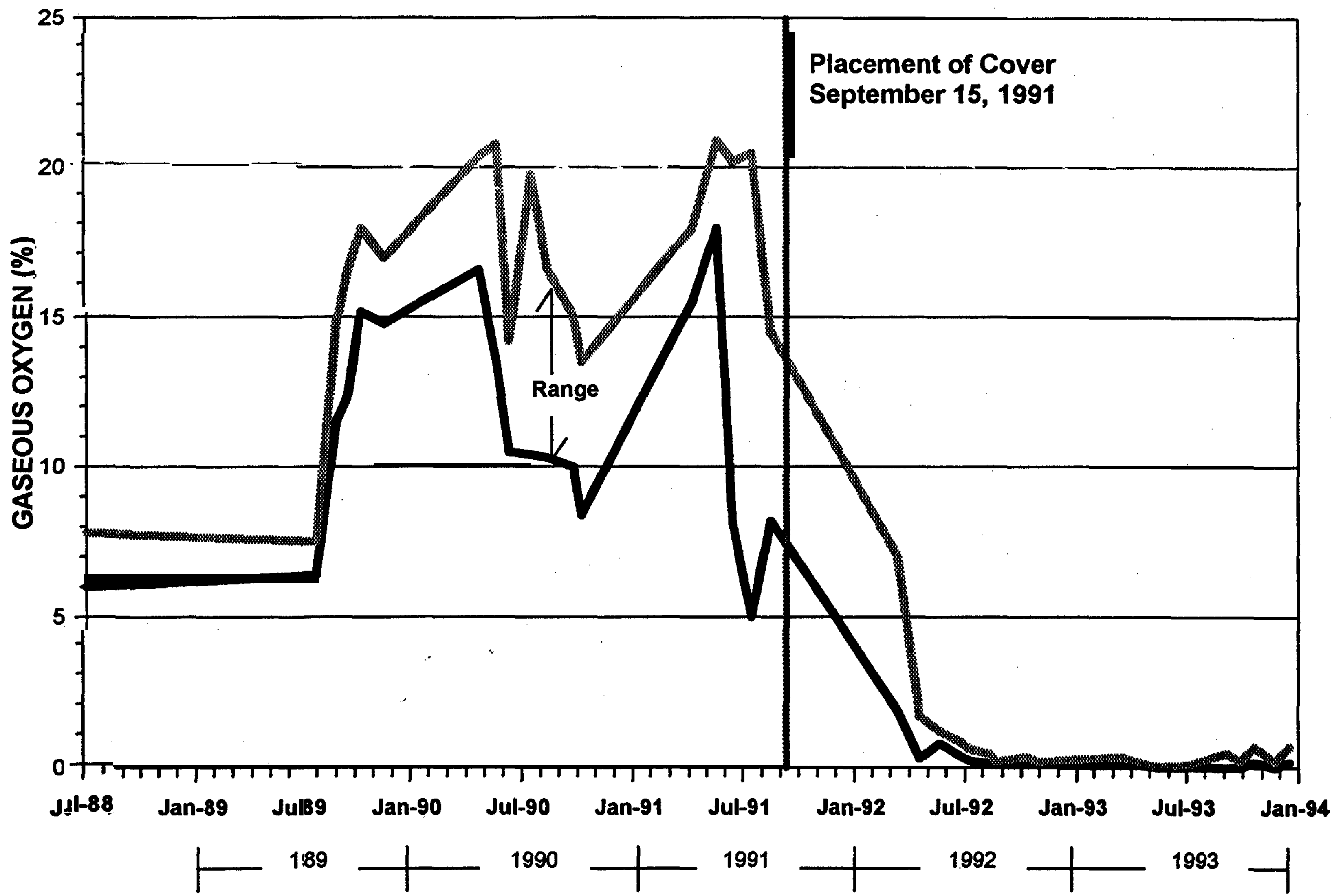

FIGURE 6-1

GASEOUS OXYGEN vs. TIME

PILE 7/12, STA. 3

JUNE 1994

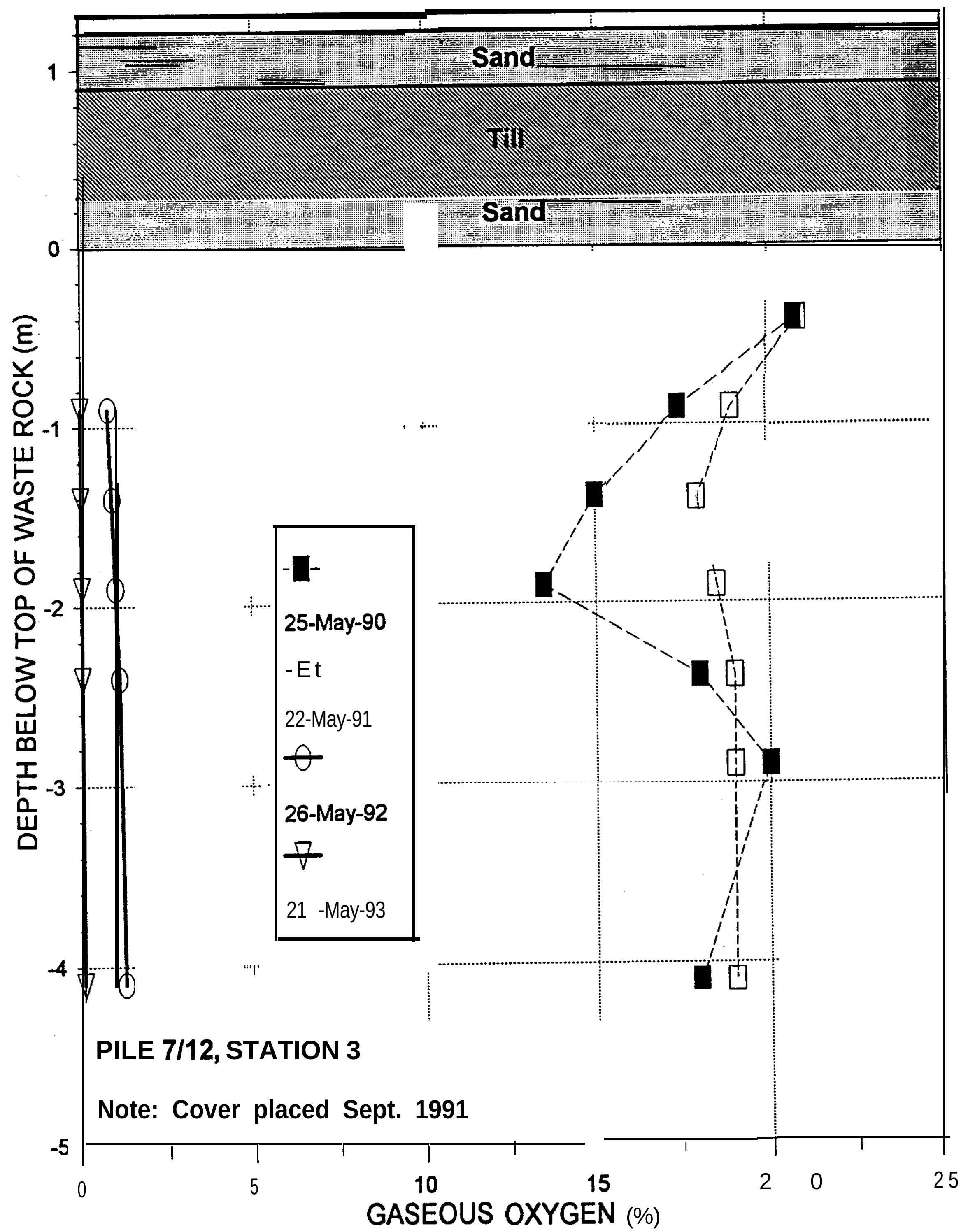

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FIGURE 6-2

GASEOUS OXYGEN PROFILE
PILE 7/12, STA. 3

JUNE 1994

6.2 Temperature.

The measured temperatures for Piles 7/12 and 18B are summarized in Tables IV-3 and IV-4 of Appendix IV and shown graphically in Figures IV-13 to IV-25. The results of temperature monitoring to October, 1993 indicate that:

- Prior to the placement of the cover, high temperatures were noted which are indicative of the existence of the endothermic oxidation process.
- Temperature decreases were evident in Pile 7/12 within one month after cover placement.
- A direct correlation between temperatures and weather conditions exists.

The magnitude of the temperature changes prior to and after cover placement is illustrated in Figures 6-3 and 6-4, which shows the range of temperature measured since May 1989 to October 1993. The most significant decrease in temperature occurred within several months after cover placement. Temperatures throughout Pile 7/12 are still decreasing, but at a much reduced rate.

6.3 Gaseous CO,

Gaseous CO, concentration measurements were initiated in November 1993 for both piles 7/12 and 18B. Tables IV-5 and IV-6 of Appendix IV sumarize the CO, measurements obtained for Pile 7/12 and 18B respectively. Although the amount of data collected to date is limited the CO, concentrations indicate that the covered Pile 7/12 has much higher concentration values than the uncovered Pile 18B. The high CO, concentration values inside the covered pile indicate a lack of oxygenation and aeration reaching the pore spaces of the waste rock, which corroborate with the gaseous oxygen concentration measurements.

6.4 Seepage Through Cover

With the completion of the composite soil cover in September, 1991 Pile 7/12 became a closed system. By design, any moisture which enters the system by seepage through the soil cover is collected either in one of the two lysimeters (northeast lysimeter and northwest lysimeter), the perimeter ditch at the base of the pile (perimeter drain) or a collection drain which extends into the middle of Pile 7/12 (centre drain) and flows to the outfall structure. A summary of the volume collected from the collection system is presented in Table 6-1. In the two years since cover placement, a total of about 1000 litres has been recovered from the four sources, of which 193.6 litres has been collected from the lysimeters. The volume collected in the two lysimeters represents the seepage through the cover in the area underlain by the two lysimeters only. The water collected from the two lysimeters has not come in contact with waste rock and hence is not considered AMD.

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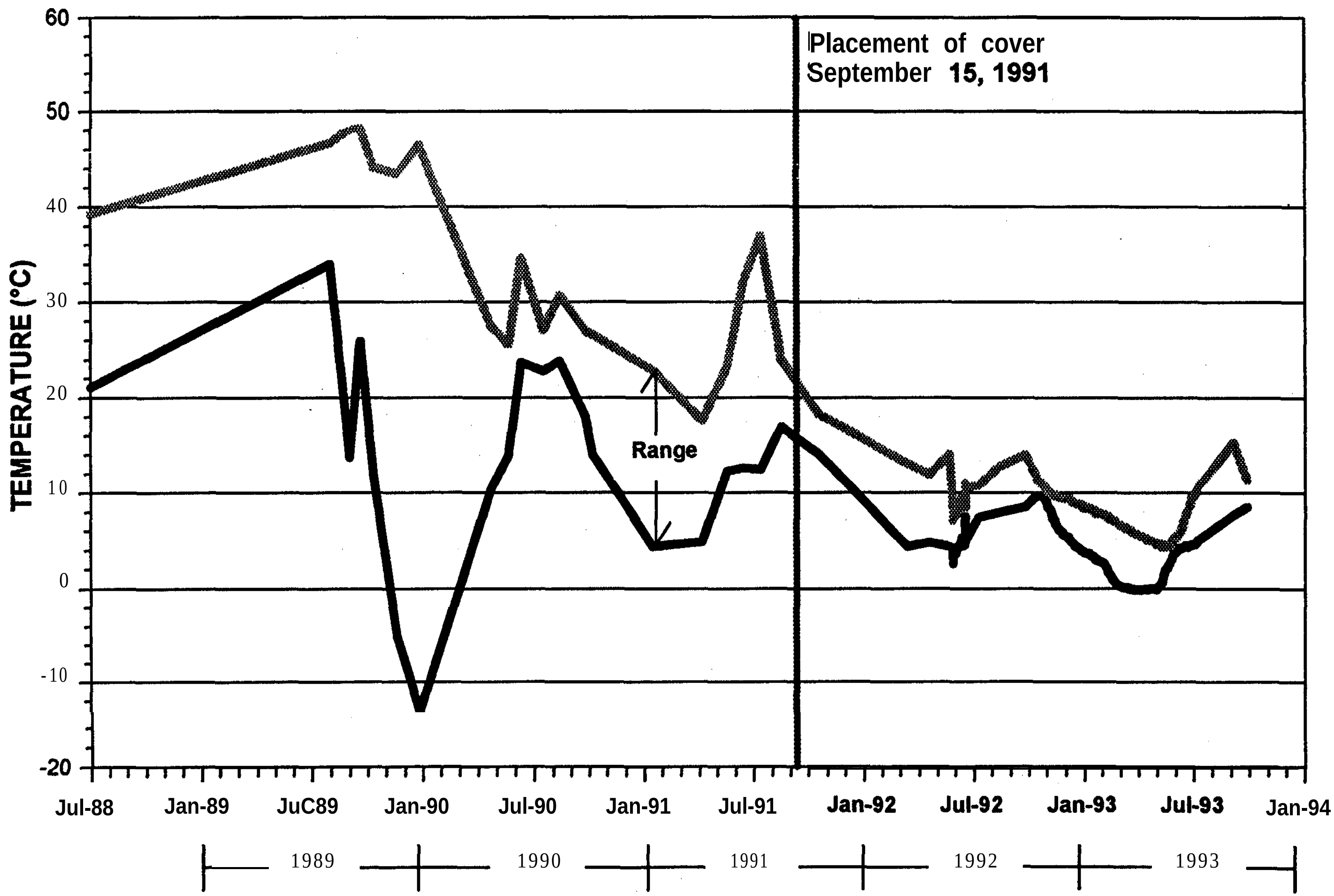
FIGURE 6–3

TEMPERATURE vs. TIME
PILE 7/12. STA. 3



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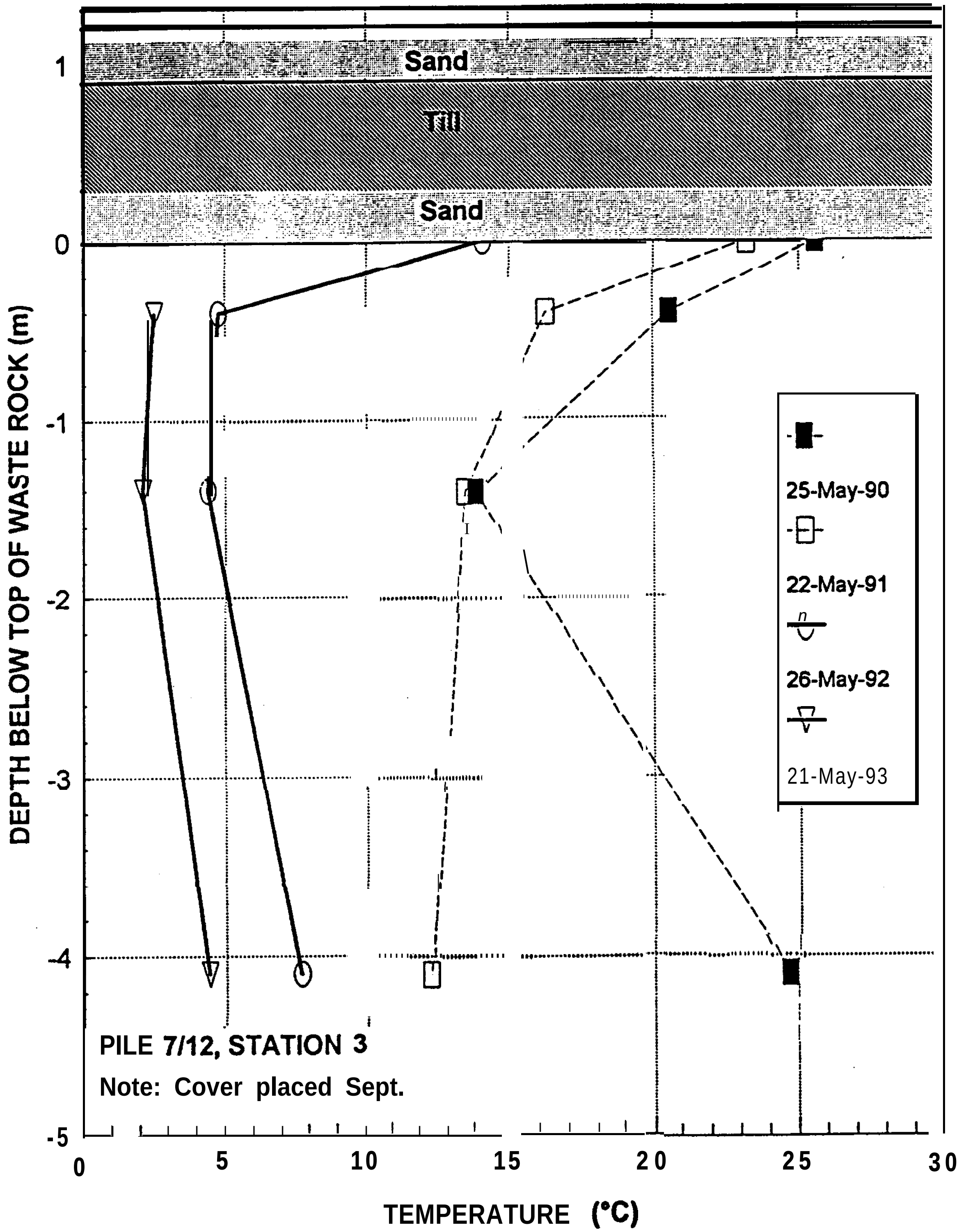

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FIGURE 6-4

TEMPERATURE PROFILE
PILE 7/12, STA. 3

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TABLE 6-l
Discharged Quantities
Outfall Structure

DATE	CENTRE DRAIN (litre)	PERIMETER DRAIN (litre)	NORTHEAST LYSIMETER (litre)	NORTHWEST LYSIMETER (litre)
1992	50.5	3 86.00	25.95	72.35
1993	65.00	443 .00	43.10	50.20
TOTAL:	115.50	729.00	69.05	124.55

Rainfall was measured at the HSM site since the installation of the meteorological station in 1992. The results of rainfall measurement over selected periods along with volume of seepage collected in the two lysiieters, are presented in Table 6-2. The results of measurements to date indicate that less than 2 percent of precipitation infiltrates through the cover to the waste rock.

TABLE 6-2
Rainfall/Lysimeter Measurements, Pile **7/12**

DATE	RAINFALL DEPTH (mm)	RAINFALL EQUIVALENT VOLUME* (litre)	INFILTRATION VOLUME (litre)	RATIO
June 24 - August 18, 1992	198	2455.2	50.3	2.0%
May 21 -July 13, 1993	188	2331.2	20	0.9%
January - December, 1993	1118.9**	13 875	100	0.7%

Note: * *Total aerial surface of lysimeters=12.4 square metre*
* * *Average annual precipitation*

6.5 Leachate Quality

The water collected from both the centre and perimeter drains has come in contact with the waste rock and hence is considered as leachate. The total volume of leachate collected in the outfall structure over the two year study period is a combination of both leachate trapped within the pile at time of cover placement which has now moved through the system plus any seepage which has passed through the composite soil cover and then moved through the encapsulated waste rock to the only discharge point at the outfall structure,

The results of analytical testing of leachate recovered from the base of Pile 7/12 are summarized in Table 6-3. Tables IV-7 and IV-8 of Appendix IV provide additional details of leachate testing. The data presented shows no significant change in water quality before and after construction of the cover. Table 6-3 indicates that there has been a noticeable increase in pH since placement of cover but in terms of leachate loadings, there is no significant change in water quality before and after construction of the cover.

TABLE 6-3
Leachate Water Quality
Centre Drain, Pile 7/12

	July 1989 - Oct 1990	1992	1993
PH	2.1 - 2.8	2.3 - 2.9	3.0 - 3.2
Acidity ($CaCO_3$) mg/L	15 800 - 73 250	15 800 - 54 450	Not Available
Sulphate (mg/L)	12 700 - 43 440	5 140 - 71042	9 970 - 73 854
Dissolved Iron	3 510 - 13 767	15 800 - 54 000	5 000 - 30 844

6.5.1 Soil Suction

The results of the soil suction or matrix potential measurements from the gypsum blocks are presented in Table 6-4 for three separate monitoring events namely fall of 1991 and the spring and summer of 1992. The results to date indicate that the matrix potential of the lower section of the glacial till and base sand are stable, which is indicative of a consistent moisture content. Variations in the soil suction measurements of the granular cover and upper glacial till are consistent with the variations in moisture content due to wetting and drying which would be expected to occur in these zones. Additional details on soil suction measurements are presented in Appendix IV, Figures IV-26 and IV-27 for the heat dissipation sensors, and in Figures IV-28 and IV-29 for the gypsum blocks.

TABLE 6-4
Soil Suction
Gypsum Block Method, Pile 7/12

	MATRIC POTENTIAL (kPa)					
	91/10/31		92/05/31		92/08/26	
	West	East	West	East	West	East
Granular Cover Glacial Till (Top 2 Glacial Till (BottcR Base Sand	[illegible]	[illegible]	[illegible]	[illegible]	100 20 20 30 30 20 20 30	

6.5.2 Moisture Content

Monitoring of the moisture content of the various layers in the composite soil cover by TDR indicate that the cover is performing as designed with the volumetric moisture contents in the glacial till and sand base showing little change from those taken immediately after cover placement. Table 6-5 summarizes volumetric moisture content measurements for three separate periods, namely fall 1991 and spring and summer, 1992.

TABLE 6-5
Volumetric Moisture Content
TDR Method, **Pile 7/12**

LAYER	VOLUMETRIC MOISTURE! CONTENT (%)					
	91/10/31		92/05/31		92/08/26	
	West	East	West	East	West	East
Granular Cover	12	8	8	7	9	8
Glacial Till (Top 200 mm)	30	32	25	30	N.A.	36
Glacial Till (Bottom 200 mm)	34	30	27	26	31	30
Base Sand	12	12	12	11	13	12

Note: N.A.= Not Available

7.0 CONCLUSIONS

1) The composite soil cover was successfully placed on waste rock Pile 7/12 between August 28 and September 17, 1991 by Atco Construction of Newcastle, N.B. Observations recorded during cover placement and the results of quality control testing, indicate the cover was constructed in accordance with the design proposed by NTC using local materials.

2) The performance monitoring of the covered waste rock pile 7/12 after the cover was placed indicates that the composite soil cover is an effective way to reduce the impact of acid generating waste rock. The placement of the cover has resulted in a depletion of oxygen within the pile as well as a reduction in pile temperatures. This reduction in both oxygen and temperature is interpreted as an indication that the oxidation process within Pile 7/12 has been severely reduced.

3) While Pile 7/12 is small compared with many waste rock piles elsewhere, the results of this study show potential for utilizing composite covers as an effective management approach for larger waste rock piles. It should be noted that despite the performance of the cover, a low volume of AMD is still being discharged from Pile 7/12 and must be treated before discharge to the environment.

4) Performance monitoring of the glacial till layer indicates that it has maintained its moisture content at the level at which it was placed after two years. Seepage through the cover has been measured at less than 2 percent of total precipitation which is consistent for a soil having a hydraulic conductivity of less than 1 x 10^{-7} cm/sec.

5) The total cost of cover construction in 1991 was $60,000 (Cdn), or about $22.50/m^2 of cover placed. For larger waste rock piles, this unit cost would be expected to decrease. The cost for engineering and construction quality control is not included in those costs because of the research nature of the project.

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APPENDIX I

Project Specifications

COMPOSITE SOIL COVER

HEATH STEELE MINES

NEWCASTLE, N.B.

Request for Proposal

August, 1991

August 7, 1991

Gentlemen:

You are invited to provide a proposal for the supply of all labour, supervision, tools and equipment necessary for placement of a composite soil cover over waste rock Pile 7/12. The scope of work is outlined in the enclosed specification package and engineering drawings.

Heath Steele Mines will assign a representative to oversee the work and maintain quality control on a full time basis. Initial surveying and grade control will also be provided by Heath Steele Mines. It must be emphasized that for this project, because of the nature of the work, any deviation from the quality control requirements without the approval of the Project Director will be unacceptable.

All work must be completed to the satisfaction of our representative on site. Your proposal is to be directed to the Project Director, Mr. Jim Duncan and is required by August 16, 1991 at 2:00 p.m. An information session with all invited contractors will be held August 9, 1990 at 10:00 at Heath Steele Mines. Project to start immediately upon issuance of Purchase Order.

Sincerely,

James Duncan
Project Director

Following Schedule of Prices does not constitute part of official contract but must be completed and submitted in Contractors proposal. Prices indicated will form basis for Purchase Order which will be issued upon award of contract.

Contractor shall complete following Schedule of Prices for placement of a composite soil liner in Waste Pile 7/12. Description of work may be found in the specifications. Prices quoted shall include the supply of all materials, plant, tools, labour and equipment necessary to carry out and properly complete cover placement and associated tasks to satisfaction of Project Director. Quantities shown on the Schedule of Prices are approximate and are subject to change.

Contractor also to provide rental rates for all equipment to be used in installation of composite soil cover. Also include standby rates and charges for delay. Work will be measured up monthly and contractor will prepare progress claims based on these measurements.

The lowest or any price proposal will not necessarily be accepted. Heath Steele Mines reserves the right to select the contractor of his choice.

Composite Soil Cover **Price Proposal**
Heath Steel Mines
Newcastle, N.B.

Schedule of Prices

Section NO.	Item	Unit of Measurement	Price Per Unit	Estimated Total Quantity'	Estimated Total Price
0200	Borrow Source	Lump Sum		1	
0210	Surface Preparation	tonne		100	
		hours		40	
0220	Sand Base	Lump Sum		700 m^3	
0230	Impermeable Cover	Lump Sum		1500 m^3	
0240	Granular Cover	Lump Sum		1000 m^3	
0250	Erosion Protection	tonne		750	
0300	Leachate Collection				
	Outfall Structure	Lump Sum		1	
	100 mm Drain	Metre		80	
0400	Instrumentation				
	Lysimeter	Lump Sum		2	

Estimated Total

1.1 General

.1 Work under this contract is divided into descriptive sections which are not intended to identify absolute contractual limits. Contractor- shall be responsible for organizing division of iabour and supply of material and equipment essential to complete project in all its parts as established in articles of agreement.

.2 Work described in this section of specifications, includes, but is not restricted to requirements for setting out procedures, project administration, safety and protection of property and people. It shall apply to work of all sections of specifications.

.3 All work subject to approval of Project Director of Heath Steele Mines.

1.2 Description of Work

.1 Work under this contract shall consist of placement of a composite soil cover on waste rock pile, known as Pile 7/12, at Heath Steele Mines. Composite soil cover comprises of a 60 cm thick impermeable soil layer sandwiched between two 30 cm thick granular layers complete with necessary monitoring instrumentation and other work related thereto.

.2 Supply and installation of leachate collection and monitoring instrumentation to waste rock pile, site grading and construction of surface drainage to sedimentation pond on site and other work related thereto.

1.3 Site Lay Out

.1 Engineer will provide only those survey control points and set one (1) bench mark and set such stakes as necessary to define general location, alignment and elevation of successive cover layers. Give Engineer reasonable notice of requirements for such control points and stakes.

.2 Set grades and lay out work in dctail from control points and gradc established by Engineer.

.3 Assume full responsibility for and exccute complete layout of work to locations, line and elevations indicated.

.4 Supply stakes and other survey markers required for laying out work.

1.4 Familiarization with site

.1 Invited contractors shall have one of his principals examine site and ensure that all possible factors concerning earthwork are investigated and that following are known in particular

.1 Methods and means available for material handling, disposal, storage and transportation.

.2 Physical conditions of site, including existing monitoring equipment, and drainage courses.

.3 Configuration and conditions of ground surfaces

.2 No allowance will be made by Heath Steele Mines for difficulties encountered or expenses incurred on account of any site condition, or any growth or item existing thereon.

.3 Prior to submission of proposals an information session will be held on site with Project Director and Project Engineer **to** discuss project requirements.

.4 Invited Contractor responsible for identifying local conditions and any other factors which may affect his proposal and performance of work.

1.5 Work Schedule

.1 In conjunction with, and in form acceptable to Project Director, provide with proposal a schedule showing dates for delivery of items of materials and construction equipment, commencement of work, overall work schedule, and completion dates for each specific task. **Schcdule** shall be based on **scopc** of work as indicated in specifications and on drawings.

.2 All work shall bc carried out continuously until completion. All work shall bc completed on or before **Octobcr 15, 1991.**

.3 Interim reviews of work progress based on schedule submitted will be conducted as decided by Project Director and schedule updated by Contractor in conjunction with Project Director.

1.6 Contractor Responsibilities

.1 Contractor to provide a list of equipment and tools (type of equipment, size, etc.) to be used on project to Heath Steele Mines security upon arrival to mine site.

.2 Safety hats, footwear, glasses, coveralls, etc. to be supplied by Contractor. Contractor responsible to ensure that safety equipment is worn by all its employees.

.3 Contractor responsible for transportation of its employees to and from work site.

.4 Contractor to supply his own lunchroom and sanitary facilities.

1.7 Provision for Traffic

.1 Create least interference with traffic consistent with faithful performance of work. Contractor should be aware that haul roads are travelled frequently by heavy equipment of Heath Steele Mines.

.2 Do not close or block roadways unless approved by Project Director.

.3 Provide construction signs, warning signs, lanterns and flood lights required.

1.1	Fires	.1	Fires and burning of rubbish on site will not be permitted.
1.2	Disposal of Wastes	.1	Do not bury rubbish and waste materials on site unless approved by Project Director.
		.2	Disposal of waste or volatile materials, such as mineral spirits, oil or paint thinner into waterways, storm or sanitary sewers prohibited.
		.3	Containers and waste fluids associated with equipment and vehicle maintenance are to be removed from site and disposed of at an approved waste disposal site.
1.3	Drainage	.1	Provide temporary drainage and pumping as necessary to keep site free from water.
		.2	Pumping of water containing silt in suspension in accordance with local authority requirements.
		.3	Control disposal or runoff of water containing suspended materials or other harmful substances in accordance with local authority requirements.
1.4	Measurement for Payment	.1	No separate measurement to **be** made under this section.

PART 1 • GENERAL

1.1 Description

.1 This section specifies requirements for development, operation, and closure of an approved source of glacial till for construction of impermeable cover.

1.2 Protection

.1 Prevent damage to trees, vegetation and natural features, outside outer boundaries of borrow source. Make good damage.

1.3 Environmental Permits

.1 Heath Steele Mines will provide necessary permit(s) for development of borrow source. Contractor responsible meeting requirements of local authorities as outlined in permit(s).

1.4 Measurement for Payment

.1 Site development and closure shall be paid as a lump sum and shall include all items specified herein.

.2 Excavation and transportation of glacial till paid under Section 0230.

PART 2 • EXECUTION

2.1 Clearing and Grubbing

.1 Cut off tree shrubs, stumps and other vegetation to within 100 mm of original ground surface.

.2 Grub out stumps and roots to not less than 300 mm below ground surface.

.3 Remove surficial sand and gravel, topsoils and other soils not suitable for cover development to top of glacial till layer.

2.2 Removal and Disposal

.1 Usable timber-becomes property of Heath Steele Mines. Stockpile at locations provided by Owner.

2.3 Storage of Materials

.1 Stockpile in separate areas all grubbed materials and all soils not suitable for cover development.

.2 Provide ditching, berms and silt traps as necessary to minimize impact of suspended materials in runoff from site.

2.4 Borrow Source Development

.1 Develop borrow source in stages. Clearing and grubbing limited to area sufficient to meet project requirements for glacial till.

.2 Do not stockpile glacial till. Excavate and transport to site only material placed during that day of work activity.

2.5 Site Restoration

.1 Site closure immediately upon completion of impermeable cover.

.2 Place stockpiled site grubbing in borrow pit and grade.

.3 Cover site grubbings with stockpiled soil not suitable for cover development.

2.6 Site Grading

.1 Shape restored borrow area to an even grade, infilling all large depressions.

.2 Slope back all pit faces in borrow area to minimum **2H:1V** slope.

.3 Grade site to **minimize** impact of silt laden runoff on environment. Provide silt traps as necessary.

PART 1 GENERAL

1.1 Description

.1 This section specifies requirements for preparation of side slopes and top of waste rock Pile 7/12 prior to placement of composite soil cover.

1.2 Measurement for Payment

.1 Payment for all construction equipment and labour on site associated with base preparation will be based on a per hour basis. Contractor to specify in **price** proposal equipment and labour costs.

.2 Payment for crushed rock will be on a per tonne basis for material delivered to site.

.3 Excavation for lysimeter to be paid for under Section 0400.

PART 2 PRODUCTS

2.1 Materials

.1 Material used for surface preparation to be a non acid generating crushed rock or approved equivalent.

.2 37.5 mm minus crushed rock meeting NBDOT specifications of 37.5 mm minus material for graduation and quality.

2.2 Material Testing

.1 Provide samples to Project Director for testing to confirm specification requirements.

PART 3 EXECUTION

3.1 Placement

.1 All depressions and large voids must be infilled with crushed rock or waste rock from other areas of pile as directed by Engineer. Depressions and voids must be filled to a level surface consistent with rest of pile.

.2 Areas requiring infilling and placement of crushed rock will be determined by Engineer at start of project.

.3 Infilling of depressions and large voids should be carried out so as to minimize disturbance to existing pile.

3.2 Slope Grading

.1 Grade high areas on side slope of waste rock pile to conform with overall pile slope. Areas requiring grading to be identified by Engineer at start of project.

.2 Grading of side slope shall be carried out so as to minimize disturbance to existing pile.

.3 Remove large size waste rock at base of pile and place as directed by Engineer.

3.3 Top of Waste Rock Pile

.1 Lysimeters (Section 0400) to be installed prior to preparation of top of pile surface.

.2 Infill voids and depressions as required by Engineer.

PART 1 GENERAL

1.1 Description

.1 This section specifies requirements for supply and placement of a sand base for composite soil cover on prepared surface of waste rock Pile 7/12.

1.2 Measurement for Payment

.1 Transportation and placement of sand base component of composite soil cover and other work performed under this section shall be measured for payment as a lump sum.

.2 Sand for lysimeter installation to be paid for under Section 0400.'

PART 2 PRODUCTS

2.1 Sand Base

.1 Sand base material to be non acid generating.

.2 Sand should be a well graded medium to coarse grained material meeting following requirements

.1 60% ranging between 0.5 and 4.0 mm diameter.

.2 D_{10} ranging between 0.35 and 0.40 mm diameter

2.2 Material Testing

.1 Provide samples to Engineer for testing to confirm specification.

PART 3 EXECUTION

3.1 Placement

.1 Sand base shall be a minimum thickness of 30 cm over entire waste rock pile. Layer thickness may be thicker in low lying or steeper sloping areas of pile.

.2 Sand base should be placed in a minimum of two layers. Initial layer of IO-15 cm thick layer placed over prepared basc to provide a smooth surface.

.3 Protect all instrumentation and leachatc collection piping during placement of sand base.

.4 Sand base shall placed as directed by Engineer.

3.2 Compaction

.1 Sand base shall be compacted with several passes of a medium size vibratory roller to 92% of its Modified Proctor Density (ASTM D1557)

.2 Shape and roll alternatively to obtain a smooth and uniformly compacted base.

.3 Apply water as necessary during compaction to obtain specified density.

.4 In areas not accessible to rolling equipment, compact to specified density with approved mechanical tampers.

3.3 Finishing

.1 Immediately prior to completion of sand base placement, entire top surface shall be rolled with a smooth cylindrical roller or other equipment as considered appropriate by Engineer so as to leave area in a smooth, even condition for drainage. Suitable equipment shall be provided on site at all times for this purpose.

.2 Finished compacted surface to be flat with surface irregularity within ± 25 mm of average grade.

.3 Final finished slopes to be at 3H:1V.

3.4 Maintenance

.1 Maintain finished surface in a condition conforming to this section until succeeding impermeable cover placement.

PART 1 GENERAL

1.1 Description

.1 This section specifies requirements for supply and placement of impermeable cover on prepared sand base over waste rock Pile 7/12

1.2 Measurement for Payment

.1 Transportation and placement of impermeable cover component of composite soil cover and other work performed under this section shall be measured for payment as a lump sum item.

.2 Payment for development and closure of Borrow Source to be paid under Section 0200.

PART 2 PRODUCTS

2.1 Impermeable Cover

.1 Impermeable cover material to be non acid generating.

.2 Impermeable cover material to be a glacial till approved by Engineer. Heath Steele Mines have identified an acceptable borrow source on Anderson Road approximately 3.2 km from site.

.3 Impermeable cover component of composite soil cover shall meet following specifications.

.1 Grain Size (ASTM D 422)
Maximum particle size of 30 mm,
Minimum percent finer than 0.075 mm particle size of 40% by dry weight
Minimum percent finer than 0.002 mm particle size of 10% by dry weight.
D_{10} ranging between 0.001 and‘0.003 mm particle size

.2 Moisture content (ASTM D 2216)
-2 to +4% of optimum moisture content

.3 Atterberg Limits (ASTM D 4318)
Liquid Limit > 30 and Plasticity Index > 15

.4 Moisture Density Relationship (ASTM D 1557)
Soil must be capable of reaching 95% of maximum dry Modified Proctor density at a moisture content of -2 to +4% of optimum.

.5 Hydraulic Conductivity (ASTM D 2434)
Coefficient of permeability (K) 1 x 10 - 7 cm/sec or less.

PART 3 EXECUTION

3.1 Compaction Equipment

.1 Compaction equipment to consist of a medium weight vibratory compactor or sheepsfoot roller as approved by Engineer capable of obtaining required densities

3.2 Water Distribution

.1 Water distribution equipment must be capable of uniform distribution of water over cover.

.2 Water distribution equipment to be present on site during entire cover placement operation.

3.3 Field Test Strip

.1 Prior to placement of impermeable cover on waste rock pile, Contractor will construct a field test strip measuring 5 m x 10 m in plan using materials, method of placement and compaction techniques proposed. A minimum of 2 layers to be placed in test strip. Compacted in situ density and hydraulic conductivity to be measured infield.

3.4 Placemcnt

.1 Final compacted thickness of impermeable cover to be minimum 60 cm

.2 Impcrmcablc cover to be placed in 20 cm thick layers spread in a loose slate

.3 Cover to be placed at moisture content ranging from -2 to +4% of optimum.

.4 Contractor shall repair and/or replace materials which do not meet specifications and be responsible for repair and/or replacement of unsuitable areas on waste rock pile at no additional cost to Heath Steele Mines.

.5 Protect all instrumentation and leachate collection piping during placement of cover.

3.5 Compaction

.1 Cover to be compacted with approved compaction equipment as soon as layer graded. Moisture loss to be kept to a minimum.

.2 Apply water as necessary during compaction to maintain specified moisture content. If cover is excessively dried out, remove from site and replace.

.3 Impermeable cover compacted to 95% of its dry Modified Proctor density (ASTM D 1557)

.4 Compacted cover layer approved by Engineer prior to placement of successive layer.

.5 Compaction equipment shall pass over impermeable cover a sufficient number of times to maximize compaction. Each lift shall receive a minimum of 4 passes of approved compaction equipment.

.6 In areas not accessiblc to rolling equipment including around monitoring casing, compact to specified density with approved mechanical tampers.

.7 During compaction operations turning of equipment shall be effected carefully to ensurc uniform compaction.

.8 Glacial till shall be kept free of lenses, pockets, streaks and layers of pervious material.

3.6 Existing Geomembrane

.1 **All** tom or deteriorated sections of geomembrane at toe of existing pile, which will no longer retain water, to be removed.

.2 Tight seal between existing geomembrane and impermeable cover is imperative.

.3 Place initial layer of impermeable cover on membrane in areas where competent membrane exists. Turn membrane up into cover before placing **next** layer.

.4 Areas where membrane deteriorated leaving it short of cover, provide additional membrane **as** directed **by** Engineer.

.5 Bond between cover and geomembrane to be approved by Engineer.

3.7 Final Grade

.1 Immediately prior to completion of impermeable cover, entire top surface to be rolled with a smooth cylindrical roller or other equipment as considered, appropriate **by** Engineer so as to leave area in a smooth even condition for drainage.

.2 Finished compacted surface to be flat with surface irregularities within ± 25 cm of average grade.

.3 Final finished slope to bc at **3H:1V.**

3.8 Weather

.1 Impermeable cover operations shall be suspended as directed by Engineer whenever climatic conditions arc unsatisfactory for placement to conform to this Specification.

.2 Immcdiatcly prior to suspension of impermeable cover placement, entire top surface shall be rolled with a smooth cylindrical roller as so to leave area in a smooth, even condition for drainage. Suitable equipment shall be provided on site at all times for this purpose.

3.9 Instrumentation

.1 Contractor shall make provision for installation of instrumentation as required by Heath Steele Mines (Section 0400).

3.10 Maintenance

.1 Maintain finished surface in a condition conforming to this section until succeeding granular cover placement.

.2 Apply moisture as required should moisture content fall below minimum requirements.

PART 1 GENERAL

1.1 Description

.1 This section specifies requirements for supply and placement of granular cover on completed impermeable cover over waste rock Pile 7/12

1.2 Measurement for Payment

.1 Transportation and placement of granular cover component of composite soil cover for waste rock pile and other work performed under this section shall be measured for payment as a lump sum item.

PART 2 PRODUCTS

2.1 Granular Cover

.1 Granular cover material to be non acid generating

.2 Granular cover material to be well graded pit run sand and gravel or equivalent crushed rock which meets following gradation requirements.

.1 Maximum particle size of 50 mm

.2 Maximum percent finer than 0.075 mm size of 8% by dry weight

.3 Source of material to be approved by Engineer

2.2 Material Testing

.1 Provide samples to Engineer for testing to confirm specification.

PART 3 EXECUTION

3.1 Placement

.1 Final thickness of granular cover shall be 30 cm.

3.2 Compaction

.1 Granular cover to be placed in maximum 15 cm lifts and compacted to 92% of its dry Modified Proctor density (ASTM D 1557).

.2 Contractor shall repair and/or replace materials which do not meet specifications and be responsible for repair and/or replacement of unsuitable areas on waste rock pile at no additional cost to Heath Steele Mines.

3.3 Final Grade

.1 Immediately prior to completion of granular cover, entire top surface to be rolled with a smooth cylindered roller or other equipment as considered, appropriate by Engineer so as to leave area in a smooth even condition for drainage.

.2 Finished compacted surface to be flat with surface irregularities within ± 50 cm of average grade.

.3 Final finished slope to be at 3H:1V.

PART 1 GENERAL

1.1 Description

.1 This section specifies requirement for supply and placement of erosion protection layer over completed composite soil cover

1.2 Measurement for Payment

.1 Payment for all construction equipment and labour associated with transportation and placement of erosion protection layer of composite soil cover and other work performed under this section shall be measured for payment on a per tonne in place basis

PART 2 PRODUCTS

2.1 Materials

.1 Erosion protection component to be a course layer of gravel or equivalent crushed rock having a maximum particle size of 75 mm and 15% by weight finer than 4.75 mm particle size.

.2 Gravel or crushed rock to be clean, well graded and free of organic and fines.

PART 3 EXECUTION

3.1 Placement

.1 Erosion protection layer is to be placed over completed composite soil cover to a minimum depth of 10 cm

.2 Placement of erosion layer shall be uniform over waste rock pile.

.3 Protect all instrumentation and leachate collection piping during placement of layer.

3.2 Final Grade

.1 Grade side slopes and top of pile to a neat condition true to line and grade.

.2 Hand finish areas that cannot be finished satisfactorily by machine.

PART 1 GENERAL

1.1 Description

.1 This section specifies requirements for site grading including requirements for surface drainage control.

1.2 Measurement for Payment

.1 Work conducted under this section shall not be measured for payment but shall be incidental to work described in Sections 0210, 0220, 0230 0240, 0250 and 0300.

PART 2 PRODUCTS

2.1 Material

.1 Products-to be those on site as deemed appropriate by Engineer.

PART 3 EXECUTION

3.1 Preparation

.1 Grade site within limits of project, eliminating uneven areas and low spots ensuring positive drainage. Remove debris, roots, branches, and other deleterious materials. Dispose of removed material as directed.

3.2 Drainage Ditch

.1 Construct a drainage ditch(s) as required to direct surface runoff to sedimentation pond on site.

.2 Direction and course of drainage ditch(s) to be determined by Engineer.

PART 1 GENERAL

1.1 Description

.1 This section specifies requirements for installation of a leachate collection system, associated piping, and/or other work as deemed appropriate by Engineer for proper completion of work under this section.

1.2 Measurement for Payment

.1 Payment for work conducted under this section will be measured separate from other sections in this specification. Installation and backfill of outfall structure will be a lump sum item.

.2 Outfall structure and required 50 mm PVC piping to be provided by Heath Steele Mines.

.3 Payment for 100 mm PVC drain tile to be based on per metre installed.

PART 2 PRODUCTS

2.1 Materials

.1 Fibreglass outfall structure (approximately 0.8 m x 1 .O m x 1.8 m) to be fabricated by speciality contractor. Portals, interior weirs etc. details to be finalized in field.

.2 50 mm PVC pipe and associated traps as per contract construction drawings for leachate piping.

.3 Sand and gravel meeting specification requirements for granular cover (Section 0250).

.4 100 mm PVC drain tile.

PART 3 EXECUTION

3.1 Collection Piping

.1 Extend existing 50 mm PVC leachate collection piping from waste rock pile to new outfall structure.

.2 Install new 50 mm PVC collection piping from toe of waste rock pile on north face near existing leachate collection piping to outfall structure.

.3 All 50 mm PVC collector piping provided with approved traps.

.4 Provide bentonite seal around area where collector piping passes through geomembrane.

3.2 Outfall Structure

.1 Construct 30 cm thick sand and gravel base for outfall structure. Base to extend 0.5 m outside dimensions of structure.

.2 Sand and gravel compacted in 15 cm lifts to 95% Modified Proctor density (ASTM 01557).

.3 Elevation of top of sand and gravel base to be determined in field by Engineer.

.4 Place fibreglass outfall structure on prepared base in accordance with fabricator requirements.

.5 Backfill around fibreglass structure to top of structure with sand and gravel compacted to 95% Modified Proctor density (ASTM D1557).

3.3 Lysimeter Piping

.1 Install collection piping from lysimeters into outfall structure as directed by Engineer.

3.4 Outlet Piping

.1 Install 100 mm PVC drain tilc at outlet of structurc.

.2 Excavate shallow trench to a maximum depth 1 m eastward and southward towards existing sedimentation pond. Length of trench to be determined in field based on elevation of outfall structure.

.3 Provide **15** cm sand base in trench prior to installing **100** mm PVC drain tile. Backfill to 15 cm above drain with sand. Backfill to surface with excavated soil.

.4 Grade surface of trench excavation.

PART1 GENERAL

1.1 Description

.1 This section specifies requirements for installation of instrumentation in waste rock Pile 7/12 and completed composite soil cover.

1.2 Measurement for Payment

.1 All instrumentation to be provided by Noranda Technology Centre.

.2 Payment for all construction equipment, labour, sand and gravel required for installation of lysimeters (2) will be based on a lump sum per unit basis.

.3 There will be no separate payment for delay of less than 2 hours at any one time due to placement of moisture sensors and pressure transducers in impermeable cover.

.4 Delay beyond 2 hours at any one time will be at an agreed standby rate.

.5 Heath Steele Mines will provide PVC piping, fittings and bentonite.

PART 2 PRODUCTS

2.1 Materials

.1 Lysimeters (2), moisture sensors, pressure transducers and associated wiring.

.2 50 mm PVC piping and associated fittings

.3 Bentonite

PART 3 EXECUTION

3.1 Existing Monitoring Equipment.

.1 Extend existing monitoring casing(s) above composite cover to an elevation approved by Engineer.

.2 Protect existing monitoring equipment from any damage during construction. Make good damage.

3.2 Lysimeters

.1 Install lysimeters at general locations indicated on drawings.

.2 Excavate waste rock at locations indicated to a minimum 150 mm below base of lysimeter. Sides of excavation to extend a minimum of 300 mm beyond lysimeter.

.3 Large voids or depressions in base and side of lysimeter excavation to be infilled with crushed rock or waste rock as outlined in Section 0210.

.4 Prepare base for lysimeter with sand used for sand base of composite soil cover as outlined in Section 0220.

.5 Sand base compacted to 92% of dry Modified Proctor density.

.6 Surface of sand base to be flat sloping in direction of outfall structure at minimum 2% gradient.

.7 Place lysimeter atop sand base and backfill around sides with sand. Infill lysimeter with sand in accordance with Noranda Technology Centre requirements.

.8 Excavate small trench for lysimeter collection piping in top of waste rock from lysimeter north to side slops of pile.

.9 Place 150 mm sand bedding in trench prior to placing 50 mm PVC drain. Backfill to 50 mm above drain with sand. Drain from lysimeter installed at minimum 2% gradient.

.10 Place 50 mm PVC lysimeter drain pipe on top of prepared side slope of waste rock pile from top of waste rock pile to outfall structure as directed by Engineer.

3.3 Moisture Sensors and Pressure Transducers

.1 Moisture sensors and pressure transducers to be installed in impermeable cover by personnel from Noranda Technology Centre.

.2 Sensors and transducers to be installed at base of impermeable cover, at top of cover, and at depth of 20 and 40 cm. Sensors to be placed as soon as glacial till has been compacted.

.3 Most sensors and transducers w-ill be distributed over top of pile. Several will be installed on one of side slopes. Locations of all sensors and transducers to be determined in field by Noranda Technology Centre.

.4 Wiring for instrumentation will be laid from sensors and transducers to an existing central monitoring casing.

.5 Contractor responsible for protection of all wiring extending from instrumentation to central monitoring casing.

.6 Impermeable cover material to be placed around instrumentation as directed by Engineer.

APPENDIX II

Laboratory Test Results

PARTICLE SIZE DISTRIBUTION

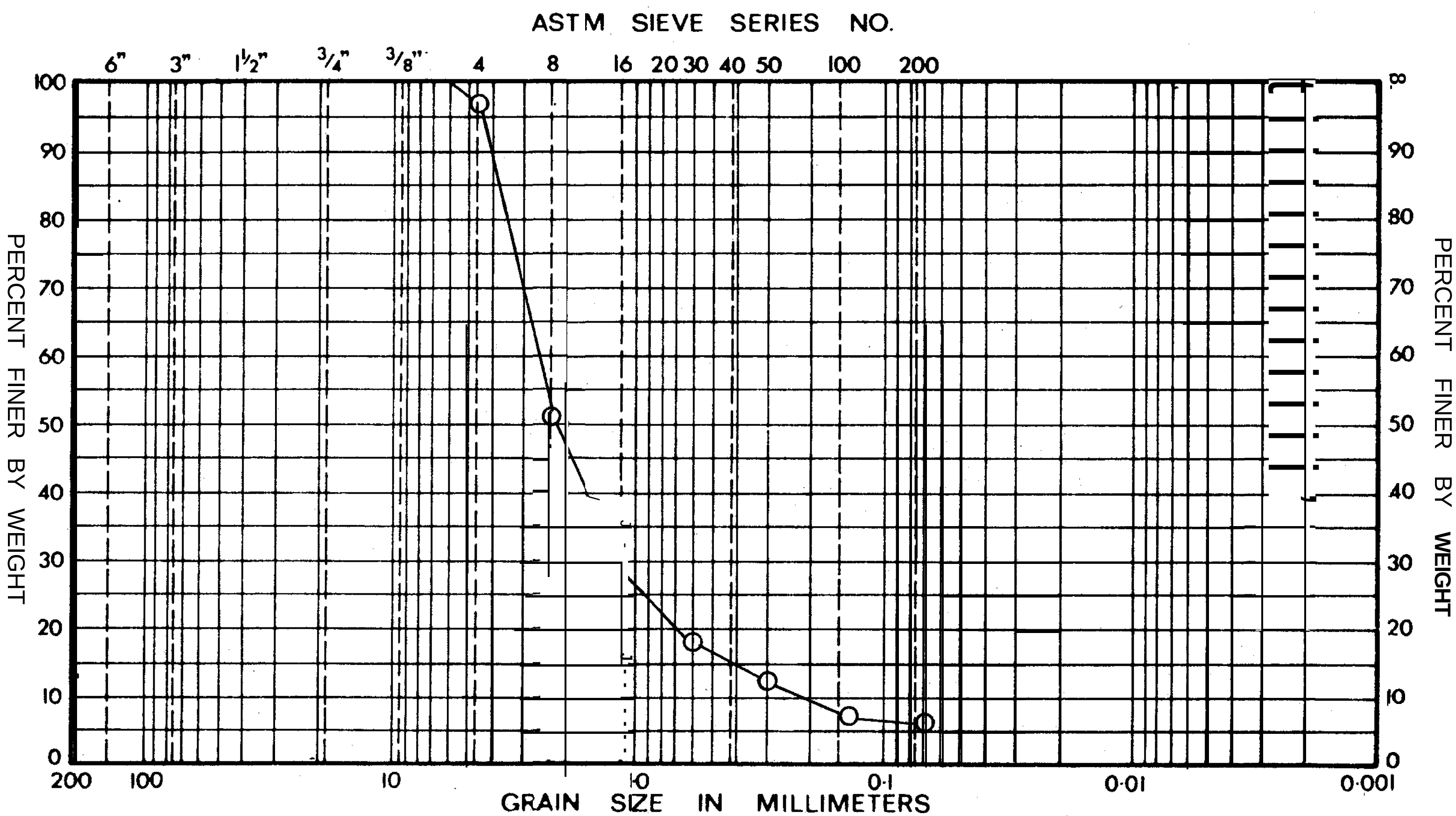
PROJECT NO. F91-057

PROJECT PHASE IV ACID WASTE ROCK STUDY . COMPOSITE SOIL COVER

LOCATION HEATH STEELE MINES

DATE JULY 1991

FIG. NO. II-1



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

UNIFIED SOIL CLASSIFICATION SYSTEM

SAMPLE NO. & LOCATION	U.S.C. SYMBOL	DESCRIPTION & REMARKS
	○	SAND BASE - SHADDICK LAKE

08/90

PARTICLE SIZE DISTRIBUTION

PROJECT NO. F91-057

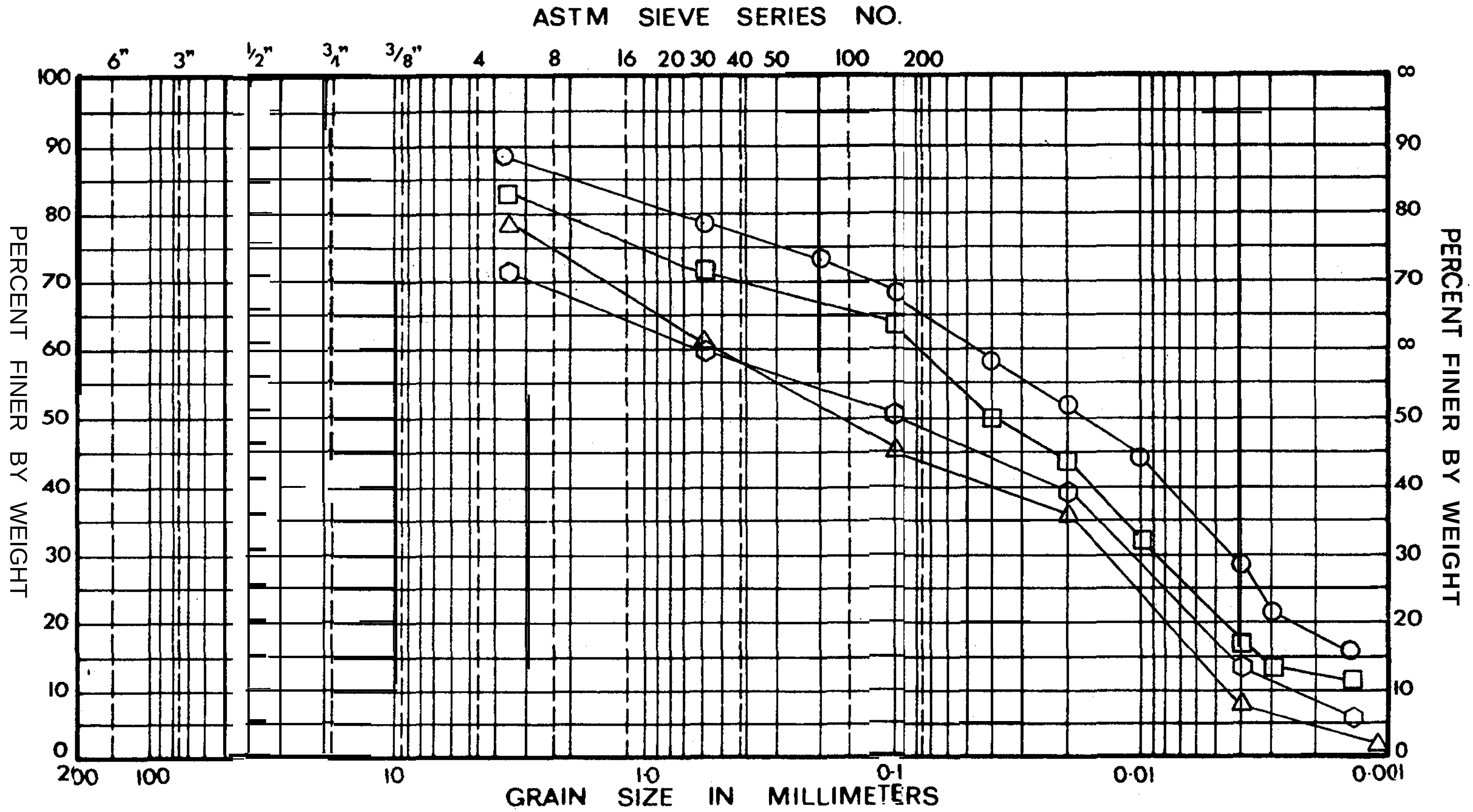
PROJECT PHASE IV ACID WASTE ROCK STUDY - COMPOSITE SOIL COVER

LOCATION HEATH STEELE MINES

DATE

FIG. NO. II-2

08/90



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

UNIFIED SOIL CLASSIFICATION SYSTEM

SAMPLE NO. & LOCATION	U.S.C. SYMBOL	DESCRIPTION & REMARKS
		GLACIAL TILL SAMPLED BY N.T.C.

PARTICLE SIZE DISTRIBUTION

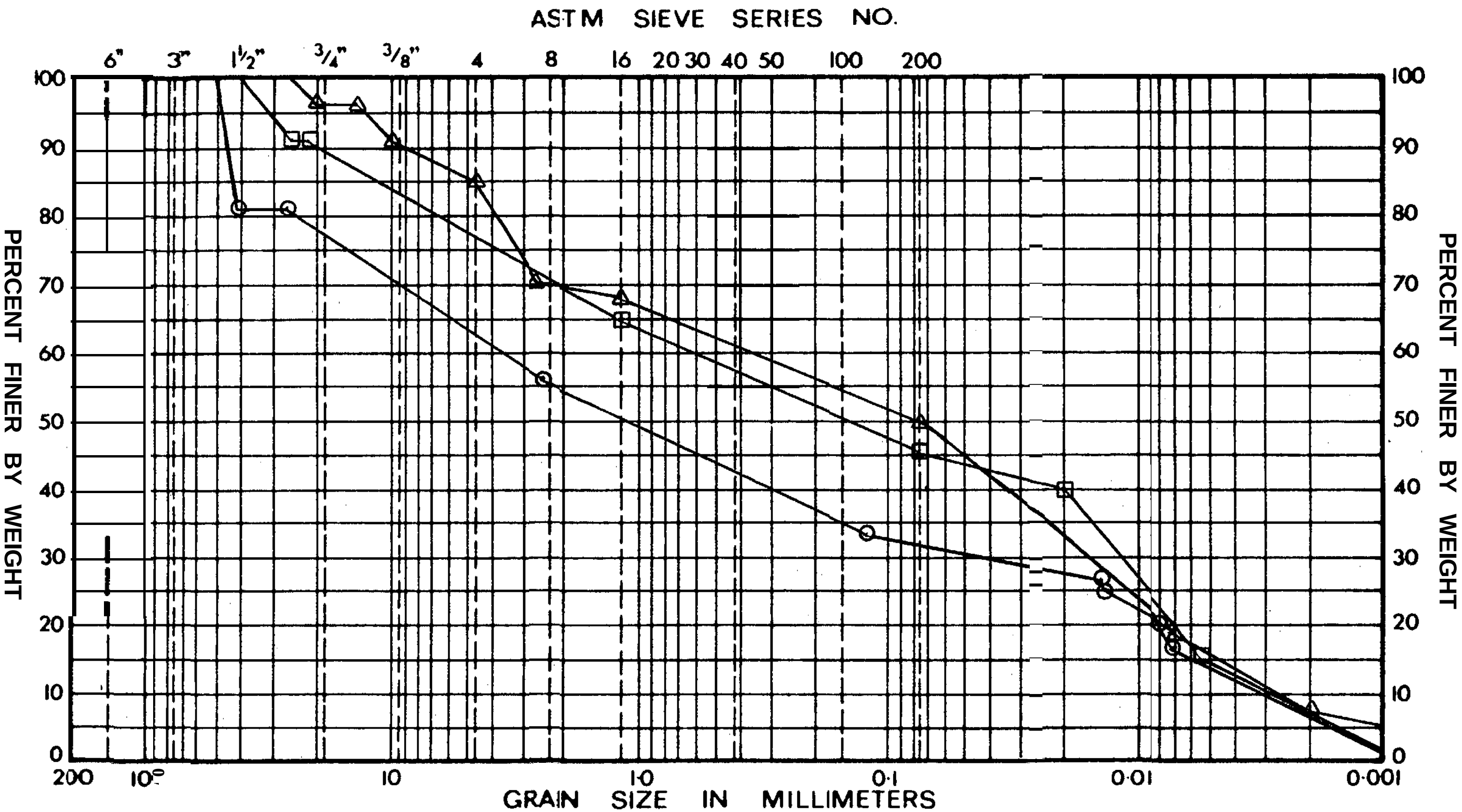
PROJECT NO. F91-057

PROJECT PHASE IV ACID WASTE ROCK STUDY - COMPOSITE SOIL COVER

LOCATION HEATH STEELE MINES

DATE DECEMBER, 1991

FIG. NO. II-3



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

UNIFIED SOIL CLASSIFICATION SYSTEM

SAMPLE NO. & LOCATION	U.S.C. SYMBOL	DESCRIPTION & REMARKS
1	○	GLACIAL TILL - SAMPLED SEPTEMBER 5
2	△	GLACIAL TILL - SAMPLED SEPTEMBER 6
3	□	GLACIAL TILL - SAMPLED SEPTEMBER 7

PARTICLE SIZE DISTRIBUTION

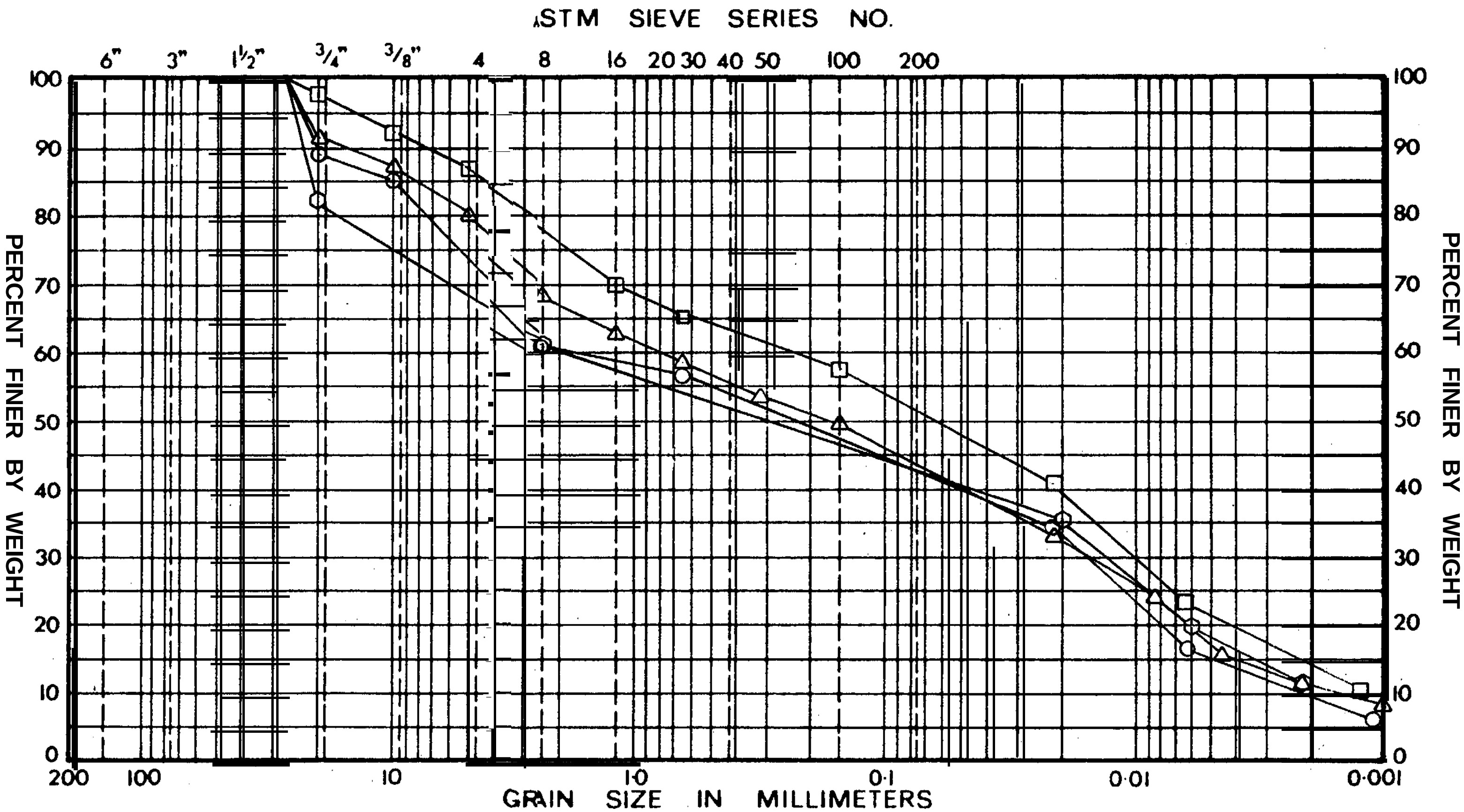
PROJECT NO. F91-057

PROJECT PHASE IV ACID WASTE ROCK STUDY - COMPOSITE SOIL COVER

LOCATION HEATH STEELE MINES

DATE DECEMBER, 1991

FIG. NO. II-4



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

UNIFIED SOIL CLASSIFICATION SYSTEM

SAMPLE NO. & LOCATION	U.S.C. SYMBOL	DESCRIPTION & REMARKS
4	○	GLACIAL TILL - SAMPLED SEPTEMBER 8
5	△	GLACIAL TILL - SAMPLED SEPTEMBER 9
6	□	GLACIAL TILL - SAMPLED SEPTEMBER 12
7	⬡	GLACIAL TILL - SAMPLED SEPTEMBER 13

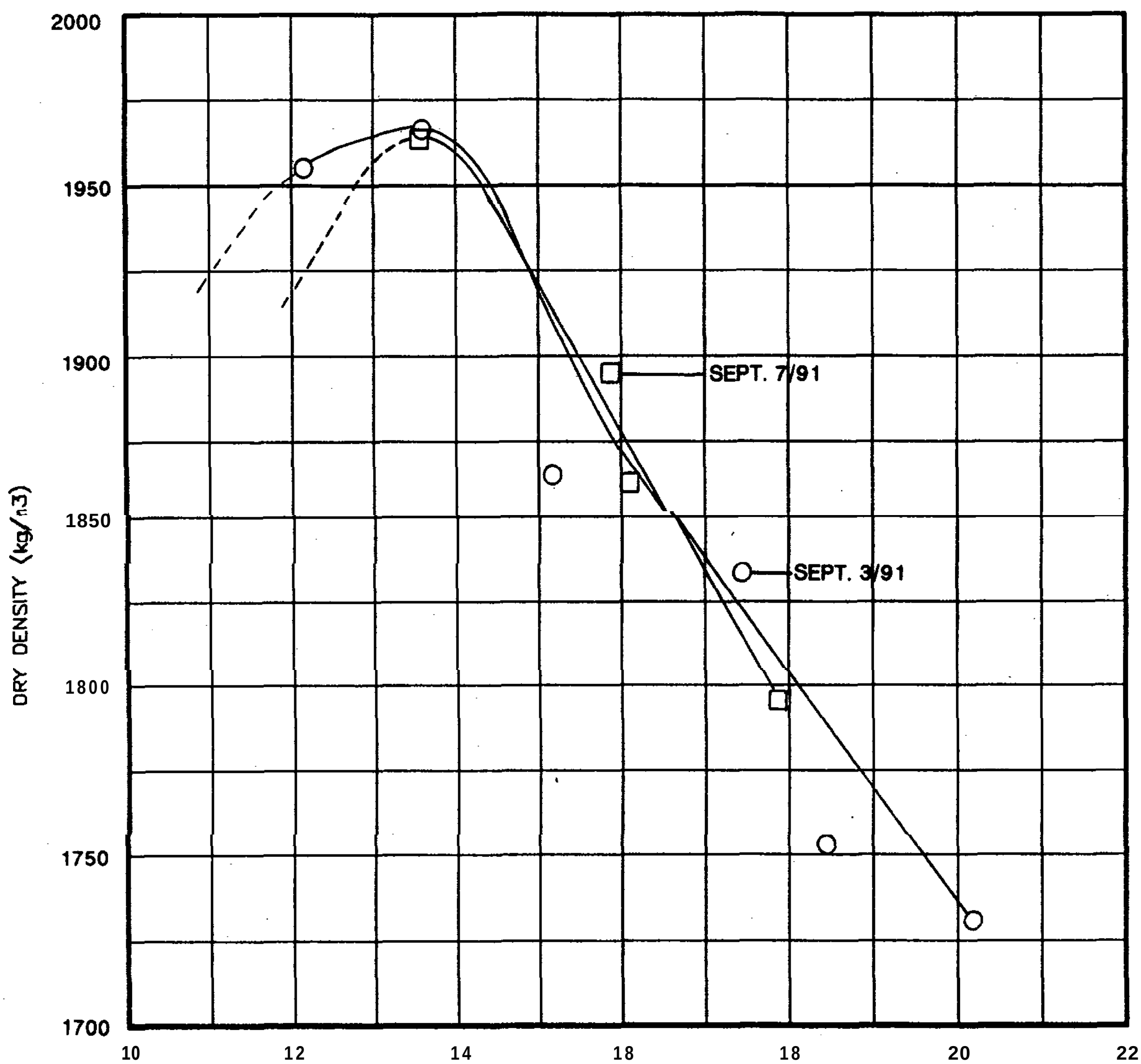
06/80

MOISTURE DENSITY RELATIONS

PROJECT NO. F91-057 FIG. NO. II-5

PROJECT PHASE IV ACID WASTE ROCK STUDY - COMPOSITE SOIL COVER

LOCATION HEATH STEELE MINES DATE SEPTEMBER 1991



SAMPLE DESCRIPTION GLACIAL TILL

TEST ASTM D 1557

γd MAX 1965 kg/m3

OPT. w. 13.5%

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PARTICLE SIZE DISTRIBUTION

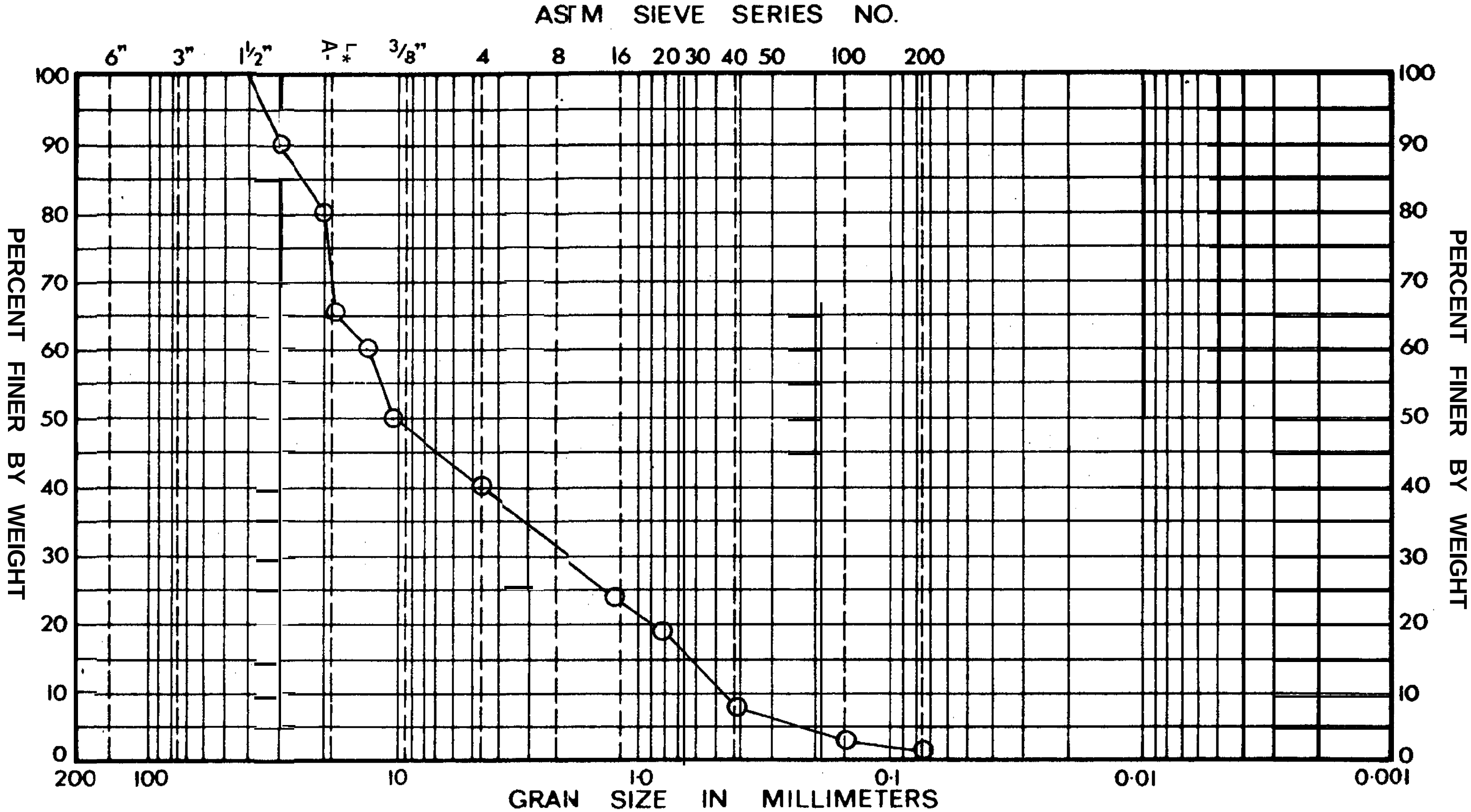
PROJECT NO. F91-057

FIG. NO. II-6

PROJECT PHASE IV ACID WASTE ROCK STUDY - COMPOSITE SOIL COVER

LOCATION HEATH STEELE MINES

DATE SEPTEMBER 1991



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

UNIFIED SOIL CLASSIFICATION SYSTEM

SAMPLE NO. & LOCATION	U.S.C. SYMBOL	DESCRIPTION & REMARKS
	○	GRANULAR COVER - SHADDICK LAKE

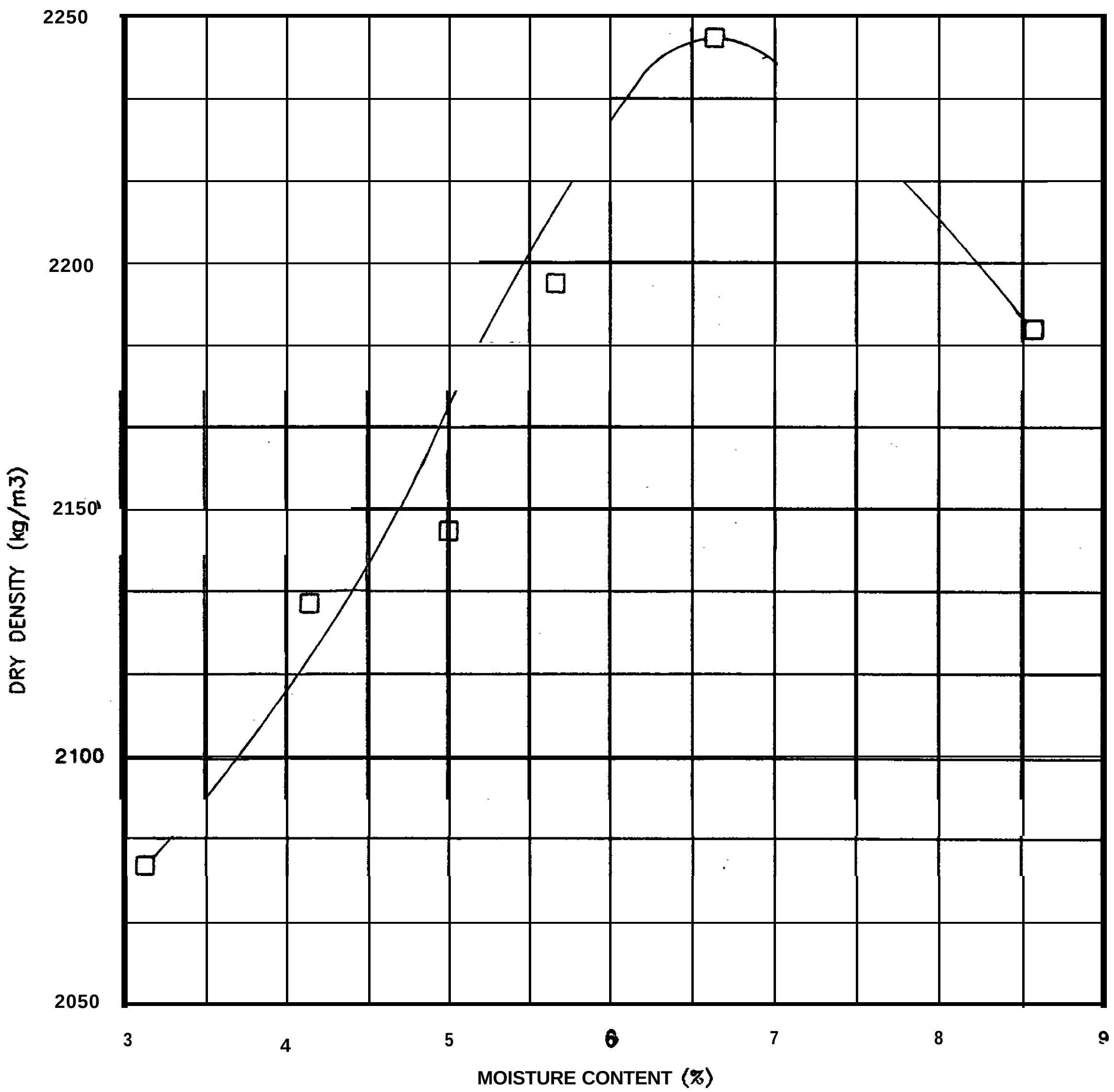
08/90

MOISTURE DENSITY RELATIONS

PROJECT NO. F91-057 FIG. NO. II-7

PROJECT PHASE IV ACID WASTE ROCK STUDY - COMPOSITE SOIL COVER

LOCATION HEATH STEELE MINES DATE SEPTEMBER 1991



SAMPLE DESCRIPTION GRANULAR COVER - SHADDICK LAKE

TEST ASTM 01557

γ_d MAX 2240 kg/m3

OPT. W. 6.5

APPENDIX III

In Situ Density Test Results

NO.	LOCATION	SOIL TYPE	MOISTURE CONTENT	DRY DENSITY (kg/m3)	% MAX DRY DENSITY	DATE TESTED
1	PILE: South Side, East End, Top of Slope First Lift	Sand & Gravel	5.6	2041	91	Sept. 10/91
6	PILE: South Side, West End, Midslope First Lift	Silty Clayey TILL	18.2	1874	96	Sept. 4/91
7	PILE: South Side, Midpile, Midslope First Slope	silty Clayey TILL	18.1	1880	96	Sept. 4/91
8	PILE: South Side, East End, Midslope First Lift	Silty Clayey TILL	18.6	1906	97	Sept. 4191
9	PILE: South Side, East End, Top of Slope First Lift	Silty Clayey TILL	17.9	1908	97	Sept. 4/91
10	PILE: South Side, West End,Top of Slope, First Lift	Silty Clayey TILL	18.4	1926	98	Sept. 4/91
11	PILE: South Side, Midpile, Top of Slope First Lift	Silty Clayey TILL	17.5	1866	95	Sept. 4/91
12	PILE: South Side, Midpile, Bottom of Slope, First Lift	Silty Clayey TILL	16.4	1893	96	Sept. 4191
13	PILE: South Side, Midpile, Bottom of Slope, First Slope	Silty Clayey TILL	17.1	1872	95	Sept. 4/91
14	PILE: South Side East End, Midslope First Lift	Silty Clayey TILL	16.5	1864	95	Sept. 4/91

NO.	LOCATION	SOIL TYPE	MOISTURE CONTENT	DRY DENSITY (kg/m3)	% MAX DRY DENSITY	DATE TESTED
15	PILE: South Side, East End, Midslope First Lift	Silty Clayey TILL	16.7	1695	97	Sept. 4/91
16	PILE: East Side, South End, Midslope . First Lift	Silty Clayey TILL	16.0	1886	96	Sept. 4/91
17	PILE: West Side, South End, Midslope First Lift	Silty Clayey TILL	16.6	1907	97	Sept. 4/91
18	PILE: West Side, South End, Top of Slope First Lift	Silty Clayey TILL	16.9	1892	96	Sept. 4/91
19	PILE: East Side, North End, Midslope First Lift	Silty Clayey TILL	17.6	1870	95	Sept. 4/91
20	PILE: East Side, North End, Top of Slope First Lift	Silty Clayey TILL	20.0	1830	93	Sept. 4/91
21	PILE: East Side, North End, Top of Slope First Lift	Silty Clayey TILL	16.6	1953	96	Sept. 4/91
22	PILE: East Side, South End, Midslope First Lift	Silty Clayey TILL	15.1	1953	100	Sept. 4/91
23	PILE: South Side, East End, Top of Slope, Second Lift	Silty Clayey TILL	18.0	1874	96	Sept. 4/91
24	PILE: South Side, Midpile, Top of Slope Second Lift	Silty Clayey TILL	17.0	1866	95	Sept. 4/91

IO.	LOCATION	SOIL TYPE	MOISTURE CONTENT	DRY DENSITY (kg/m3)	% MAX DRY DENSITY	DATE TESTED
25	PILE: South Side, West End, Midslope Second Lift	Silty Clayey TILL	16.5	1864	95	Sept. 4/91
26	PILE: South Side Midpile, Midslope Second Lift	Silty Clayey TILL	16.4	1885	96	Sept. 4/91
27	PKE: South Side, East End, Top of Slope Second Lift	Silty Clayey TILL	17.2	1891	96	Sept. 4/91
28	PILE: East Side South End, Midslope Second Lift	Silty Clayey TILL	17.8	1885	96	Sept. 4/91
29	PILE: West Side South End, Top of Slope Second Lift	Silty Clayey TILL	15.6	1978	101	Sept. 4/91
30	PILE: West Side Midpile, Midslope Second Lift	Silty Clayey TILL	17.7	1923	98	Sept. 4/91
31	PILE: East Side Midpile, Midslope Second Lift	Silty Clayey TILL	15.8	1979	101	Sept. 4/91
32	PILE: East Side Midpile, Bottom of Slope, Second Lift	Silty Clayey TILL	17.3	1906	97	Sept. 4/91
33	PILE: East Side North End, Midslope Second Lift	Silty Clayey TILL	17.0	1942	99	Sept. 4/91
34	PILE: East Side North End, Bottom of Slope, Second Lift	Silty Clayey TILL	17.7	1927	98	Sept. 4/91

NO.	LOCATION	SOIL TYPE	MOISTURE CONTENT	DRY DENSITY (kg/m3)	% MAX DRY DENSITY	DATE TESTED
35	PILE: East Side, North End, Midslope Second Lift	Silty Clayey TILL	14.7	1962	100	Sept. 4/91
36	PILE: East Side, South End, Top of Slope, Second Lift	Silty Clayey TILL	15.4	1947	99	Sept. 4/91
37	PILE: East Side, South End, Midslope, Second Lift	Silty Clayey TILL	16.4	1887	96	Sept. 4/91
38	PILE: South Side East End, Top of Slope Third Lift	Silty Clayey TILL	17.3	1906	97	Sept. 4/91
39	PILE: South Side Midpile, Top of Slope, Third Lift	Silty Clayey TILL	16.4	1880	96	Sept. 4/91
40	PILE: South Side, West End, Top of Slope, Third Lift	Silty Clayey TILL	15.8	1899	97	Sept. 4/91
41	PILE: South Side, West End, Bottom of Slope, Third Lift	Silty Clayey TILL	16.8	1901	97	Sept. 4/91
42	PILE: South Side, Midpile, Bottom of Slope, Third Lift	Silty Clayey TILL	18.4	1857	95	Sept. 4/91
43	PILE: South Side, Midpile, Bottom of Slope(retest)Third Lift	Silty Clayey TILL	16.6	1927	98	Sept. 4/91
44	PILE: South Side, East End, Midslope, Third Lift	Silty Clayey TILL	17.8	1912	97	Sept. 4/91

NO.	LOCATION	SOIL TYPE	MOISTURE CONTENT	DRY DENSITY (kg/m3)	% MAX DRY DENSITY	DATE TESTED
45	PILE: South Side, East End, Top of Slope Third Lift	silty Clayey TILL	17.9	1903	97	Sept. 4/91
46	PILE: West Side, South End, Top of Slope, Third Lift	Silty Clayey TILL	18.7	1850	94	Sept. 4/91
47	PILE: West Side, Midpile, Top of Slope Third Lift	Silty Clayey TILL	17.7	1852	94	Sept. 4/91
48	PILE: West Side, North End, Bottom of Slope, Third Lift	Silty Clayey TILL	18.6	1837	94	Sept. 4/91
49	PILE: West Side, North End, Bottom of Slope, Third Lift	Silty Clayey TILL	18.2	1892	96	Sept. 4/91
50	PILE: West Side, Retest South End, Midslope, Fortysix, Third Lift	Silty Clayey TILL	15.6	1930	98	Sept. 4/91
51	PILE: West Side, North End, Top of Slope Third Lift	Silty Clayey TILL	16.4	1951	99	Sept. 8/91
52	PILE: West Side, Retest Midpile, Midslope, Fortyseven, Third Lift	Silty Clayey TILL	17.0	1915	98	Sept. 8/91
53	PILE: Top East End, Midpile, First Lift	Silty Clayey TILL	18.3	1883	96	Sept. 8/91
54	PILE: Top North End, Midpile, First Lift	Silty Clayey TILL	18.4	1872	95	Sept. 8/91

luo.	LOCATION	SOIL TYPE	MOISTURE CONTENT	DRY DENSITY (kg/m3)	% MAX DRY DENSITY	DATE TESTED
55	PILE: Top Northwest Comer, First Lift	Silty Clayey TILL	17.4	1878	98	Sept. 8/91
56	PILE: North Side, West End, Midpile, First Lift	W Y Clayey TILL	15.2	1924	98	Sept. 8/91
57	PILE: North Side, East Side, Midslope, First Lift	Silty Clayey TILL	18.7	1920	98	Sept. 8/91
58	PILE: Top Noerth End, Midpile, First Lift	Silty Clayey TILL	17.5	1869	95	Sept. 8/91
59	PILE: Top Southeast Comer, First Lift	Silty Clayey TILL	17.0	1889	96	Sept. 8/91
60	PILE: North Side Midpile, Midslope, Second Lift	Silty Clayey TILL	17.5	1940	99	Sept. 8/91
61	PILE: Top West Side, Midslope, Second Lift	Silty Clayey TILL	17.8	1908	97	Sept. 8/91
62	PILE: Top East Side, Midpile Second Lift	Silty Clayey TILL	18.4	1875	96	Sept. 8/91
63	PILE: Top West Side, North End, Second Lift	Silty Clayey TILL	16.3	1894	97	Sept. 8/91
64	PILE: North Side, East End, Midslope Second Lift	Silty Clayey TILL	17.8	1885	96	Sept. 8/91

IUO.	LOCATION	SOIL TYPE	MOISTURE CONTENT	DRY DENSITY (kg/m3)	% MAX DRY DENSITY	DATE TESTED
65	PILE: North Side, East End, Top of Slope Second Lift	Silty Clayey TILL	18.4	1895	97	Sept. 8/91
66	PILE: Top, Center of Pile, . Third Lift	Silty Clayey TILL	14.7	1908	97	Sept. 8/91
67	PILE: Top, South Side, Center Third Lift	Silty Clayey TILL	16.5	1940	99	Sept. 8/91
68	PILE: Top, North Side, Center, Third Lift	Silty Clayey TILL	17.0	1885	96	Sept. 8/91
69	PILE: Top, East End, Center, Third Lift	Silty Clayey TILL	15.6	1976	101	Sept. 8/91
70	PILE: North Side, West End, Top of Slope, Second Lift	Silty Clayey TILL	16.3	1915	98	Sept. 8/91
71	PILE: North Slope East End, Top of Slope Second Lift	Silty Clayey TILL	14.5	1965	100	Sept. 8/91
72	PILE: North Slope, East End, Top of Slope Second Lift	Silty Clayey TILL	16.5	1915	98	Sept. 8/91
73	PILE: North Slope, East End, Midslope, Second Lift	Silty Clayey TILL	16.6	1887	96	Sept. 8/91
74	PILE: North Side, Midpile, Midslope Second Lift	Silty Clayey TILL	16.4	1887	96	Sept. 8/91

NO.	LOCATION	SOIL TYPE	MOISTURE CONTENT	DRY DENSITY (kg/m3)	% MAX DRY DENSITY	DATE TESTED
75	PILE: North Side West End, Midslope Thrid Lift	Silty Clayey TILL	15.6	1955	100	Sept. 8/91
76	PILE: North Slope East End, Bottom of Slope, Third Lift	Silty Clayey TILL	15.9	1950	99	Sept. 8/91
77	PILE: North Side West End, Bottom of Slope, Third Lift	Silty Clayey TILL	16.8	1935	99	Sept. 8/91
78	PILE: North Side, East End, Midslope Third Lift	Silty Clayey TILL	18.4	1916	98	Sept. 8/91
79	PILE: North Side, West End, Top of Slope, Third Lift	Silty Clayey TILL	14.5	1983	101	Sept. 8/91
80	PILE: North Side, Midpile, Bottom of Slope, Third Lift	Silty Clayey TILL	17.0	1884	96	Sept. 8/91
81	PILE: North Side, Midpile, Midslope Third Lift	Silty Clayey TILL	16.7	1916	98	Sept. 8/91
82	PILE: North Side, Midpile, Top of Slope Third Lift	Silty Clayey TILL	17.1	1896	97	Sept. 8/91
83	PILE: North Side, East End, Bottom of Slope, Third Lift	Silty Clayey TILL	15.5	1971	100	Sept. 8/91
84	PILE: North Side, East End, Midslope, Third Lift	Silty Clayey TILL	15.9	1943	99	Sept. 8/91

NO.	LOCATION	SOIL TYPE	MOISTURE CONTENT	DRY DENSITY (kg/m3)	% MAX DRY DENSITY	DATE TESTED
85	PILE: North Side, East End, Top of Slope, Third Lift	Silty Clayey TILL	15.5	1939	99	Sept. 8/91
86	PILE: North Side, Midpile Top of Slope, Third Lift	Silty Clayey TILL	18.5	1880	96	Sept. 8/91
87	PILE: North Side, East End,Bottom of Slope,Third Lift	Silty Clayey TILL	17.2	1915	98	Sept. 8/91
88	PILE: North Side, West End, Bottom of Slope, Third Lift	Silty Clayey TILL	18.5	1860	95	Sept. 8/91
89	PILE: South Side, West End, Midslope, Third Lift	Silty Clayey TILL	20.3	1851	94	Sept. 8/91
90	PILE: South Side, Midpile, Midslope, Third Lift	Silty Clayey TILL	18.6	1878	96	Sept. 8/91
91	PILE: South Side, East End, Midslope, Third Lift	Silty Clayey TILL	18.1	1880	96	Sept. 8/91
92	PILE: East Side, South End, Top of Slope, Third Lift	Silty Clayey TILL	16.2	1906	97	Sept. 8/91
93	PILE: East Side, Midpile, Top of Slope Third Lift	Silty Clayey TILL	16.5	1895	97	Sept. 8/91
94	PILE: East Side, North End, Bottom of Slope, Third Lift	Silty Clayey TILL	18.0	1871	95	Sept. 8/91

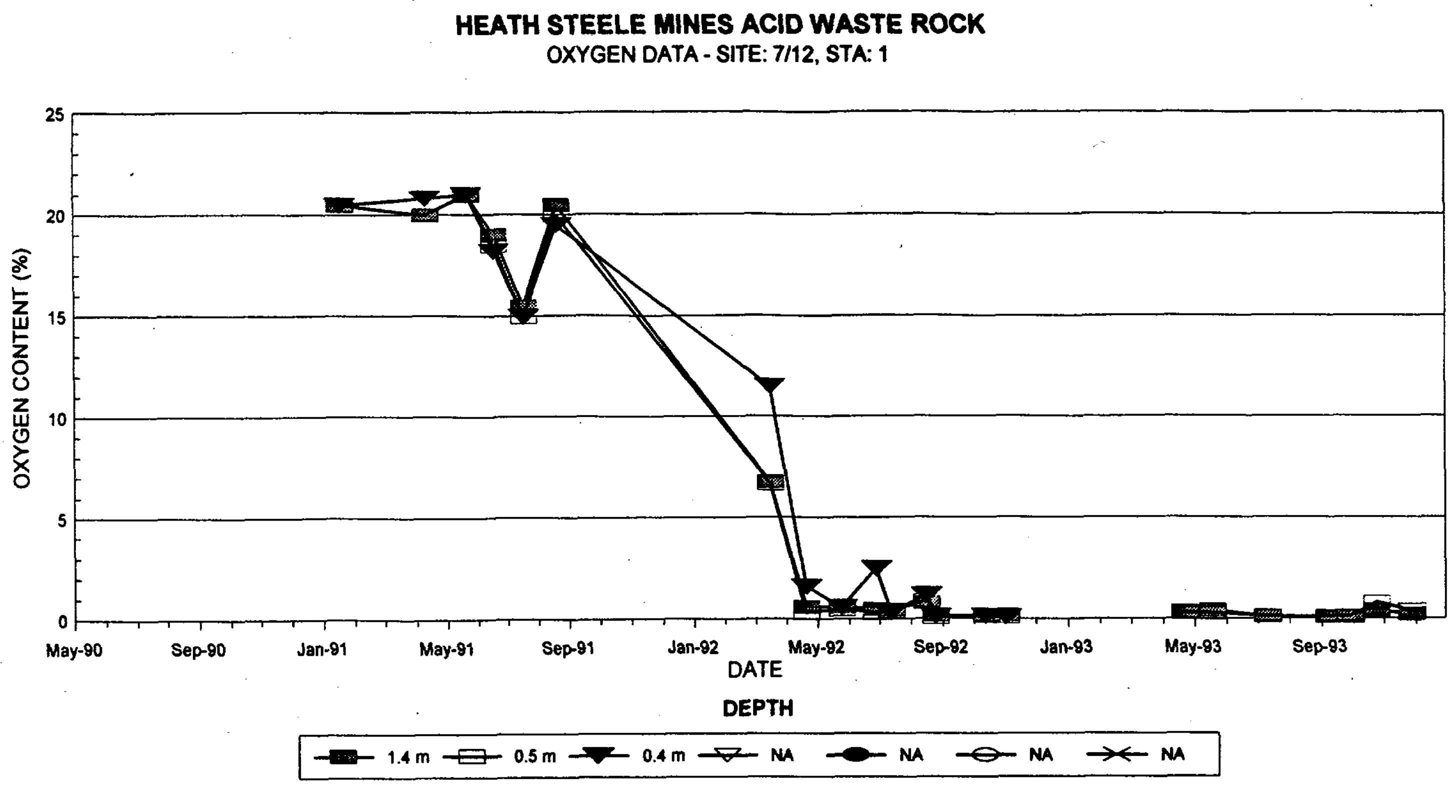
NO.	LOCATION	SOIL TYPE	MOISTURE CONTENT	DRY DENSITY (kg/m3)	% MAX DRY DENSITY	DATE TESTED
95	PILE: West Side, North End, Bottom of Slope, Third Lift	Silty Clayey TILL	16.7	1898	97	Sept. 8/91
96	PILE: West Side, Midpile, Midslope, Third Lift	Silty Clayey TILL	16.3	1888	96	Sept. 8/91
97	PILE: West Side, South End, Top of Slope , Third Lift	Silty Clayey TILL	20.0	1863	95	Sept. 8/91
98	PILE: Top, Northwest Comer, Second Lift	Silty Clayey TILL	17.8	1885	96	Sept. 8/91
99	PILE: Top, Center Third Lift	Silty Clayey TILL	15.6	1969	100	Sept. 8/91
102	PILE: South Side, Midpile, Midslope First Lift	Sand & Gravel	5.2	2064	92	Sept. 10191
103	PILE: South Side, West Side, Bottom of Slope, First Lift	Sand & Gravel	4.6	2083	93	Sept. 10/91
104	PILE: South Side, Midpile, Midslope, First Lift	Sand& Gravel	5.0	2091	93	Sept. 10/91
105	PILE: South Side, West End, Top of Slope First Lift	Sand & Gravel	6 . 2	2240	92	Sept. 10191
106	PILE: West Side, South End, Top of Slope, First Lift	Sand & Gravel	6.2	2068	92	Sept. 10191

NO.	LOCATION	SOIL TYPE	MOISTURE CONTENT	DRY DENSITY (kg/m3)	% MAX DRY DENSITY	DATE TESTED
107	PILE: West Side, Midpile, Midslope, First Slope	Sand & Gravel	6.2	2068	92	Sept. 13/91
108	PILE: West Side, North End, Bottom of Slope, First Lift	Sand & Gravel	6.2	2090	93	Sept. 13/91
109	PILE: West Side, South End, Bottom of Slope, Second Lift	Sand & Gravel	6.4	2094	94	Sept. 13/91
110	PILE: West Side, Midpile, Top of Slope, Second Lift	Sand & Gravel	6.9	2099	94	Sept. 13/91
111	PILE:WestSide, North End, Midslope, Second Lift	Sand& Gravel	4.9	2112	94	Sept. 16/91
112	PILE: East Side, North End, Top of Slope, First Lift	Sand& Gravel	6.9	2114	94	Sept. 16/91
113	PILE: East Side, Midpile, Midslope, First Lift	Sand & Gravel	4.5	2135	95	Sept. 16/91
114	PILE: East Side, South End, Bottom of Slope, First Lift	Sand & Gravel	5.7	2100	94	Sept. 16/91
115	PILE: East Side, North End, Bottom of Slope, Second Lift	Sand & Gravel	5.9	2096	94	Sept. 16/91
116	PILE: East Side, Midpile, Top of Slope, Second Lift	Sand& Gravel	4.1	2133	95	Sept. 16/91

APPENDIX IV

Monitoring Data

FIGURE IV-1



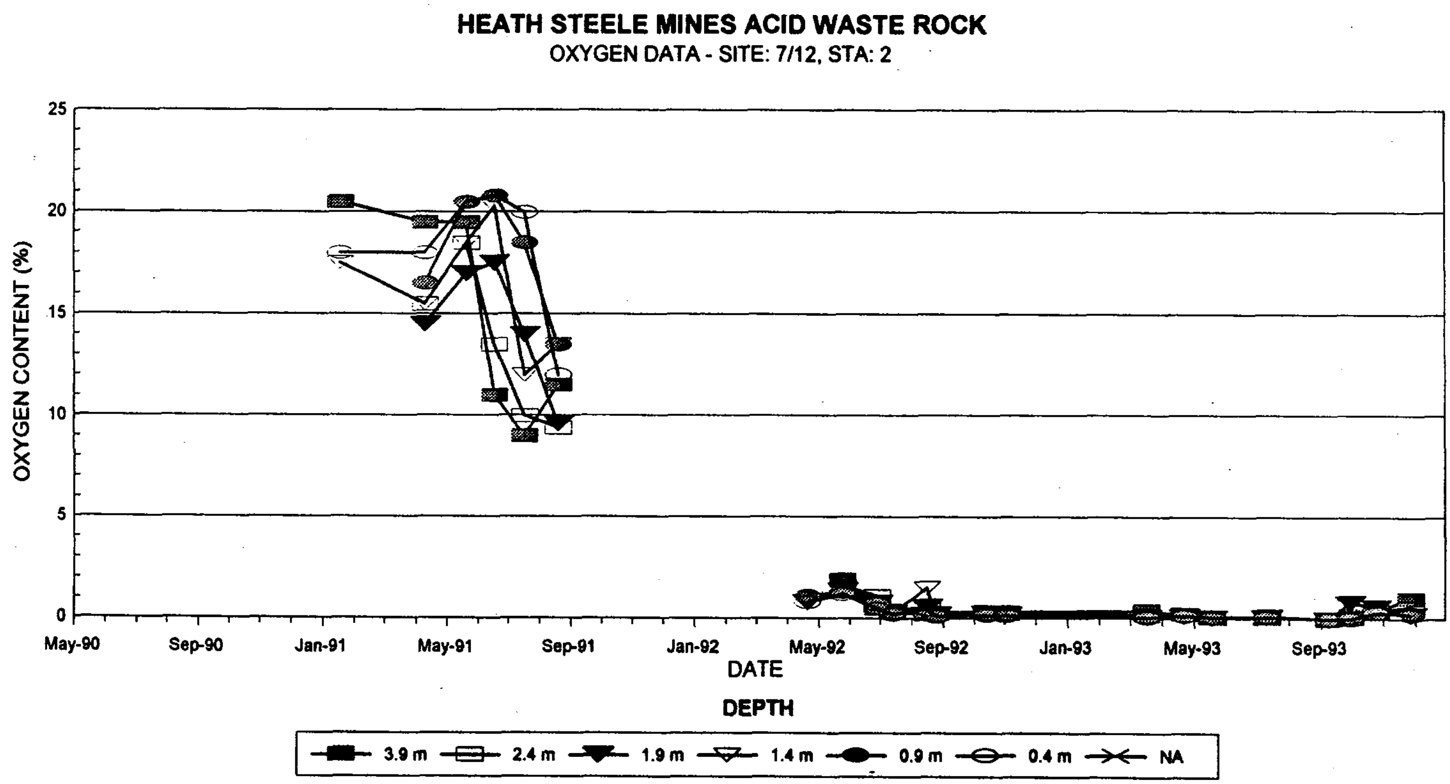
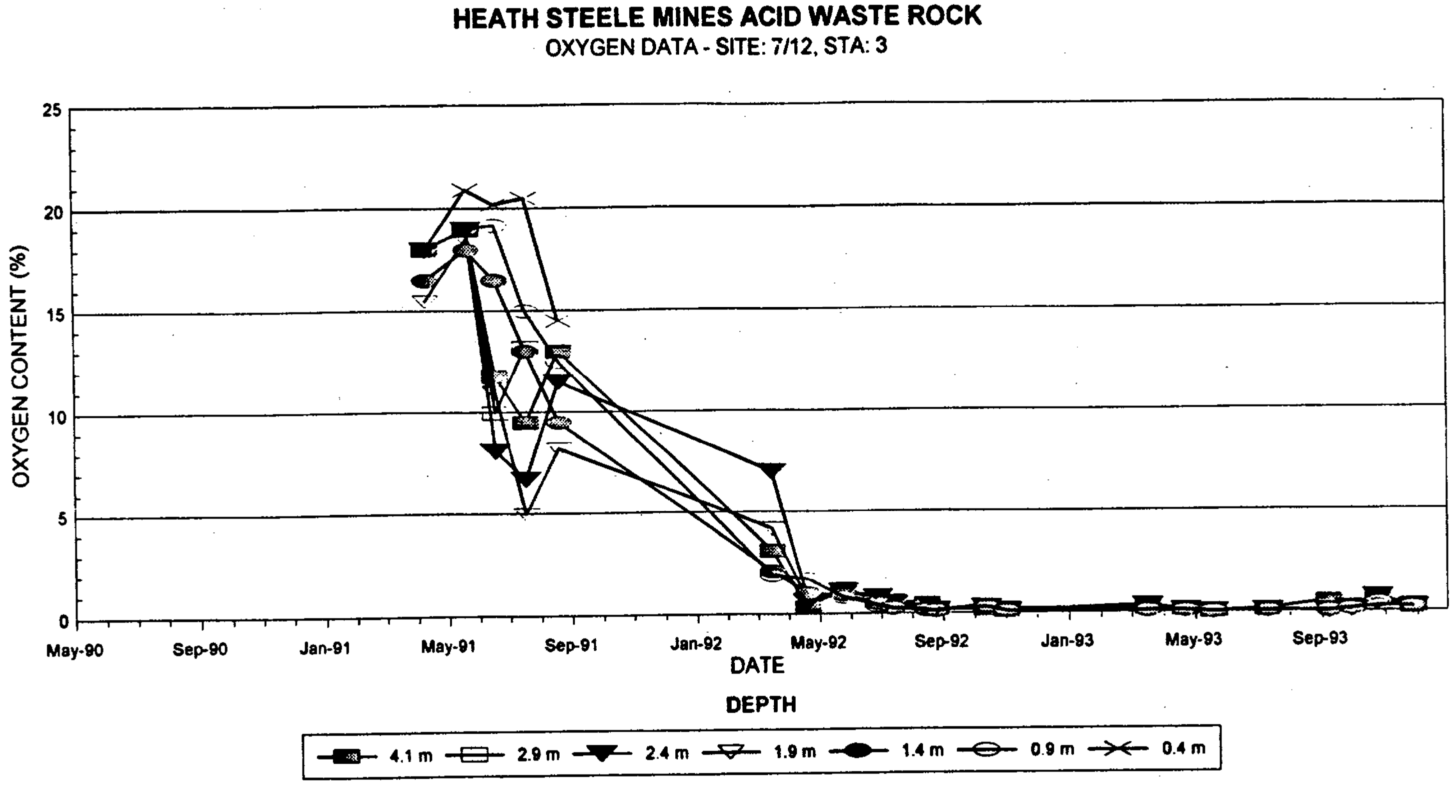


FIGURE IV-2

FIGURE IV-3



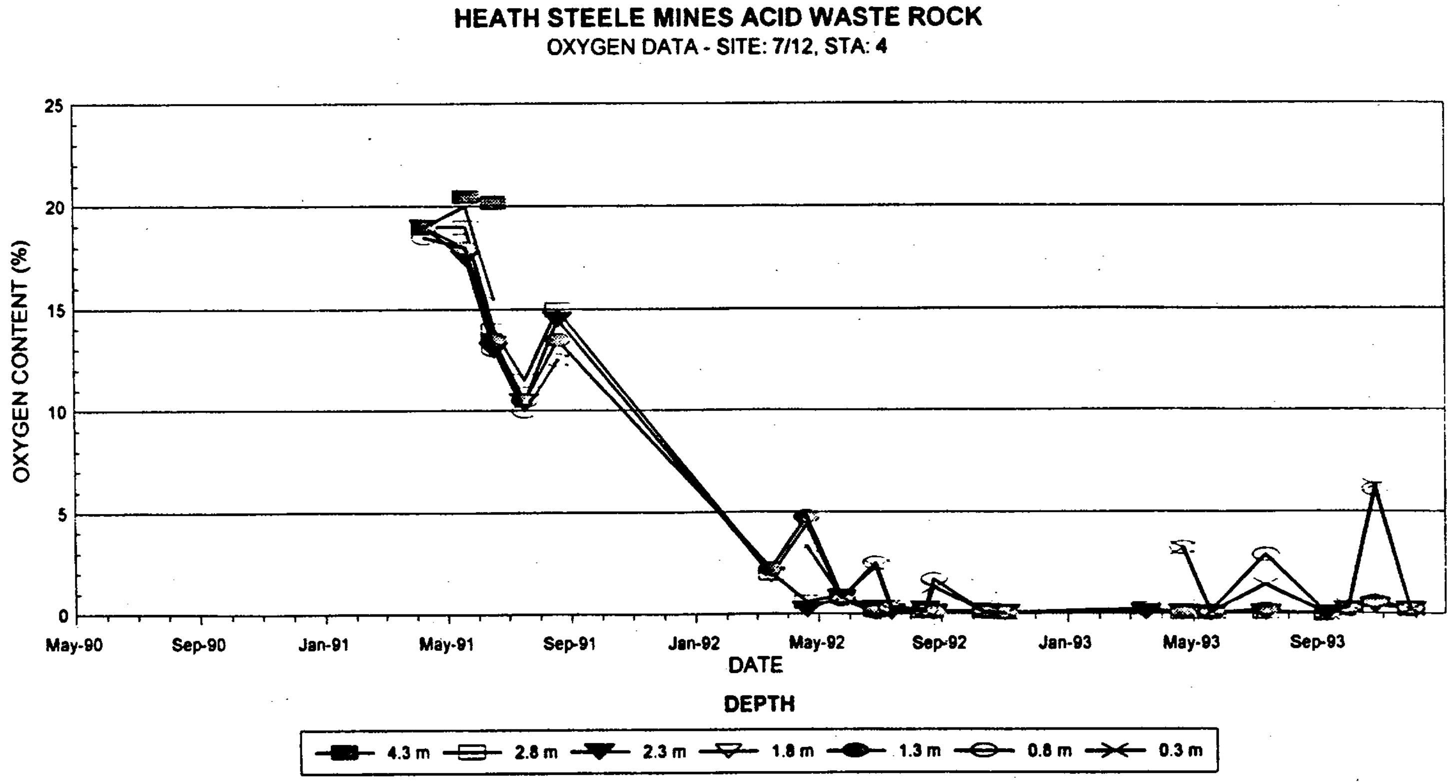
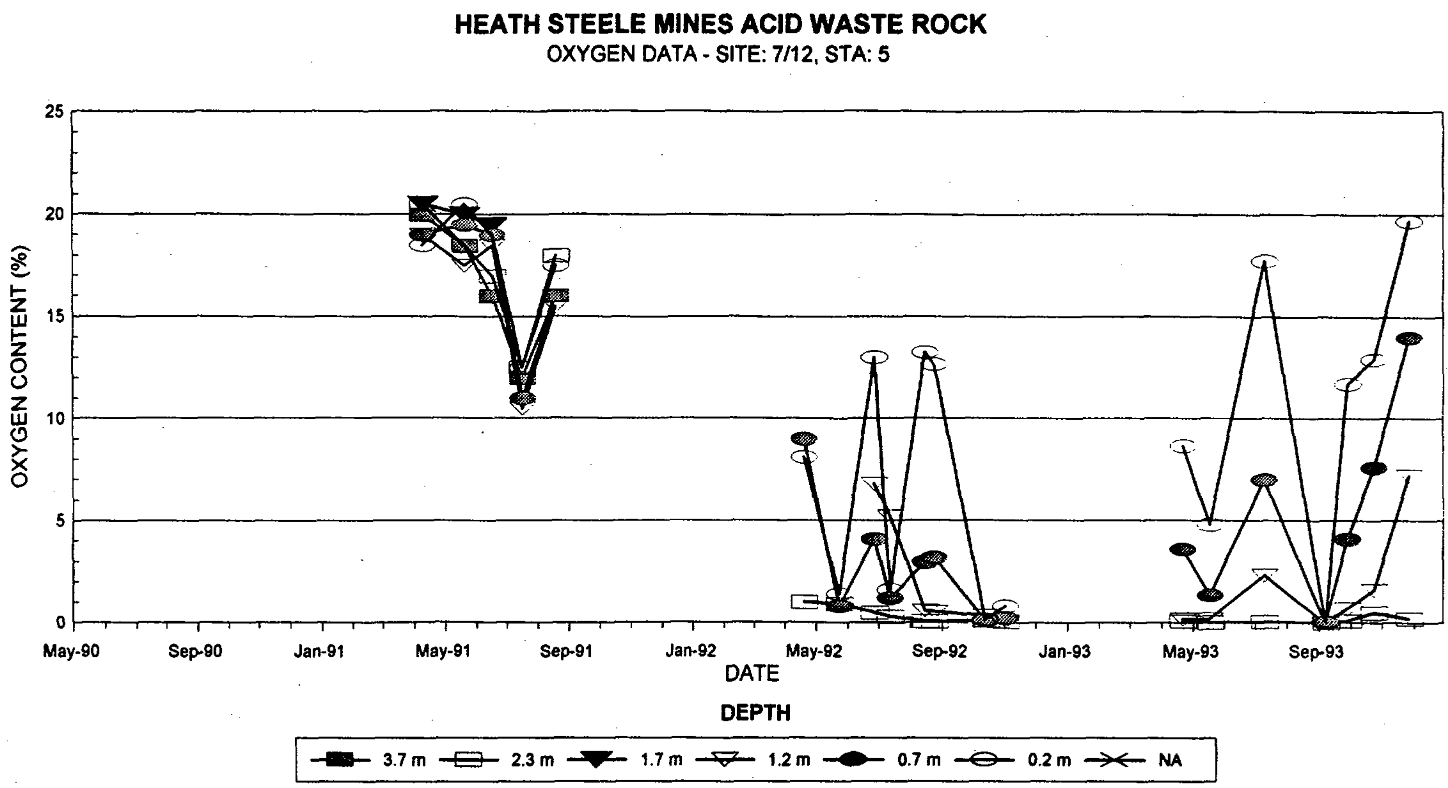


FIGURE IV-4

FIGURE IV-5



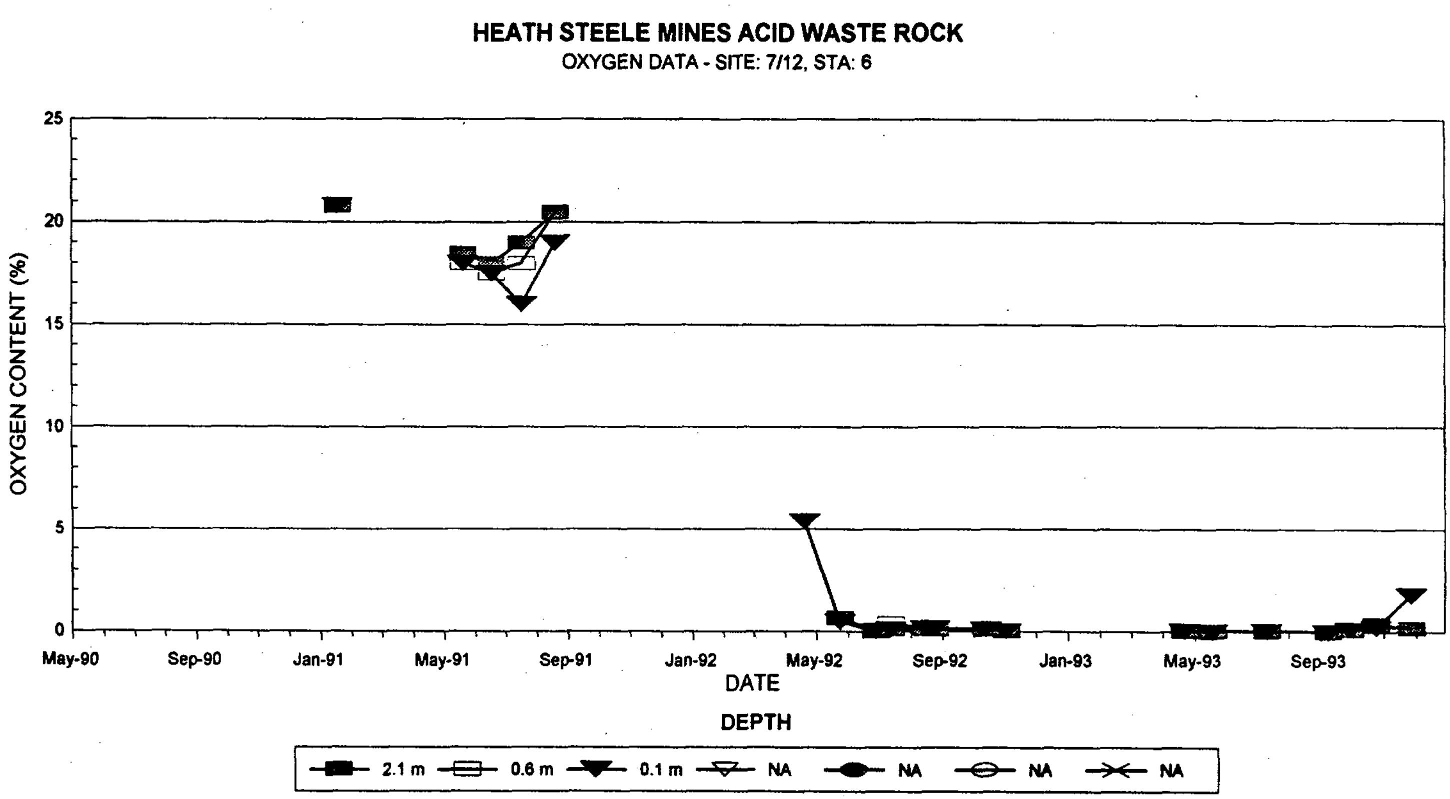
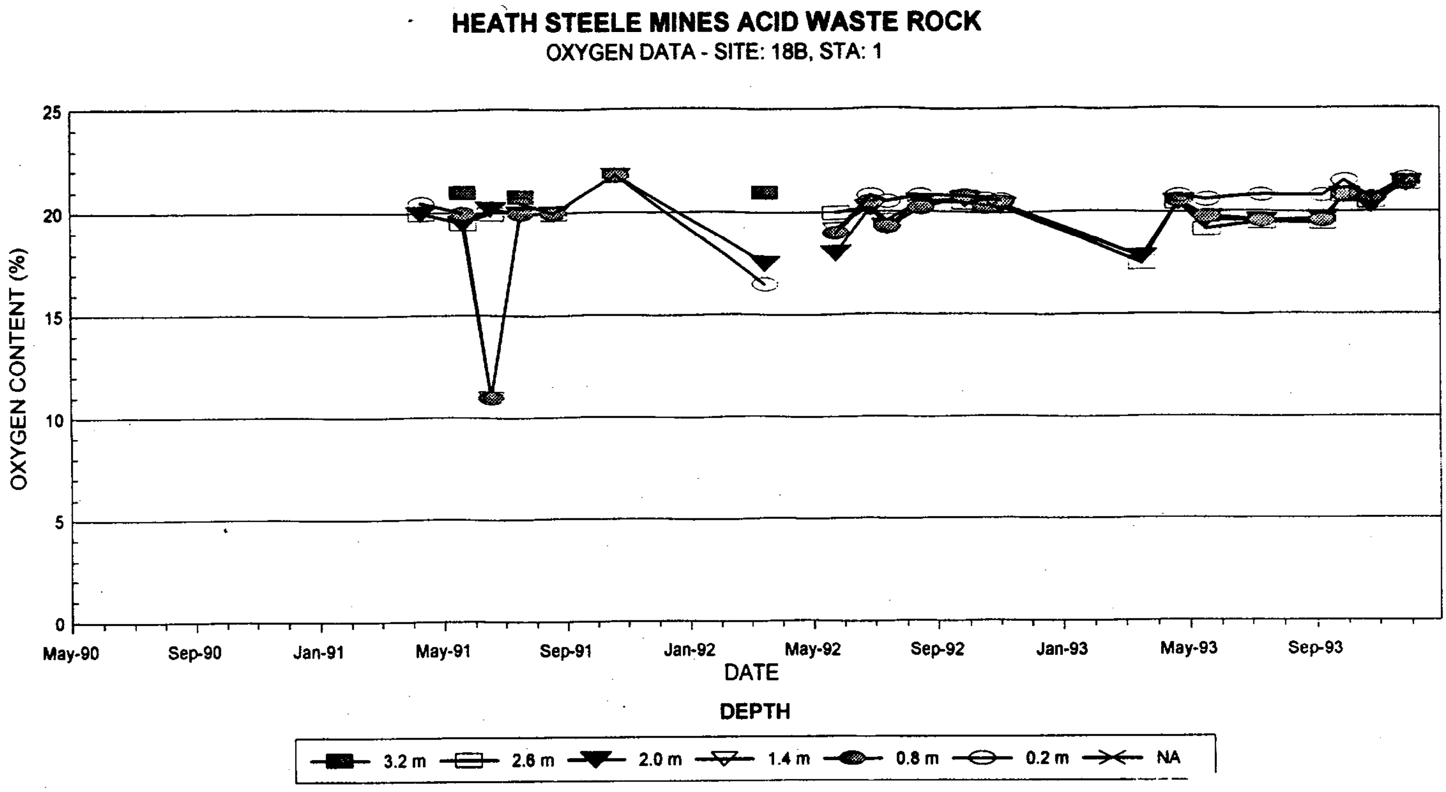


FIGURE IV-6

FIGURE IV-7



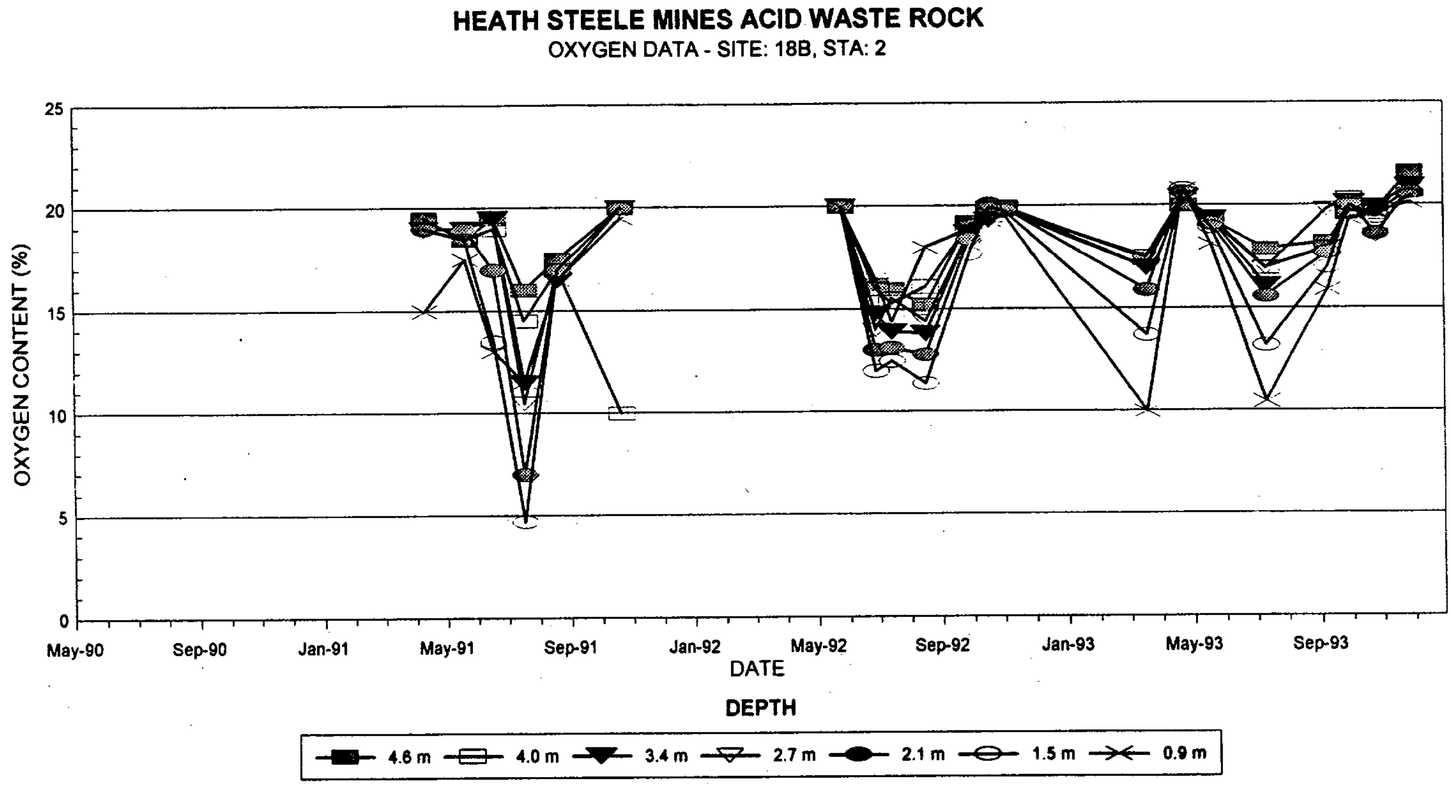
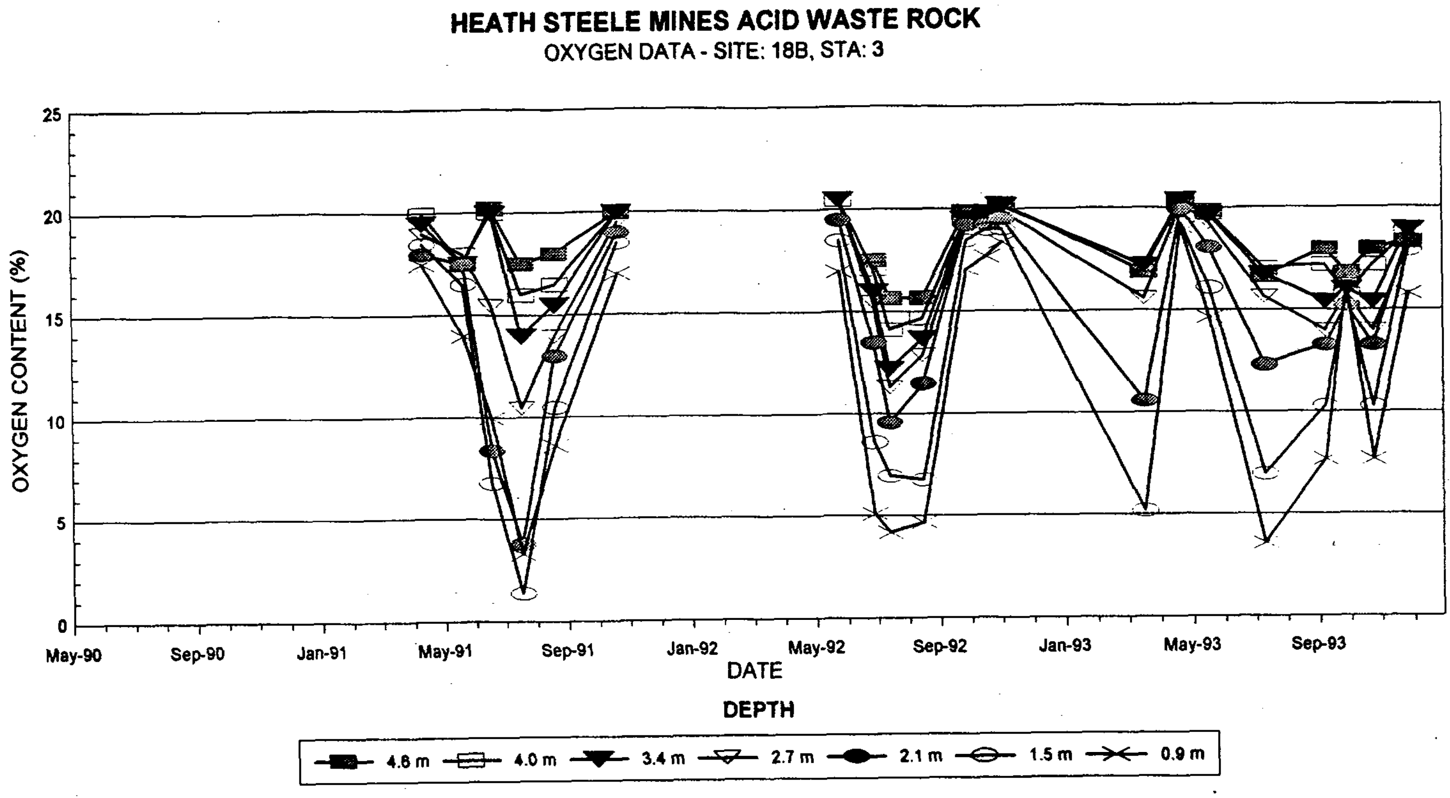


FIGURE IV-8

FIGURE IV-9



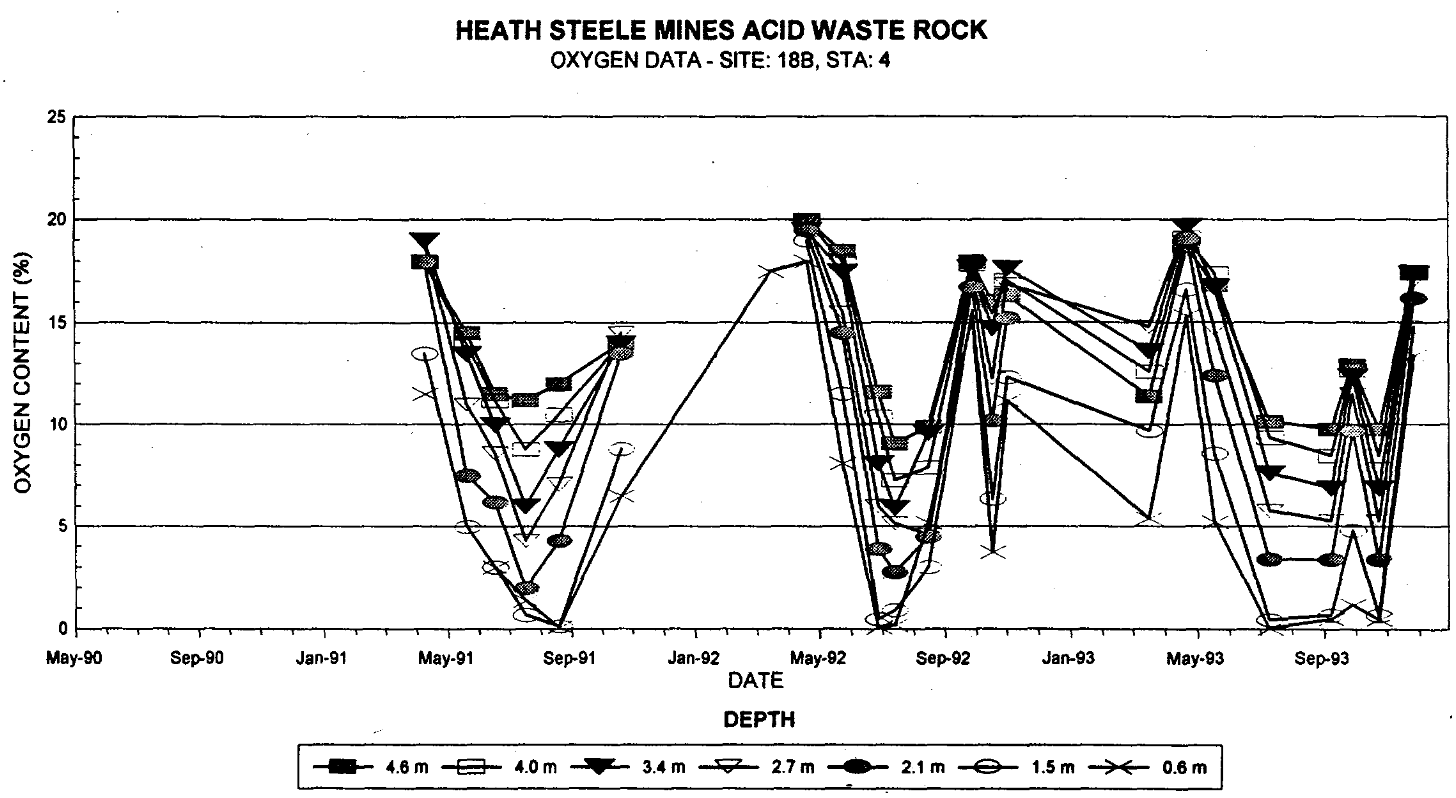
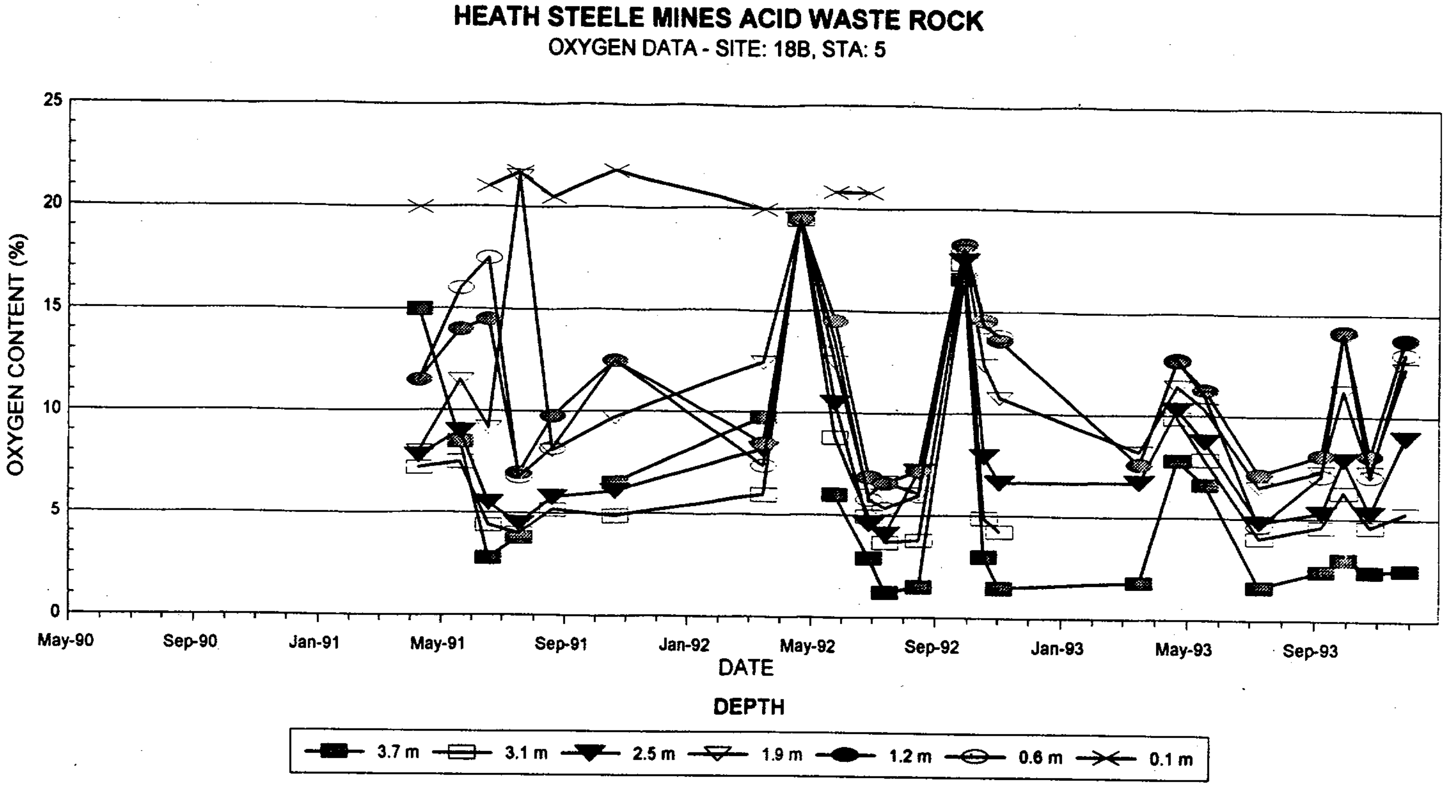


FIGURE IV-10

FIGURE IV-11



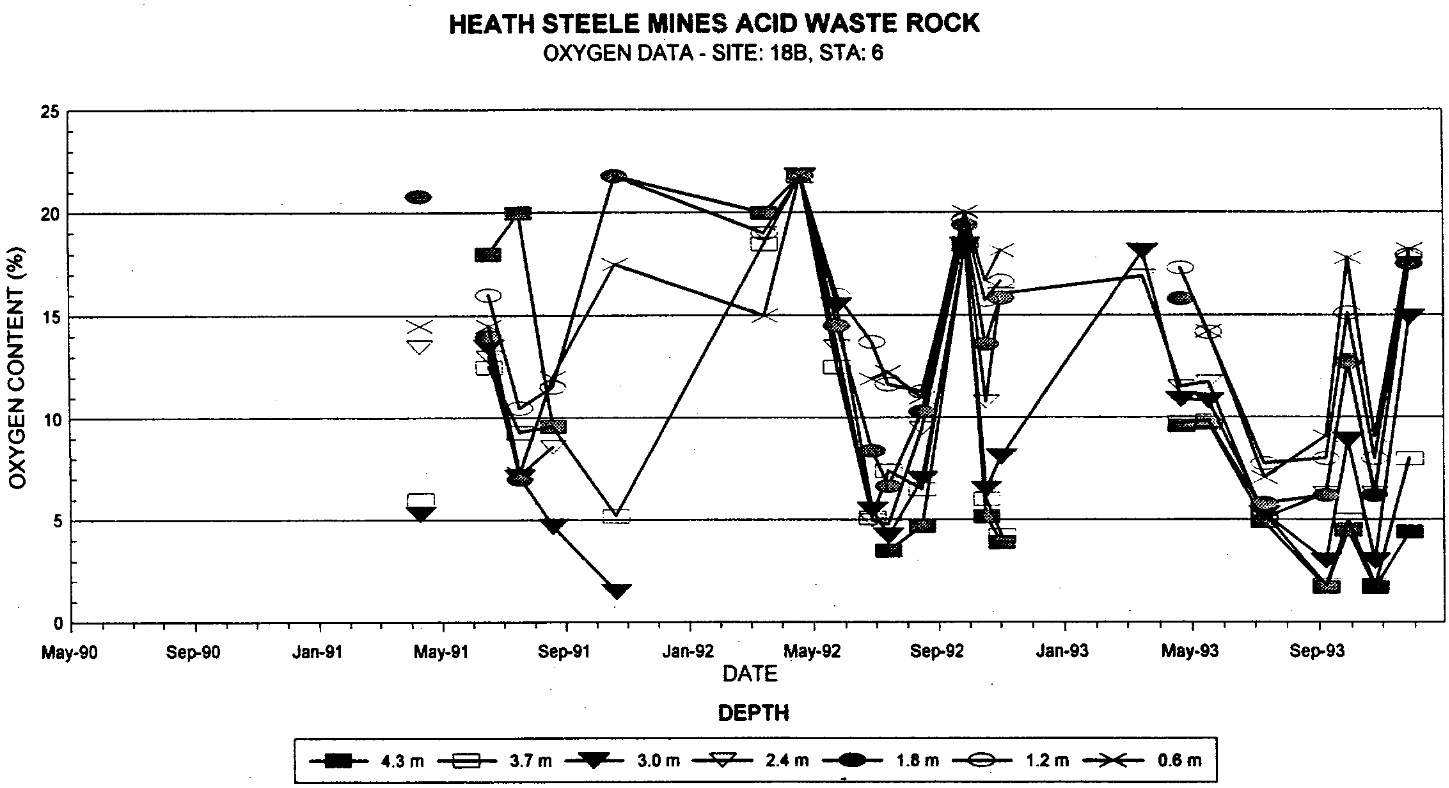
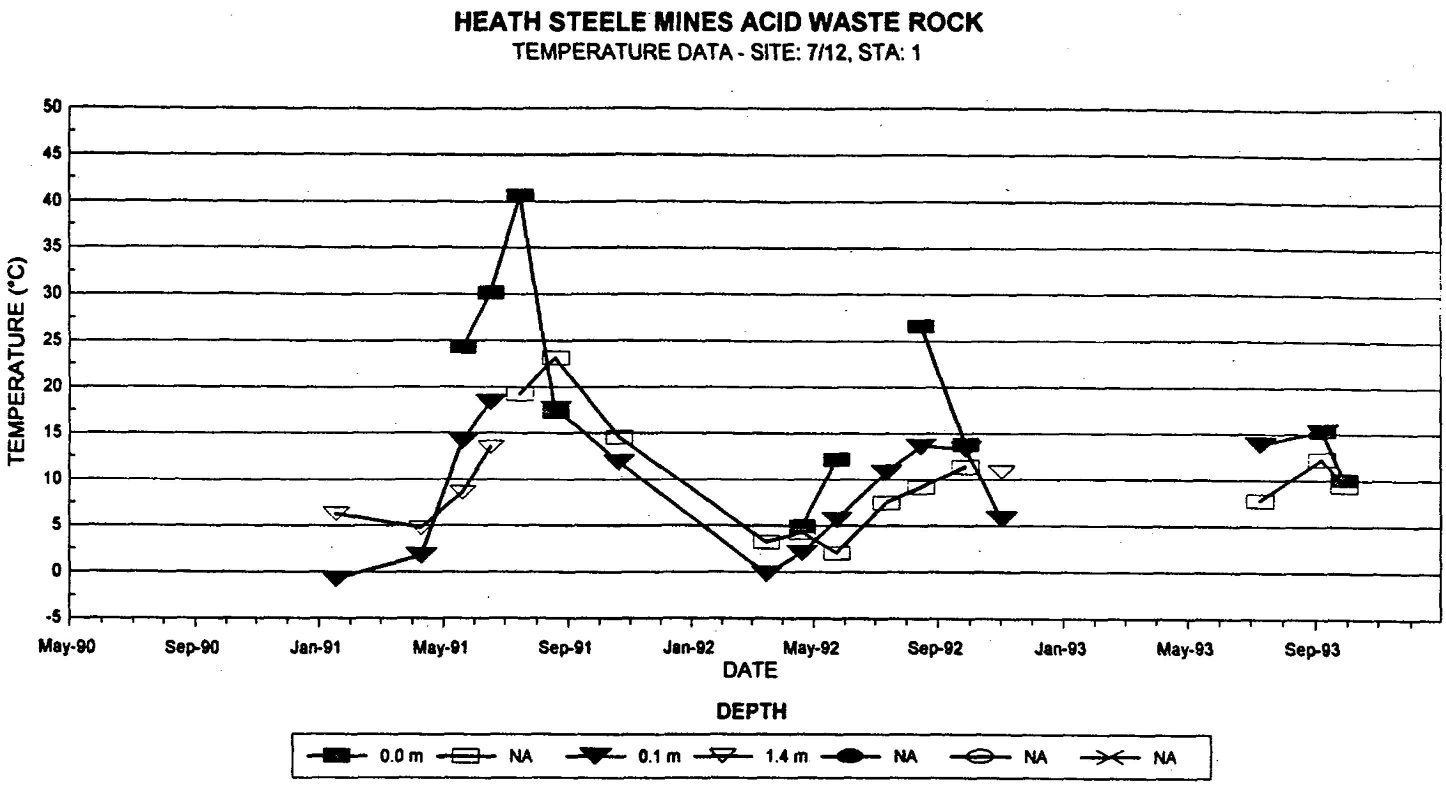


FIGURE IV-12

FIGURE IV-13



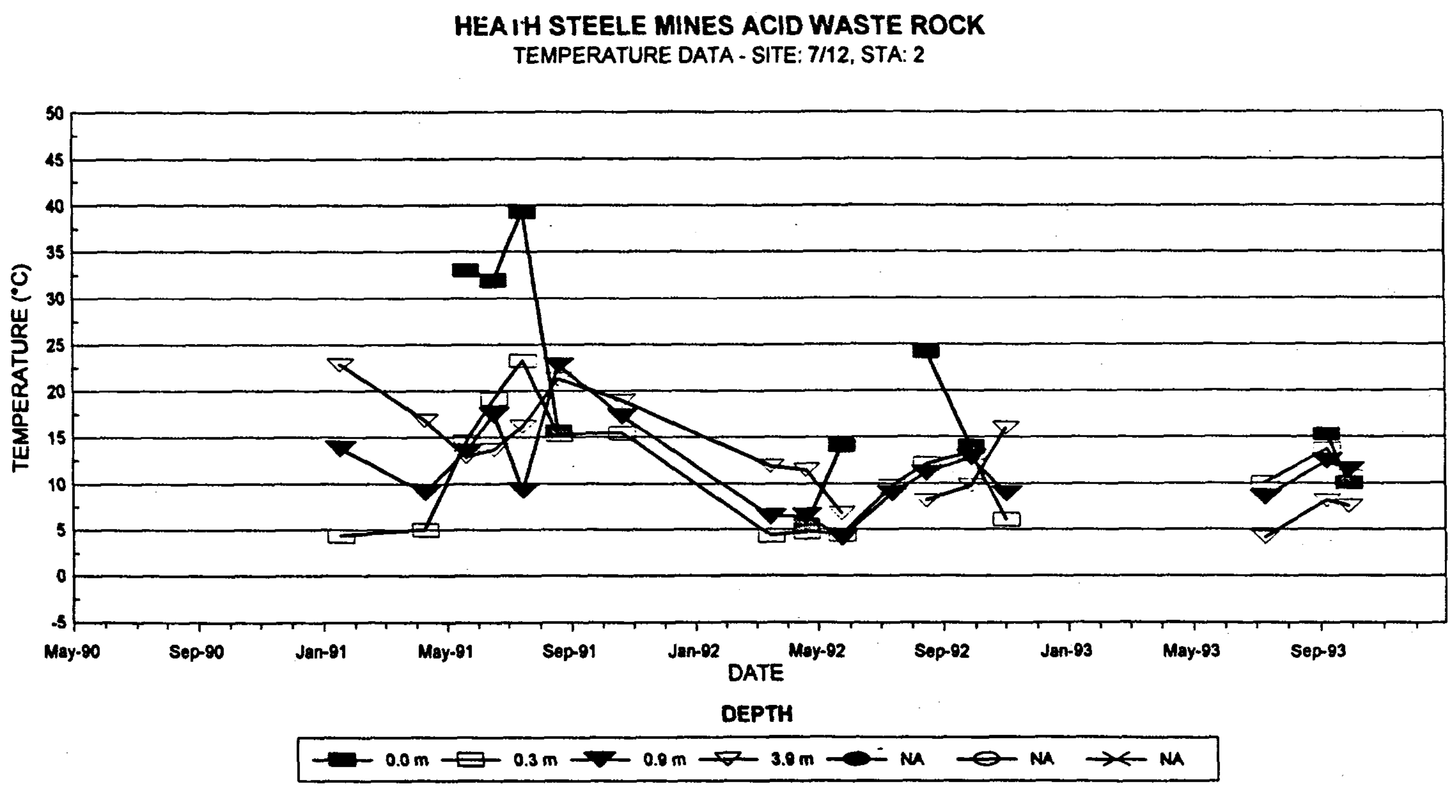
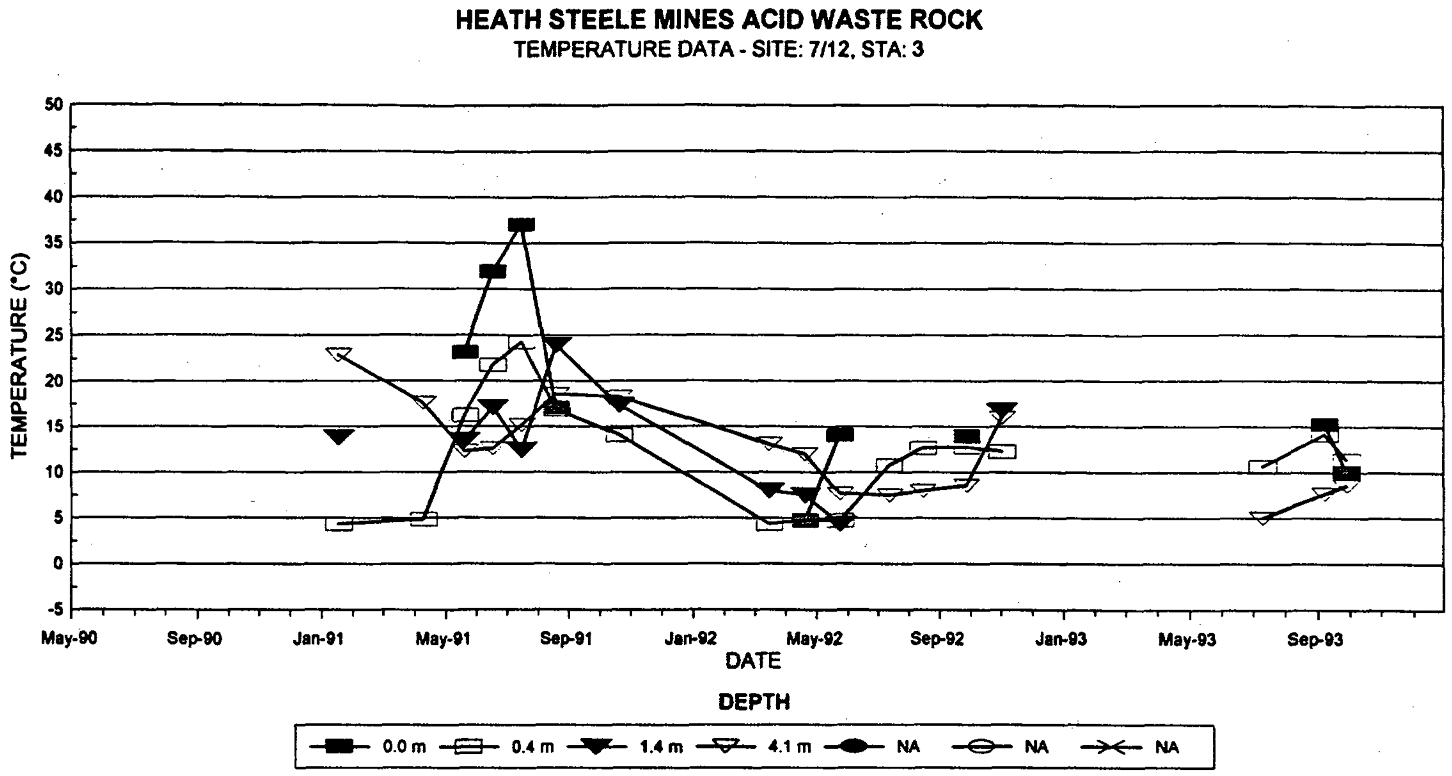


FIGURE IV-14

FIGURE IV-15



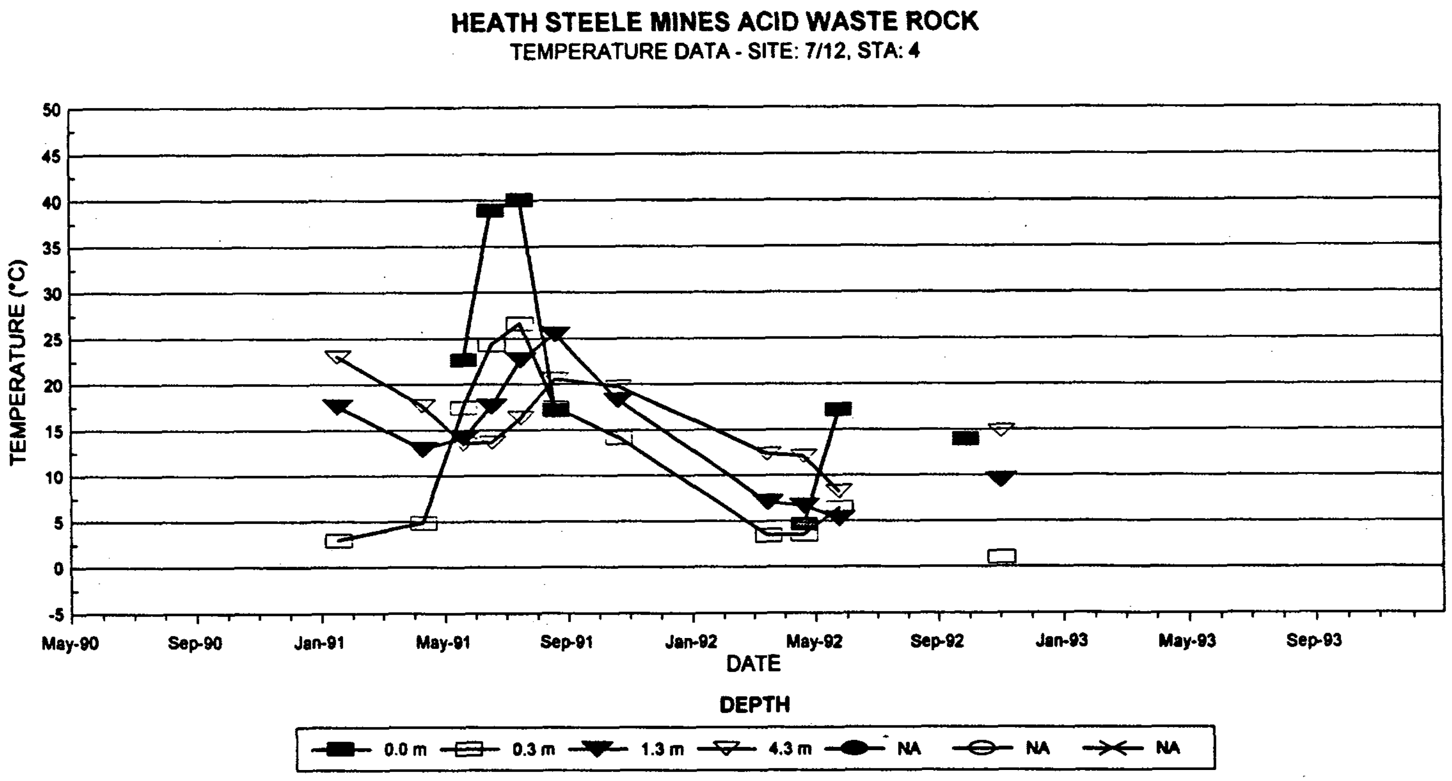
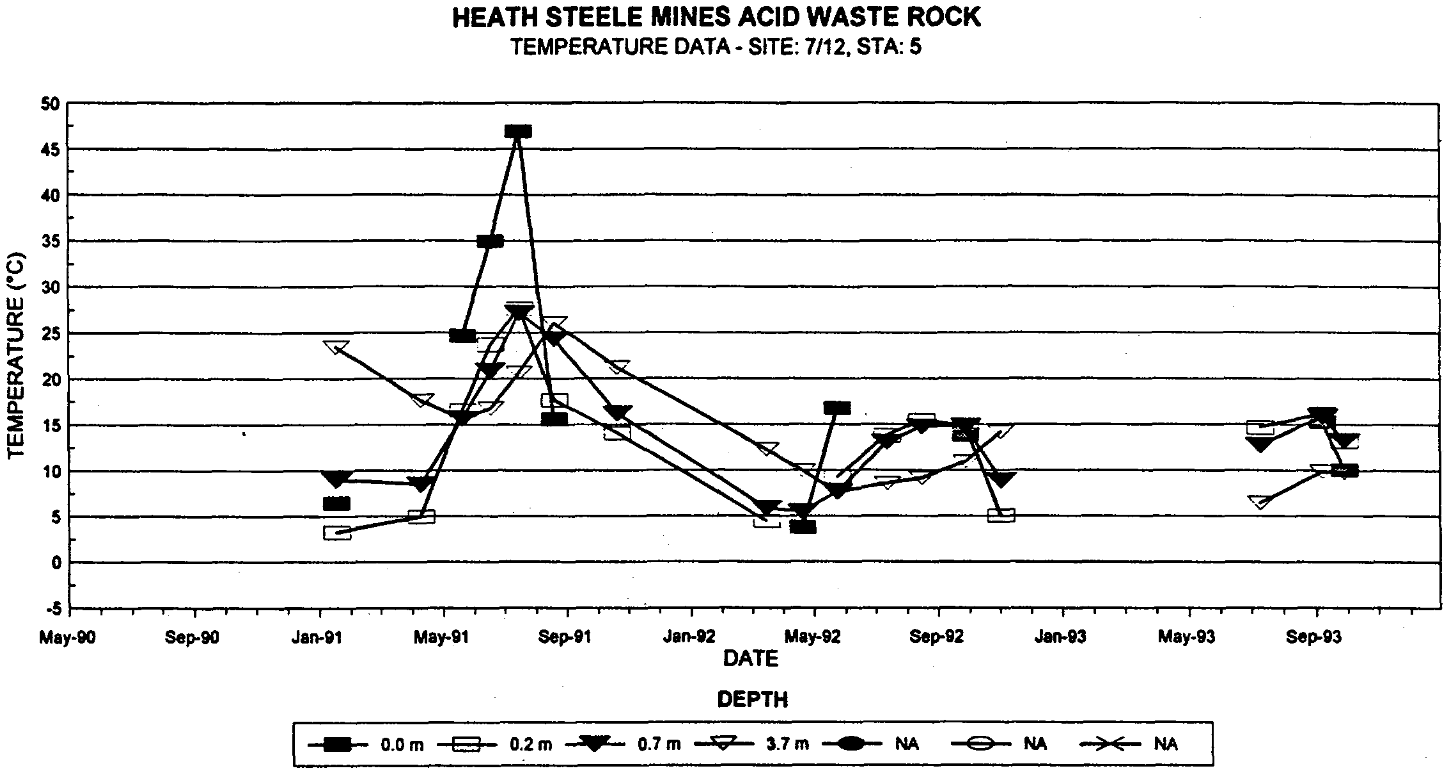


FIGURE IV-16

FIGURE IV-17



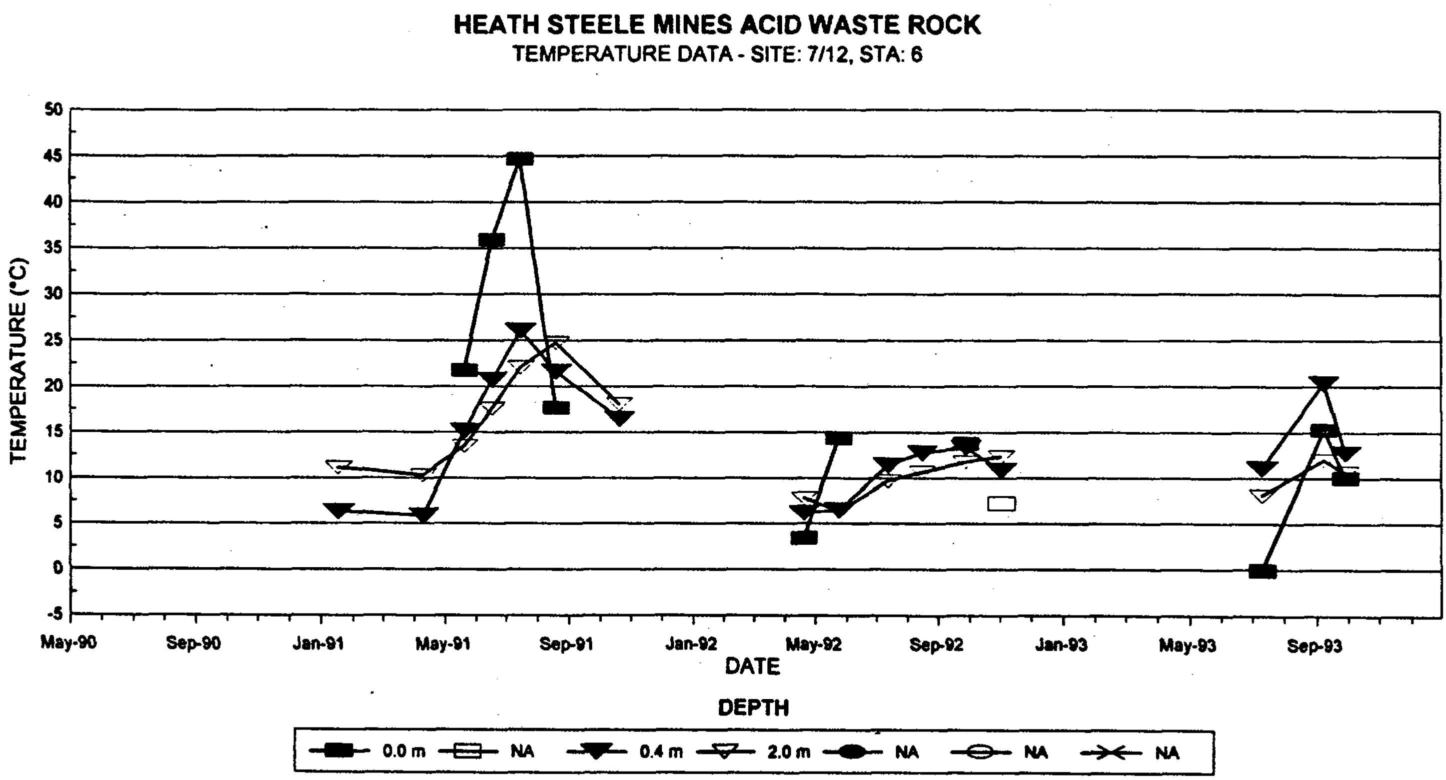


FIGURE IV-18

FIGURE IV-19

HEATH STEELE MINES ACID WASTE ROCK

TEMPERATURE DATA - SITE: 7/12, STA: 7

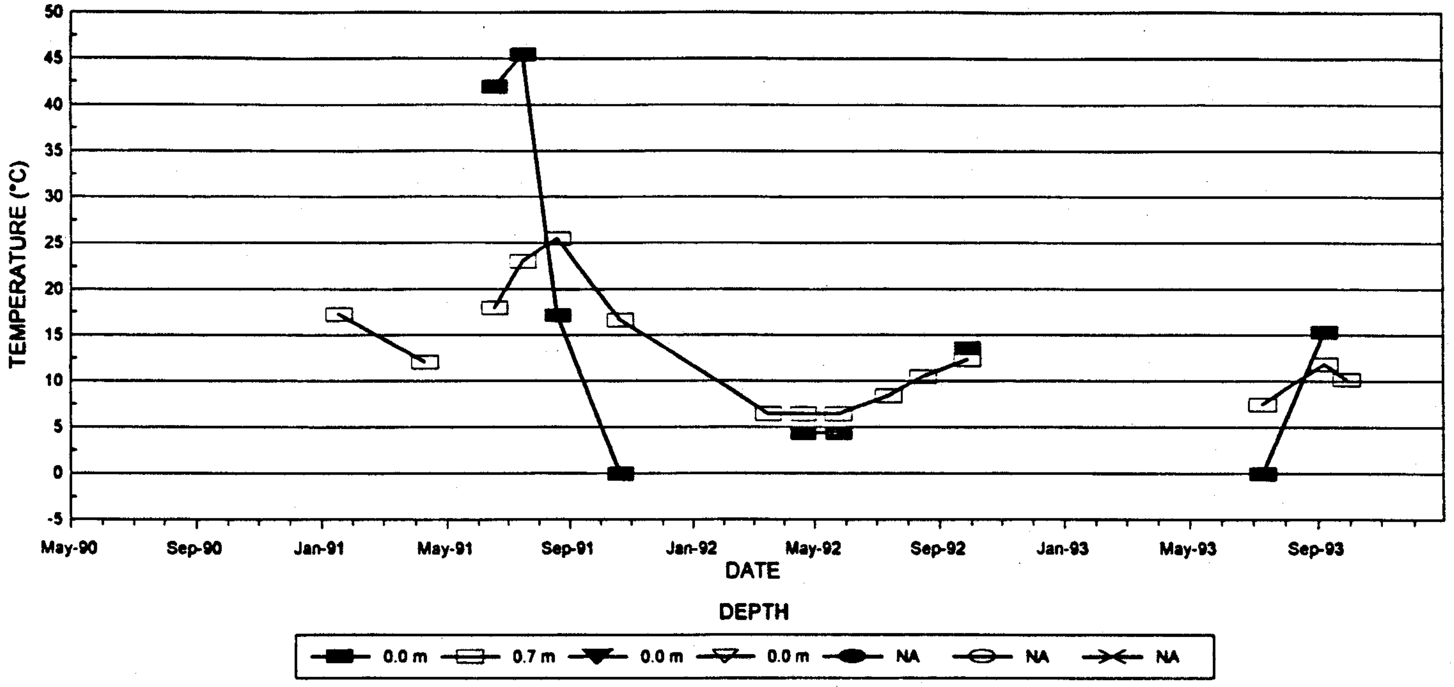
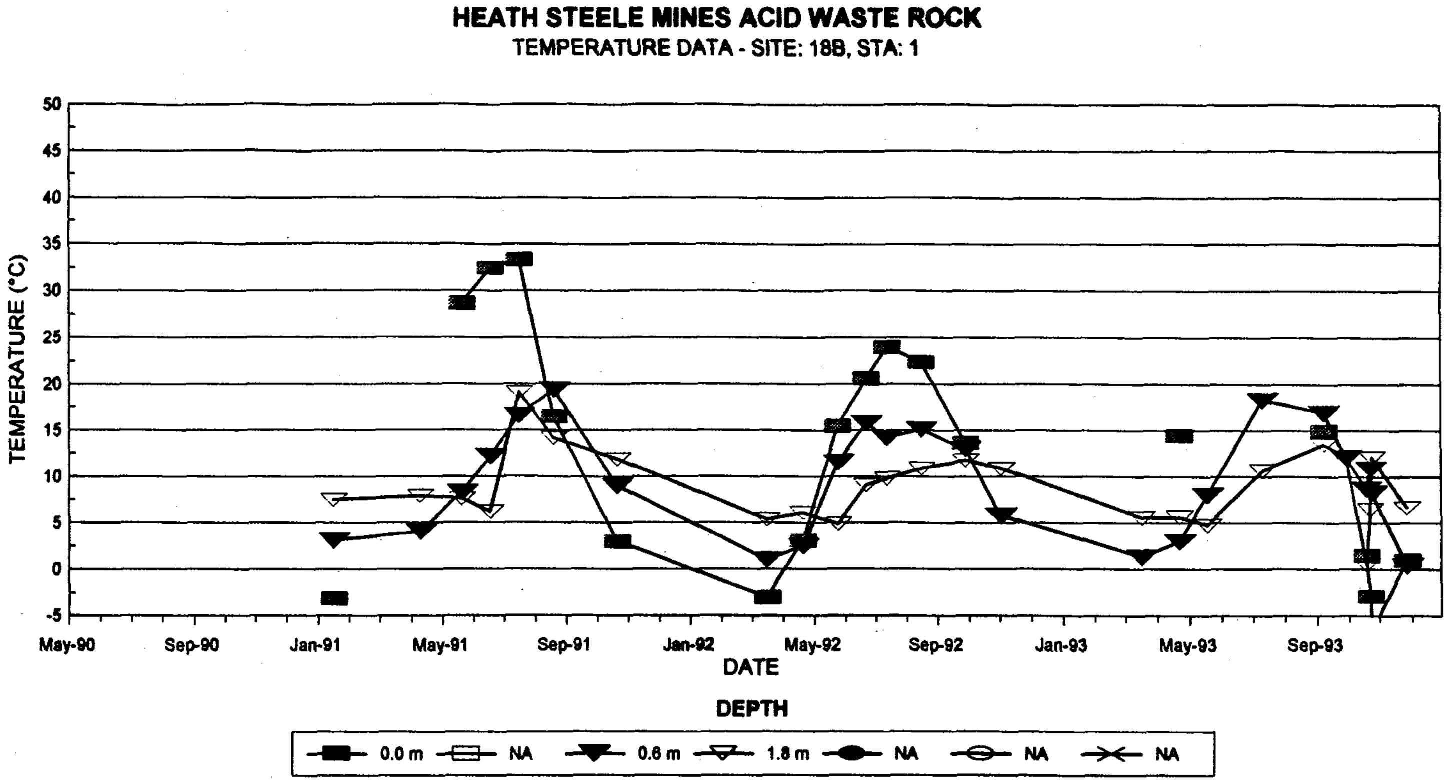


FIGURE IV-20



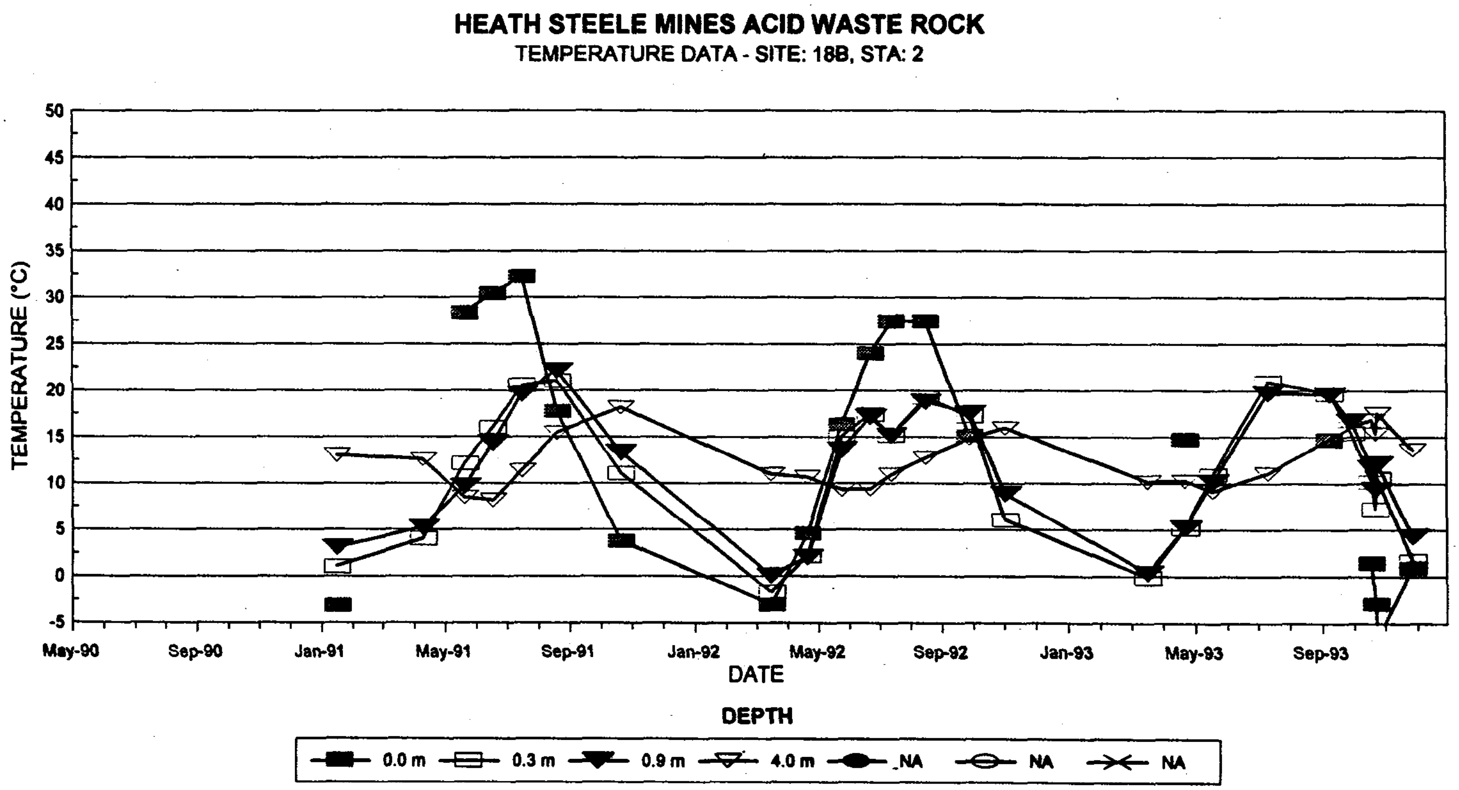


FIGURE IV-21

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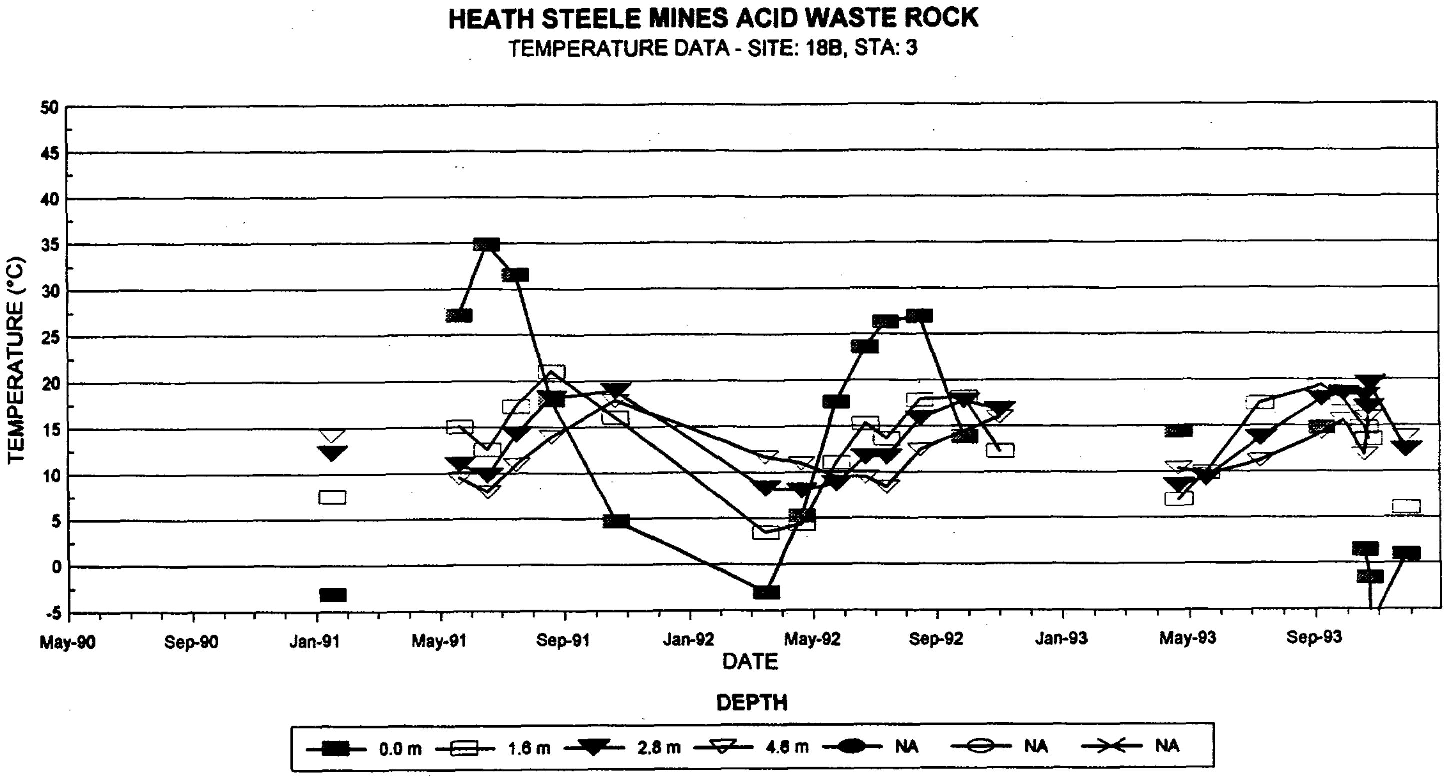
FIGURE IV-22



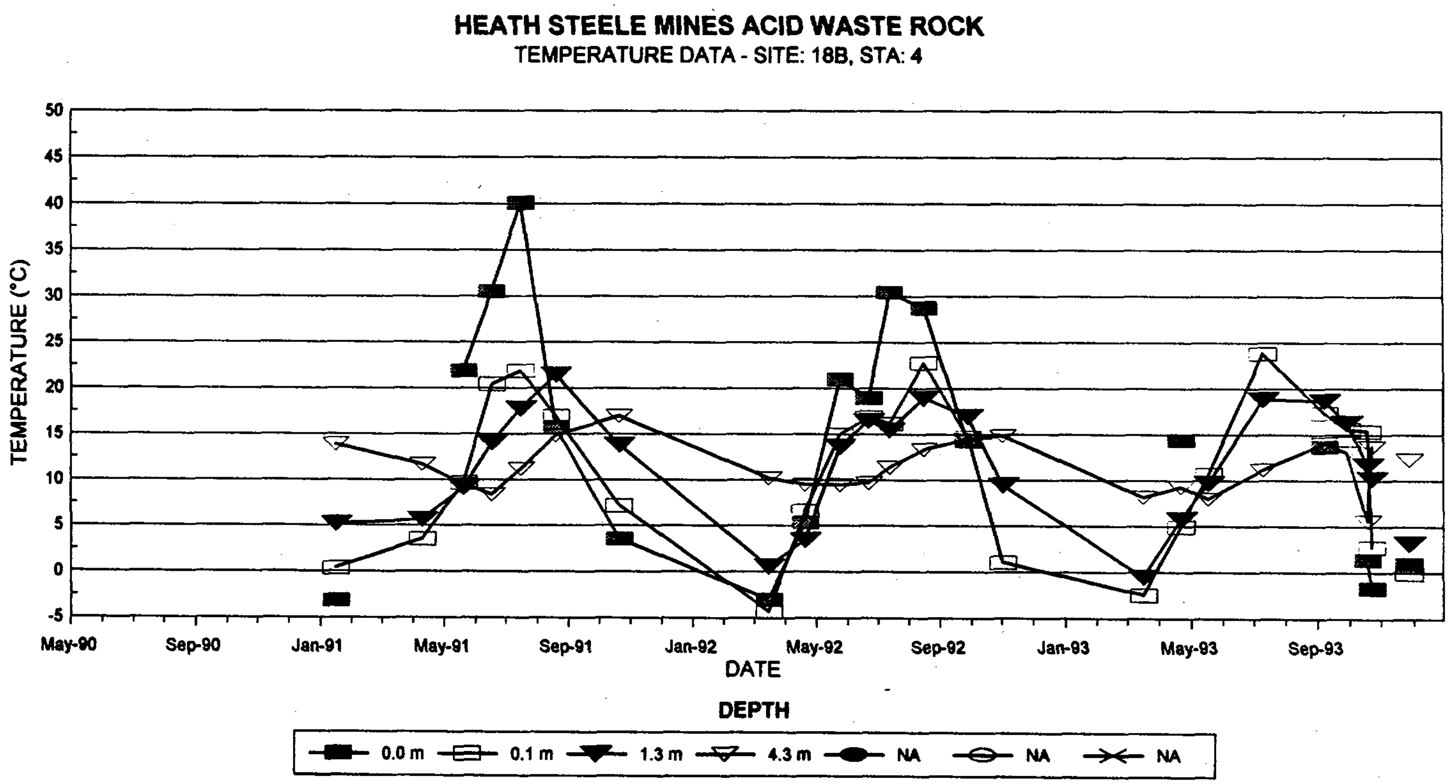
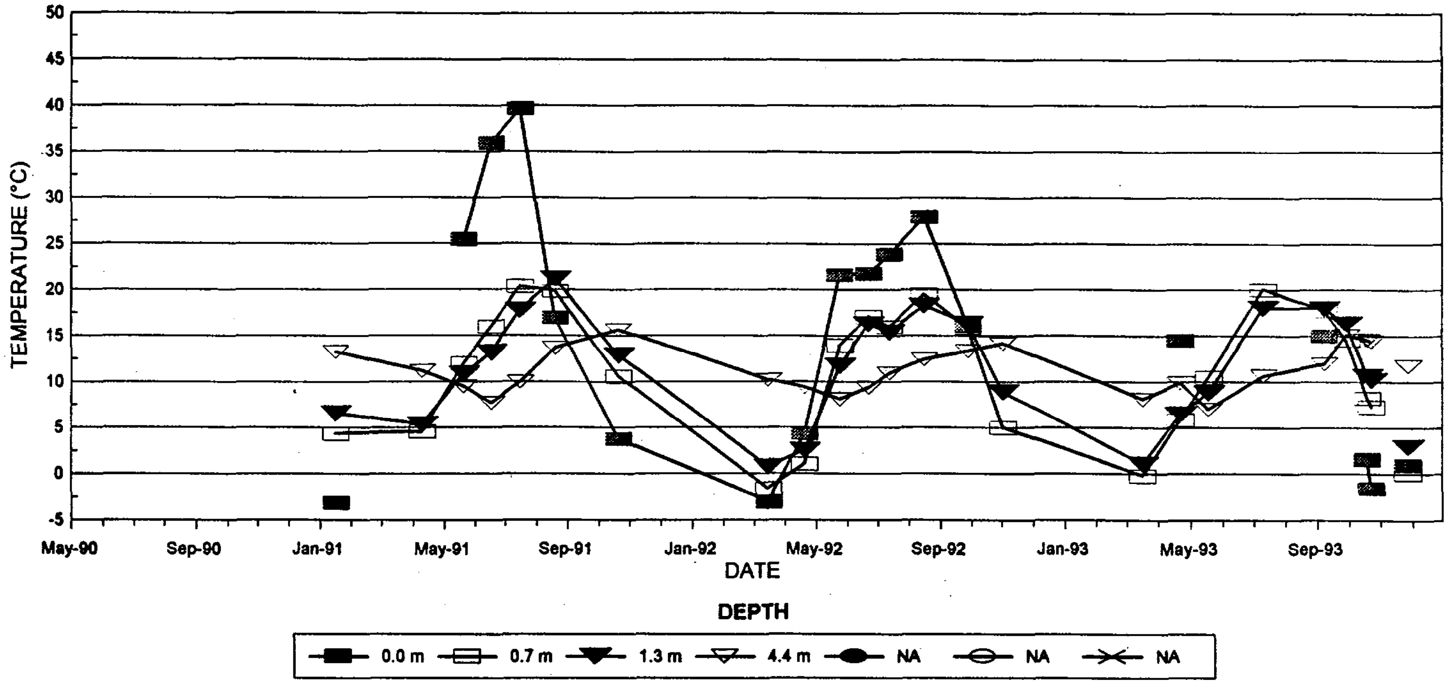


FIGURE IV-23

FIGURE IV-24

HEATH STEELE MINES ACID WASTE ROCK
TEMPERATURE DATA - SITE: 18B, STA: 5



HEATH STEELE MINES ACID WASTE ROCK
TEMPERATURE DATA - SITE: 18B, STA: 6

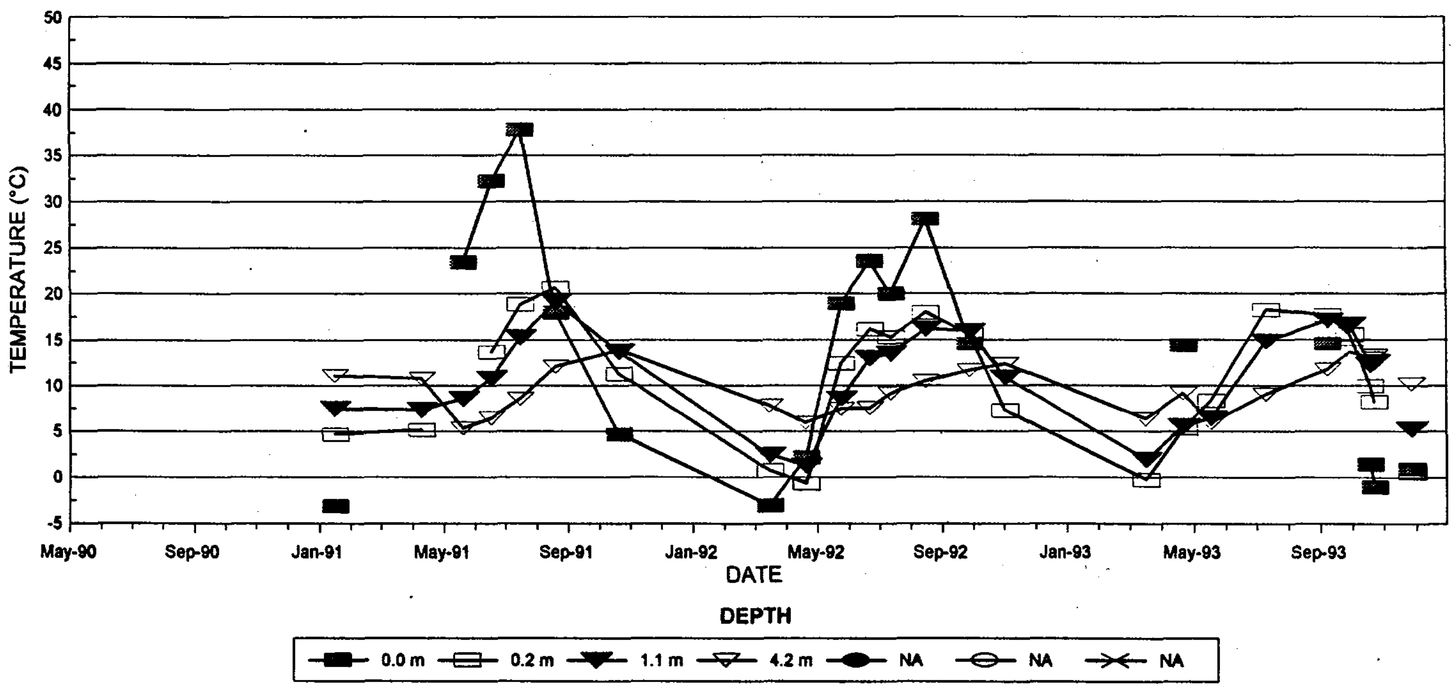
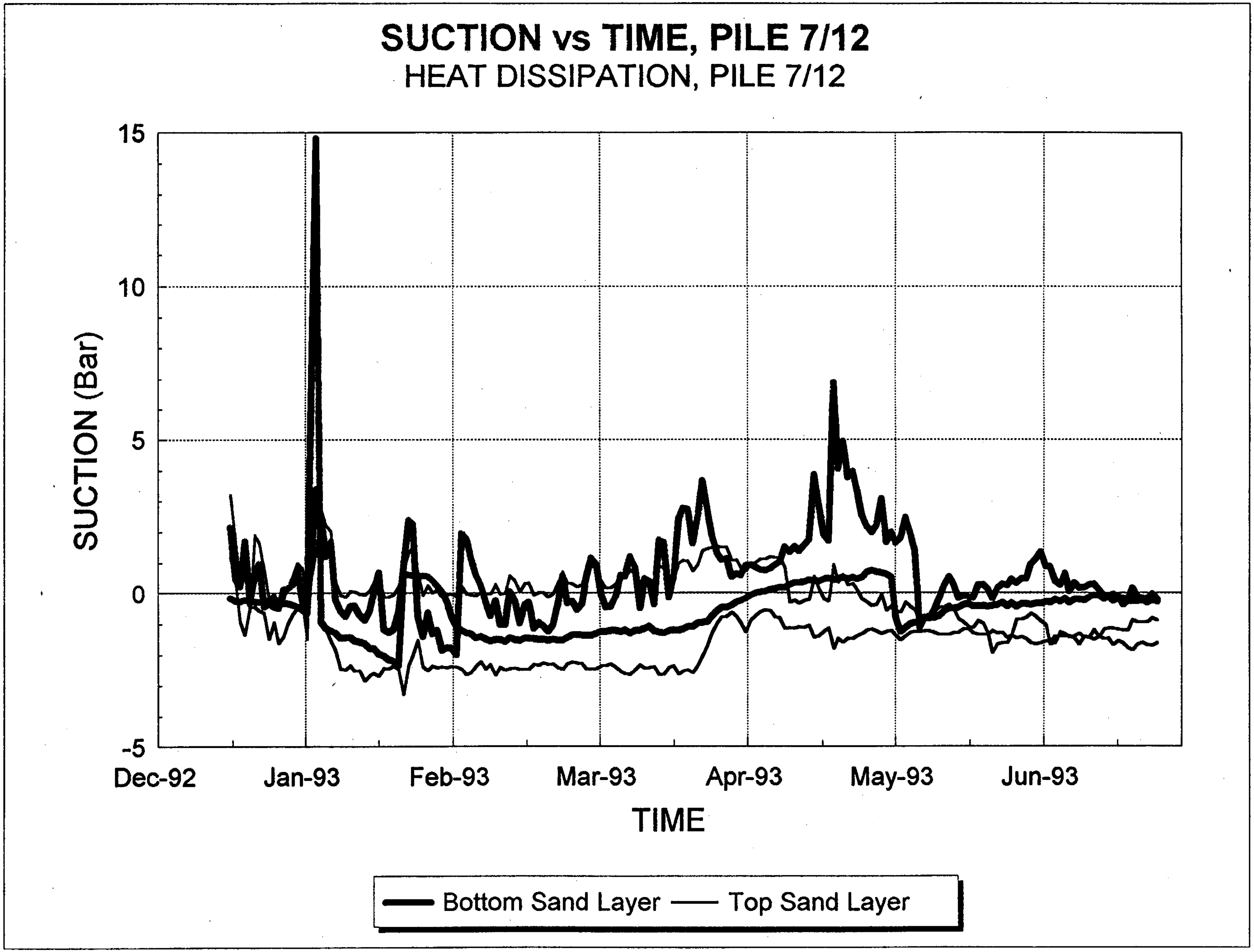


FIGURE IV-25



SUCTION vs TIME, PILE 7/12
HEAT DISSIPATION, PILE 7/12
SUCTION (Bar)
15
10
5
0
-5
Dec-92
Jan-93
Feb-93
Mar-93
Apr-93
May-93
Jun-93
TIME
Bottom Sand Layer
Top Sand Layer

FIGURE IV-26

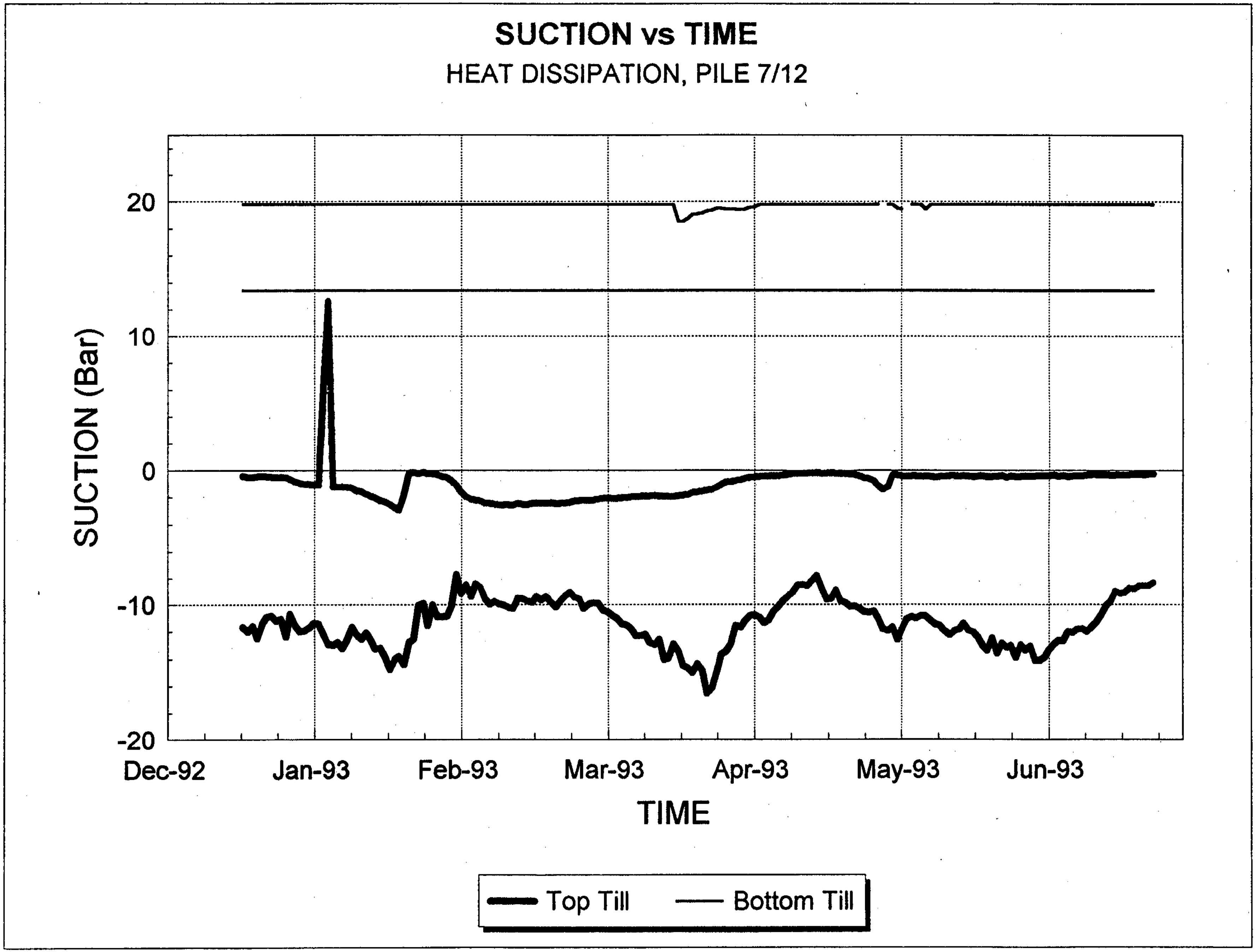

SUCTION vs TIME
HEAT DISSIPATION, PILE 7/12
SUCTION (Bar)
20
10
0
-10
-20
Dec-92
Jan-93
Feb-93
Mar-93
Apr-93
May-93
Jun-93
TIME
Top Till
Bottom Till

FIGURE IV-27

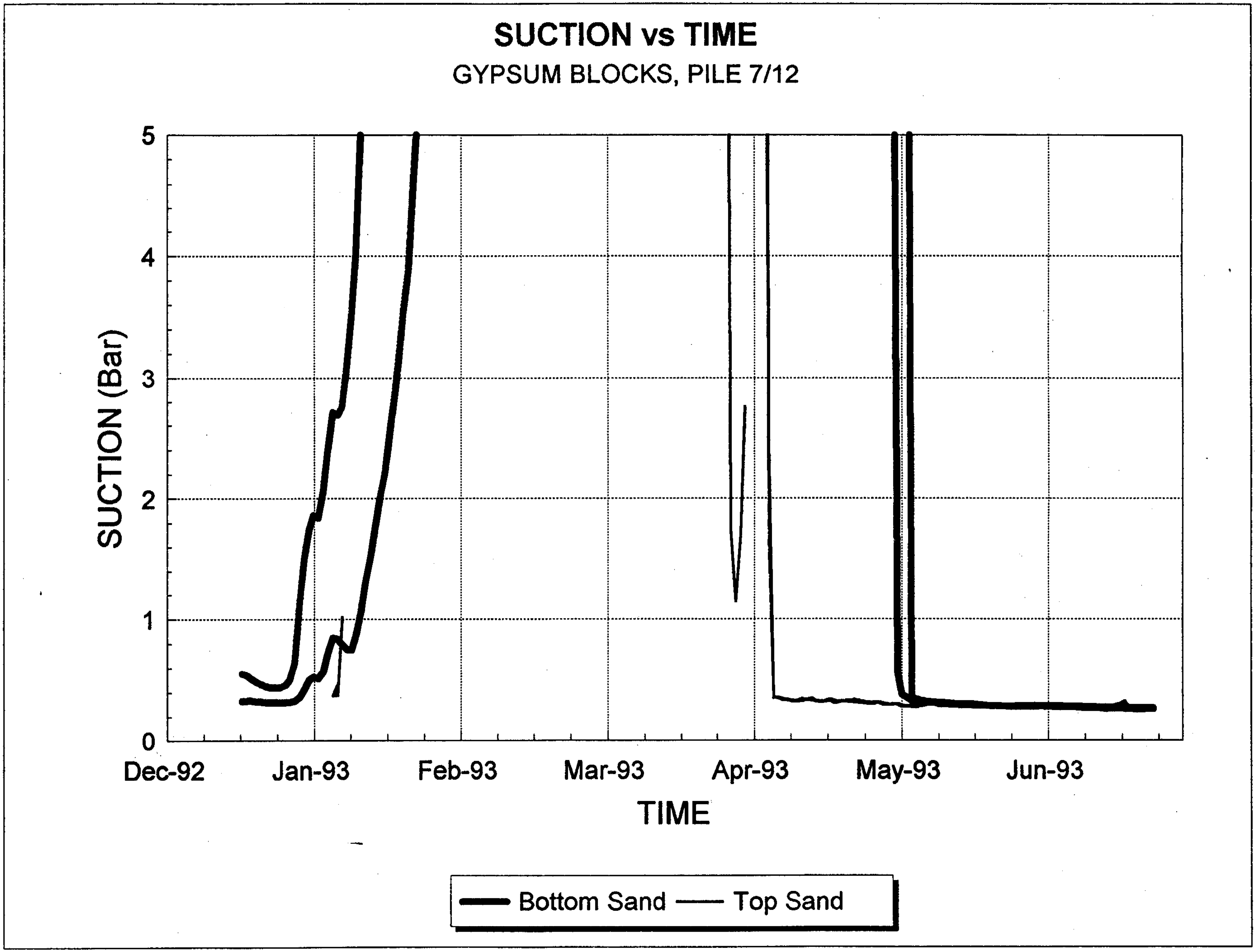

SUCTION vs TIME
GYPSUM BLOCKS, PILE 7/12
SUCTION (Bar)
0
1
2
3
4
5
Dec-92
Jan-93
Feb-93
Mar-93
Apr-93
May-93
Jun-93
TIME
Bottom Sand
Top Sand

FIGURE IV-28

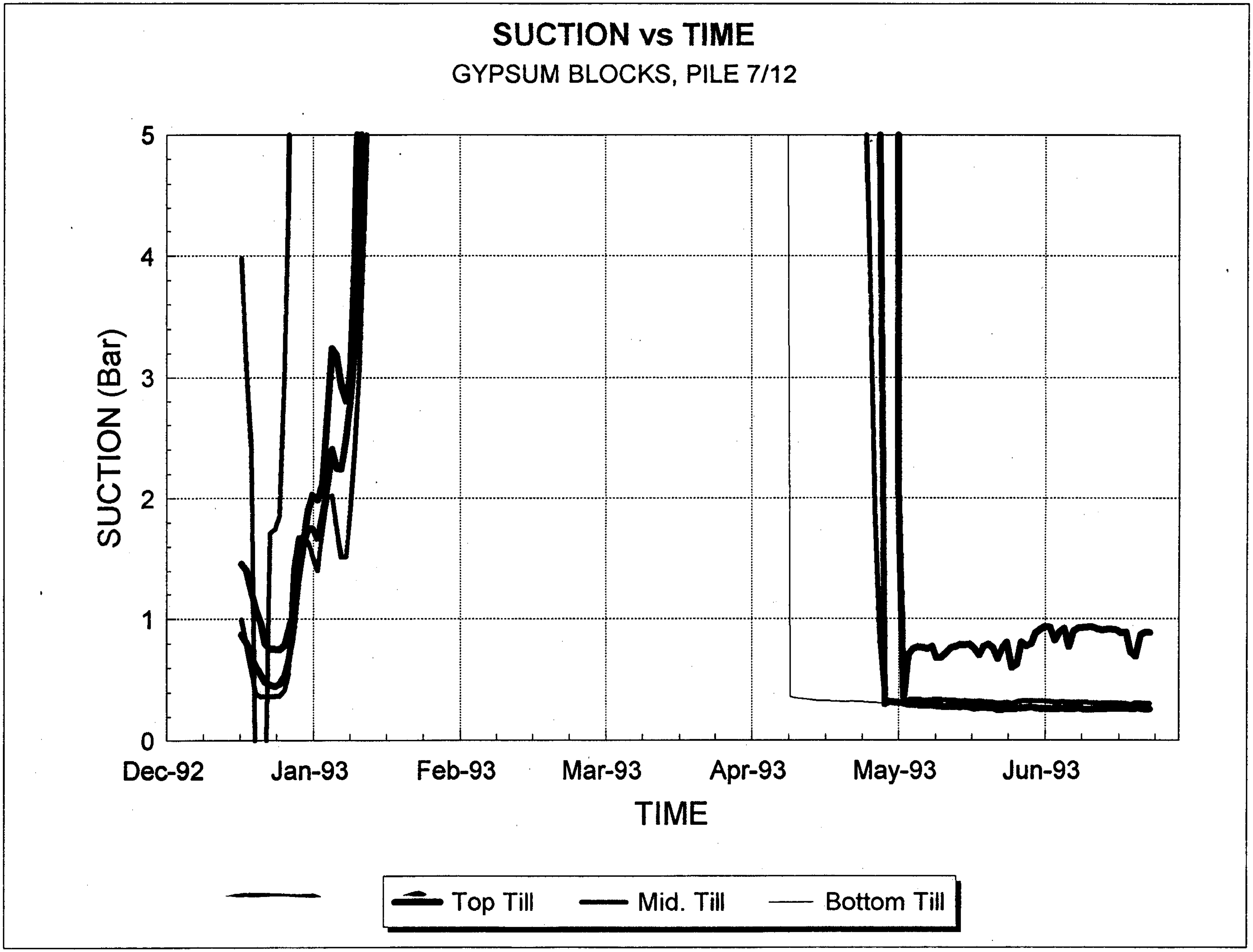

SUCTION vs TIME
GYPSUM BLOCKS, PILE 7/12
SUCTION (Bar)
5
4
3
2
1
0
Dec-92
Jan-93
Feb-93
Mar-93
Apr-93
May-93
Jun-93
TIME
Top Till
Mid. Till
Bottom Till

FIGURE IV-29

GASEOUS OXYGEN (%), PILE 7/12

Station	Port	Depth (m)	28 91/01/18	91/04/11	91/05/22	91/06/19	91/07/19	91/08/21	92/03/17	92/04/22	92/05/26	92/06/29	92/07/14	92/08/17
1	1	1.40	20.50	20.00	21.00	19.00	15.50	20.50	6.80	0.60	0.60	0.50	0.46	0.80
	2	0.50	20.50	20.00	21.00	18.50	15.00	20.00	6.70	0.30	0.50	0.30	0.40	0.90
	3	0.40	20.50	20.80	21.00	18.20	15.00	19.50	11.50	1.60	0.60	2.50	0.32	1.20
2	1	3.90	20.50	19.50	19.50	11.00	9.00	11.50	NA	NA	1.90	0.50	0.29	0.22
	2	2.40	NA	15.50	18.50	13.50	10.00	9.40	NA	NA	1.60	1.10	0.39	0.60
	3	1.90	NA	14.50	17.00	17.50	14.00	9.60	NA	0.80	1.40	0.80	0.31	0.60
	4	1.40	17.50	15.50	18.50	20.30	12.00	13.50	NA	0.80	1.50	0.85	0.27	1.50
	5	0.90	NA	16.50	20.50	20.80	18.50	13.50	NA	1.10	1.30	0.72	0.29	0.20
	6	0.40	18.00	18.00	20.50	20.80	20.00	12.00	NA	0.80	1.20	0.50	0.21	0.45
3	1	4.10	NA	18.00	19.00	11.80	9.50	13.00	3.10	0.30	1.20	0.60	0.60	0.45
	2	2.90	NA	NA	19.00	10.00	13.20	NA	NA	NA	NA	NA	NA	NA
	3	2.40	NA	18.00	19.00	8.10	6.70	11.50	7.00	0.60	1.10	0.80	0.47	NA
	4	1.90	NA	15.50	18.50	11.00	5.00	8.20	4.20	0.60	1.00	0.85	0.42	0.32
	5	1.40	NA	16.50	18.00	16.50	13.00	9.50	2.10	1.00	0.90	0.50	0.27	0.20
	6	0.90	NA	18.00	19.00	19.20	15.00	12.50	1.90	1.70	0.80	0.40	0.25	0.14
	7	0.40	NA	18.00	20.90	20.20	20.50	14.50	NA	NA	NA	NA	NA	NA
4	1	4.30	NA	NA	20.50	20.20	NA	NA	NA	NA	NA	NA	NA	NA
	2	2.80	NA	19.00	19.00	14.00	11.50	15.00	2.00	0.60	0.90	0.20	0.35	0.15
	3	2.30	NA	19.00	17.50	13.00	10.50	14.50	NA	0.20	0.80	0.30	0.10	0.24
	4	1.80	NA	19.00	19.00	13.50	10.50	14.50	1.90	4.40	0.70	0.05	0.09	0.15
	5	1.30	NA	19.00	18.00	13.50	10.50	13.50	2.20	4.80	0.70	0.10	0.29	0.13
	6	0.80	NA	18.50	18.00	13.00	10.00	12.50	NA	4.80	0.80	2.50	0.36	0.21
	7	0.30	NA	19.00	20.00	15.50	NA	12.50	NA	3.30	0.80	2.35	0.21	0.13
5	1	3.70	NA	20.00	18.50	16.00	12.00	16.00	NA	NA	NA	NA	NA	NA
	2	2.30	NA	20.50	18.50	17.00	12.50	18.00	NA	1.00	0.90	0.50	0.29	0.07
	3	1.70	NA	20.50	20.00	19.50	NA	NA	NA	NA	NA	NA	NA	NA
	4	1.20	NA	19.00	17.50	18.50	10.50	15.50	NA	NA	NA	6.80	5.21	0.58
	5	0.70	NA	19.00	19.50	19.00	11.00	16.00	NA	9.00	0.80	4.10	1.20	2.94
	6	0.20	NA	18.50	20.50	19.00	12.50	17.50	NA	8.10	1.40	13.00	1.61	13.25
6	1	2.10	20.80	NA	18.50	18.00	19.00	20.50	NA	NA	0.70	0.05	0.12	0.15
	2	0.60	20.80	NA	18.00	17.50	18.00	20.50	NA	NA	0.70	0.05	0.41	0.21
	3	0.10	20.80	NA	18.00	17.50	16.00	19.00	NA	5.40	0.50	0.05	0.13	0.18

GASEOUS OXYGEN (%), PILE 7/12

Station	Port	Depth (m)	92/08/26	92/10/14	92/11/03	93/03/19	93/04/24	93/05/21	93/07/13	93/09/10	93/10/01	93/10/26	93/11/29	93/12/22
1	1	1.40	0.17	0.15	0.19	NA	0.35	0.41	0.13	0.10	0.10	0.40	0.20	0.10
	2	0.50	0.07	0.15	0.11	NA	0.28	0.28	0.13	0.10	0.10	0.80	0.40	0.20
	3	0.40	0.12	0.12	0.11	NA	NA	NA	NA	NA	NA	NA	NA	0.30
2	1	3.90	0.28	0.35	0.33	0.40	0.23	0.13	0.11	0.00	0.20	0.40	1.00	0.20
	2	2.40	0.26	0.30	0.26	0.20	0.25	0.08	0.08	0.00	0.10	0.40	0.60	0.20
	3	1.90	0.20	0.27	0.21	0.10	0.14	0.07	0.11	0.00	0.80	0.60	0.20	0.20
	4	1.40	0.16	0.23	0.18	0.15	0.18	0.06	0.10	0.00	0.10	0.30	0.20	0.30
	5	0.90	0.13	0.20	0.18	0.10	0.17	0.06	0.10	0.00	0.10	0.30	0.30	0.20
	6	0.40	0.11	0.16	0.14	0.07	0.14	0.07	0.09	0.00	0.00	0.30	0.20	0.20
3	1	4.10	0.20	0.18	0.11	0.20	0.14	0.02	0.10	0.50	0.20	0.50	0.20	0.20
	2	2.90	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	3	2.40	0.14	0.29	0.11	0.35	0.11	0.02	0.06	0.00	0.10	0.70	0.20	0.20
	4	1.90	0.13	0.32	0.20	0.20	0.09	0.02	0.06	0.00	0.00	0.60	0.30	0.30
	5	1.40	0.12	0.35	0.15	0.10	0.08	0.01	0.06	0.00	0.10	0.40	0.20	0.20
	6	0.90	0.11	0.28	0.11	0.08	0.08	0.01	0.04	0.00	0.10	0.20	0.20	0.30
	7	0.40	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4	1	4.30	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	2	2.80	0.12	0.15	0.08	0.25	0.08	0.07	0.10	0.00	0.20	0.50	0.20	0.30
	3	2.30	0.10	0.12	0.08	0.10	0.08	0.04	0.06	0.00	0.20	0.40	0.20	0.20
	4	1.80	0.09	0.15	0.07	NA	0.07	0.02	0.06	0.00	0.20	0.50	0.20	0.20
	5	1.30	0.09	0.14	0.06	NA	0.07	0.02	0.21	NA	0.20	0.60	0.20	0.30
	6	0.80	1.70	0.09	0.06	NA	3.23	0.15	2.88	0.00	0.30	6.10	0.20	0.30
	7	0.30	1.34	0.11	0.04	NA	3.22	0.09	1.43	0.00	0.40	6.30	0.20	0.30
5	1	3.70	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	2	2.30	0.06	0.10	0.07	NA	0.09	0.03	0.06	0.00	0.10	0.50	0.20	0.20
	3	1.70	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	4	1.20	0.54	0.32	0.08	NA	0.19	0.18	2.34	0.00	0.70	1.60	7.20	2.30
	5	0.70	3.19	0.10	0.22	NA	3.59	1.36	6.99	0.00	4.10	7.60	14.00	8.60
	6	0.20	12.66	0.12	0.80	NA	8.65	4.81	17.76	0.00	11.70	12.90	19.70	18.20
6	1	2.10	0.12	0.10	0.06	NA	0.07	0.04	0.06	0.00	0.10	0.40	0.20	0.30
	2	0.60	0.13	0.12	0.04	NA	0.05	0.01	0.04	0.00	0.10	0.30	0.20	0.40
	3	0.10	0.19	0.12	0.04	NA	0.05	0.01	0.04	0.00	0.10	0.20	1.80	0.50

Station	Port	Depth (m)	93/02/18	94/03/30	94/05/03
1	1	1.40	0.20	0.50	0.60
	2	0.50	0.20	0.30	0.20
	3	0.40	NA	NA	NA
2	1	3.90	NA	NA	0.50
	2	2.40	0.20	NA	0.30
	3	1.90	NA	NA	0.40
	4	1.40	0.20	0.20	0.30
	5	0.90	0.20	NA	0.30
	6	0.40	0.20	NA	0.40
3	1	4.10	0.50	NA	0.80
	2	2.90	NA	NA	NA
	3	2.40	0.30	NA	0.60
	4	1.90	0.30	NA	0.80
	5	1.40	NA	NA	NA
	6	0.90	NA	NA	NA
	7	0.40	NA	NA	NA
4	1	4.30	NA	NA	NA
	2	2.80	0.30	NA	0.30
	3	2.30	0.20	0.20	0.30
	4	1.80	0.20	0.20	0.90
	5	1.30	0.20	NA	0.60
	6	0.80	0.20	0.20	0.50
	7	0.30	0.10	0.20	0.50
5	1	3.70	0.50	NA	NA
	2	2.30	0.30	0.20	0.50
	3	1.70	NA	NA	NA
	4	1.20	0.20	0.10	0.60
	5	0.70	1.20	0.10	0.40
	6	0.20	5.10	0.20	0.40
6	1	2.10	0.20	0.20	1.10
	2	0.60	0.20	0.30	0.80
	3	0.10	0.20	NA	0.60

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TABLE IV-2

GASEOUS OXYGEN (%), PILE 10B

HEATH STEELE MINES

Station	Port	depth (m)	31.00 91/04/11	91/05/22	91/06/19	91/07/19	91/08/21	91/10/22	92/03/17	92/04/22	92/05/26	92/06/29	92/07/15	92/08/17
1	1	3.20	NA	21.00	NA	20.80	NA	NA	21.00	NA	NA	NA	NA	NA
	2	2.60	20.00	19.50	20.00	NA	20.00	21.80	NA	NA	20.00	20.20	19.59	20.50
	3	2.00	20.00	19.50	20.20	20.00	20.00	21.80	17.50	NA	18.00	20.20	19.29	20.50
	4	1.40	20.00	19.50	11.00	20.00	20.00	21.80	NA	NA	19.20	20.30	19.22	20.20
	5	0.80	NA	20.00	11.00	20.00	20.00	21.80	NA	NA	19.00	20.50	19.28	20.20
	6	0.20	20.50	20.00	NA	20.50	20.00	21.80	16.50	NA	19.00	20.80	20.50	20.80
2	1	4.60	19.50	18.50	19.50	16.00	17.50	20.00	NA	NA	20.00	16.20	15.96	15.20
	2	4.00	19.50	18.50	19.00	14.50	17.00	10.00	NA	NA	20.00	16.00	15.26	16.10
	3	3.40	19.00	19.00	19.50	11.50	16.50	20.00	NA	NA	20.00	14.80	13.91	13.80
	4	2.70	19.00	19.00	19.50	10.50	17.00	20.00	NA	NA	20.00	14.00	15.54	14.40
	5	2.10	19.00	19.00	17.00	7.00	17.00	20.00	NA	NA	20.00	13.00	13.10	12.80
	6	1.50	19.00	18.50	13.50	4.70	17.00	20.00	NA	NA	20.00	12.00	12.48	11.40
	7	0.90	15.00	17.50	13.00	11.50	16.50	19.50	NA	NA	20.00	16.50	14.39	18.00
3	1	4.60	NA	17.50	20.20	17.50	18.00	20.00	NA	NA	NA	17.50	15.68	15.70
	2	4.00	20.00	17.50	20.00	16.00	16.50	20.00	NA	NA	20.50	17.10	14.14	14.70
	3	3.40	19.50	17.50	20.00	14.00	15.50	20.00	NA	NA	20.50	16.00	12.21	13.70
	4	2.70	19.00	18.00	15.50	10.50	14.00	19.50	NA	NA	20.50	15.50	11.34	12.90
	5	2.10	18.00	17.50	8.40	3.80	13.00	19.00	NA	NA	19.50	13.50	9.59	11.50
	6	1.50	18.50	16.50	6.80	1.40	10.50	18.50	NA	NA	18.50	8.60	6.96	6.80
	7	0.90	17.50	14.00	10.00	3.30	8.60	17.00	NA	NA	17.00	5.10	4.20	4.70
4	1	4.60	18.00	14.50	11.50	11.20	12.00	14.00	NA	20.00	18.50	11.60	9.09	9.90
	2	4.00	18.00	14.00	11.20	8.80	10.50	14.00	NA	20.00	18.00	10.40	7.29	7.90
	3	3.40	19.00	13.50	10.00	6.00	8.80	14.00	NA	19.50	17.50	8.10	5.91	9.60
	4	2.70	19.00	11.00	8.60	4.30	7.10	14.50	NA	20.00	15.50	6.00	5.17	4.60
	5	2.10	18.00	7.50	6.20	2.00	4.30	13.50	NA	19.50	14.50	3.90	2.78	4.50
	6	1.50	13.50	5.00	3.00	0.70	0.15	8.80	NA	19.00	11.50	0.50	0.93	3.00
	7	0.60	11.50	NA	3.00	1.40	0.10	6.50	17.50	18.00	8.10	0.08	0.20	5.20
5	1	3.70	15.00	8.50	2.80	3.80	NA	6.50	9.80	NA	6.00	2.90	1.24	1.50
	2	3.10	7.20	7.50	4.40	4.00	5.20	4.90	6.00	19.50	8.80	5.00	3.68	3.80
	3	2.50	7.80	9.00	5.50	4.50	5.80	6.10	8.20	19.50	10.50	4.60	4.12	7.20
	4	1.90	8.00	11.50	9.20	21.50	8.10	9.70	12.50	19.50	12.50	6.00	6.64	6.10
	5	1.20	11.50	14.00	14.50	7.00	9.80	12.50	8.50	19.50	14.50	6.90	6.59	7.20
	6	0.60	11.50	16.00	17.50	6.80	8.20	12.50	7.40	19.50	13.50	5.80	5.38	6.00
	7	0.10	20.00	NA	21.00	21.70	20.50	21.80	20.00	NA	20.80	20.80	NA	NA
6	1	4.30	NA	NA	18.00	20.00	9.60	NA	20.00	NA	NA	NA	3.51	4.70
	2	3.70	6.00	NA	12.50	9.30	9.60	5.20	18.50	21.80	12.50	5.10	7.41	6.50
	3	3.00	5.30	NA	13.50	7.10	4.70	1.50	NA	21.80	15.50	5.50	4.23	7.00
	4	2.40	13.50	NA	13.00	7.20	8.60	NA	19.00	21.80	13.50	5.00	4.78	9.50
	5	1.80	20.80	NA	14.00	7.00	NA	21.80	20.00	21.80	14.50	8.40	6.65	10.30
	6	1.20	NA	NA	16.00	10.50	11.50	21.80	19.00	21.80	16.00	13.70	11.64	11.30
	7	0.60	14.50	NA	14.50	7.30	12.00	17.50	15.00	21.80	NA	11.90	12.24	11.00

Station	Port	depth (m)	92/09/29	92/10/19	92/11/03	93/03/19	93/04/24	93/05/21	93/07/13	93/09/10	93/10/01	93/10/26	93/11/29	93/12/22
1	1	3.20	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	2	2.60	20.48	20.35	20.33	17.50	20.50	19.20	19.49	19.50	20.80	20.50	21.40	20.30
	3	2.00	20.63	20.46	20.35	17.80	20.50	19.70	19.54	19.70	20.80	20.30	21.40	20.30
	4	1.40	20.75	20.46	20.45	17.80	20.55	19.60	19.54	19.70	20.80	20.60	21.30	20.40
	5	0.80	20.81	20.28	20.51	NA	20.60	19.80	19.56	19.60	20.80	20.60	21.40	20.50
	6	0.20	20.81	20.68	20.61	NA	20.80	20.60	20.80	20.80	21.50	20.70	21.60	NA
2	1	4.60	19.21	19.69	19.95	17.40	20.00	19.30	17.86	18.20	19.60	19.70	21.60	19.60
	2	4.00	19.06	19.55	19.86	17.50	20.40	19.41	16.97	17.90	19.70	19.60	20.70	19.60
	3	3.40	18.73	19.31	19.78	17.00	20.40	19.35	16.11	NA	20.10	19.90	20.90	19.70
	4	2.70	18.66	19.92	19.93	17.00	20.50	19.31	16.93	19.80	20.30	18.50	20.80	19.90
	5	2.10	18.39	20.09	19.91	15.90	20.65	19.12	15.58	17.70	20.10	18.60	20.60	19.90
	6	1.50	17.68	19.91	19.78	13.70	20.80	18.93	13.21	17.00	20.00	19.40	20.40	19.70
	7	0.90	18.88	19.27	19.61	10.00	20.80	18.12	10.45	15.90	19.30	19.60	20.10	19.00
3	1	4.60	19.91	19.88	20.29	16.90	20.40	19.87	16.65	18.00	16.80	18.00	18.30	19.10
	2	4.00	19.61	19.86	20.16	17.20	20.40	19.77	17.05	17.20	15.70	17.20	18.70	19.10
	3	3.40	19.53	19.79	20.18	17.20	20.40	19.65	16.75	15.40	16.00	15.40	18.90	19.30
	4	2.70	19.28	19.58	19.95	15.60	20.25	19.28	15.66	14.00	15.80	14.00	18.00	19.50
	5	2.10	19.23	19.23	19.55	10.60	19.95	18.09	12.32	13.30	15.20	13.30	18.40	19.20
	6	1.50	18.46	18.98	19.01	5.20	19.25	16.09	6.98	10.30	15.80	10.30	17.90	NA
	7	0.90	17.04	17.67	18.37	NA	19.00	14.65	3.58	7.70	16.30	7.70	15.80	18.80
4	1	4.60	17.97	16.07	16.33	11.40	18.70	16.86	10.16	9.80	12.90	9.80	17.40	18.30
	2	4.00	17.85	15.44	17.08	12.60	19.15	17.42	9.38	8.50	12.70	8.50	17.50	18.50
	3	3.40	17.71	14.74	17.68	13.60	19.70	16.76	7.63	6.90	12.40	6.90	17.40	18.90
	4	2.70	17.55	12.26	16.89	14.80	19.75	14.74	5.79	5.30	11.50	5.30	17.10	18.90
	5	2.10	16.75	10.21	15.22	NA	19.10	12.42	3.40	3.40	9.70	3.40	16.20	NA
	6	1.50	15.62	6.35	12.32	9.70	16.60	8.58	0.46	0.70	4.80	0.70	14.80	19.10
	7	0.60	15.28	3.74	11.18	5.40	15.35	5.22	0.04	0.50	1.20	0.50	13.40	NA
5	1	3.70	16.63	2.98	1.46	1.80	7.80	6.62	1.62	2.40	3.00	2.40	2.50	2.70
	2	3.10	17.38	4.89	4.23	NA	9.90	7.87	4.01	4.60	6.30	4.60	5.30	5.00
	3	2.50	17.51	7.92	6.62	6.70	10.30	8.77	4.80	5.30	7.90	5.30	9.00	7.80
	4	1.90	17.94	12.42	10.79	8.20	11.45	10.35	6.55	7.30	11.30	7.30	12.40	10.70
	5	1.20	18.29	14.59	13.61	7.60	12.70	11.30	7.16	8.10	14.20	8.10	13.80	11.50
	6	0.60	18.02	14.31	13.82	NA	12.75	10.98	4.62	7.10	14.10	7.10	13.10	10.80
	7	0.10	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
6	1	4.30	18.43	5.16	3.91	NA	9.60	9.73	4.91	1.70	4.50	1.70	4.40	2.80
	2	3.70	18.49	6.04	4.26	NA	9.75	9.85	5.35	1.80	5.00	1.80	8.00	3.10
	3	3.00	18.43	6.51	8.11	18.10	10.90	10.82	5.32	3.00	8.90	3.00	14.90	5.90
	4	2.40	19.13	10.78	16.03	16.90	11.50	11.77	5.07	6.30	12.80	6.30	17.50	15.10
	5	1.80	19.39	13.60	15.85	NA	15.80	NA	5.81	6.20	12.70	6.20	17.50	14.90
	6	1.20	19.66	15.75	16.67	NA	17.30	14.18	7.76	8.00	15.10	8.00	17.90	14.70
	7	0.60	20.05	16.70	18.17	NA	NA	14.23	7.08	9.10	17.80	9.10	18.20	14.60

Station	Port	depth (m)	93/10/01	93/11/29	93/12/22	94/02/18	94/03/30	94/05/03
1	1	3.20	NA	NA	NA	NA	NA	NA
	2	2.60	20.80	21.40	20.30	18.70	12.20	20.40
	3	2.00	20.80	21.40	20.30	18.70	12.10	20.20
	4	1.40	20.80	21.30	20.40	18.80	12.40	20.00
	5	0.80	20.80	21.40	20.50	18.90	12.00	19.80
	6	0.20	21.50	21.60	NA	NA	NA	19.70
2	1	4.60	19.60	20.60	19.60	18.10	NA	17.30
	2	4.00	19.70	20.70	19.60	18.50	NA	19.30
	3	3.40	20.10	20.90	19.70	19.00	NA	19.90
	4	2.70	20.30	20.80	19.90	18.80	NA	20.20
	5	2.10	20.10	20.60	19.90	NA	NA	20.00
	6	1.50	20.00	20.40	19.70	17.30	NA	19.70
	7	0.90	19.30	20.10	19.00	NA	NA	NA
3	1	4.60	16.80	18.30	19.10	15.40	NA	16.80
	2	4.00	15.70	18.70	19.10	15.70	NA	17.00
	3	3.40	16.00	18.90	19.30	NA	NA	17.30
	4	2.70	15.80	18.00	19.50	NA	NA	17.20
	5	2.10	15.20	18.40	19.20	NA	NA	16.90
	6	1.50	15.80	17.90	NA	NA	NA	16.70
	7	0.90	16.30	15.80	18.80	NA	2.30	17.30
4	1	4.60	12.90	17.40	18.30	15.30	11.30	16.70
	2	4.00	12.70	17.50	18.50	15.10	11.60	16.50
	3	3.40	12.40	17.40	18.90	14.80	12.10	16.40
	4	2.70	11.50	17.10	18.90	NA	NA	16.30
	5	2.10	9.70	16.20	NA	NA	11.00	15.90
	6	1.50	4.80	14.80	19.10	14.00	6.80	13.90
	7	0.60	1.20	13.40	NA	13.70	4.00	13.00
5	1	3.70	3.00	2.50	2.70	2.00	0.60	3.70
	2	3.10	6.30	5.30	5.00	5.60	1.40	6.10
	3	2.50	7.90	9.00	7.80	9.40	2.00	7.80
	4	1.90	11.30	12.40	10.70	11.90	2.60	10.90
	5	1.20	14.20	13.80	11.50	11.20	2.70	12.70
	6	0.60	14.10	13.10	10.80	NA	NA	14.10
	7	0.10	NA	NA	NA	NA	NA	NA
6	1	4.30	4.50	4.40	2.80	16.20	12.70	NA
	2	3.70	5.00	8.00	3.10	17.40	12.20	9.00
	3	3.00	8.90	14.90	5.90	18.80	13.30	9.60
	4	2.40	12.80	17.50	15.10	18.90	15.20	10.10
	5	1.80	12.70	17.50	14.90	18.90	15.20	13.10
	6	1.20	15.10	17.90	14.70	18.40	9.40	17.10
	7	0.60	17.80	18.20	14.60	17.40	5.30	19.20

Station	Port	DEPTH (m)	21.0 91/01/18	91/04/11	91/05/22	91/06/19	91/07/17	91/08/21	91/10/22	92/03/17	92/04/22	92/05/26	92/07/14	92/08/17
1	Surface	0	NA	NA	24.3	30.2	40.7	17.3	NA	NA	5.0	12.2	NA	26.7
	Black	NA	NA	NA	NA	NA	19.3	23.2	14.6	3.3	4.3	2.1	7.5	9.2
	Blue	0.1	-0.7	1.8	14.2	18.4	NA	17.7	11.9	-0.2	2.1	5.7	10.8	13.6
	Red	1.4	6.3	4.8	8.6	13.5	NA	NA	NA	NA	NA	NA	NA	NA
2	Surface	0	NA	NA	33.1	32.0	39.4	15.7	NA	NA	5.5	14.1	NA	24.2
	Black	0.3	4.4	5.1	14.6	19.2	23.3	15.3	15.5	4.4	4.8	4.5	9.7	12.1
	Blue	0.9	13.8	9.1	13.5	17.5	9.3	22.8	17.3	6.4	6.5	4.2	8.9	11.1
	Red	3.9	22.9	16.9	12.9	13.7	16.2	21.3	19.0	11.9	11.5	6.8	NA	8.1
3	Surface	0	NA	NA	23.2	32.0	37.1	17.1	NA	NA	4.8	14.1	NA	NA
	Black	0.4	4.4	4.9	16.3	21.8	24.3	16.9	14.1	4.4	4.8	4.8	10.8	12.7
	Blue	1.4	13.8	NA	13.5	17.1	12.5	24.0	17.4	8.0	7.5	4.4	NA	NA
	Red	4.1	22.9	17.6	12.3	12.6	15.2	18.6	18.3	13.1	12.0	7.7	7.5	8.0
4	Surface	0	NA	NA	22.7	39.0	40.1	17.2	NA	NA	4.7	17.2	NA	NA
	Black	0.3	3.0	4.9	17.5	24.4	26.7	17.5	14.2	3.5	3.6	6.5	NA	NA
	Blue	1.3	17.6	12.9	14.2	17.6	22.7	25.5	18.3	7.1	6.7	5.3	NA	NA
	Red	4.3	23.1	17.7	13.5	13.7	16.4	20.6	19.8	12.4	12.1	8.3	NA	NA
5	Surface	0	6.5	NA	24.7	35.0	47.0	15.6	NA	NA	3.8	16.8	NA	NA
	Black	0.2	3.3	5.0	16.6	23.8	27.7	17.7	14.1	4.5	NA	9.3	13.8	15.5
	Blue	0.7	9.0	8.5	15.7	20.9	27.2	24.4	16.2	5.9	5.5	7.7	13.1	14.8
	Red	3.7	23.5	17.6	15.6	16.8	20.7	26.1	21.2	12.3	10.0	7.6	8.6	9.2
6	Surface	0	NA	NA	21.8	36.0	44.7	17.7	NA	NA	3.5	14.4	NA	NA
	Black	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Blue	0.4	6.3	5.9	15.2	20.8	26.1	21.7	16.5	NA	6.2	6.5	11.4	12.8
	Red	2	11.1	10.3	13.5	17.6	22.1	24.8	18.1	NA	7.8	6.3	9.7	10.7
7	Surface	0	NA	NA	NA	42.0	45.5	17.2		NA	4.4	4.4	NA	NA
	Black	0.7	17.3	12.1	NA	18.0	23.1	25.6	16.7	6.5	6.5	6.5	8.4	10.5

Station	Port	DEPTH (m)	92/09/29	92/11/03	93/03/19	93/04/24	93/05/21	93/07/13	93/09/10	93/10/01
1	Surface	0	13.8	NA	NA	NA	NA	NA	15.3	10.1
	Black	NA	11.4	NA	NA	NA	NA	7.8	12.3	9.4
	Blue	0.1	13.4	5.8	NA	NA	NA	13.9	15.3	NA
	Red	1.4	NA	10.9	NA	NA	NA	NA	NA	NA
2	Surface	0	14.0	NA	NA	NA	NA	NA	15.3	10.1
	Black	0.3	13.3	6.1	NA	NA	NA	10.1	13.7	10.7
	Blue	0.9	12.8	8.9	NA	NA	NA	8.5	12.4	11.5
	Red	3.9	9.8	16.0	NA	NA	NA	4.2	8.1	7.5
3	Surface	0	14.0	NA	NA	NA	NA	NA	15.3	10.1
	Black	0.4	12.8	12.3	NA	NA	NA	10.7	14.2	11.4
	Blue	1.4	NA	16.8	NA	NA	NA	NA	NA	NA
	Red	4.1	8.6	16.0	NA	NA	NA	5.1	7.7	8.6
4	Surface	0	14.0	NA	NA	NA	NA	NA	NA	NA
	Black	0.3	NA	1.1	NA	NA	NA	NA	NA	NA
	Blue	1.3	NA	9.5	NA	NA	NA	NA	NA	NA
	Red	4.3	NA	14.9	NA	NA	NA	NA	NA	NA
5	Surface	0	13.9	NA	NA	NA	NA	NA	15.3	10.1
	Black	0.2	14.9	5.1	NA	NA	NA	14.7	16.2	13.2
	Blue	0.7	14.9	8.9	NA	NA	NA	12.8	15.9	13.3
	Red	3.7	11.0	14.2	NA	NA	NA	6.5	9.9	9.8
6	Surface	0	13.8	NA	NA	NA	NA	NA	15.3	10.1
	Black	NA	NA	7.3	NA	NA	NA	NA	NA	NA
	Blue	0.4	13.4	10.9	NA	NA	NA	11.1	20.4	12.8
	Red	2	11.8	12.4	NA	NA	NA	8.1	12.0	10.7
7	Surface	0	13.6	NA	NA	NA	NA	NA	15.3	NA
	Black	0.7	12.4	NA	NA	NA	NA	7.5	11.9	10.2

Station	Port	DEPTH (m)	30.0 91/01/16	91/04/11	91/05/22	91/06/19	91/07/17	91/08/21	91/10/22	92/03/17	92/04/22	92/05/26	92/06/24	92/07/14
1	Surface	0	-3.1	NA	28.7	32.5	33.4	16.5	3.0	-3.0	3.1	15.5	20.6	24.0
	Black	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Blue	0.6	3.1	4.1	8.3	12.2	16.6	19.4	9.0	1.0	2.5	11.6	15.8	14.2
	Red	1.8	7.5	7.9	7.6	6.2	19.1	14.2	11.9	5.4	6.1	4.9	9.1	9.8
2	Surface	0	-3.1	NA	28.4	30.5	32.3	17.8	3.8	-3.0	4.6	16.4	24.1	27.5
	Black	0.3	1.1	4.1	12.2	16.1	20.6	21.1	11.1	-1.7	2.2	15.1	17.5	15.2
	Blue	0.9	3.1	5.3	9.7	14.4	19.7	22.2	13.4	0.1	2.1	13.7	17.2	15.2
	Red	4	13.1	12.6	8.5	8.2	11.4	15.5	18.2	11.0	10.7	9.3	9.4	11.0
3	Surface	0	-3.1	NA	27.2	34.9	31.6	18.0	4.8	-3.0	5.3	17.7	23.6	26.4
	Black	1.6	7.6	NA	15.1	12.6	17.3	21.1	16.1	3.5	4.4	11.1	15.3	13.7
	Blue	2.8	12.3	NA	11.0	9.8	14.3	18.2	19.0	8.3	8.0	8.8	11.7	11.7
	Red	4.6	14.2	NA	9.5	8.0	11.0	14.0	17.9	11.7	11.0	9.5	9.5	8.4
4	Surface	0	-3.1	NA	21.9	30.6	40.1	15.8	3.6	-3.0	5.4	21.0	19.0	30.5
	Black	0.1	0.4	3.6	9.7	20.5	21.9	17.0	7.2	-4.3	6.6	15.0	16.9	16.2
	Blue	1.3	5.2	5.7	9.2	14.1	17.8	21.5	13.8	0.6	3.5	13.7	16.5	15.5
	Red	4.3	13.9	11.7	9.5	8.4	11.2	14.9	17.0	10.2	9.5	9.5	9.7	11.4
5	Surface	0	-3.1	NA	25.5	36.0	39.7	17.0	3.8	-3.0	4.4	21.7	21.8	23.9
	Black	0.7	4.4	4.6	12.0	16.0	20.4	19.9	10.6	-1.6	1.1	14.0	17.1	16.0
	Blue	1.3	6.6	5.4	10.9	13.2	17.8	21.2	12.9	0.8	2.6	11.8	16.3	15.4
	Red	4.4	13.3	11.2	9.5	7.7	10.0	13.7	15.7	10.2	9.4	8.1	9.4	11.0
6	Surface	0	-3.1	NA	23.5	32.3	37.9	18.0	4.7	-3.0	2.2	19.0	23.6	20.0
	Black	0.2	4.7	5.2	NA	13.7	18.9	20.7	11.3	0.8	-0.6	12.5	16.2	15.3
	Blue	1.1	7.5	7.4	8.6	10.8	15.3	19.2	13.7	2.5	1.3	8.6	13.0	13.5
	Red	4.2	11.1	10.8	5.4	6.5	8.6	12.1	13.9	7.8	6.0	7.5	7.6	9.2

Station	Port	DEPTH (m)	92/08/17	92/09/29	92/11/03	93/03/19	93/04/24	93/05/21	93/07/13	93/09/10	93/10/01	93/10/21	93/10/25	93/10/26
1	Surface	0	22.4	13.7	NA	NA	14.5	NA	NA	15.0	NA	1.5	-2.9	-6.7
	Black	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Blue	0.6	15.1	13.0	5.8	1.3	3.0	8.0	18.3	16.9	12.1	8.7	10.9	8.3
	Red	1.8	10.9	11.8	10.9	5.6	5.7	4.8	10.7	13.5	12.2	0.5	6.5	12.1
2	Surface	0	27.5	15.2	NA	NA	14.8	NA	NA	14.7	NA	1.5	-2.9	-6.7
	Black	0.3	19.3	17.3	6.1	-0.1	5.2	11.0	21.0	19.7	15.5	10.2	7.3	10.6
	Blue	0.9	18.8	17.6	8.9	0.4	5.3	10.2	19.8	19.6	16.8	11.8	9.4	12.2
	Red	4	12.8	14.9	16.0	10.2	10.3	9.2	11.1	14.8	16.1	16.9	15.4	17.6
3	Surface	0	27.0	13.9	NA	NA	14.4	NA	NA	14.8	NA	1.5	-1.5	-6.7
	Black	1.6	17.9	18.2	12.3	NA	7.0	9.9	17.5	19.4	17.9	14.9	13.6	NA
	Blue	2.8	15.9	17.8	16.8	NA	8.5	9.3	13.7	17.9	18.5	18.3	17.0	19.6
	Red	4.6	12.5	14.5	16.0	NA	10.4	9.6	11.2	14.2	15.6	11.9	15.9	NA
4	Surface	0	28.8	14.3	NA	NA	14.4	NA	NA	13.7	NA	1.4	-1.7	NA
	Black	0.1	22.8	14.7	1.1	-2.4	5.0	10.7	23.9	17.4	15.6	15.4	2.8	NA
	Blue	1.3	19.0	17.0	9.5	-0.5	5.8	9.7	18.9	18.7	16.4	11.7	10.2	NA
	Red	4.3	13.4	14.5	14.9	8.2	9.3	8.0	11.2	14.1	13.1	5.6	13.7	NA
5	Surface	0	28.0	16.1	NA	NA	14.5	NA	NA	15.0	NA	1.6	-1.5	NA
	Black	0.7	19.5	15.9	5.1	-0.2	5.9	10.5	20.1	17.8	14.6	8.3	7.3	NA
	Blue	1.3	18.3	16.4	8.9	1.1	6.5	8.8	18.1	18.0	16.4	10.7	10.2	NA
	Red	4.4	12.5	13.4	14.2	8.1	9.9	7.0	10.7	12.0	15.1	14.6	14.4	NA
6	Surface	0	28.2	14.6	NA	NA	14.4	NA	NA	14.6	NA	1.5	-1.0	NA
	Black	0.2	18.0	15.6	7.3	-0.2	5.4	8.4	18.3	17.7	15.6	10.0	8.3	NA
	Blue	1.1	16.2	16.0	10.9	2.0	5.6	6.5	14.9	17.1	16.7	12.3	12.6	NA
	Red	4.2	10.5	11.7	12.4	6.4	9.2	6.0	9.1	11.8	13.7	13.0	13.3	NA

Station	Port	DEPTH (m)	93/11/29	93/12/22	94/02/18	94/03/30	94/05/03
1	Surface	0	1.0	NA	NA	NA	18.5
	Black	NA	NA	NA	NA	NA	NA
	Blue	0.6	0.4	3.5	-0.3	0.4	1.7
	Red	1.8	6.7	8.1	5.3	3.6	4.4
2	Surface	0	1.0	NA	NA	NA	12.1
	Black	0.3	1.8	4.3	-1.0	-0.7	3.9
	Blue	0.9	4.4	5.3	0.5	0.9	3.4
	Red	4	13.7	13.5	10.7	8.1	7.8
3	Surface	0	1.0	NA	NA	NA	16.1
	Black	1.6	6.1	8.0	3.0	NA	4.1
	Blue	2.8	12.4	13.2	NA	NA	4.0
	Red	4.6	13.8	14.9	NA	NA	7.7
4	Surface	0	1.0	NA	NA	NA	15.8
	Black	0.1	0.0	2.2	NA	0.2	4.6
	Blue	1.3	3.2	3.3	NA	0.6	6.1
	Red	4.3	12.3	12.9	NA	8.2	7.8
5	Surface	0	1.0	NA	NA	NA	12.3
	Black	0.7	0.1	3.0	NA	0.3	7.5
	Blue	1.3	3.0	6.0	NA	0.9	4.1
	Red	4.4	11.8	13.5	NA	8.5	7.3
6	Surface	0	1.0	NA	NA	NA	12.5
	Black	0.2	0.6	3.5	NA	-0.6	1.9
	Blue	1.1	5.3	5.9	NA	1.2	1.6
	Red	4.2	10.2	10.0	NA	6.6	6.2

Station	Port	Depth (m)	93/11/29	93/12/22	93/02/18	94/03/30	94/05/03
1	1	1.40	9.98	9.32	10.80	8.49	8.32
	2	0.50	10.16	9.48	10.78	8.32	8.29
	3	0.40	9.42	8.96	NA	NA	NA
2	1	3.90	11.00	10.50	NA	NA	9.38
	2	2.40	9.69	9.36	12.19	NA	9.27
	3	1.90	8.49	8.18	NA	NA	8.77
	4	1.40	7.60	7.40	9.62	8.31	8.20
	5	0.90	7.41	7.14	9.53	NA	8.08
	6	0.40	6.86	6.76	9.05	NA	7.85
3	1	4.10	10.89	10.55	11.72	NA	9.45
	2	2.90	NA	NA	NA	NA	NA
	3	2.40	9.65	9.62	11.66	NA	9.33
	4	1.90	8.08	7.98	10.65	NA	8.55
	5	1.40	7.48	7.42	NA	NA	NA
	6	0.90	7.12	7.12	0.57	NA	8.14
	7	0.40	NA	NA	NA	NA	NA
4	1	4.30	NA	NA	NA	NA	NA
	2	2.80	9.70	9.84	11.05	NA	9.29
	3	2.30	9.12	9.34	10.93	9.00	9.27
	4	1.80	8.56	8.53	10.18	8.90	8.80
	5	1.30	8.28	8.13	9.85	NA	8.56
	6	0.80	6.64	6.61	8.69	7.98	8.06
	7	0.30	6.42	6.44	8.44	7.84	7.96
5	1	3.70	NA	10.38	10.81	NA	NA
	2	2.30	9.29	9.37	10.74	9.29	9.28
	3	1.70	NA	NA	NA	NA	NA
	4	1.20	6.33	7.91	9.78	8.97	8.91
	5	0.70	4.41	6.56	8.77	8.32	8.42
	6	0.20	0.92	3.41	7.72	8.09	8.04
6	1	2.10	10.40	10.05	10.45	9.26	9.24
	2	0.60	10.09	9.94	10.61	9.23	9.26
	3	0.10	8.79	9.14	10.24	NA	8.99

Station	Port	depth (m)	93/11/29	93/12/22	94/03/30	94/05/03
1	1	3.20	NA	NA	NA	NA
	2	2.60	0.33	0.30	0.94	0.17
	3	2.00	0.27	0.19	0.86	0.14
	4	1.40	0.27	0.14	0.85	0.13
	5	0.80	0.29	0.13	0.86	0.13
	6	0.20	0.18	NA	NA	-0.02
2	1	4.60	0.27	0.39	NA	0.68
	2	4.00	0.25	0.35	NA	0.64
	3	3.40	0.12	0.17	NA	0.16
	4	2.70	0.11	0.13	NA	0.12
	5	2.10	0.11	0.12	NA	0.14
	6	1.50	0.11	0.13	NA	0.16
	7	0.90	0.12	0.13	NA	NA
3	1	4.60	0.52	0.31	NA	0.39
	2	4.00	0.44	0.29	NA	0.37
	3	3.40	0.43	0.25	NA	0.31
	4	2.70	0.48	0.23	NA	0.30
	5	2.10	0.44	0.23	NA	0.32
	6	1.50	0.43	NA	NA	0.26
	7	0.90	0.43	0.22	0.71	0.19
4	1	4.60	0.64	0.43	0.62	0.37
	2	4.00	0.58	0.37	0.59	0.39
	3	3.40	0.57	0.33	0.56	0.42
	4	2.70	0.57	0.32	NA	0.43
	5	2.10	0.57	NA	0.84	0.44
	6	1.50	0.47	0.28	0.71	0.45
	7	0.60	0.44	NA	1.02	0.48
5	1	3.70	2.58	2.65	5.43	1.83
	2	3.10	2.37	2.30	3.73	1.54
	3	2.50	1.70	1.62	1.83	1.33
	4	1.90	1.20	1.04	1.22	1.11
	5	1.20	0.91	0.75	0.90	0.88
	6	0.60	0.80	0.70	NA	0.76
	7	0.10	NA	NA	NA	NA
6	1	4.30	4.90	4.80	3.41	NA
	2	3.70	4.22	4.67	3.14	2.85
	3	3.00	1.80	3.04	2.68	2.60
	4	2.40	1.32	1.23	1.39	2.39
	5	1.80	1.31	1.32	1.35	1.95
	6	1.20	1.01	1.30	1.17	0.89
	7	0.60	0.59	0.71	0.82	0.32

	SAMPLING DATE (YY/MM/DD)	CENTRE DRAIN pH	Acidity (mg/L CaCo3)	Fe (mg/L)	SO4 (mg/L)	PERIMETER DRAIN pH	Acidity (mg/L CaCo3)	Fe (mg/L)	SO4 (mg/L)	WEST LYSIMETER pH	Acidity (mg/L CaCo3)	Fe (mg/L)	SO4 (mg/L)	EAST LYSIMETER pH	Acidity (mg/L CaCo3)	Fe (mg/L)	SO4 (mg/L)
T	90/09/28	2.31	67500	14620	20440	2.27	80700	23020	96330								
T	90/10/12	2.30	13420	24120	94272	2.35	11800	18046	75690								
T	90/11/26	2.22	71500	25880	70080	2.1	75650	27480	80100								
T	91/08/21	2.19	80350	22860	67710												
T	91/08/21	2.21	75950	22600	68069												
T	91/08/21	2.19	77220	18904	59489												
T	91/08/21	2.28	43560	10638	34616												
T	91/08/21	2.20	42570	13122	37935												
	91/09/15	**Composite Soil Cover in Place**															
T	91/10/30	2.30	54450	19590	71042	2.5	1980	651	2706								
T	92/04/22									7.36							
T	92/06/24	3.10	401	12.7	428												
T	92/06/24	3.30	162	2.0	201												
T	92/06/29	2.40	35000	10500	5140												
T	92/07/14	2.80				3.76				6.55				5.9			
T	92/08/17		14400	3720	14800		3950	1250	4300								
T	92/09/29	2.87	15800	5250	15400	3.25	4200	1600	3880	6.21				6.16			
T	92/10/19	2.94				3.29											
T	92/11/03	3.00				3.63				NA				6.78			
T	93/05/21					3		51.3	8380	6.5		0.5	32				
T	93/07/13	3.20		5000	9970	3.2		5300	11490								
T	93/09/10	3.00		30600	71440	3.3		12600	27100								
T	93/10/01	3.00		30844	73854	3.6		726	1710	6		0.04	59.4	5.8		0.07	305
T	93/11/05	2.80		29840	2184	2.9		317	708	6		<0.01	65.58	5.7		<0.01	256
T	94/06/09	2.90	63500	33600	74100	2.8	4070	1100	5850	5.9	96	1.1	229	5.9	124	0.33	266
D	94/06/09			26900	73600			747	4990			<0.01	228			0.03	264
T	94/07/15	3.0	28900	73600	43400	3.0	10800	28900	14500	6.0	47.9	3.71	290	6.3	47.9	<0.01	398
D	94/07/15			35800				12200				3.65				<0.01	
T	94/08/17	3.10	13200	7750	16300	3.1	2910	1310	3450					6.1	66.4	<0.5	422
D	94/08/07			8050				1500								202	
T	94/09/21	2.30	5750	5850	11200	2.4	2086	787	3273	6.1	47.4	0.1	495	6	90.1	0.1	798
D	94/09/21			3560				587				0.05				0.06	

Note: T-Unfiltered sample (Total Metals), D-Filtered and acidified (Dissolved Metals)

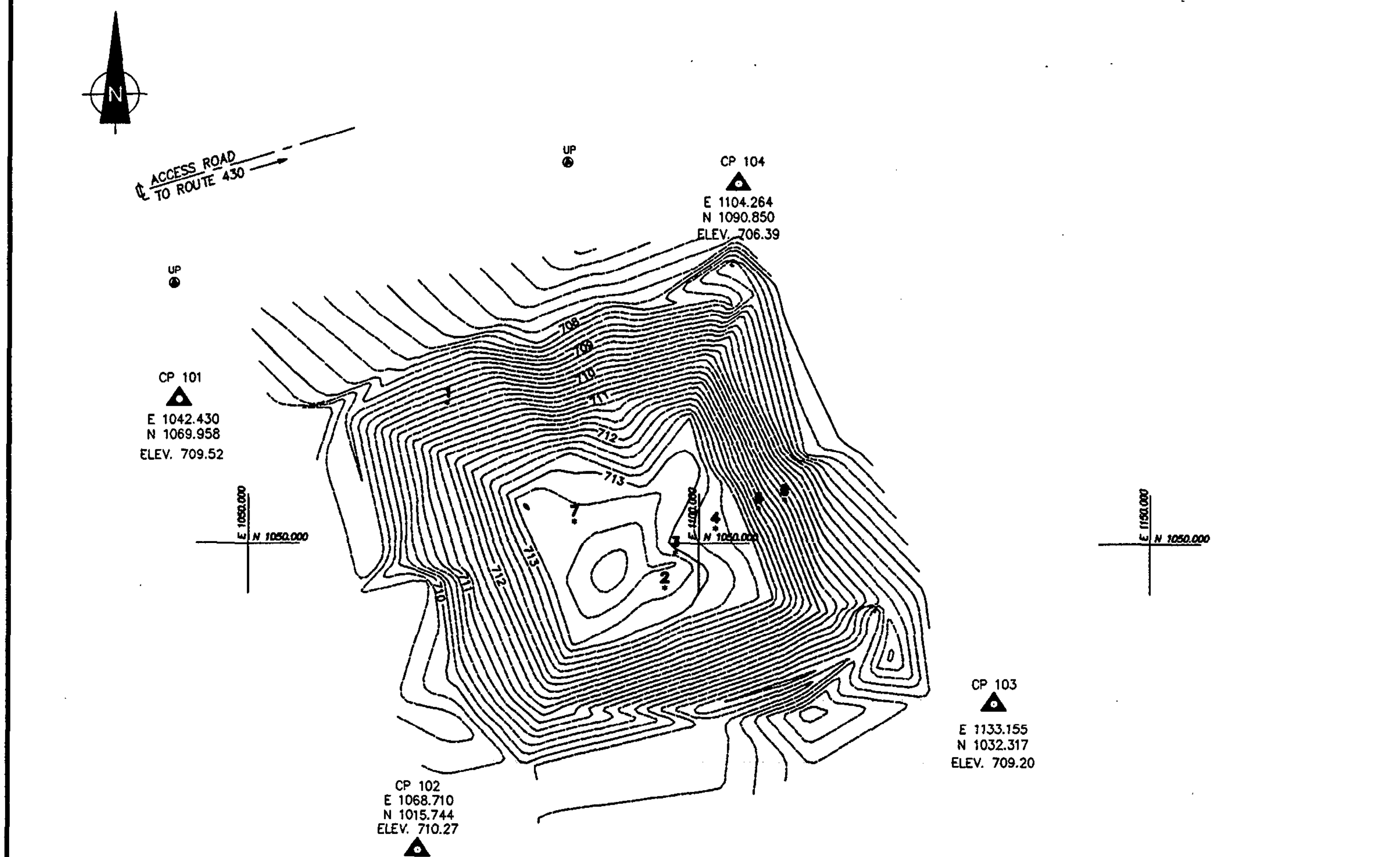
DESCRIPTION	CENTER DRAIN									
	Total 93-07-13	Total 93-09-10	Total 93-10-01	Total 93-11-05	Soluble 94-06-09	Total 94-06-09	Soluble 94-07-15	Total 94-07-15	Soluble 94-08-15	Total 94-08-15
Al (mg/l)	89.8	681	806	416	940	983	581	633	229	141
Ca (mg/l)	98.8	503	555	496	139	376	429	459	203	164
Cu (mg/l)	2.5	16.5	10.9	10.78	3.73	4.07	2.51	2.78	0.6	0.46
Fe (mg/l)	5000	30600	30844	29840	26900	33600	35800	73600	8050	7750
K (mg/l)	24.6	19.7	592	0.28	1	1	4.48	5.52	<2	40
Mg (mg/l)	128	1044	589	693	286	707	577	614	159	146
Mn (mg/l)	51.6	331	278	<0.01	47.3	163	122	141	68	69
Na (mg/l)	9.8	<0.01	<0.01	4.87	<5	<5	2.1	3.4	0.5	<1
S (g/l)	3.3	23.8	113		24.5	24.7	16.0	19.5	7.115	6.93
Zn (mg/l)	496	3015	2860	1835	1700	2470	2790	3060	722	660
Chloride (mg/l)	4.1	4.6	5.3	5.4	29			<0.5		<0.5
Conductivity (umhos)	8400	35000	29000	25000		74700		44400		34000
pH	3.2	3.0	3.0	2.8		2.9		3.0		3.1
Sulphate (g/l)	9.97	71.44	73.854	2.184		73.6		43.4		16.3

DESCRIPTION	PERIMETER DRAIN									
	Total 93-05-21	Total 93-07-13	Total 93-09-10	Total 93-11-05	Soluble 94-06-09	Total 94-06-09	Soluble 94-07-15	Total 94-07-15	Soluble 94-08-15	Total 94-08-15
Al (mg/l)		107	255	7.28	171	173	187	221	58.5	53
Ca (mg/l)	65.8	98.6	256	13.19	46.4	116	205	231	61	36
Cu (mg/l)	10.5	2.3	2.8	0.1	3.85	3.89	2.1	2.22	0.37	0.53
Fe (mg/l)	3.69	5300	12600	317	747	1100	12200	28900	1500	1310
K (mg/l)	0.3	18.9	5.5	2.22	0.31	1.3	5.57	7.22	10	7
Mg (mg/l)	51.3	148	390	16.24	61.8	67.0	204	234	41.9	35
Mn (mg/l)	117	56.5	139	1.82	18.6	26.9	51	53.2	21	19
Na (mg/l)	18.1	5	4.9	2.35	<5	<5	2.7	2.8	4.7	3
S (g/l)		3.8	9		1.66	1.85	5.92	6.01	1.85	0.997
Zn (mg/l)	753	573	1479	40.11	239	239	1070	2500	195	171
Chloride (mg/l)	3.9	3.4	3.7	1.6		18.5		1.1		<0.5
Conductivity (umhos)	29200	9600	20000	1440		9450		21000		4660
pH	3	3.2	3.3	2.9		2.8		3.0		3.1
Sulphate (g/l)	8.38	11.49	27.1	0.708		4.99		14.5		3.45

DESCRIPTION	WEST LYSIMETER						EAST LYSIMETER						
	Total 93-05-21	Total 93-11-05	Soluble 94-06-09	Total 94-06-09	Soluble 94-07-15	Total 94-07-15	Total 93-11-05	Soluble 94-06-09	Total 94-06-09	Soluble 94-07-15	Total 94-07-15	Soluble 94-08-15	Total 94-08-15
Al (mg/l)		<0.01	0.08	0.24	0.21	0.23	<0.01	0.07	0.45	0.23	0.23	6.2	2
Ca (mg/l)	45.3	19.31	37.6	41.6	78.3	124	53.4	34.9	34.9	58.8	75.2	70	36
Cu (mg/l)	<0.01	<0.01	0.01	0.06	0.01	0.01	<0.01	0.01	0.06	0.01	0.02	0.01	<0.01
Fe (mg/l)	0.5	<0.01	<0.01	1.1	3.65	3.71	<0.01	0.03	0.33	<0.01	<0.01	202	<0.5
K (mg/l)	4.8	3.8	2.7	2.8	3.5	3.63	4.77	2.7	3.2	4.93	5.89	7	4
Mg (mg/l)	9.8	7.58	12	12.9	24.6	27.2	35.05	15	15.8	32.8	43.3	35.7	29
Mn (mg/l)	6.2	2.94	19.6	22.1	20.0	21.7	56.53	43	55.9	62.4	75.2	82	81
Na (mg/l)	13	18.68	8.0	9.0	8.5	8.5	25.99	6.0	9.0	8.2	12.7	13.5	16
S (g/l)			0.0759	0.0763	0.097	0.0993		0.088	0.0886	0.124	0.165	0.427	0.096
Zn (mg/l)	0.43	0.1	1.03	1.55	3.6	4.2	<0.01	0.16	0.17	0.4	0.5	27	3.1
Chloride (mg/l)	7.1	3.9		2.7		2.9	2.8		2.2		3.2		1.5
Conductivity (umhos)	369	330		660		635	7200		703		794		910
pH	6.5	6		5.9		6.0	5.7		5.9		6.3		6.1
Sulphate (g/l)	32	0.06558		228		290	0.256		0.264		0.398		0.422

DRAWINGS

Welcome Screen | Search | Report List



NOTE:
COORDINATES AND ELEVATIONS ARE BASED ON AN ASSUMED LOCAL GRID.

CONTOUR INTERVAL 200mm

LEGEND

UP UTILITY POLE

INSTRUMENT CLUSTER AND NUMBER

CP 101 IRON BAR CONTROL POINT & NUMBER

4 2 0 5 10m

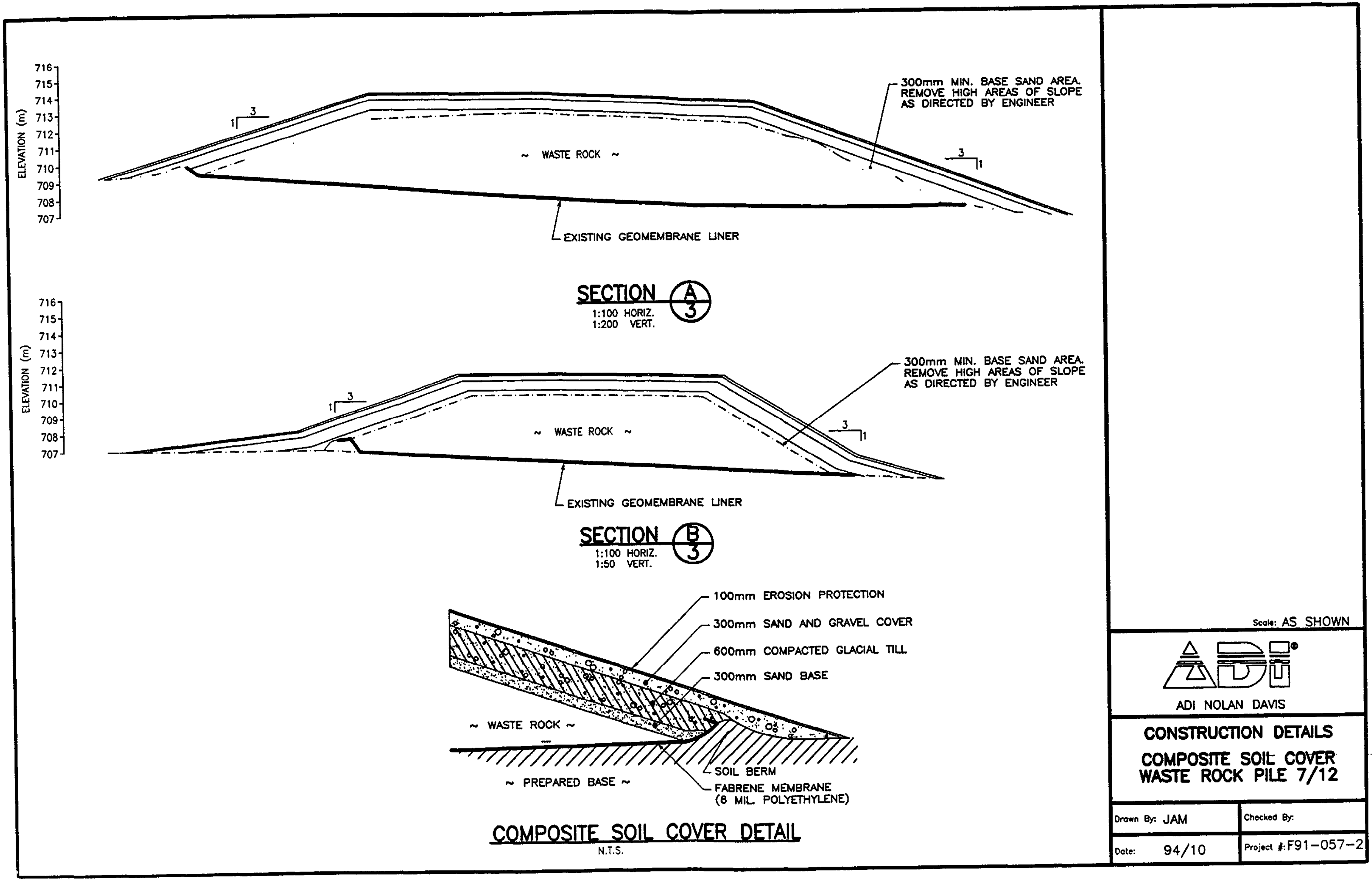
Scale: 1:500

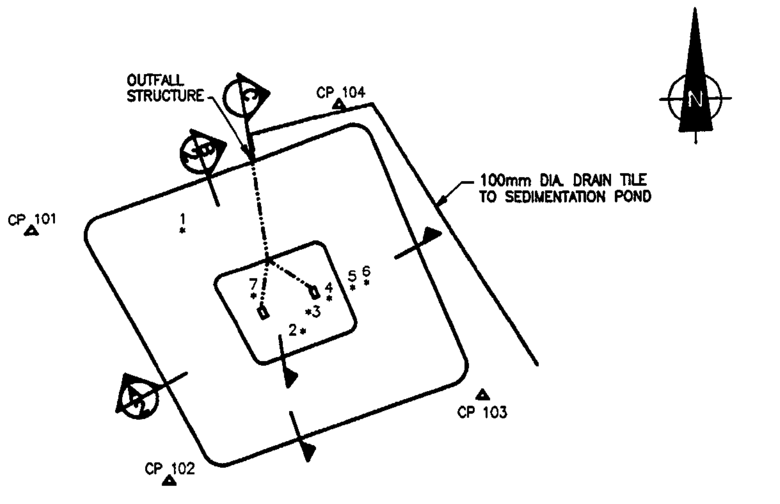
ADI NOLAN DAVIS

SITE PLAN

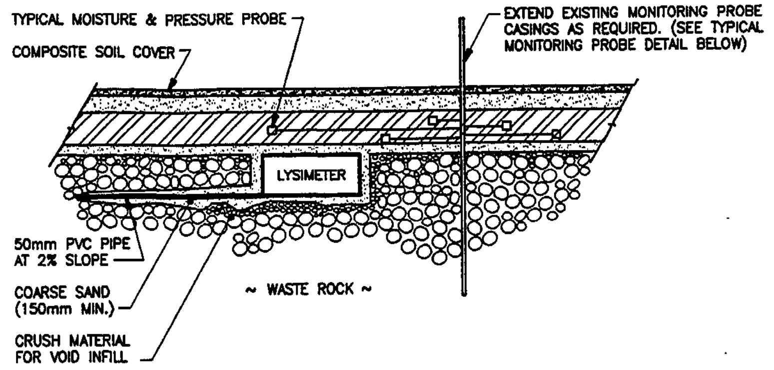
COMPOSITE SOIL COVER WASTE ROCK PILE 7/12

Drawn By: JAM	Checked By:
Date: JULY 1994	Project #: F91-057-1


ELEVATION (m)
716 715 714 713 712 711 710 709 708 707
1 3
300mm MIN. BASE SAND AREA.
REMOVE HIGH AREAS OF SLOPE
AS DIRECTED BY ENGINEER
~ WASTE ROCK ~
3 1
EXISTING GEOMEMBRANE LINER
SECTION A/3
1:100 HORIZ.
1:200 VERT.
ELEVATION (m)
716 715 714 713 712 711 710 709 708 707
1 3
300mm MIN. BASE SAND AREA.
REMOVE HIGH AREAS OF SLOPE
AS DIRECTED BY ENGINEER
~ WASTE ROCK ~
3 1
EXISTING GEOMEMBRANE LINER
SECTION B/3
1:100 HORIZ.
1:50 VERT.
100mm EROSION PROTECTION
300mm SAND AND GRAVEL COVER
600mm COMPACTED GLACIAL TILL
300mm SAND BASE
~ WASTE ROCK ~
~ PREPARED BASE ~
SOIL BERM
FABRENE MEMBRANE
(6 MIL. POLYETHYLENE)
COMPOSITE SOIL COVER DETAIL
N.T.S.
Scale: AS SHOWN
ADI NOLAN DAVIS
CONSTRUCTION DETAILS
COMPOSITE SOIL COVER
WASTE ROCK PILE 7/12
Drawn By: JAM
Checked By:
Date: 94/10
Project #: F91-057-2

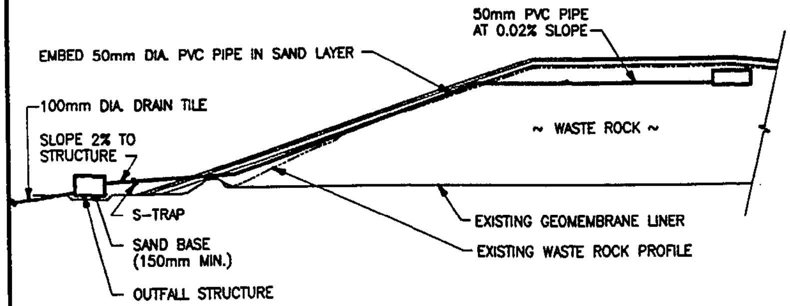


SITE PLAN – COMPLETED COVER



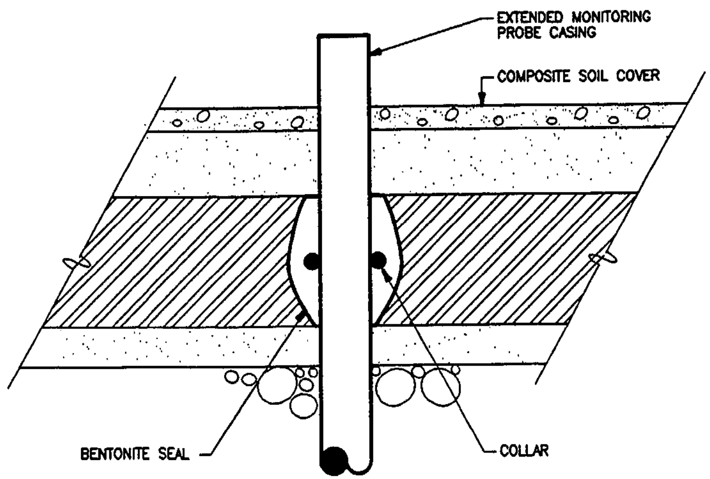
LYSIMETER PLACEMENT DETAIL

N.T.S.



SECTION C

N.T.S.



TYPICAL MONITORING PROBE DETAIL

N.T.S.

LEGEND

- EXISTING MONITORING PROBE
- CP 101 IRON BAR CONTROL POINT & NUMBER
- SECTION LETTER / DRAWING DESTINATION (IF REQUIRED)

Scale: AS SHOWN

ADI NOLAN DAVIS

CONSTRUCTION DETAILS

COMPOSITE SOIL COVER
WASTE ROCK PILE 7/12

Drawn By: JAM	Checked By:
Date: 94/10	Project #: F91-057-3