STATE OF SOUTH DAKOTA
William J. Janklow, Governor

DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES
Nettie H. Myers, Secretary

DIVISION OF FINANCIAL AND TECHNICAL ASSISTANCE
Kelly A. Wheeler, Director

GEOLOGICAL SURVEY
C.M. Christensen, State Geologist

OPEN-FILE REPORT 9-BAS

HYDROGEOLOGY AND HYDROCHEMISTRY OF CLAYEY TILL AT THE SIOUX FALLS LANDFILL, SIOUX FALLS, SOUTH DAKOTA

by

RALPH K. DAVIS
DERRIC L. ILES
VERNON R. SCHAEFER
JEFFREY M. KORTRAN
BILL KOCH
ERIC W. PETERSON

Science Center
University of South Dakota
Vermillion, South Dakota

1997

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Introduction

The city of Sioux Falls, South Dakota will expand their municipal landfill in the near future. The landfill is constructed in fractured clayey till. During the last several years, sites with low-permeability sediments, such as clayey till, have often been selected for landfills and other disposal facilities. The clayey till at the Sioux Falls landfill is a low-permeability sediment of this type. This research project was designed to further the understanding of water movement in the till. A better understanding of water movement in till will facilitate an efficient design for an environmentally sound landfill. During the research, the general concept of water movement in till was examined. The results obtained in this study are applicable to other similar low-permeability settings.

Increased environmental awareness and documented cases of ground-water contamination resulting from landfill leachate and other sources, including Love Canal and Times Beach, have grasped the public's attention. As a result, the U.S. Environmental Protection Agency (U. S. EPA) has adopted more stringent construction and monitoring requirements for landfills. In general, all new facilities are currently required to construct a liner system, a leachate detection and collection system, and a ground-water monitoring system (Federal Register, 1988). The liner system can consist of a synthetic membrane or a compacted clay liner or a combination of both types (Bagchi, 1990). The minimum monitoring system must consist of at least four ground-water monitoring wells. At least one well is to be located upgradient from the landfill and three wells are to be downgradient (Federal Register, 1988). There is significant cost associated with the construction of the liner, leachate collection system and the monitoring systems. Some issues that warrant consideration are whether or not the current liner and monitoring requirements are justified for landfills constructed in a low-permeability hydrogeologic setting.

The U.S. EPA landfill construction and monitoring requirements are applied nationwide. They are not designed for any specific landfill or hydrogeologic setting. They do, however, allow the design and operation of each proposed landfill to be evaluated on site-specific hydrogeologic data. The regulations provide a mechanism for modifying construction and monitoring to more adequately meet the needs of the individual facility (40 CFR, Part 258.50, Subpart E, Ground Water Monitoring Systems and Corrective Actions, 1993).

> "Ground-water monitoring requirements under 258.51 through 258.55 of this part may be suspended by the Director of an approved State for a MSWCF [Municipal Solid Waste Land Fill] unit if the owner or operator can demonstrate that there is no potential for migration of hazardous constituents from that MSWCF unit to the uppermost aquifer as defined in 258.2 during the active life of the unit and the post closure period."

There are several important questions that must be addressed prior to the expansion of the Sioux Falls landfill. Questions directly related to this research project are presented below.

- Does the till, weathered or unweathered, prevent vertical movement of contaminants to underlying aquifers?

- Does the till, weathered or unweathered, prevent lateral movement of contaminants to usable water supplies?
- Is there a necessity for the construction of a bottom liner in the landfill?
- Is there a necessity for the construction of a side-wall liner in the landfill?
- What is the proper ground-water monitoring technique at the landfill?

Answers to these questions have a direct influence on landfill design and monitoring, and also on the overall cost of landfill operation. This is why it is essential to have an adequate understanding of water movement in low-permeability sediments like those at the landfill.

Location of Study Area

The Sioux Falls landfill is located approximately 12 km (7.5 miles) west of Sioux Falls, South Dakota (Figure 1). The site is located near the boundary between the Coteau des Prairies and the James Basin physiographic provinces (Tomhave, 1994). A detailed map of the site including the locations of wells, boreholes and other features relevant to the project is included as Figure 2.

Previous Work

The basic geology of Minnehaha County, including the study area, has been described in detail by Tomhave (1994). Lindgren and Niehas (1992) prepared a report describing the water resources of Minnehaha County. This report includes information on surface water and ground water quantity and quality. The report also describes each of the major aquifers within the county including the Wall Lake aquifer which underlies the till at the site.

Iles (1989) conducted a study of the landfill site which presented hydrogeologic and hydrochemical data for the Sioux Falls landfill. The geologic interpretation is based on a series of test holes drilled in 1984 by the South Dakota Department of Environment and Natural Resources, Division of Geological Survey (SDGS). A portion of these were completed as monitoring wells for assessment of water levels and collection of water samples.

Twin City Testing Corporation (TCT) conducted a series of investigations at the Sioux Falls landfill (TCT, 1988; TCT, 1991; and TCT, 1992). The 1988 and 1991 projects contain basic data presented as a series of borehole logs. The 1992 investigation was designed to more completely define a sand body that had been previously identified by Iles (1989). The 1992 TCT project included installation of monitoring wells, and collection and analysis of water samples from these wells.

There has been a significant amount of work conducted in recent years related to characterization of hydraulic conductivity (K) and other hydraulic parameters for both the surficial

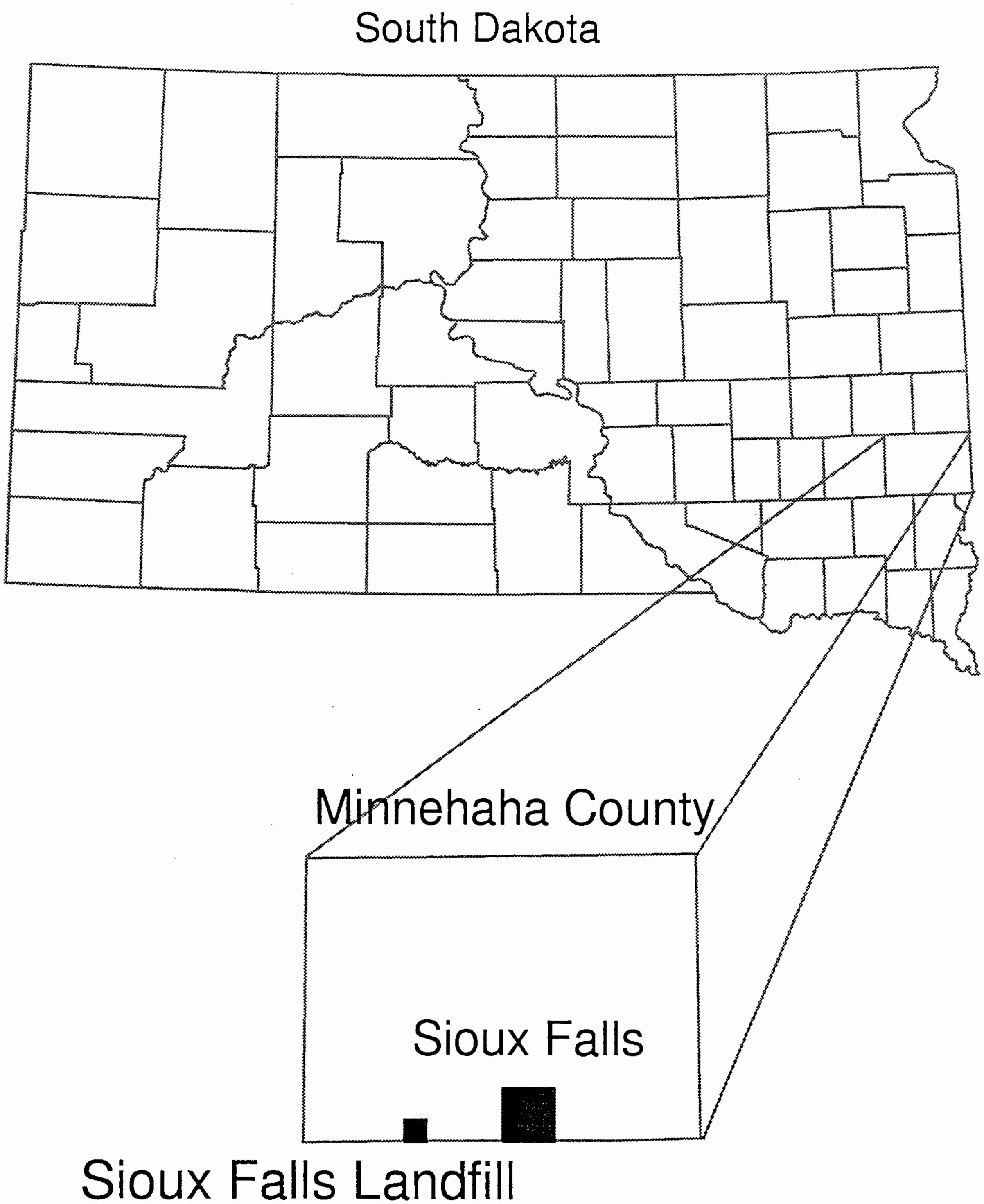


Figure 1 - Location of Study Area

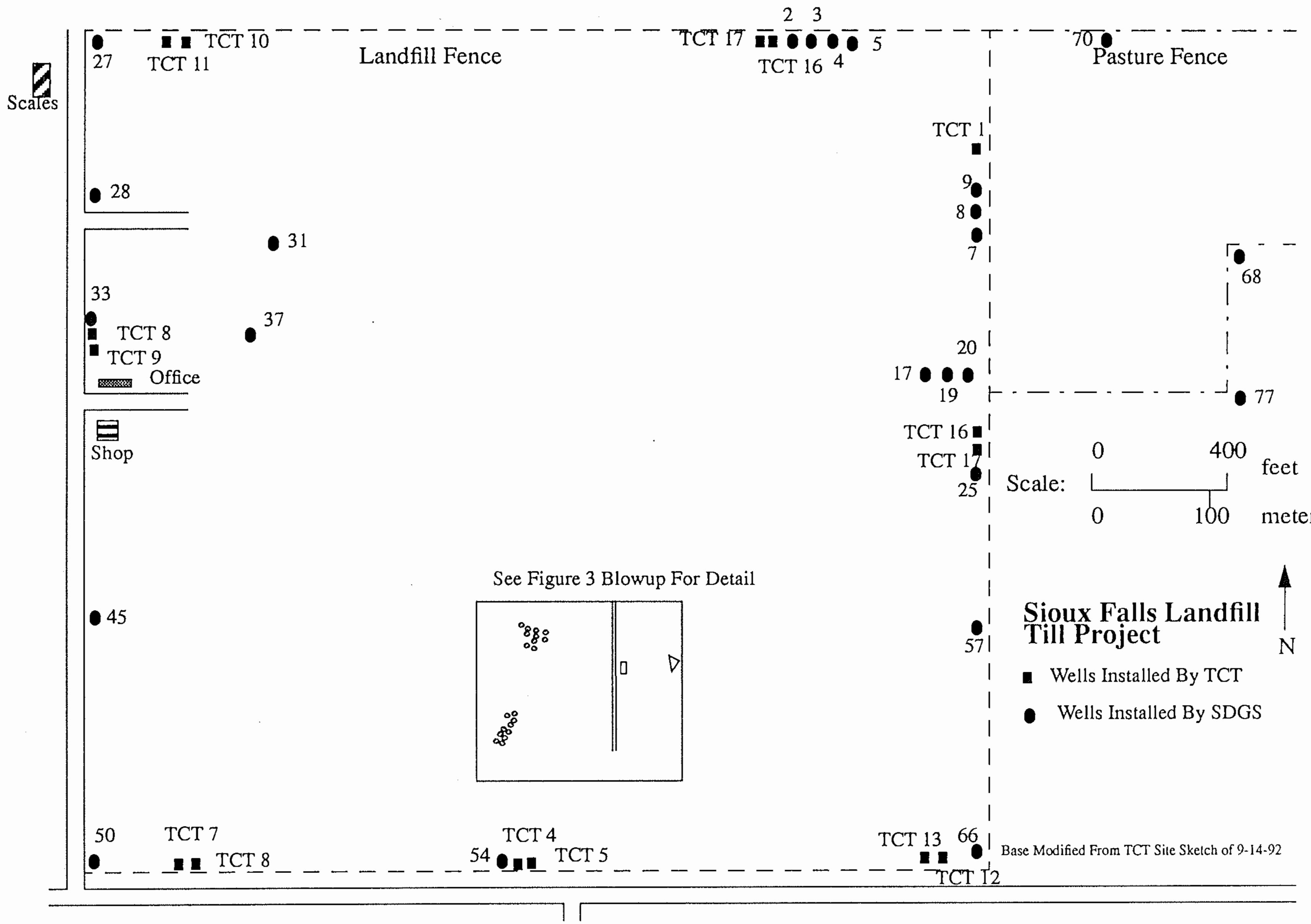


Figure 2 - Sioux Falls Landfill Till Project, Sioux Falls, South Dakota - Site Map

weathered (fractured) till and the deeper unweathered (unfractured) till. This research generally indicates significantly higher K in the fractured till than in the lower unfractured till (CENDAK, 1987; CENDAK, 1988; Hendry, 1988; Cravens and Ruedisili, 1987; D'Astous et al., 1989)

Determining hydraulic parameters of the clayey till is a difficult task. Davis et al. (1993) and Fredericia (1993) have shown that hydraulic conductivities determined in laboratory tests of cores are 1 to 2 orders of magnitude lower than K values determined from field slug tests. Both investigations have also concluded that due to significant variability in the K values determined from field slug tests it is probable that the tests do not encompass a representative elementary volume (REV). The REV is a volume that includes a sufficient number of pores to permit a meaningful statistical average over a continuum.

D'Astous et al. (1989) and McKay et al. (1993) have performed tracer studies in weathered till in an attempt to encompass a larger volume and more closely approximate a REV. These studies do seem to more accurately characterize hydraulic parameters in these types of geologic settings. D'Astous et al. (1989) concluded that K values determined from slug tests (10^{-11} to 10^{-9} m/s; 10^{-9} to 10^{-7} ft/min) are 1 to 2 orders of magnitude lower than K values determined for larger scale trench tests (10^{-9} to 10^{-7} m/s; 10^{-7} to 10^{-5} ft/min).

Jones (1993) and Jones et al. (1992) performed very low rate pump tests in clay till in central Iowa. They concluded that it is feasible to perform these types of tests in weathered till. Values of K determined from the pump tests are on the same order of magnitude as K values determined from slug tests but are 1 to 2 orders of magnitude higher than K values determined by laboratory methods on geologic cores from their study sites.

The complexity of water movement through clayey till is evidenced by different conclusions from various research projects in the United States and Canada. Conclusions reached by the Central South Dakota Water Supply Steering Committee (CENDAK) suggest that most of the water entering the system is returned to the atmosphere via evapotranspiration (ET). They further indicate that downward movement of water through unweathered till is insignificant and that lateral flow, as a means of dissipating recharged water, cannot account for a major portion of the water that enters the system as recharge (Barari and Hedges, 1985; Barari et al., 1992; CENDAK, 1987; CENDAK, 1988). Others have reached similar conclusions throughout the U.S. and Canada (Cherry et al., 1973; Grisak and Cherry, 1975; Hendry, 1988; Cravens and Ruedisili, 1987).

Hendry (1988) investigated water movement in clay till in southern Alberta, Canada. He also concluded that lateral and vertical flow was insignificant and that most of water was being returned to the atmosphere via ET. He showed that hydraulic heads within the weathered till had significant response to precipitation. Hendry calculated vertical seepage rates of 2 to 6 m/1000 yrs (6.6 to 19.7 ft/1000 yrs) and lateral flow rates of 9 m/1000 yrs (29.5 ft/1000 yrs). He indicates that the geochemistry of the system supports the conclusion that no significant lateral or vertically downward flow occurs.

Hendry (1983) performed tritium analysis to determine the relative age of water in the weathered till. He concluded that intergranular flow rates were on the order of 0.1 m/yr (0.3 ft/yr) He also showed that macropore flow is occurring. Water is moving into the fracture system, replacing dead water in sand lenses and entering the till matrix via diffusion. Hendry did not provide an explanation of where the dead water in the sand bodies, which was being displaced, was moving.

Hendry et al. (1986) conducted a detailed investigation of the sources of sulfate in weathered till. The results of this study indicated that sulfate in the weathered till is derived from oxidation of organic sulfur after deposition of the till. Higher concentrations of sulfate in the weathered till cannot be attributed to evaporative concentration because there is no corresponding enrichment of chloride. They showed that no appreciable losses of sulfate via ground-water flow were occurring. They concluded from this that ground-water flow systems are small and localized (0 to about 1 km, with most flow systems on the order of 0.5 km) and that sulfate may be redistributed locally but is not removed from the system.

Prudic (1986) investigated the movement of water and radionuclides from a radioactive waste facility constructed in fine-grained till in Carttaraugus County, New York. He concluded that lateral and vertical migration of ground water would take from 300 to 2,300 years to travel about 25 m (0.08 to 0.01 m/yr; 0.3 to 0.03 ft/yr).

Cravens and Ruedisili (1987) looked at several sites in east-central South Dakota. They concluded that no significant water movement occurs below the oxidized (weathered) till. Their study also supported the theory that water movement below the weathered till is not significant in terms of recharge to underlying aquifers or as part of a regional ground-water flow system. Their conclusions were based on hydrographs, field K tests and major ion analysis of water samples. They also dated the water in the till using ^{14}C analysis. Water in the unweathered till had an age of about 9,000 years before present (b.p.), which is about the same age as the till. As others, they concluded that ET is the main path for water movement out of the weathered till.

Desaulniers et al. (1981) determined the average vertical velocity in clayey till was 0.0013 to 0.0026 m/yr (0.0043 to 0.0085 ft/yr) for a site in southwestern Ontario. They showed that tritiated water had moved to depths of only 3 to 6 m (9.8 to 19.7 ft) below land surface. Carbon-14 tests showed the age of the water in the unweathered till to be greater than 8,000 yrs b.p. The age of the formation is about 11,000 to 14,000 yrs b.p. They concluded that molecular diffusion into the clay matrix, rather than hydraulic flow, controls vertical and lateral ground-water flow.

Daniels et al. (1991) analyzed tritium data for a site on the Tipton till plain in Indiana. They used the data to calculate a recharge rate through the till of 0.035 to 0.047 m/yr (0.115 to 0.154 ft/yr). This is significantly higher than some of the studies that indicate no vertical or lateral flow in the system.

Simpkins and Parkin (1993) investigated a site in central Iowa. They concluded that K in the unweathered till is about 10^{-8} m/s (10^{-6} ft/min). Hydraulic head in piezometers indicated both vertical and lateral components of hydraulic gradient. Simpkins and Parkin also concluded that downward vertical recharge is occurring through the till, and that the average velocity ranges from 0.009 to 0.27 m/yr (0.03 to 0.886 ft/yr). These interpretations are supported by tritium and other geochemical data for their site.

Although different researchers have studied various aspects of the issue of water movement in till, the thesis set forth by Barari and Hedges (1985) remains central to nearly all research of water movement in low-permeability sediments. Their thesis encompasses the broader issue of the direction of dissipation of water from the till. They suggest that ground-water movement through the unweathered clayey till is insignificant or nonexistent. They also suggested that the major portion of ground-water discharge from weathered till is upward movement by capillary action and evaporation, and that only a small portion of the water discharge can be attributed to local lateral flow.

The driving force behind all of the research mentioned above is the need to understand the direction and magnitude of water movement in till. This understanding has implications beyond the issue of landfill construction and monitoring. The understanding will impact regulations and practices of irrigation on low-permeability sediments, and will impact predictions of recharge to buried aquifers. Much work has been done to further the understanding and prediction of water dissipation from the till. Yet, the quantification of this dissipation remains an elusive determination and is complicated in part due to the general low-permeability nature of most tills and to the general small-scale heterogeneity of most tills.

Multiple Working Hypotheses For Movement of Ground Water at the Landfill

A review of the available information and the personal experiences of the authors of this report resulted in the following hypotheses to be considered during the research. All three hypotheses have the assumed component of infiltration of surface water into the fracture system in the till and recharge of the water table. The difference between the hypotheses is the primary direction of water dissipation after it reaches the water table. The direction in which most of the water is dissipated is central to the issue of the potential movement of contaminants at the landfill.

1. The major component of water dissipation from the till is by downward movement through the unweathered till to a buried aquifer.

2. The major component of water dissipation from the till is by lateral movement to nearby discharge areas such as sloughs, rivers, or ponds.

3. The major component of water dissipation from the till is by upward movement (dissipation by evapotranspiration (ET)).

Objectives

The primary objectives of this project were to:

- Characterize till at the Sioux Falls landfill in terms of the fracture network in both the weathered till and the underlying unweathered till.

- Determine the relationship between the weathered and unweathered till in terms of water movement.

- Examine the need for artificial liners in facilities constructed where there is a significant thickness of underlying unweathered clayey till.

Methods of Investigation

Field Methods

Borehole and Monitoring Well Installation and Development

Twenty three boreholes were advanced into the till by hollowstem auger methods to depths ranging from about 4.6 m (15 ft) below land surface (bls) to about 23 m (75 ft) bls. All of the boreholes were completed as monitoring wells with the exception of boreholes R20-93-01, R20-93-04, and R20-93-10. Borehole R20-93-01 was backfilled with bentonite to the land surface and was subsequently used as a marker for locating the area to be mapped as the new trench for the landfill was being excavated. Boreholes R20-93-04 and R20-93-10 were abandoned because of problems associated with monitoring well completion at these two locations. Figure 3 shows the location of boreholes and monitoring wells utilized in this study and the location of geologic cross-sections A-A', B-B' and C-C'.

Split-spoon cores were collected from boreholes R20-93-01, R20-93-02 and R20-93-14 from the land surface to total depth. Shelby-tube cores were collected from within the interval to be screened or the interval to be left as open borehole for the remainder of the holes. Geologists logs of boreholes are included as Appendix A. Boreholes R20-93-01, R20-93-02, and R20-93-14 provide a more detailed geologic description based on field inspection and description of the split-spoon cores. Other holes were logged from cuttings at the top of the holes and cuttings that remained attached to the auger flights as they were removed from the hole. The Shelby-tube cores were wrapped in plastic and transferred to the Civil Engineering Laboratory at South Dakota State University (SDSU) for determination of K and soils classification.

Figure 3 shows two areas of monitoring well installation. This was done to provide a second set of data for comparison of the geology and the hydraulic parameters of the site. This was important since the potential exists for the till to be rather heterogeneous.

Monitoring wells were completed at multiple depths and with multiple completion methods. Wells completed at depths ranging from about 5.5 to 6.3 m (18 to 22 ft) bls are considered to be completed in the most weathered, fractured section of the till. Wells completed at depths ranging from 7.5 to 12.2 m (24 to 40 ft) bls are considered to be in a transition zone between the weathered till and the unweathered till. Finally, wells completed below about 12.2 m (40 ft) bls

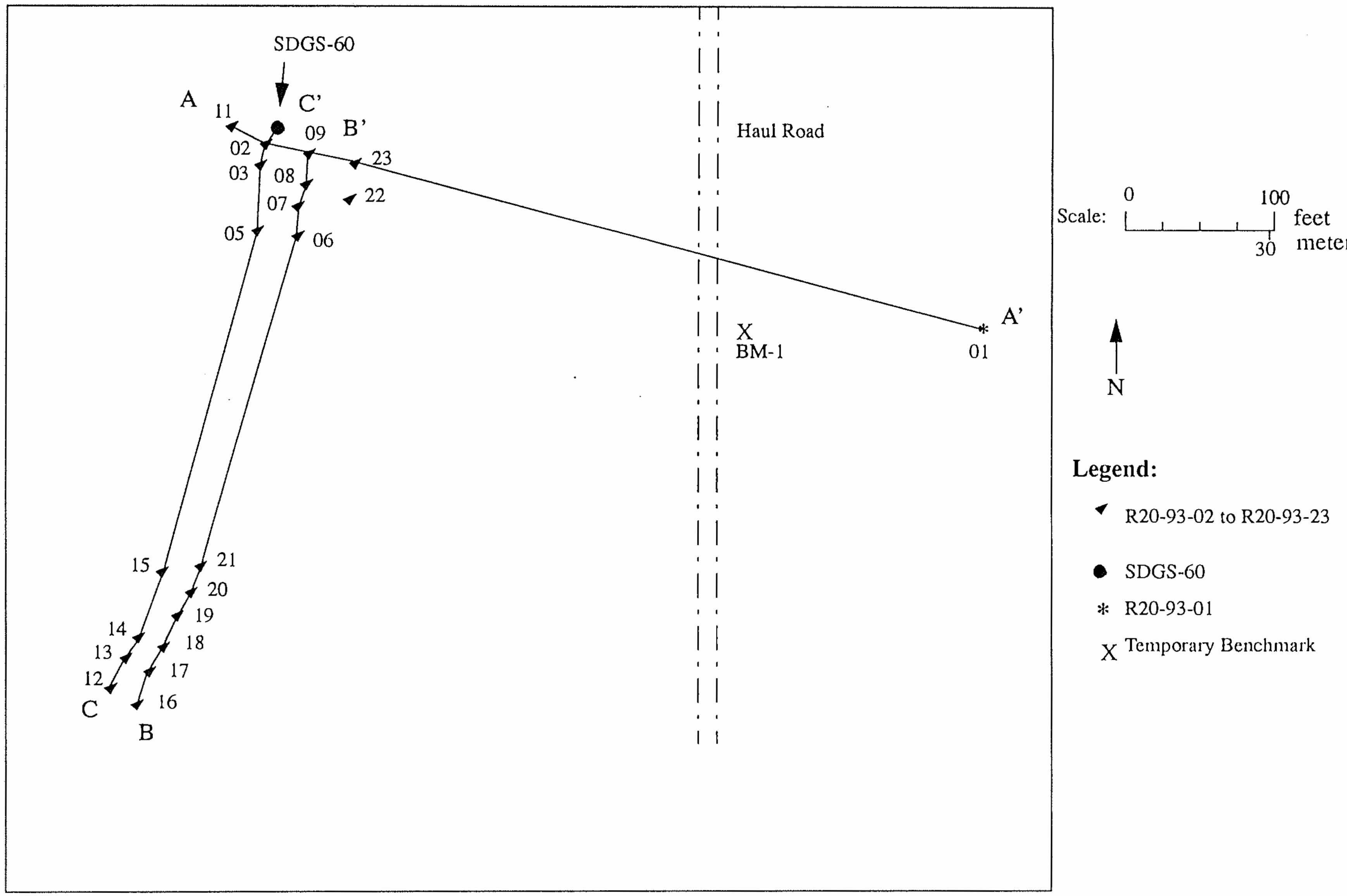


Figure 3 - Till Project Observation Well Network and Location of Cross Sections Sioux Falls Landfill, Sioux Falls, South Dakota

Table 1: Monitoring Well Completion

Monitoring Well Number	Type of Well Completion (diameter)	Depth Below Top Casing m (ft)	Screen Length m (ft)	Top Casing Elevation m (ft)	Land Surface Elevation m (ft)
R20-93-07	Screen 50 mm	5.6 (18.36)	1.5 (5)	470.9 (1544.97	470.5 (1543.47)
R20-93-08	Screen 50 mm	7.0 (22.98)	3.1 (10)	471.1 (1545.44)	470.6 (1543.84)
R20-93-09	Core 50 mm	5.7 (18.62)	0.3 (0.8)	471.3 (1546.08)	470.9 (1544.78)
R20-93-13	Core 50 mm	5.8 (19.17)	0.4 (1.25)	469.4 (1540.04)	468.9 (1538.24)
R20-93-18	Screen 50 mm	7.2 (23.68)	3.1 (10)	469.4 (1539.89)	468.8 (1537.99)
R20-93-19	Screen 50 mm	5.8 (18.92)	1.5 (5)	469.6 (1540.57)	469.0 (1538.77)
R20-93-20	Core 100 mm	6.3 (20.74)	0.6 (2)	469.9 (1541.56	469.5 (1540.26)
R20-93-21	Screen 100 mm	7.0 (22.96)	1.4 (4.73)	470.1 (1542.36)	469.7 (1540.96)
R20-93-22	Core 100 mm	5.9 (19.25)	0.5 (1.58)	471.0 (1545.18)	470.5 (1543.68)
R20-93-23	Screen 100 mm	7.5 (24.49)	1.4 (4.73)	471.0 (1541.51)	470.7 (1544.31)
R20-93-05	Screen 50 mm	10.8 (35.31)	3.1 (10)	470.6 (1543.99)	470.4 (1543.39)
R20-93-06	Core 50 mm	9.1 (29.83)	0.4 (1.25)	470.8 (1544.64)	470.3 (1543.04)
R20-93-11	Screen 50 mm	9.2 (30.3)	1.5 (5)	471.2 (1546.00)	470.9 (1545.00)
R20-93-12	Screen 50 mm	10.8 (35.28)	3.1 (10)	469.1 (1539.06)	468.7 (1537.86)
R20-93-16	Screen 50 mm	9.2 (30.27)	1.5 (5)	469.1 (1538.94)	468.6 (1537.24)
R20-93-17	Core 50 mm	9.1 (29.71)	0.3 (1)	469.1 (1539.18)	468.7 (1537.58)
R20-93-02	Screen 50 mm	22.3 (73.24)	1.5 (5)	471.2 (1545.93)	470.8 (1544.53)
R20-93-03	Screen 50 mm	16.4 (53.64)	1.5 (5)	471.1 (1545.55)	470.6 (1544.30)
R20-93-14	Screen 50 mm	23.0 (75.33)	1.5 (5)	469.5 (1540.38)	469.0 (1538.58)
R20-93-15	Screen 50 mm	15.6 (51.15)	1.5 (5)	469.8 (1541.39)	469.4 (1539.89)

are considered to be completed in unweathered, unfractured till. Table 1 and Appendix A provide information on monitoring well completion and depths.

Five different well completion methods were used for this project. This was to provide a comparison of K values from wells installed by different methods. The five methods are described below:

- Installation of a 50 mm (2-inch) diameter, flush joint polyvinyl chloride (PVC) casing with about 1.5 m (5 ft) of 0.25 mm (0.010 inch) slot screen at the lower end. Figure 4 shows the general installation for all screened wells.

- Installation of a 50 mm (2-inch) diameter, flush joint PVC casing with about 3 m (10 ft) of 0.25 mm (0.010 inch) slot screen at the lower end.

- Installation of a 100 mm (4-inch) diameter, flush joint PVC casing with about 1.4 m (4.7 ft) of 0.25 mm (0.010 inch) slot screen at the lower end.

- Installation of a 50 mm (2-inch) diameter, flush joint PVC casing to desired depth and pushing the sharpened end of the casing into the bottom sediment. The bottom of the casing was left open and a 25 mm (1-inch) diameter Shelby-tube core was collected to create a water-intake at the base of the hole. Generally, this water-intake hole extended from 0.24 to 0.38 m (0.8 to 1.25 ft) below the base of the casing. Figure 5 shows the general method of completion for the cored wells.

- Installation of a 100 mm (4-inch) diameter, flush joint PVC casing to desired depth and pushing the sharpened end of the casing into the bottom sediment. The bottom of the hole was left open and a 76 mm (3-inch) diameter Shelby- tube core was collected to create a water-intake at the base of the hole. This water-intake was extended from 0.48 to 0.61 m (1.58 to 2 ft) below the base of the casing.

In general, the screened wells were filter packed to approximately 0.61 m (2 ft) above the top of the screened interval with 0.65 to 0.75 mm quartz sand. Bentonite grout was placed from the top of the sand pack to about 0.91 m (3 ft) bls. Neat cement was placed in the top of the hole in which a steel well protector was set. The ground surface was leveled with cuttings after the cement had set. Detailed well completion for each of the wells is included in Appendix A.

The wells were developed by bailing multiple times with a PVC bailer. Since the wells were completed in clayey till, it was generally possible to bail the wells "dry" after one to two casing volumes had been removed. In addition, because of the low K conditions, water-level recovery took several hours, days or even months.

The well locations, elevations of casing tops, and the land surface adjacent to the well, were determined using a spirit level. A temporary bench mark (BM-1) was installed adjacent to the haul road (Figure 3). BM-1 was installed to determine the location and elevation of the monitoring wells, and to determine the elevation and location of the mapping area in the newly excavated landfill trench. BM-1 consists of a 1.5 m (5-ft) steel fence post set in cement. Approximately 100 mm (4 inches) of the post were exposed above land surface.

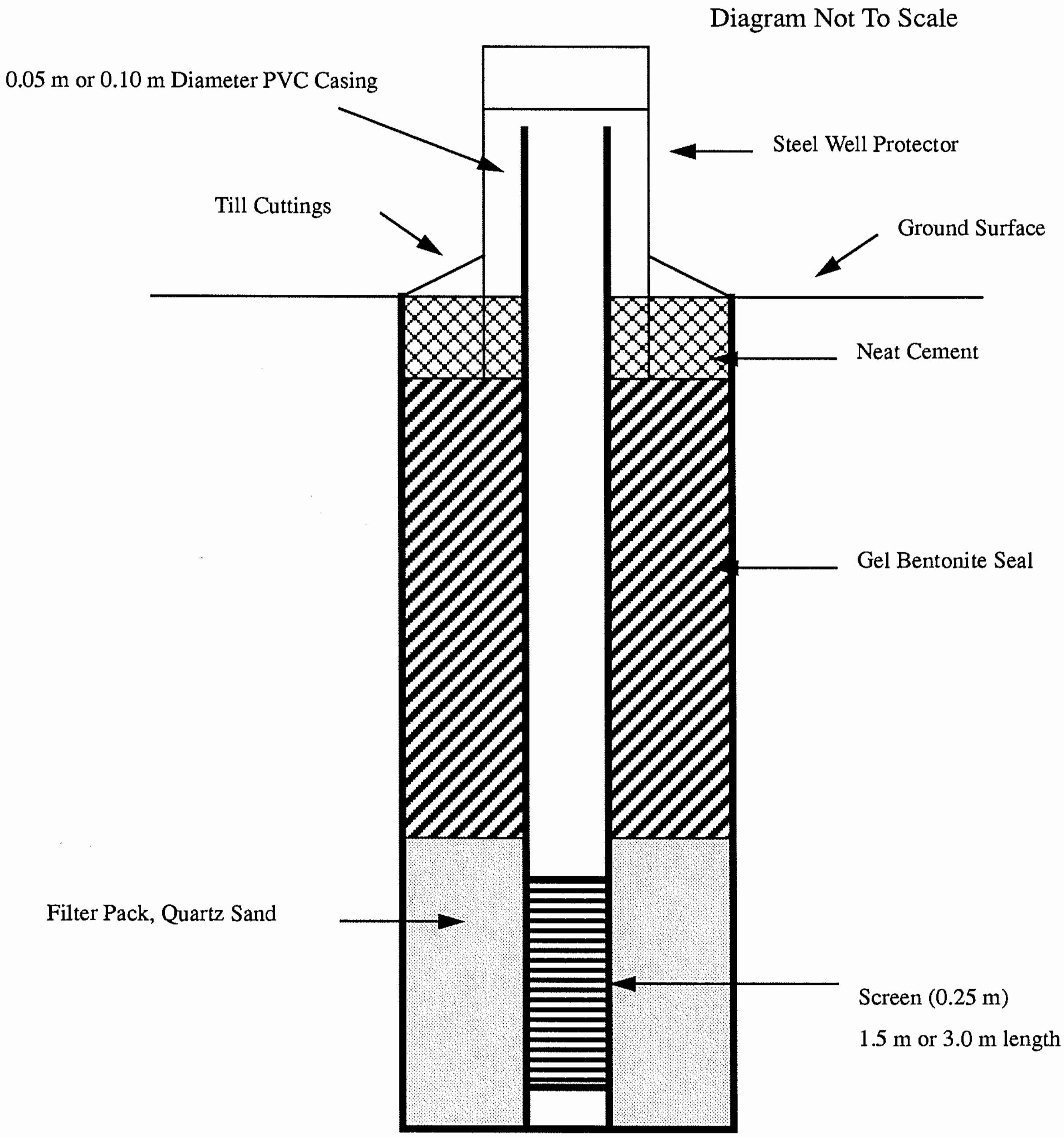


Figure 4 - Screened Intake Piezometer Construction

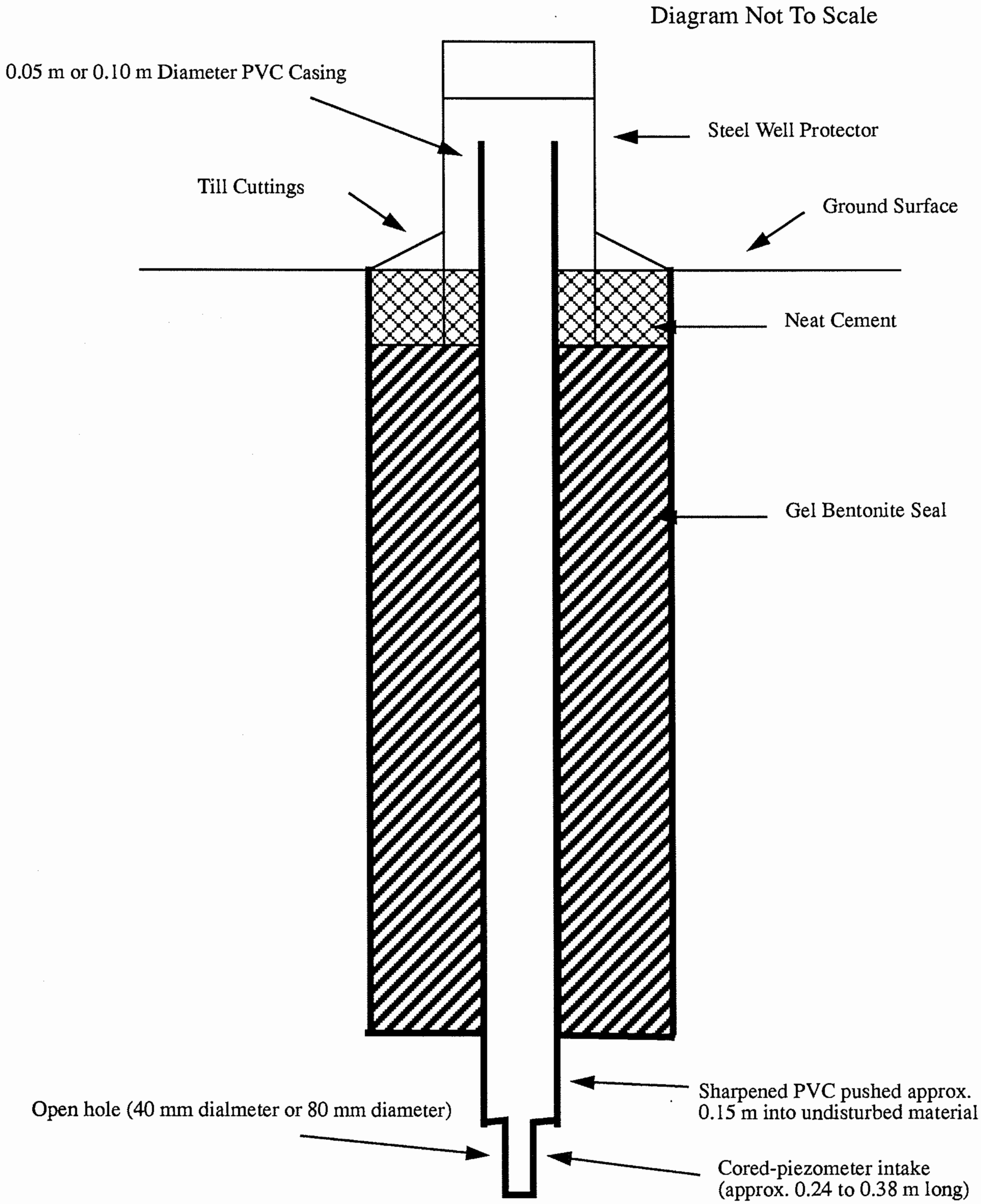


Figure 5 - Cored Intake Piezometer Construction

Slug Tests of Monitoring Wells

In situ hydraulic conductivity tests were conducted for all monitoring wells. The tests were conducted by the "bail-down" method. This procedure involves bailing the wells "dry" and measuring water-level recovery rates. These data were used to calculate K using both the Hvorslev (1951) and the Bouwer-Rice (1976) methods.

Multiple bail-down tests were conducted on many of the wells providing a comparison of K over time for the wells. This was important since it is often difficult to assess when a well in these very low-permeability units is fully developed.

Slug-test data and charts showing compaison of these data for different completion zones, well diameters and completion methods are included as Appendix B.

Water-Level Data

Water-level measurements were made on all monitoring wells in 1993 and 1994. These measurements were made with a Solinst tape. Two of the monitoring wells (R20-93-14 and R20-93-19) were instrumented with a pressure transducer and automated data logging equipment during a portion of 1993 and 1994. Water-level data from these wells provided a mechanism to help resolve questions related to water-level data from the periodic measurements of the other wells. Water-level data are included as Appendix C.

Water-Quality Sampling

Water samples were collected from the wells for a variety of purposes. One set of samples was collected to analyze for major inorganic chemistry. A second set was collected from selected wells for determination of tritium, and a final smaller subset of water samples was collected and analyzed for ^{14}C and isotopes, $\delta^{18}O$ and $\delta^{2}H$. The tritium analysis and ^{14}C analysis were used to assess the age of the ground water in the till.

Samples to be analyzed for major inorganic chemistry were collected by SDGS personnel. The wells were bailed "dry" and allowed to recover immediately prior to sampling for most wells. Some wells recovered so slowly that it was necessary to bail them only partially, leaving sufficient volume for the sample in the casing, prior to sample collection. These wells were allowed to recover until near the end of the day and were then sampled. The samples were collected with a clean PVC bailer. Alkalinity, specific conductance, pH and temperature were determined in the field at the time of sample collection. The samples were field filtered using a 0.45 µm filter. Nitric acid was added as a preservative to the samples collected for metals analysis. The samples were stored on ice while awaiting transfer to the SDGS laboratory in Vermillion, South Dakota. Results of major inorganic chemistry are included as Appendix D.

Water samples were collected in March 1994 for tritium analysis. The wells were bailed "dry" where possible and bailed to near the bottom for those that recovered very slowly. The wells were allowed to recover only enough to provide sufficient sample volume. Samples were collected with a clean PVC bailer from wells R20-93-02, R20-93-03, R20-93-07, R20-93-11, R20-93-14, R20-93-15, R20-93-16 and R20-93-21. Each sample was transferred to a clean 250 mL polyethylene bottle. The bottles were shipped to the Rosenstiel School of Marine and Atmospheric Science Laboratory for analysis. Wells R20-93-03 and R20-93-14 were resampled in June 1994. Results of the tritium analyses are included as Appendix E.

Based on the results of the tritium analyses, wells R20-93-02, R20-93-03, R20-93-11, R20-93-14, R20-93-15 and R20-93-16 were selected for sampling and analysis of ^{14}C from which ground-water age determinations were made. Sampling of wells R20-93-02, R20-93-11, R20-93-15 and R20-93-16 occurred in June 1994. Wells R20-93-03 and R20-93-14 were sampled in October 1994 after the results of the June 1994 tritium samples were available. Again, the wells were bailed "dry" where possible. The samples were collected as soon as sufficient water was available in the wellbore. Samples were collected with a clean PVC bailer and immediately transferred to a clean 1000 mL polyethylene bottle. The bottle lids were sealed to the bottle with electrical insulating tape. The samples were shipped to Geochron Laboratories for analysis of ^{14}C by the accelerator mass spectrometry method. The age determination from these analyses were ^{13}C corrected. Results of ^{14}C analyses are included as Appendix F.

Samples for analysis of isotopes of $\delta^{18}O$ and $\delta^{2}H$ were collected from wells R20-93-02, R20-93-03, R20-93-07, R20-93-11, R20-93-14, R20-93-15, R20-93-16 and R20-93-21 in June 1994 at the same time and by the same procedure as the ^{14}C samples were collected. These samples were also shipped to Geochron Laboratories for analysis. Results of $\delta^{18}O$ and $\delta^{2}H$ isotope analyses are included as Appendix G.

Mapping in New Landfill Trench

One of the main aspects of the project was to characterize the fracture pattern and lithology of an area of till from land surface to the contact with the unweathered (unfractured) till. This was accomplished by mapping and describing the till as excavation of a new waste cell for the landfill was completed in the summers of 1993 and 1994. A grid 3.1 m x 3.1 m (10 ft x 10 ft) was mapped. A PVC grid 3.1 m (10 ft) on a side was used to bound the mapping area. Nylon string was used to divide the grid area into 1.5 m x 1.5 m (5 ft x 5 ft) quadrants.

The till surface in the trench was mapped at approximately 0.6 to 0.76 m (2 to 2.5 ft) depth intervals. The earth moving equipment (scrapers) peeled off the till in about 0.1 m (4-inch) increments. After nearing the target depth, the scrapers cut the till with a little more finesse. This left a surface that was smooth but somewhat smeared. The map area surface was further prepared by gently removing the smear coating by hand with a hoe and shovel.

After the surface was prepared, a 35 mm slide photograph was taken from each quadrant. The camera was mounted on a drill-rig mast on a 1-ton truck. The mount allowed the camera to be leveled with respect to the grid. The drill rig mast provided up-down movement so the camera was always about the same height above the till surface. Once this was completed, the till within the quadrant was mapped. Notes were compiled on fracture density, fracture strike and dip, fracture thickness, fracture spacing, fracture fill and coatings, and the lithology of the till at each horizon. The general character of the till in the area outside the grid was also noted. This provided a check to be certain the area being mapped was not an anomaly for that horizon in the till.

Large diameter core samples, 0.3 m (12-inch) diameter, were collected at several horizons. The method of collection for these large diameter cores is described by Kortran (1995). In general, it involved placing a 0.3 m (12-inch) diameter x 0.46 m (18-inch) long section of PVC, used as a core tube, on top of a segment of till that had been shaped with a shovel slightly larger than the core tube. A small amount of down pressure was placed on the top of the core tube with the drill rig to keep it in place. Then the sides of the block were gently shaved with a sharp object until the core tube slid down over the outer section of the block. The core was then gently popped loose from the till and lifted into a plastic bag on a steel plate. Once wrapped in the plastic bag, the core was transferred to the Civil Engineering Laboratory at SDSU for determination of K and soil classification.

The grid area was relocated at each depth horizon by setting the southwest corner of the grid at the center of R20-93-01 (Figure 3) which had been drilled and filled with bentonite prior to trench excavation. This borehole was usually very easy to locate. On at least two occasions, the borehole became obscured by overburden and it was necessary to relocate it by triangulation and measurement from BM-1 (Figure 3).

The elevation of each mapping horizon was determined with a spirit level using BM-1 as the reference. A Brunton compass was used to orient the grid north-south once the southwest corner was located at the center of R20-93-01. The Brunton compass was also used to determine strike and dip of the fractures.

The only major problem encountered during the mapping was the loss of one set of 35 mm slides. The slide set for the lower 3 layers of the trench was destroyed during the development process. Therefore, the only information related to these layers are field notes, the hand drawn maps of the grid area, and data from the 0.3 m (12-inch) diameter cores.

Laboratory Analysis of Cores

Laboratory analysis of Shelby-tube cores and the larger diameter cores was completed at the Department of Civil Engineering, SDSU, to assess hydraulic conductivity. The laboratory methods employed have been described by Kortran (1995). Falling-head tests were utilized on the Shelby-tube core samples which were cut into approximately 0.15 m (0.5 ft) lengths and placed in the falling-head permeameter. Constant-head tests were utilized on the larger diameter, 0.3 m (12-inch) diameter, cores. The design of the permeameter is described in Kortran (1995).

In addition, soil properties were determined for samples at various elevations between 468 to 459 m (1535 to 1505 ft) above mean sea level (msl). This classification includes percent clay, silt, sand and gravel, moisture content, average liquid limit, plasticity index and activity values. The soil classification data are included in Appendix H.

Acknowledgments

The following individuals from the Geological Survey Program, South Dakota Department of Environment and Natural Resources, were essential to the success of the project. Dennis Iverson was instrumental in the well installation process and Sonny Thompson was always there to help with equipment problems. Layne Schulz provided much needed advice and assistance on methods of well development in the till. Clark Christensen and Layne Stewart spent many hours collecting water samples from the wells and delivered them to the laboratory where Marjory Coker and Duane Hansen took great care in analyzing them.

Finally, the students involved in the project were a tremendous help. Eric Peterson and Bill Koch from the Earth Sciences/Physics Department, University of South Dakota, were vital to the success of the project. Jeff Kortran, Department of Civil Engineering, SDSU, helped with mapping, surveying, and collection and analysis of the cores. The team effort between the universities and the close relationship between the students is commended.

Geology and Hydrogeology of Study Area

Tomhave (1994) described the geology of Minnehaha County, South Dakota, including the study area. The Sioux Falls landfill is situated at the southern extent of the Coteau Des Prairies, almost on the divide between this physiographic province and the James Basin physiographic province. The entire county is underlain by Precambrian Sioux Quartzite and/or Corson Diabase (Tomhave, 1994). Geologic cross sections presented by Tomhave (1994) indicate the bedrock underlying the landfill is Sioux Quartzite. This is overlain by 9 to 15 m (30 to 50 ft) of Cretaceous Split Rock Creek Formation. This formation consists of sands derived from the Sioux Quartzite, carbonaceous claystone, bedded cherts, calcium bentonite and sandy siltstone deposited in a near shore marine environment (Tomhave, 1994). Approximately 3 to 4.5 m (10 to 15 ft) of pre-Illinoian outwash unconformably overlies the Cretaceous bedrock surface. The outwash is overlain by about 15 m (50 ft) of pre-Illinoian till. A thin veneer of Illinoian outwash may or may not be present on top of this till. The upper 30.5 to 38 m (100 to 125 ft) consists of late-Wisconsin till (Tomhave, 1994). From land surface to approximately 12.2 m (40 ft) bls the till is oxidized, weathered and fractured. Fracture density and spacing decrease with increasing depth bls. Below about 12.2 m (40 ft) bls the till is unoxidized, unweathered and unfractured.

Lindgren and Niehas (1992) show the Wall Lake aquifer underlying the study area. The aquifer thickness varies across the subcrop area in the county from 6 to 62 m (19 to 205 ft) with an average thickness of about 32 m (106 ft) (Lindgren and Niehas, 1992). This aquifer is underlain by bedrock and overlain by till in the study area. The Wall Lake aquifer is a pre-Illinoian age outwash described by Tomhave (1994).

The remainder of this report will concentrate on the hydrogeology and hydrochemistry of the upper 23 m (75 ft) of the late-Wisconsin till within the study area.

Hydrogeology of Late-Wisconsin Till at Sioux Falls Landfill

The late-Wisconsin till at the Sioux Falls landfill can be divided into three fairly distinct zones. The upper zone extends to a depth of approximately 6.3 m (22 ft) bls. This zone is characterized by oxidized, yellowish-brown to reddish brown, fractured clay. There are also several thin layers of gray silty clay within this upper 6.3 m (22 ft). The silty clay layers tend to be separated by very thin fine grained sand seams. The silty clay and sand sequence does appear to be stratified. This may represent ice contact deposits interbedded with the fractured till or lacustrine sediments deposited near the edge of the ice margin. TCT (1992) indicates a zone of alluvial clay from about 3 m (10 ft) to approximately 5.5 m (18 ft) below grade. This corresponds with the interbedded silty clay and sand observed in the cores of R20-93-01, R20-93-02, and the trench map area. The till and other deposits are very fractured and nearly completely oxidized to a depth of 6.3 m (22 ft) bls. Till is typically heterogeneous. It is not surprising to identify other deposits such as stratified ice contact deposits, alluvial deposits and/or lacustrine deposits interbedded with the till. However, this does not necessarily change the hydraulic parameters of these units. The deposits in the upper 6.3 m (22 ft) at the site are weathered and fractured to the extent that the till and associated stratified silty clay and sand deposits behave hydraulically as a continuum. The strike of the primary fractures is N10E to about N30E. The fractures have mineralized coatings, probably iron and manganese, along the surfaces. There is also a significant amount of gypsum coating the fracture surfaces and separating laminations in the silty clay. A secondary set of fractures is orthogonal to the primary fractures. The secondary fracture set strikes N40W to N20W. Fracture dip varies from near 60^{o} to 90^{o}. Fracture width varies from about 0.254 mm (0.01 inches) to about 1.27 mm (0.05 inches). Weathering halo thickness adjacent to the fractures varies from about 6.4 mm (0.25 inches) to approximately 25.4 mm (1 inch), where individual fractures and weathering halos were identified. This zone is so thoroughly fractured and weathered that it is difficult to identify individual fractures and weathering halos. Figures 6 through 13 show the general character of the layers that were mapped in the trench from layer 1 through layer 8. These top 8 layers are thought to represent the oxidized, fractured upper zone.

Observation of the trench areas adjacent to the sediment column that was mapped as the trench was deepened also showed several areas where significant accumulations of sand were present as isolated "pockets". These sand pockets were saturated and drained ground water into the trench for hours, or several days after being breached by the excavating equipment. Iles (1989) and TCT (1992) also noted some of these sand pockets in their investigations. Boreholes R20-93-04 and R20-93-10 of this study were abandoned when one of these sand pockets was encountered creating well completion problems.

The second zone is a transition zone extending from about 6.3 m (22 ft) bls to about 12 m (40 ft) bls. This zone is characterized by decreasing fracture density with depth. The fractures within this zone are separated by distinct areas of plastic, gray, sandy clay. The strike of fractures within this zone is predominantly N-S to N10E. A secondary set of fractures strike N90E to N80E. The fractures within this zone are essentially vertical. The fracture surfaces are iron and manganese stained, and the fractures have been coated with gypsum. The actual fracture width is similar to that in the upper zone. The fracture weathering halo varies from about 6.4 mm (0.25 inches) to over 76 mm (3 inches). The increase in the halo width in the transition zone may be

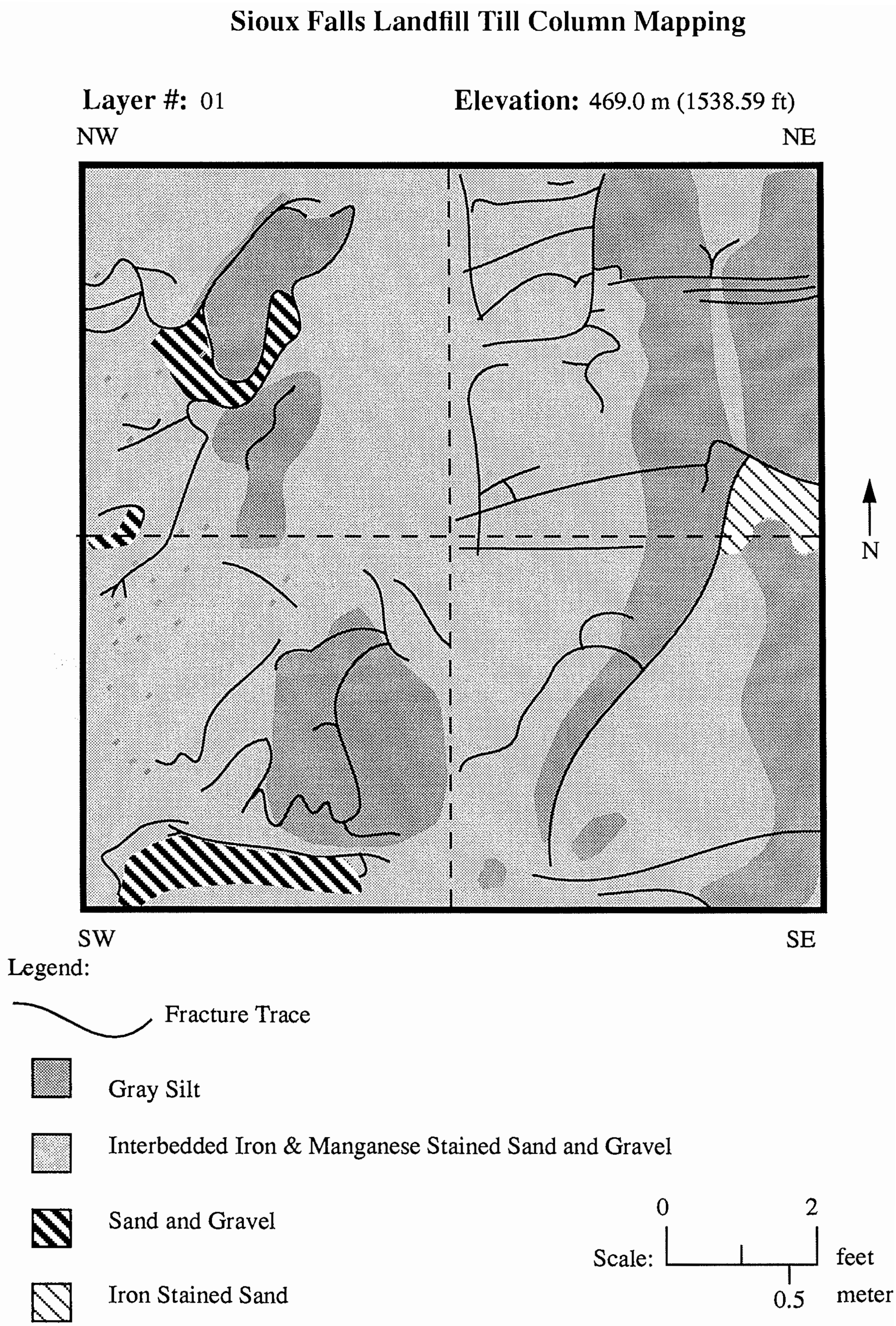


Figure 6 - Layer #01 - Weathered Zone

Sioux Falls Landfill Till Column Mapping

Layer #: 02 **Elevation:** 468.3 m (1536.37 ft)

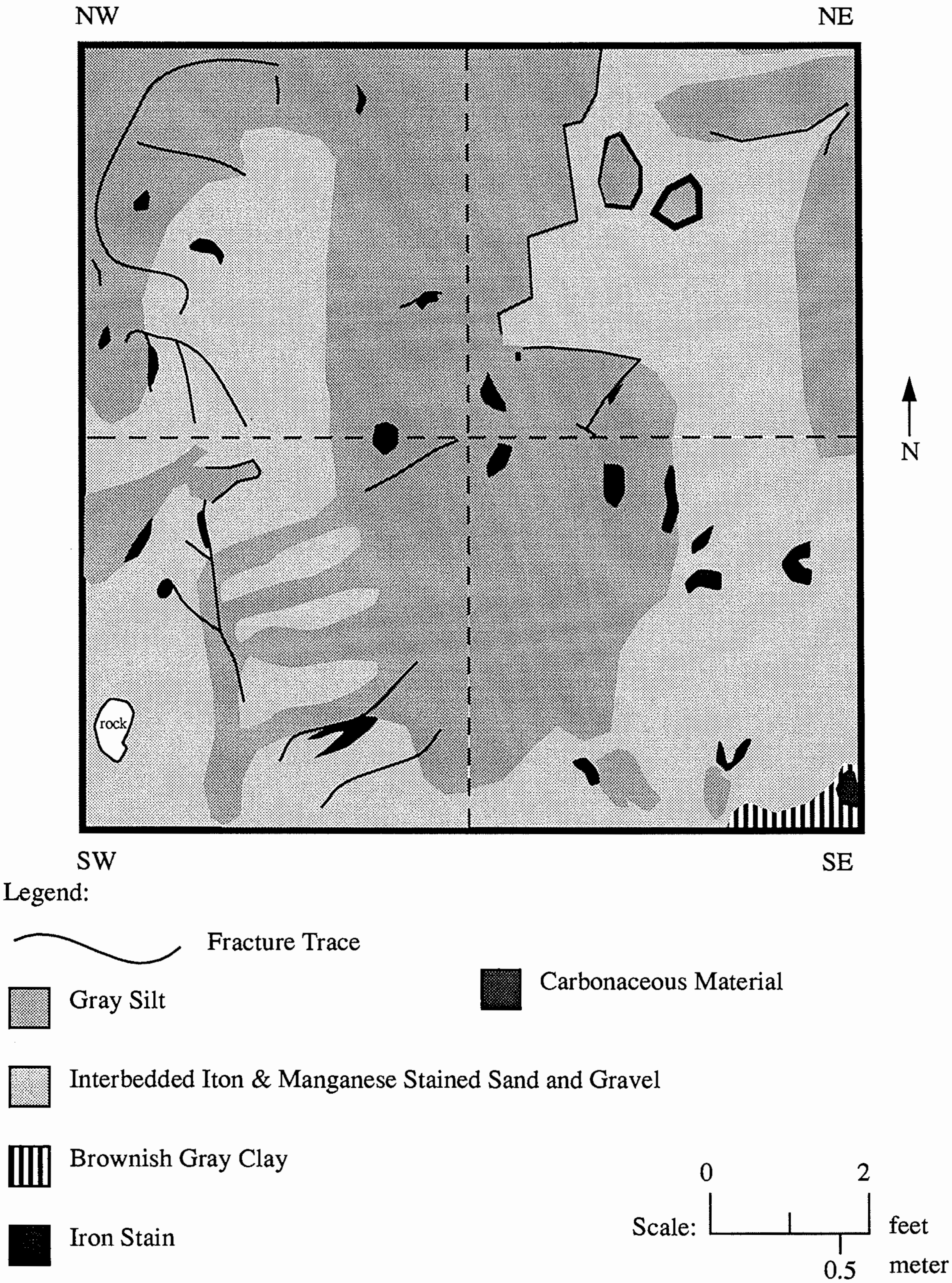


Figure 7 - Layer #02 - Weathered Till Zone

Sioux Falls Landfill Till Column Mapping

Layer #: 03 **Elevation:** 467.8 m (1534.79)

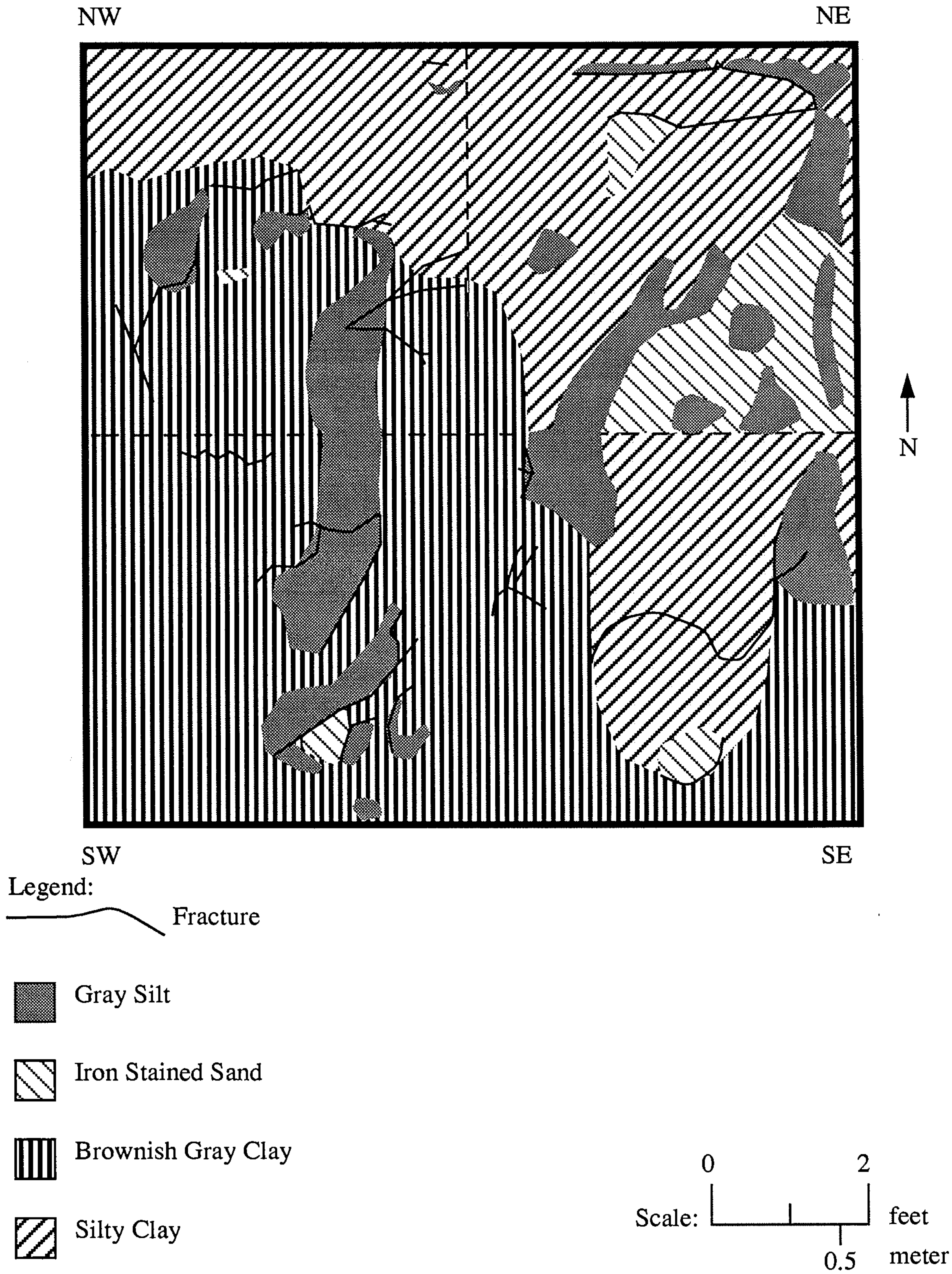


Figure 8 - Layer #03 - Weathered Till Zone

Sioux Falls Landfill Till Column Mapping

Layer #: 04 **Elevation:** 467.4 m (1533.43 ft)

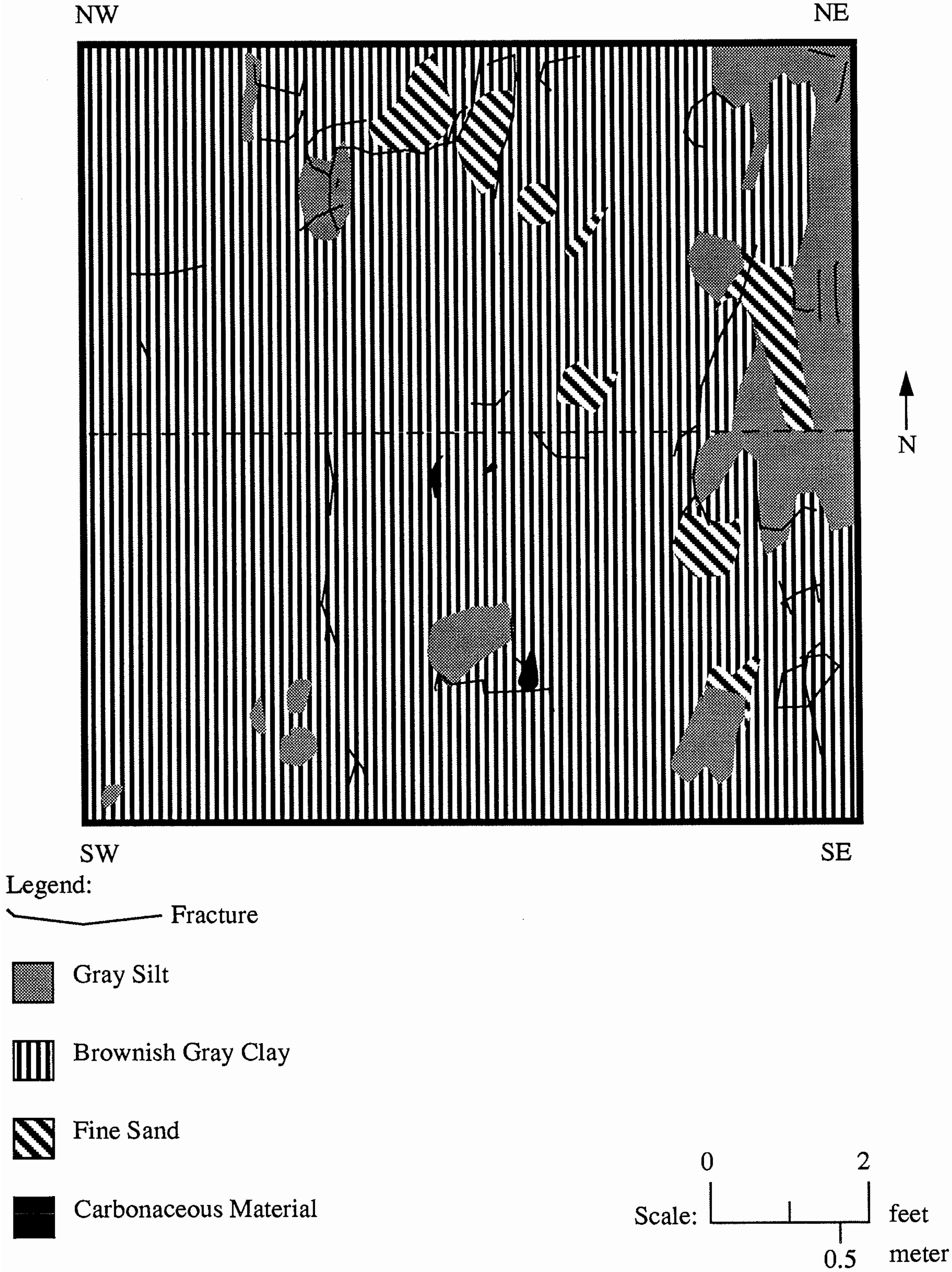


Figure 9 - Layer #04 - Weathered Till Zone

Sioux Falls Landfill Till Column Mapping

Layer #: 05 **Elevation:** 466.8 m (1531.63 ft)

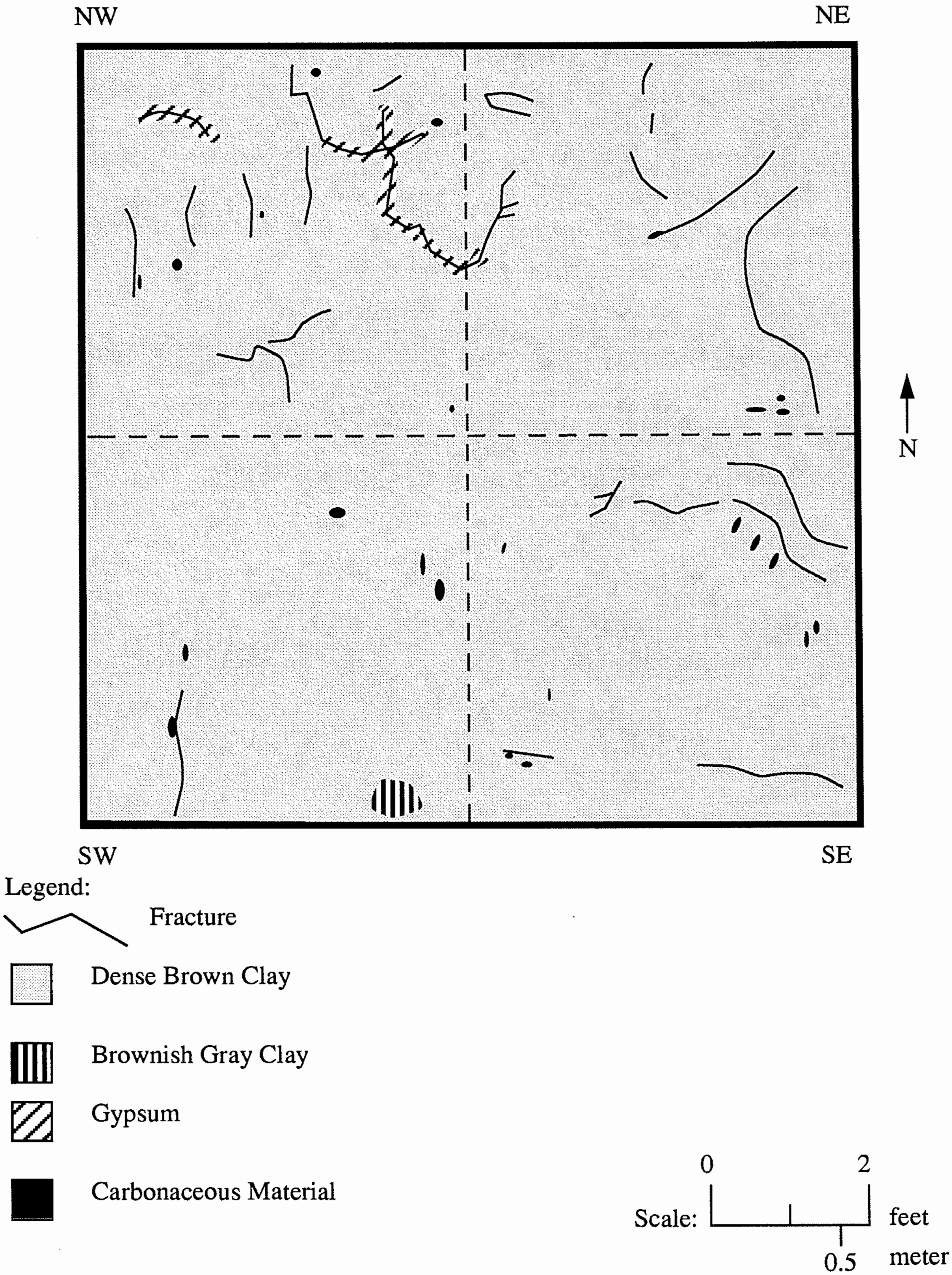
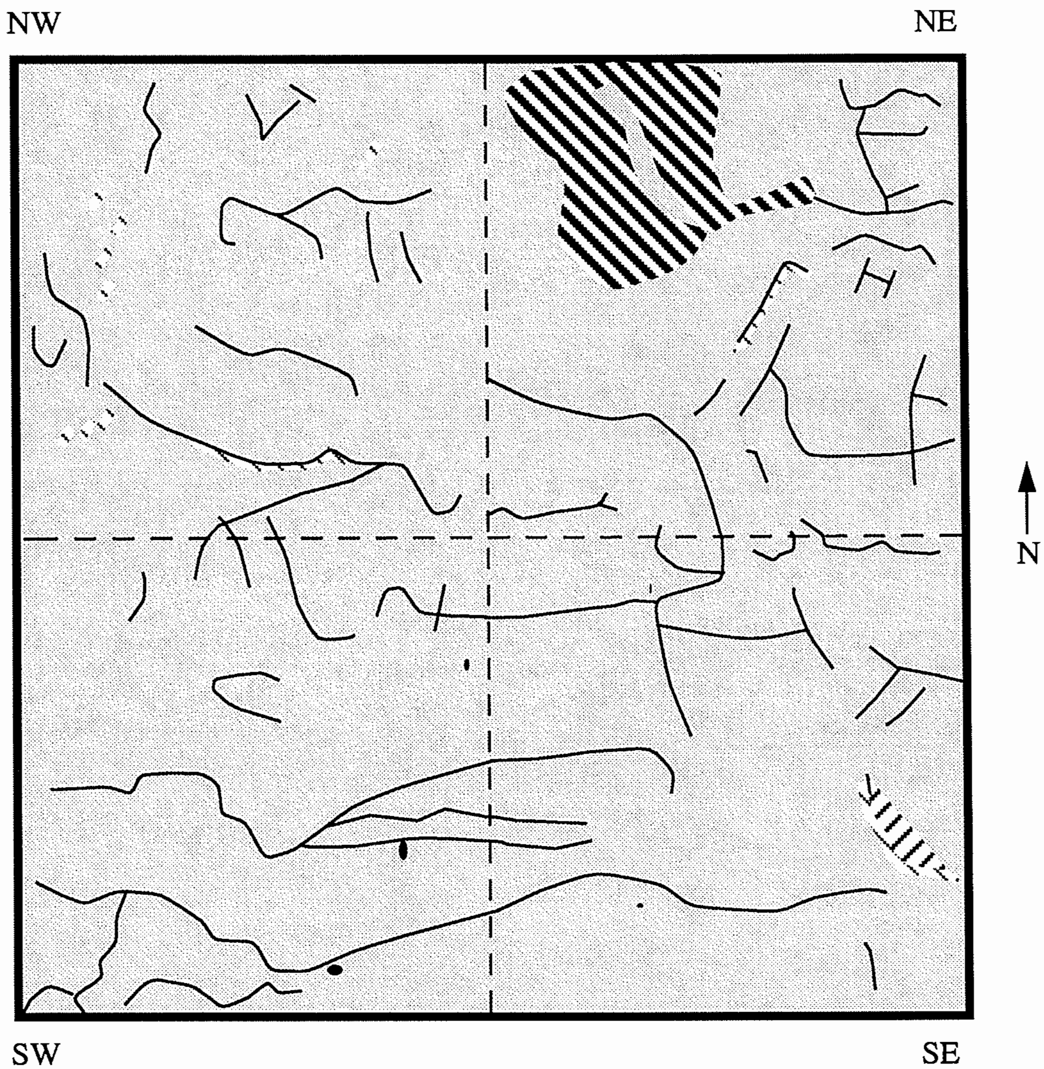


Figure 10 - Layer #05 - Weathered Till Zone

Sioux Falls Landfill Till Column Mapping

Layer #: 06 **Elevation:** 465.6 m (1527.47 ft)



Legend:

Fracture Trace

Dense Brown Clay

Sand

Carbonaceous Material

Gypsum

Scale: 0 2 feet, 0.5 meter

Figure 11 - Layer #06 - Weathered Till Zone

Sioux Falls Landfill Till Column Mapping

Layer #: 07 **Elevation:** 464.9 m (1525.22 ft)

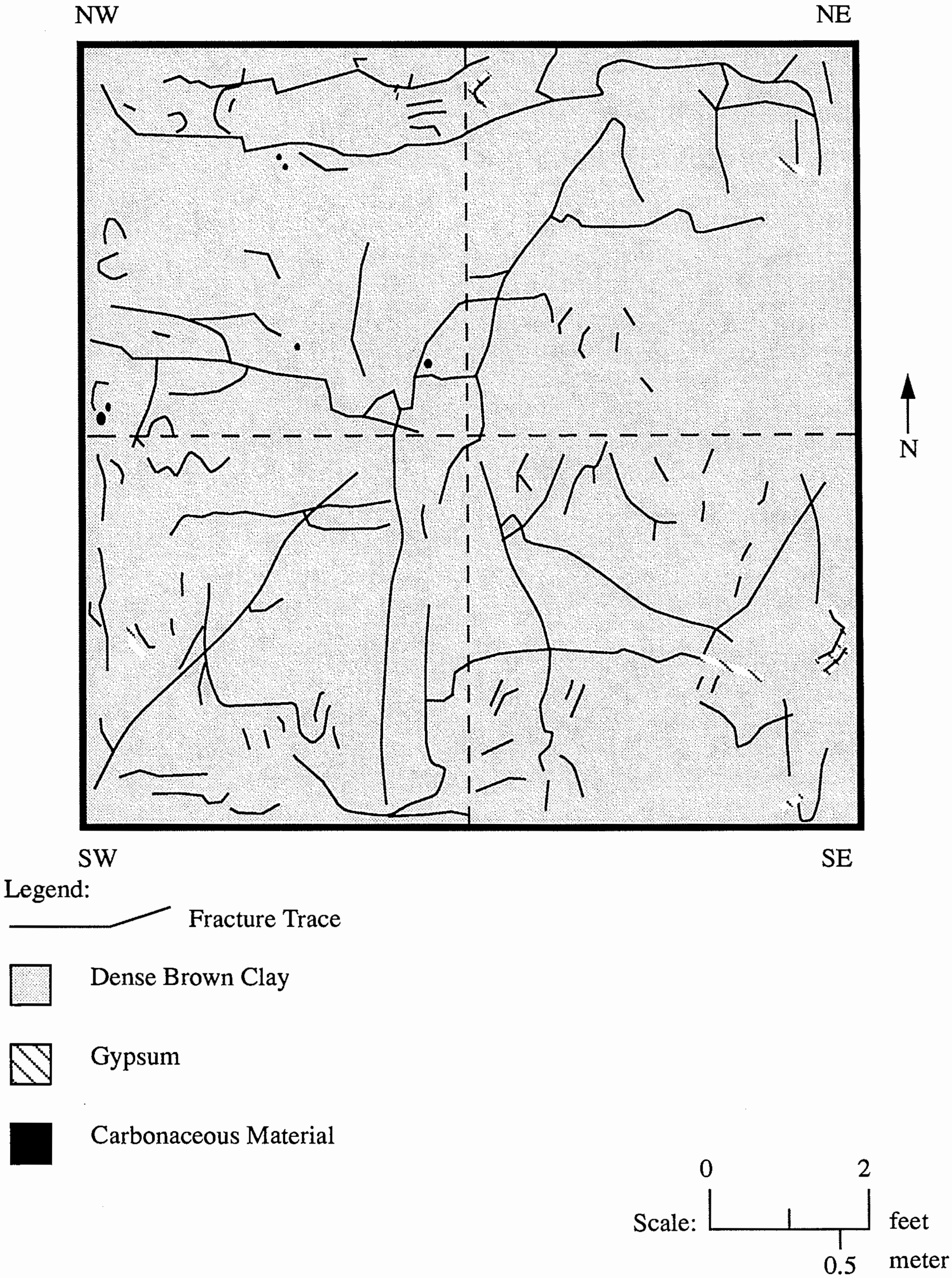


Figure 12 - Layer #07 - Weathered Till Zone

Sioux Falls Landfill Till Column Mapping

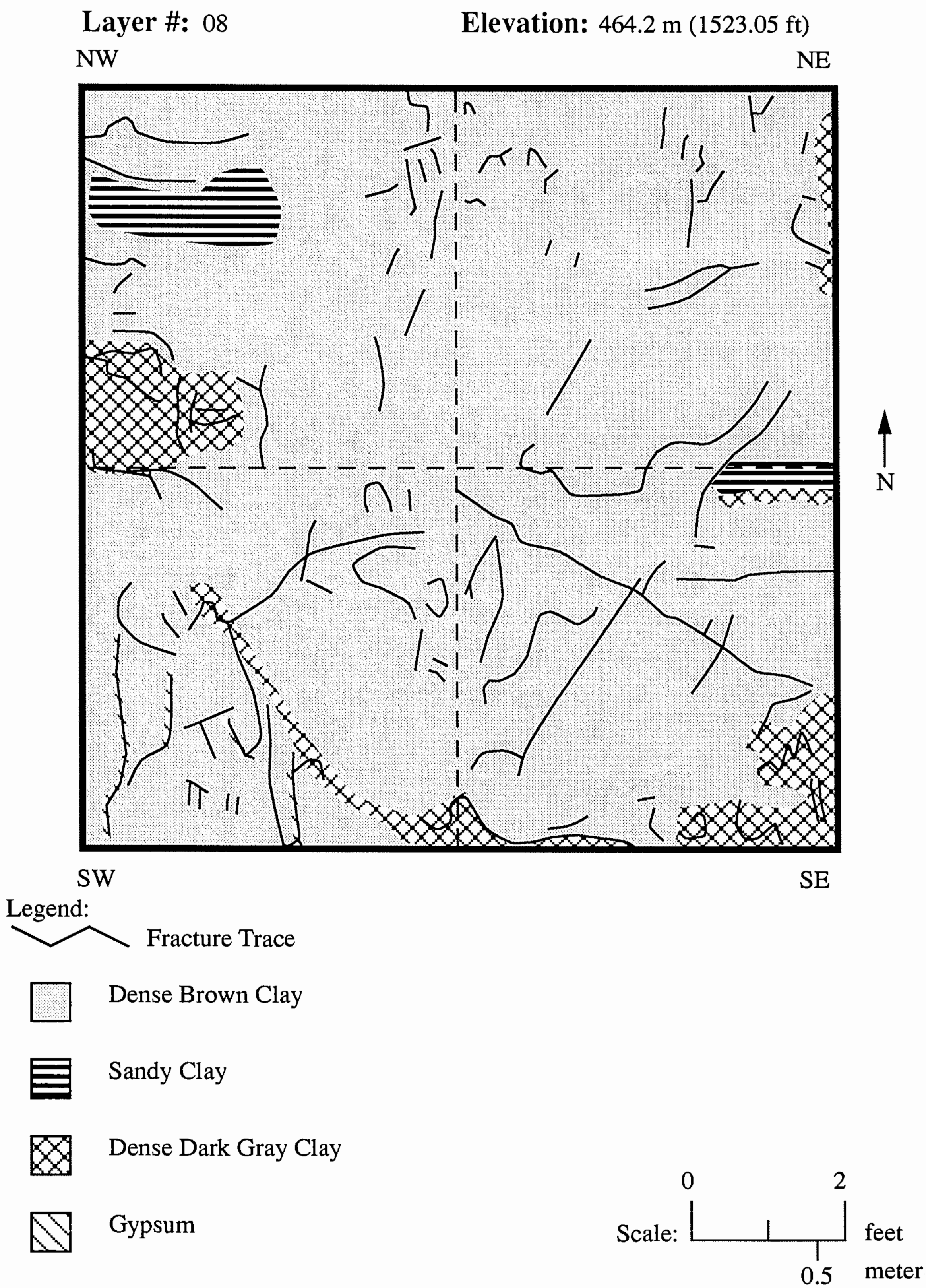


Figure 13 - Layer #08 - Weathered Till Zone

more a case of being able to clearly distinguish the total width because of the significant contrast with the gray clay matrix than an actual increase in the width of the weathering halo. In the upper zone, the system is so highly fractured and weathered it is difficult to tell where one halo stops and the next begins. Figures 14 through 22 show trench map layers 9 through 16. These layers include the transition zone from about 7 m (23 ft) bls to about 12 m (40 ft) bls.

It is interesting to note that the log of R20-93-01 describes no fractures below 10.4 m (34 ft) bls. The trench mapping work clearly shows distinct fractures to a depth of about 12.2 m (40 ft) bls. The log of monitoring well R20-93-02 indicates no vertical fractures below about 9 m (30 ft) bls. This is probably a result of these two boreholes being centered in an unoxidized portion of the till in this transition zone. In the upper zone, the fracture density is high enough that the probability of intersecting a fracture with the borehole is greatly increased.

Figure 17 represents the till below about 12.2 m (40 ft) bls. At this depth the till consists of plastic, gray, sandy, pebbly clay. There are a few very thin horizontal sand seams filled with fine to medium sand at several levels within the unoxidized till.

Figures 23 to 25 are very generalized geologic cross-sections of the till based on the logs of boreholes. These geologic sections show the general boundaries between the upper highly weathered and fractured zone, the intermediate fractured transition zone and the unoxidized till below about 12 m (40 ft) bls.

Water-Level Information

Direction and Gradient of Ground-Water Flow

Iles (1989) prepared a water-level map for the till based on a series of test holes drilled in 1983 and 1984. Figure 26 is modified from Iles (1989). The gradient of the water table based on the map prepared by Iles (1989) ranged from about 0.0124 to 0.0160 to the south-southwest.

Figures 27 through 33 are representative hydrographs from the three till zones previously described. Hydrographs for wells R20-93-07, R20-93-09, R20-93-13 and R20-93-20 are representative of the shallow highly weathered zone. The period when the wells were installed was extremely wet. Water levels in the shallow zone reflect this as a time of relatively high water table. The steep rise at the beginning of each hydrograph is a result of recovery after bailing the wells dry during developement and/or slug testing. Water levels in the upper portion of the till show a general decline in the period October 1993 through early March 1994. It is very obvious when the spring snow melt occurred and the spring rains began. The hydrographs show a definite response to this spring recharge event. Water levels continue to rise until mid-May followed by a general decline through mid-August 1994. Static water levels in the monitoring wells installed for this project vary from less than 0.61 m (2 ft) bls to over 12 m (40 ft) bls. Static water levels in the shallow zone are generally in the range of 1.2 m to 3.1 m (4 to 10 ft) bls but may rise as high as 0.3 m (1 ft) bls, or drop to over 4.6 m (15 ft) bls during dry periods.

Hydrographs for wells R20-93-11 and R20-93-16 are representative of the transition zone (Figures 31 and 32). These wells also clearly show a response to the recharge events although somewhat subdued compared to the wells in the shallow zone. Water levels in the transition zone fluctuated by 0.3 m to 0.61 m (1 to 2 ft) for the spring 1994 recharge event while the water level in

Sioux Falls Landfill Till Column Mapping

Layer #: 09 **Elevation:** 463.6 m (1520.98 ft)

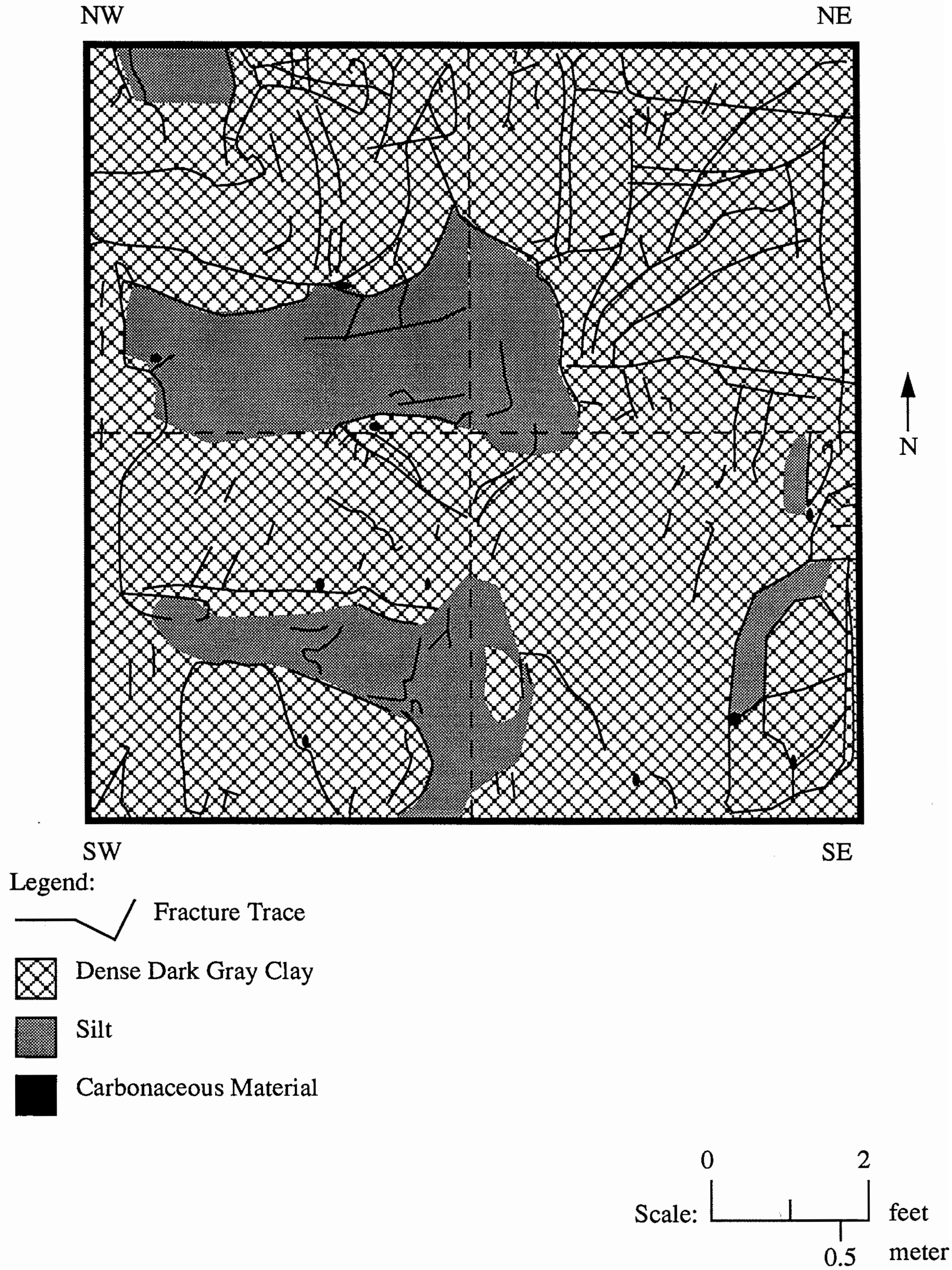


Figure 14 - Layer #09 - Transition Zone

Sioux Falls Landfill Till Column Mapping

Layer #: 10 **Elevation:** 463.0 m (1519.03 ft)

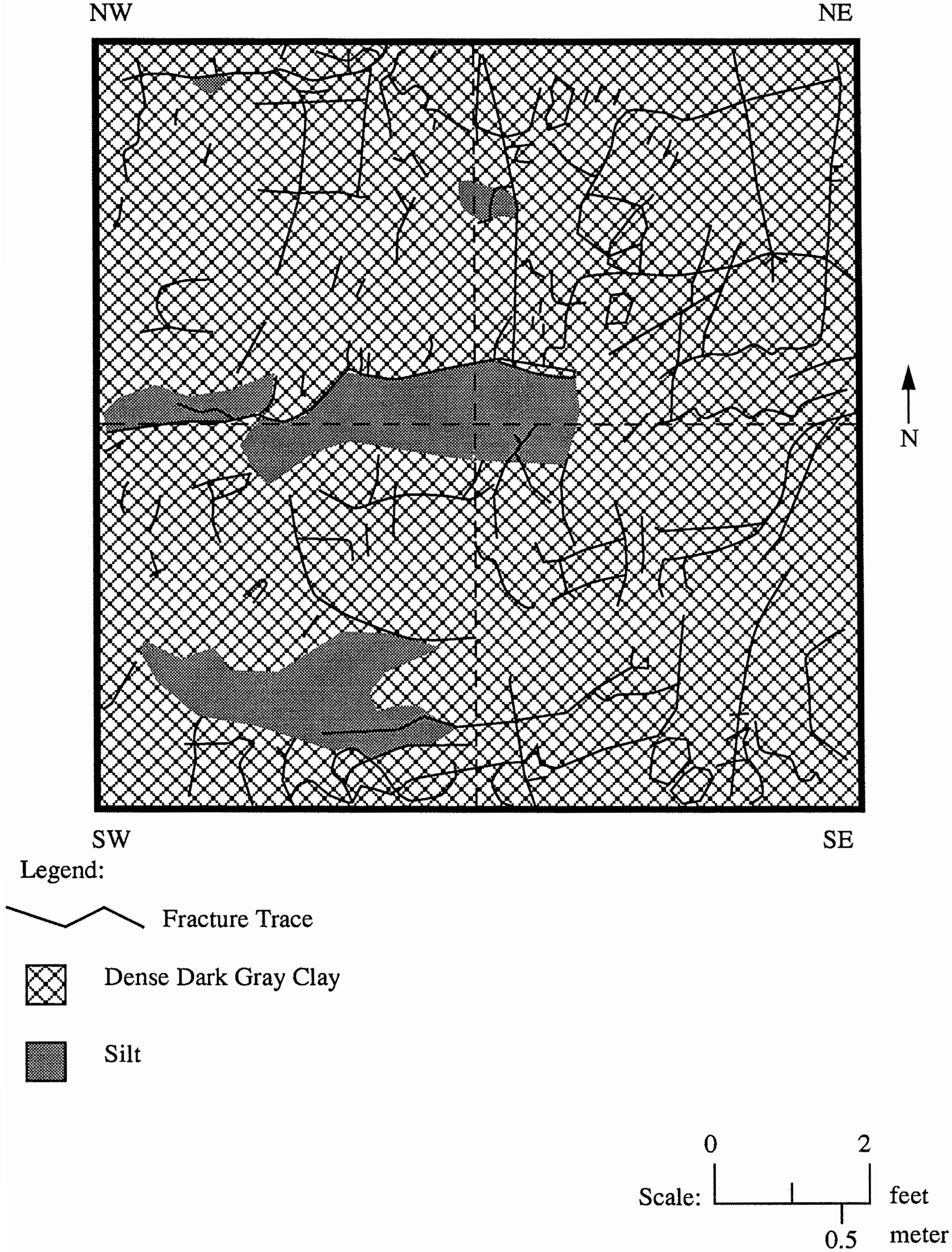


Figure 15 - Layer #10 - Transition Zone

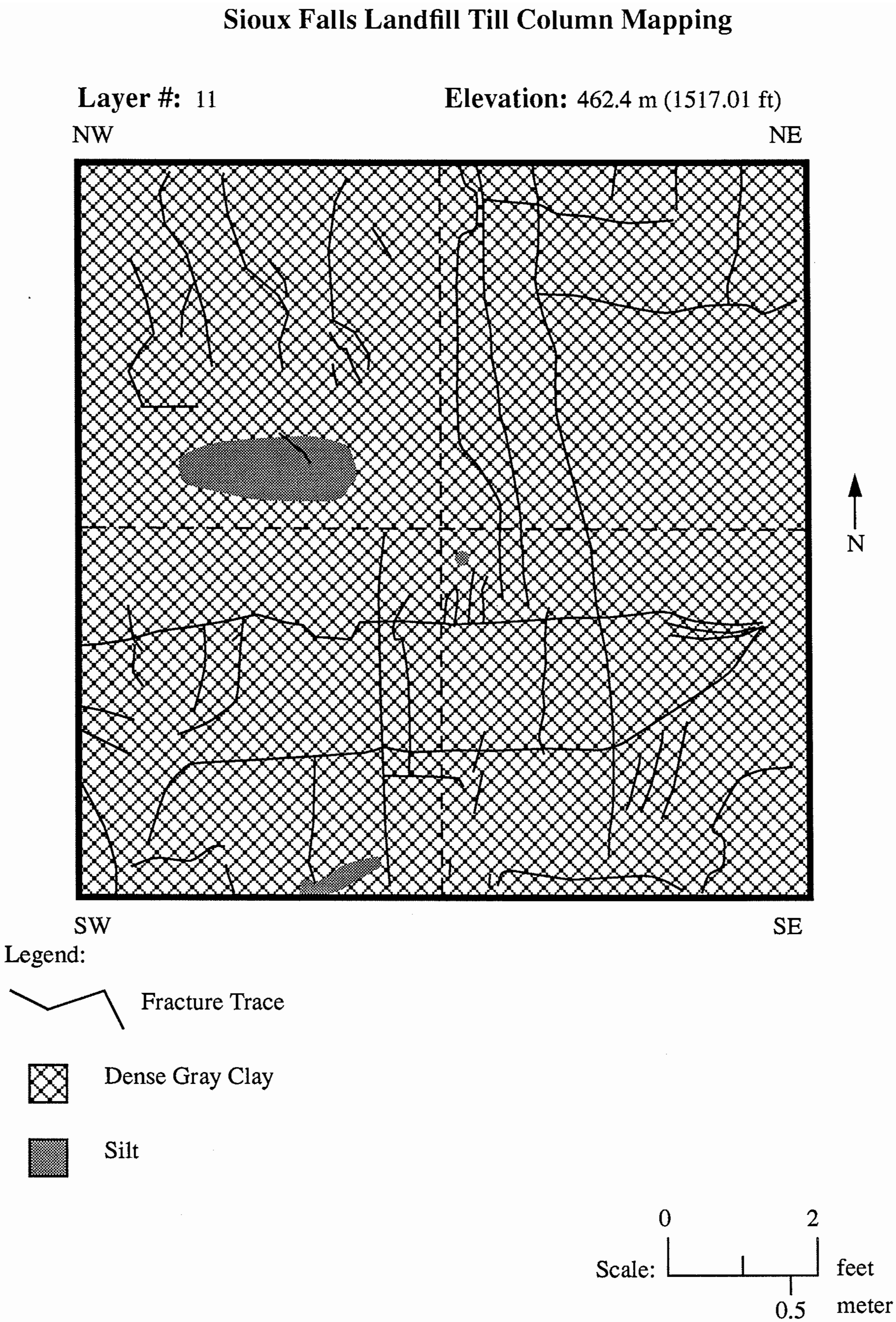


Figure 16 - Layer #11 - Transition Zone

Sioux Falls Landfill Till Column Mapping

Layer #: 12 **Elevation:** 461.7 m (1514.78 ft)

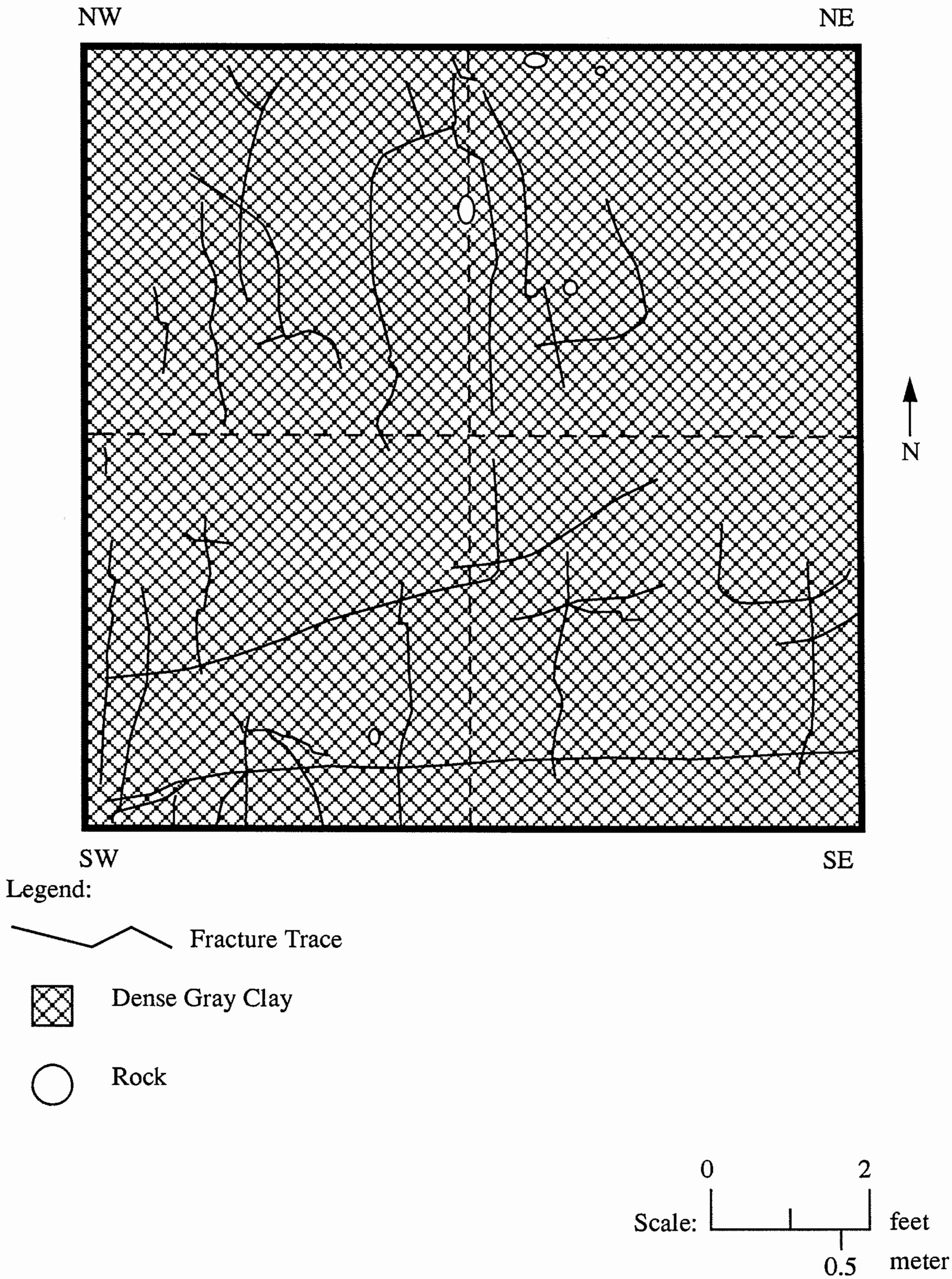


Figure 17 - Layer #12 - Transition Zone

Sioux Falls Landfill Till Column Mapping

Layer #: 13 **Elevation:** 461.1 (1512.65 ft)

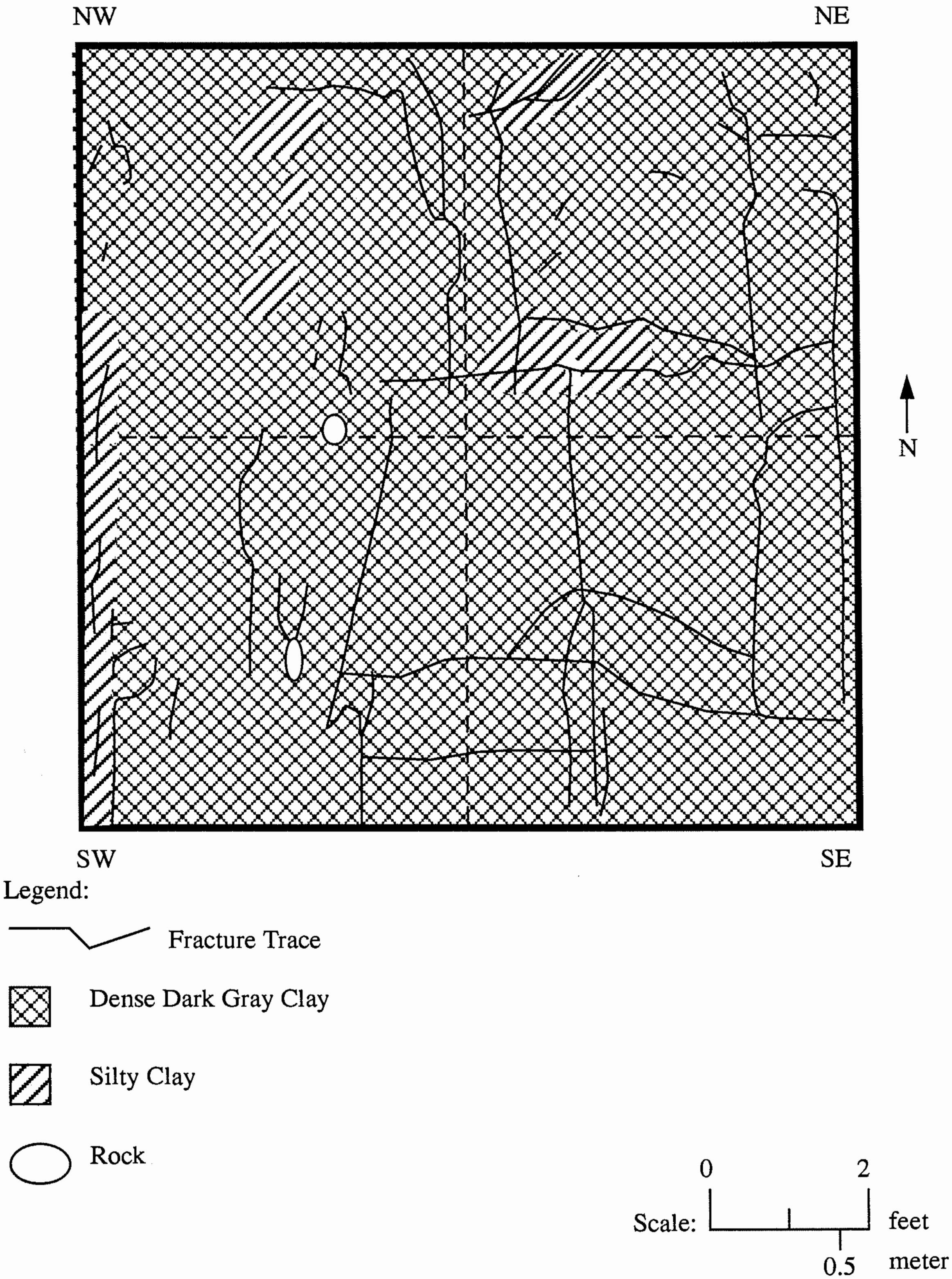


Figure 18 - Layer #13 - Transition Zone

Sioux Falls Landfill Till Column Mapping

Layer #: 14 **Elevation:** 460.4 m (1510.56 ft)

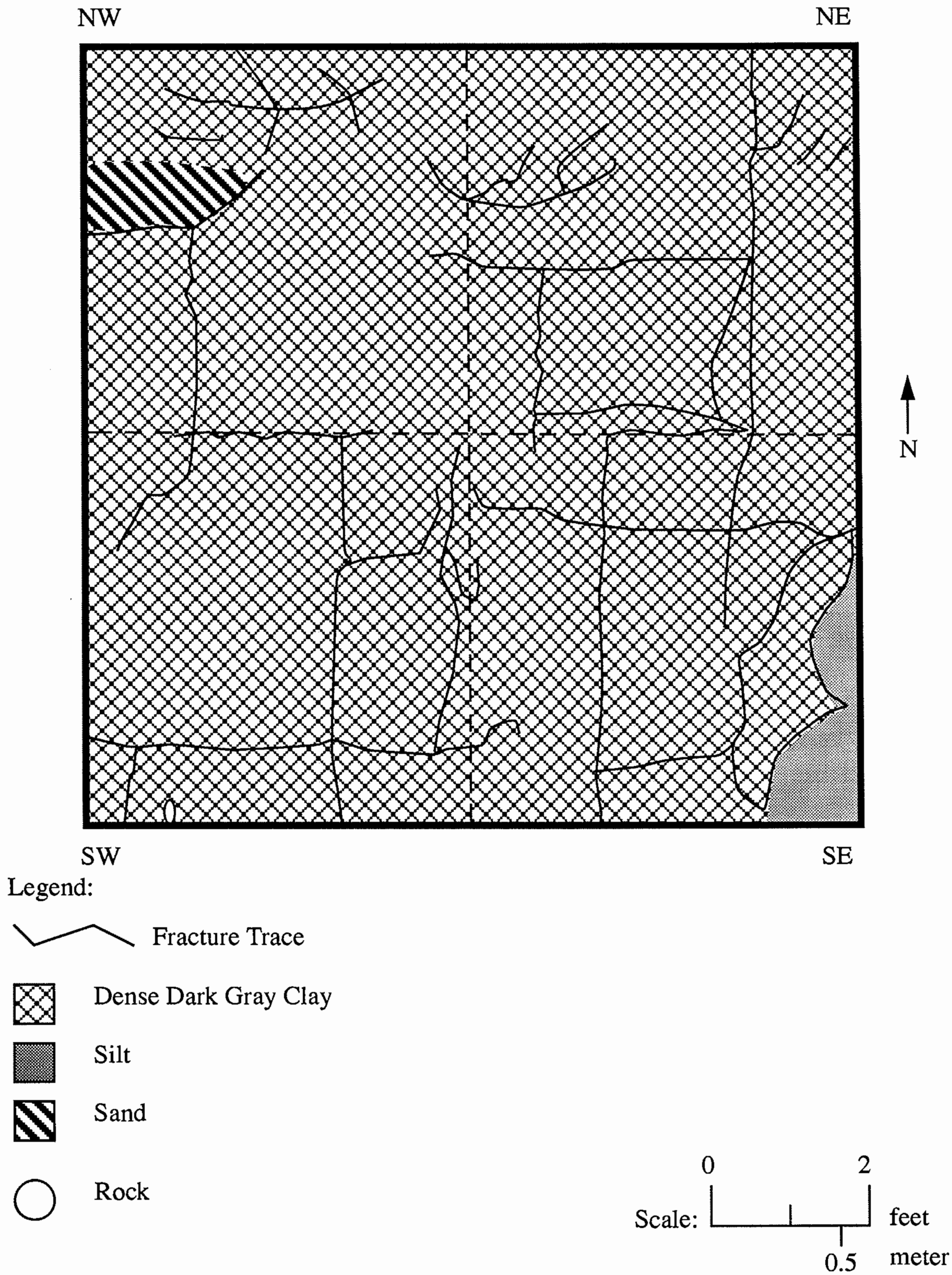


Figure 19 - Layer #14 - Transition Zone

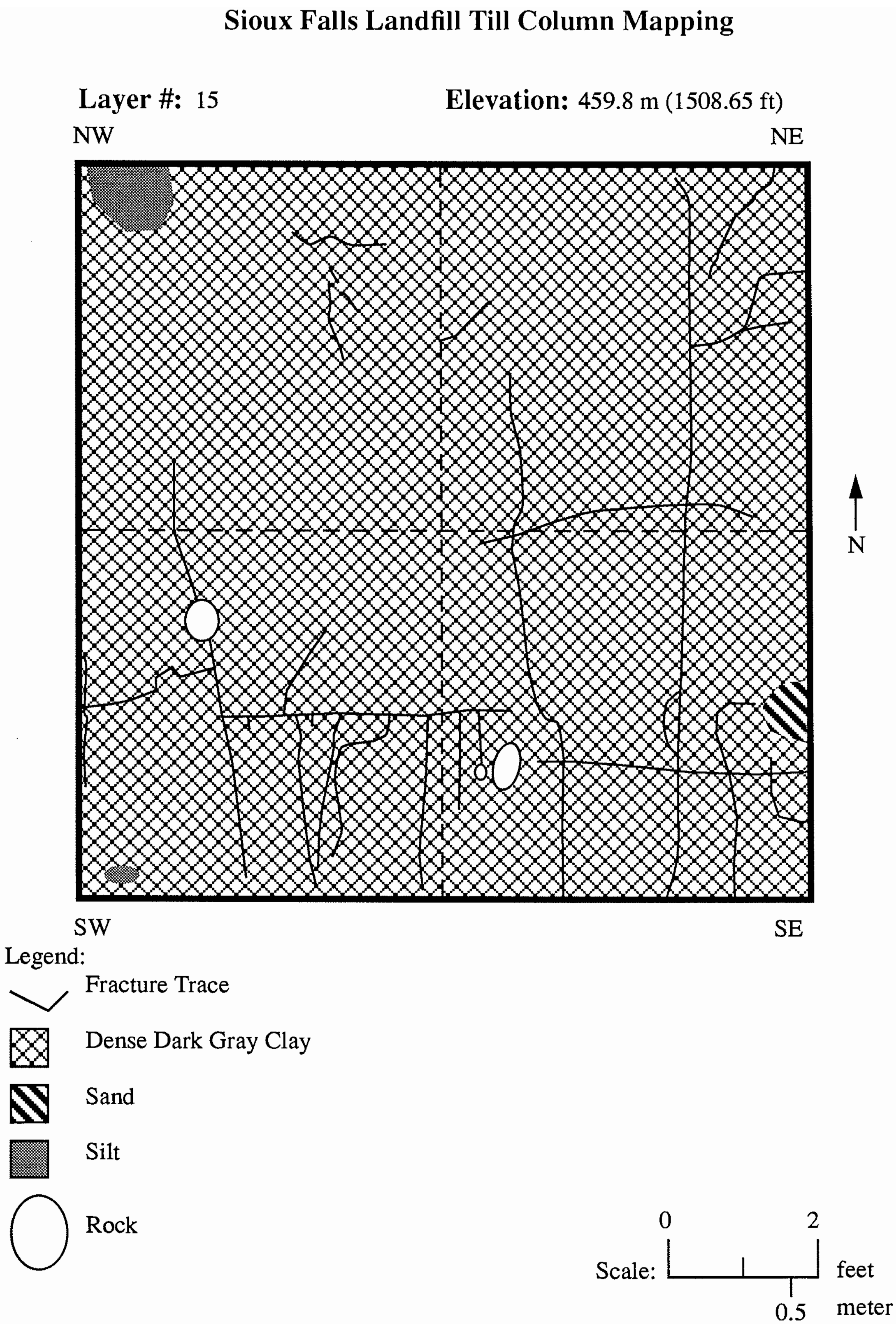


Figure 20 - Layer #15 - Transition Zone

Sioux Falls Landfill Till Column Mapping

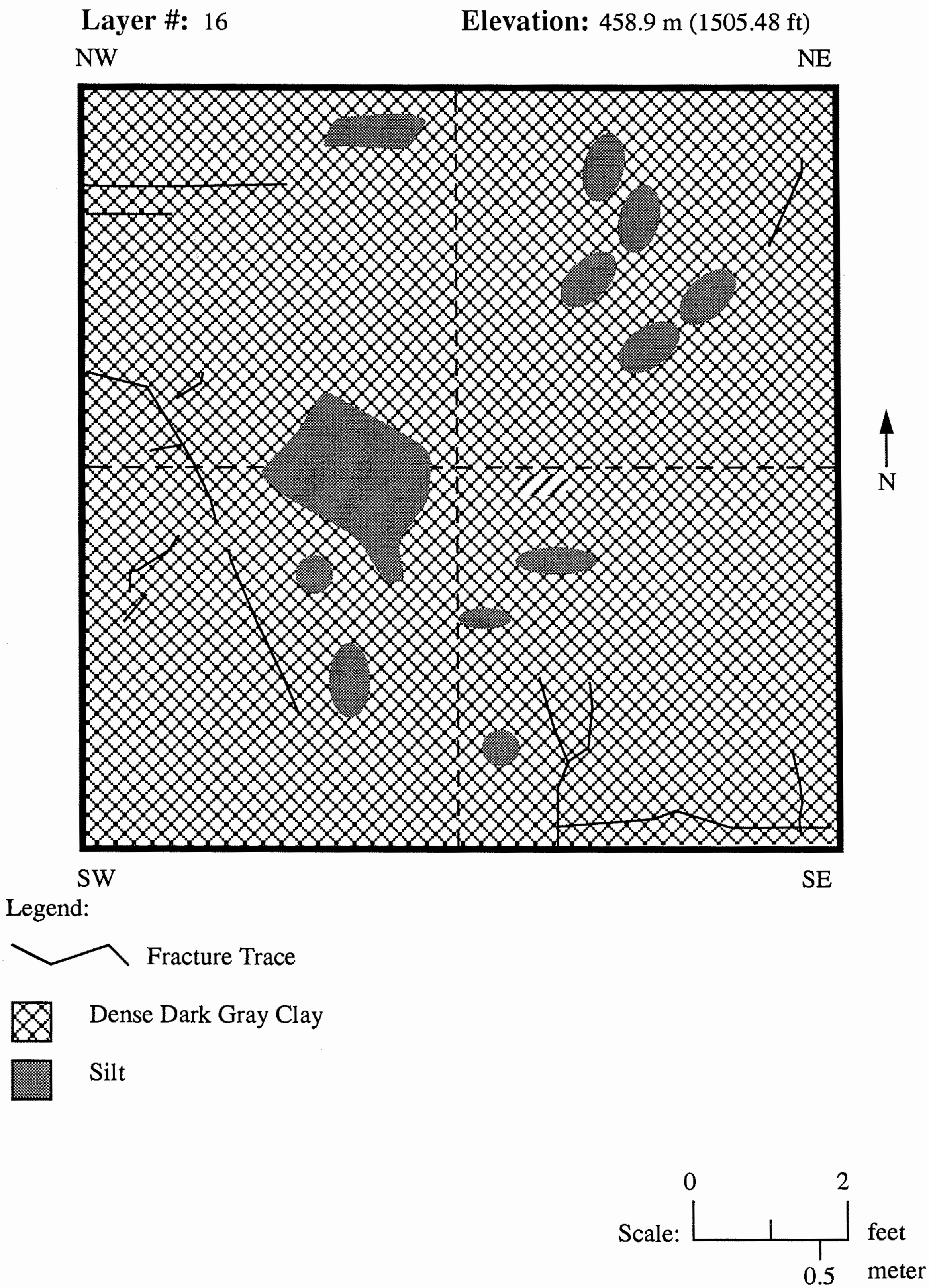


Figure 21 - Layer #16 - Bottom of Transition Zone

Sioux Falls Landfill Till Column Mapping

Layer #: 17 **Elevation:** 458.1 m (1502.84 ft)

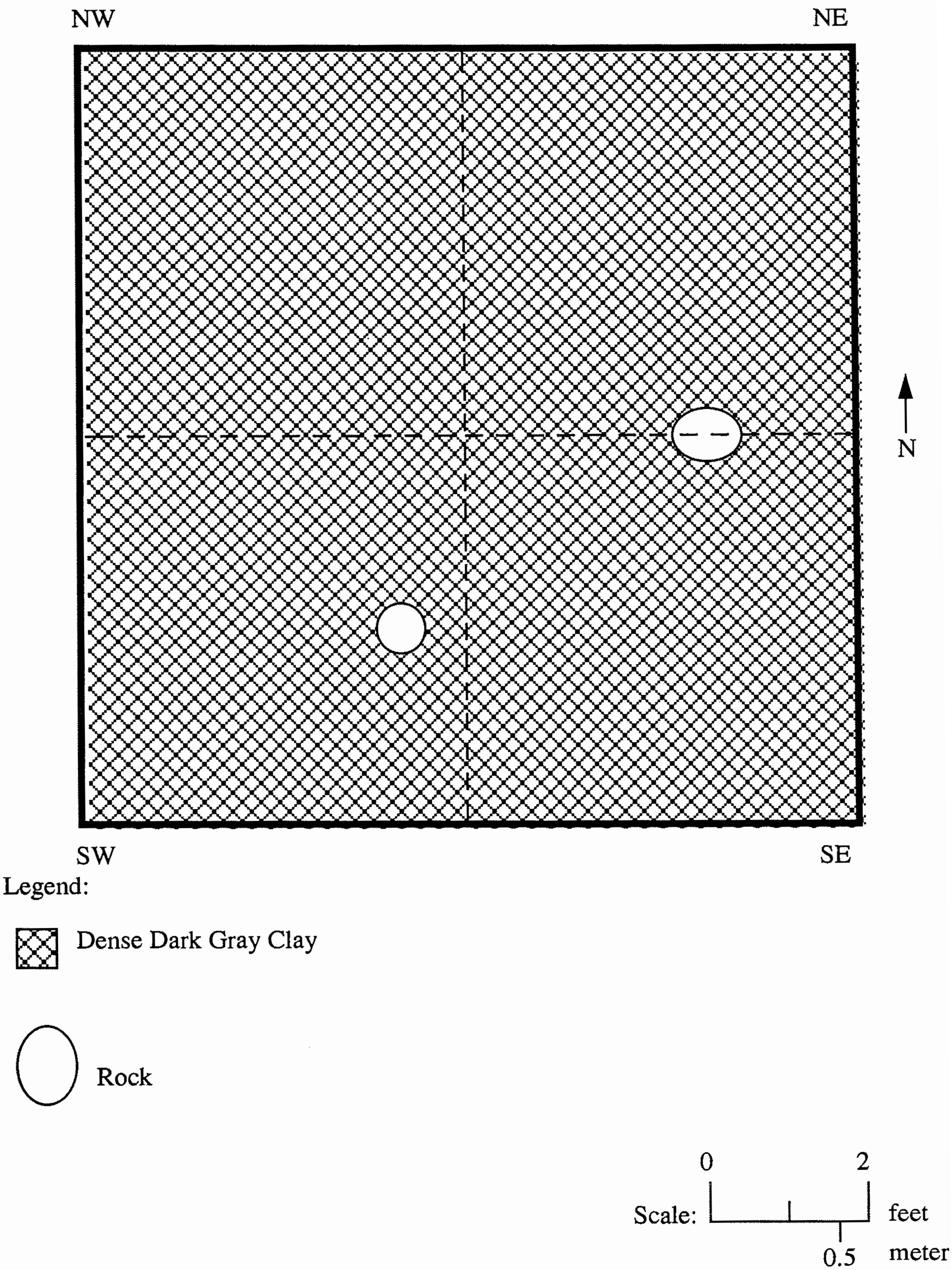


Figure 22 - Layer #17 - Unweathered Till Zone

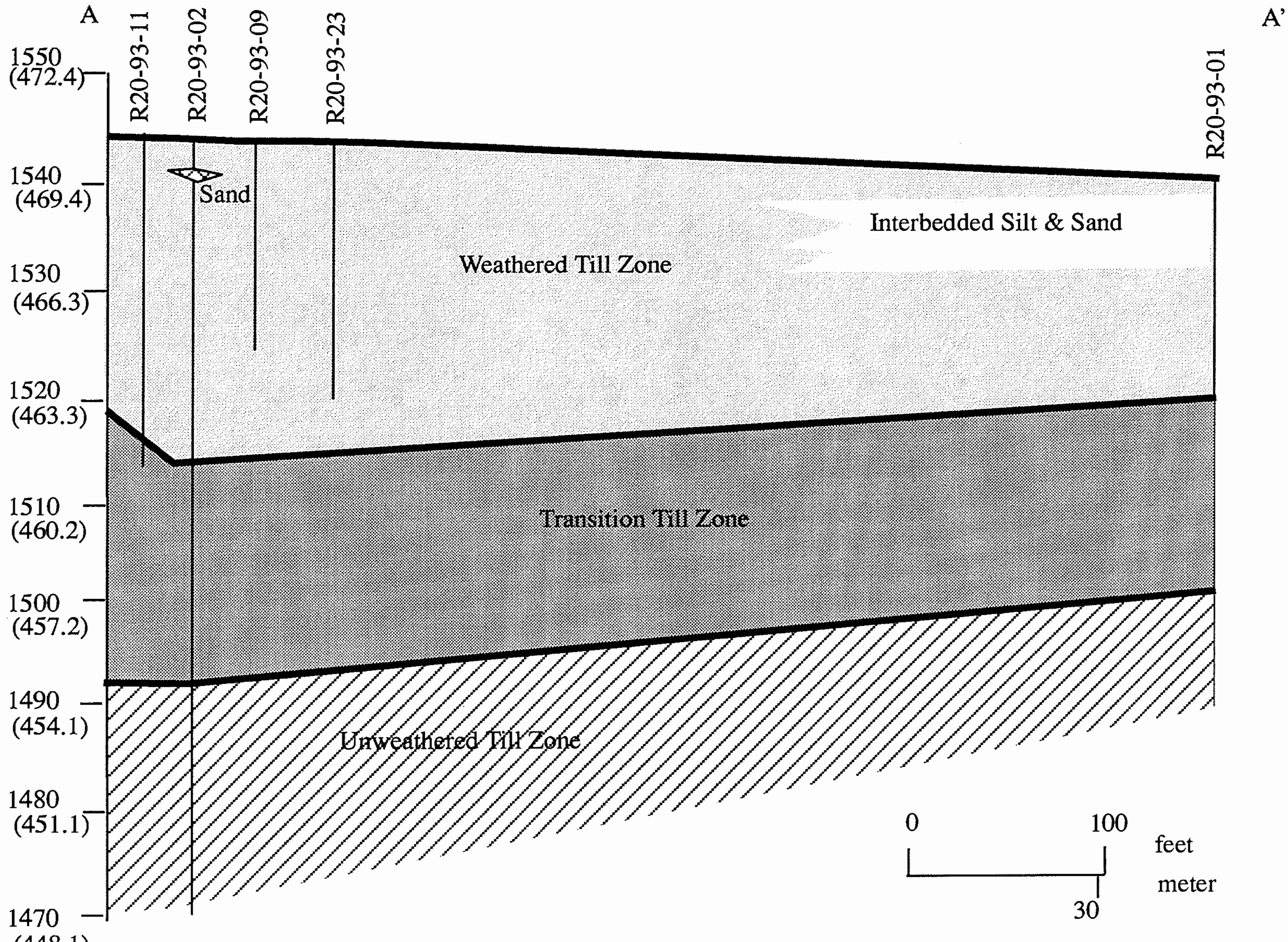


Figure 23 - Cross-Section A-A'

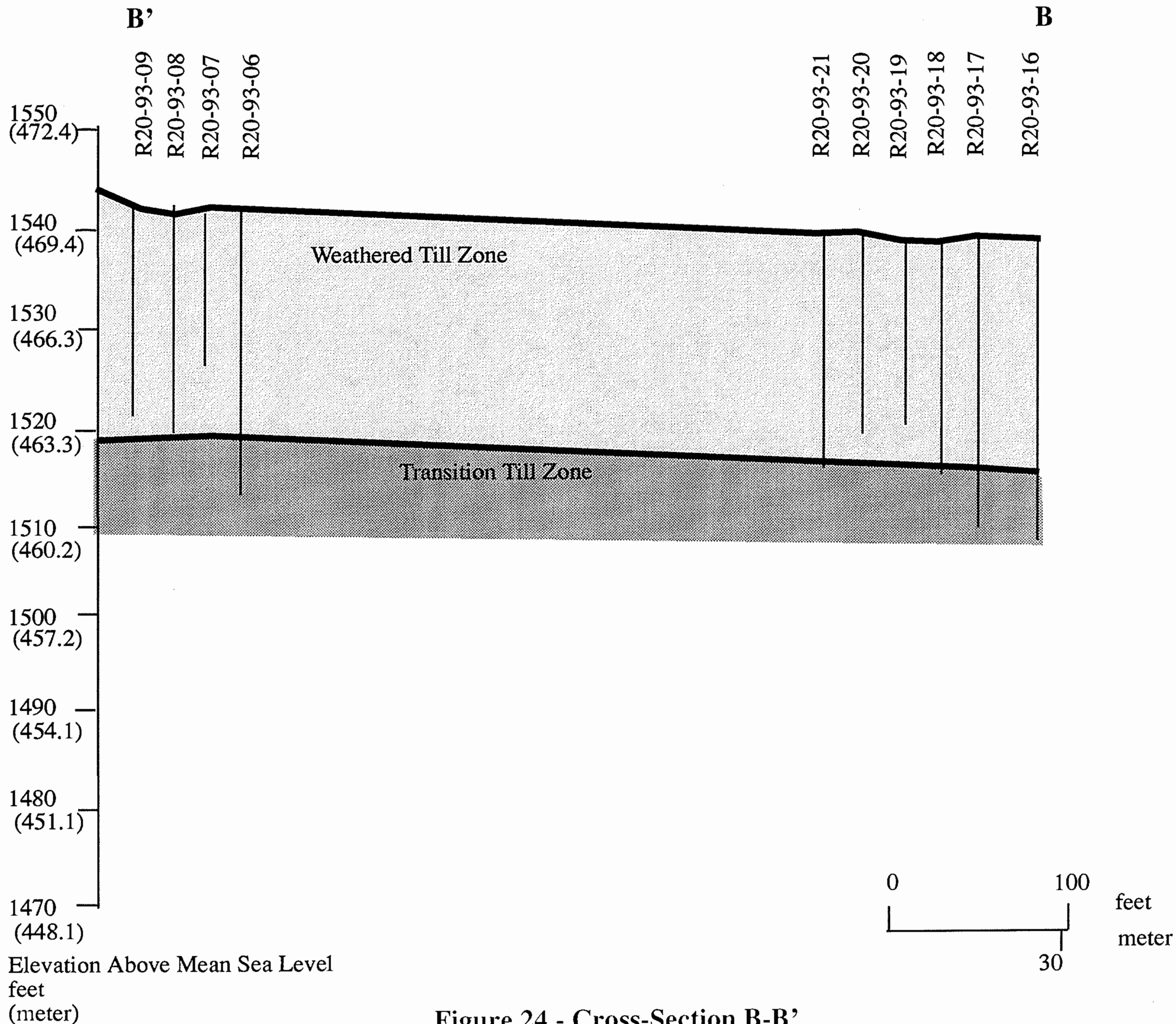


Figure 24 - Cross-Section B-B'

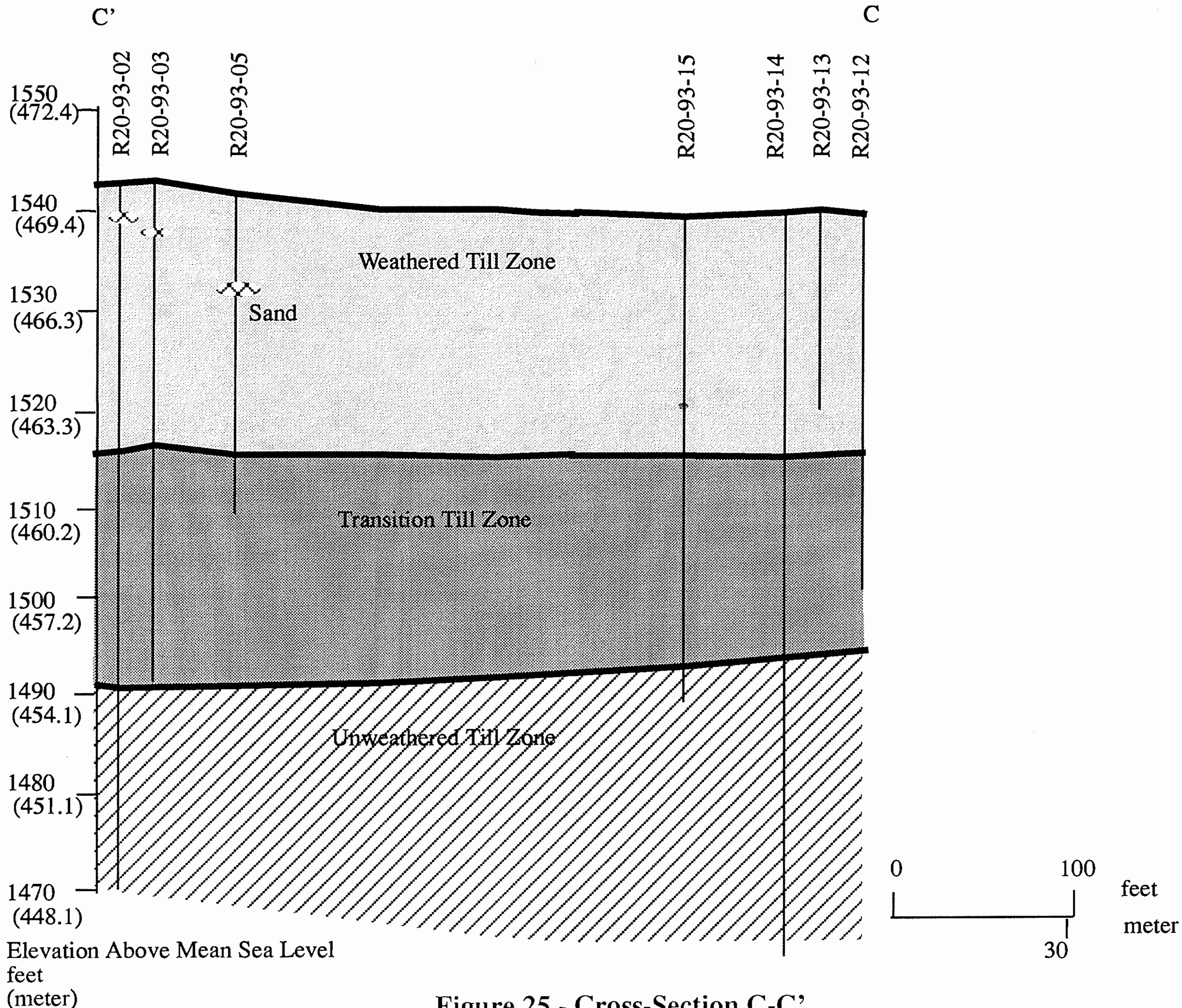


Figure 25 - Cross-Section C-C'

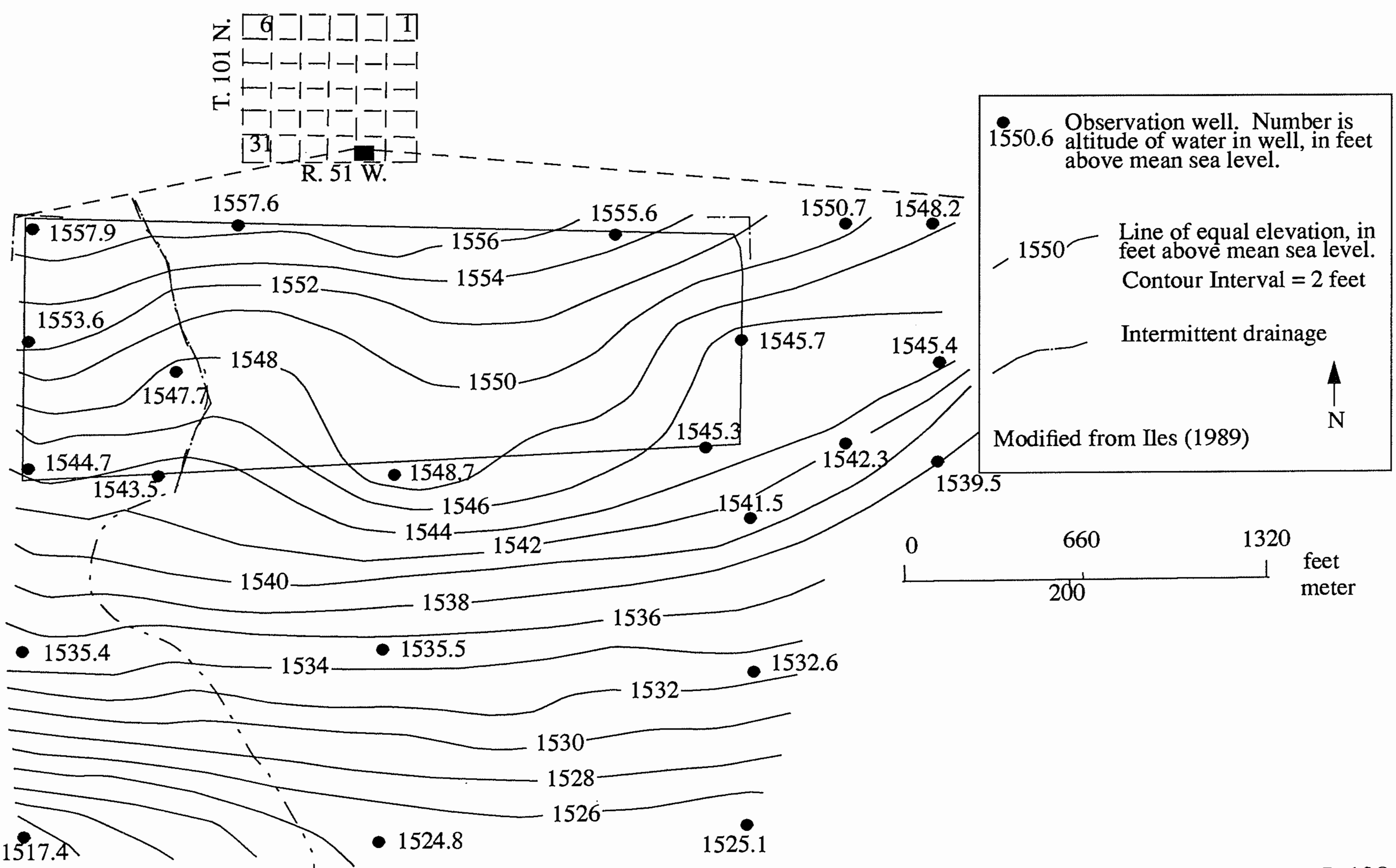


Figure 26 - Water-Table Elevation on September 5, 1984

Figure 27 - Hydrograph R20-93-07
Weathered Zone - Screened 3.5 m - 5.1 m bls (11.5 ft - 16.8 ft)

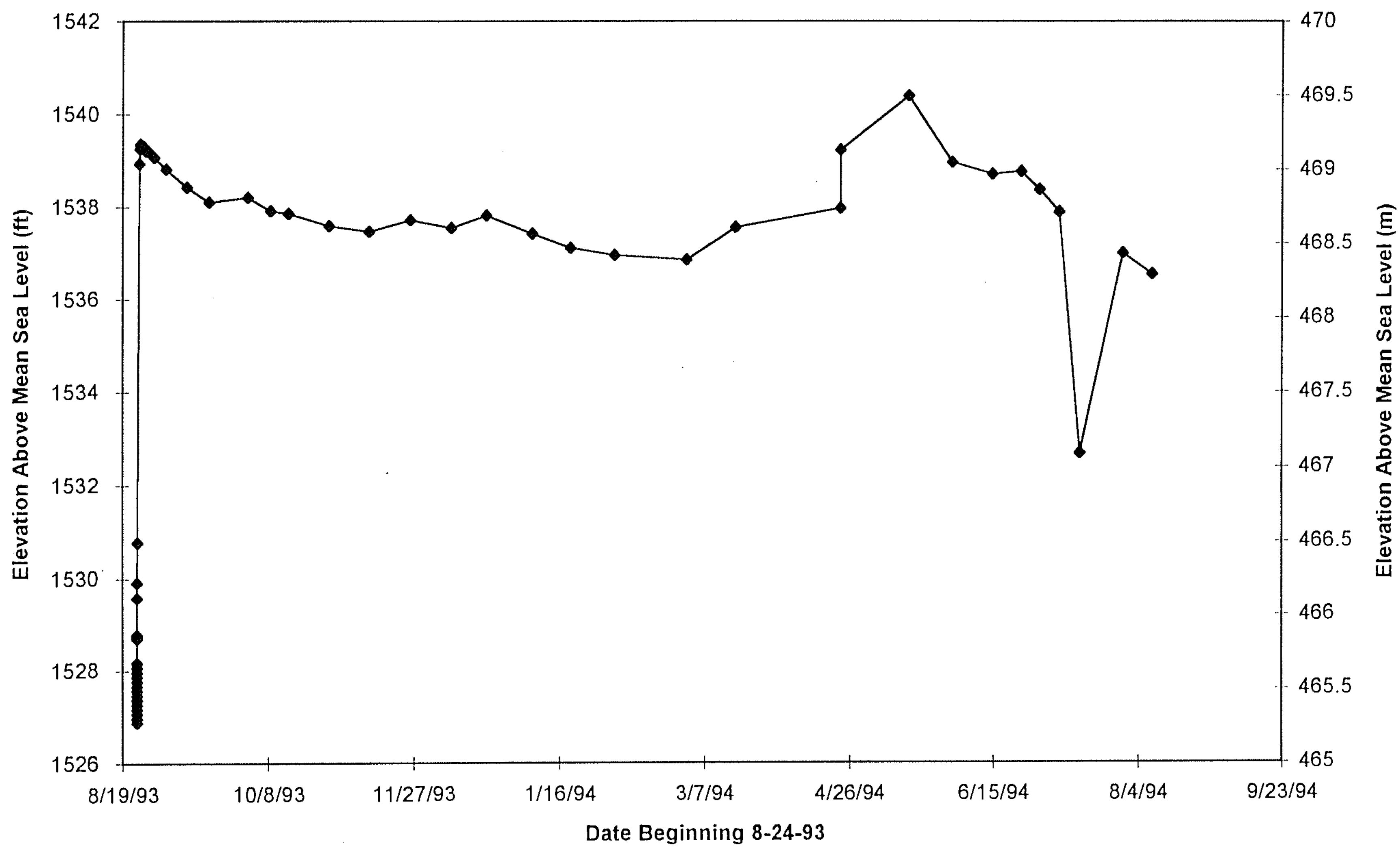


Figure 28 - Hydrograph R20-93-09
Weathered Zone - Cored 5.2 m - 5.3 m bls (17.1-17.4 ft)

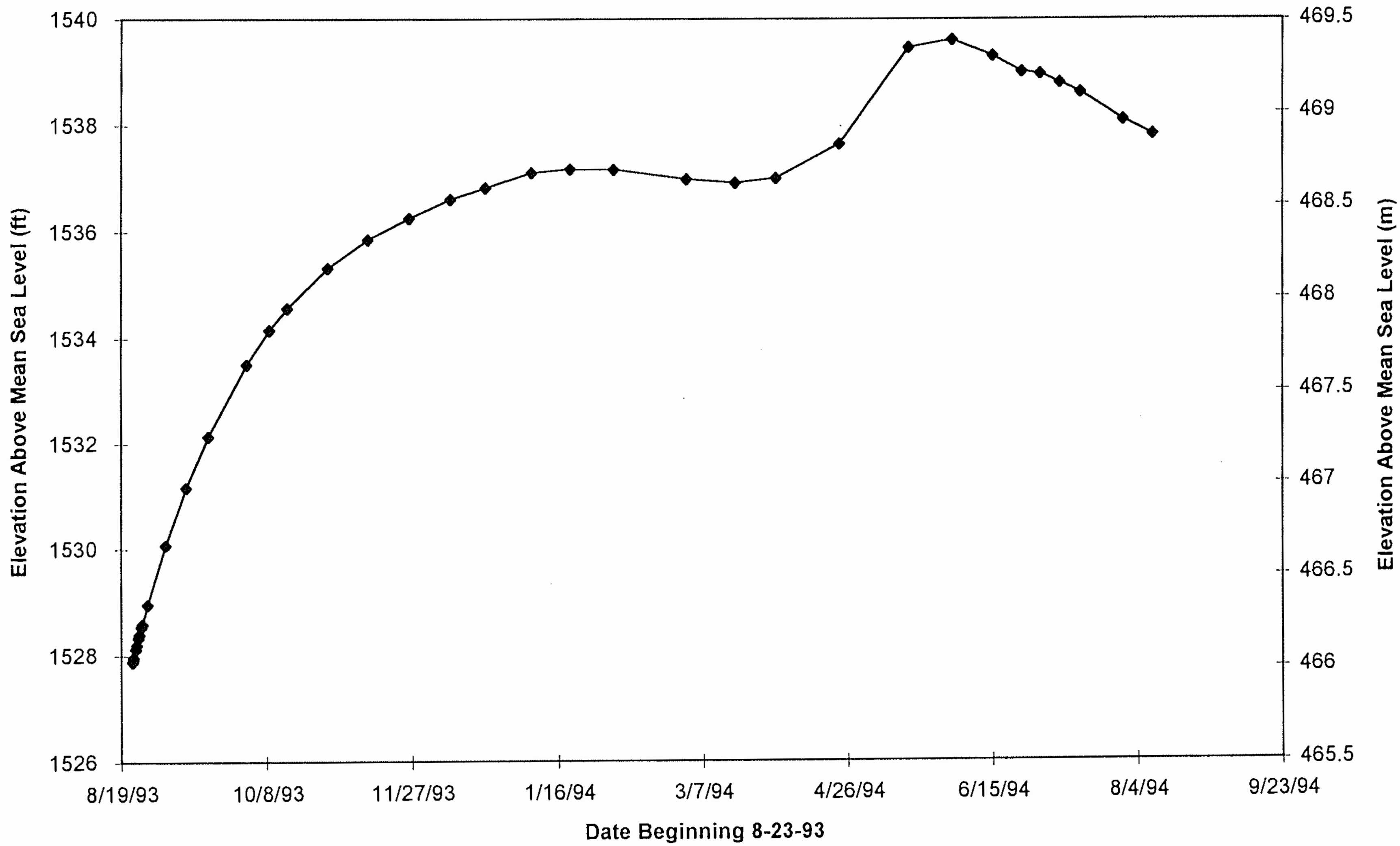


Figure 29 - Hydrograph R20-93-13
Weathered Zone - Cored 5.2m - 5.4 m (16.9-17.7 ft)

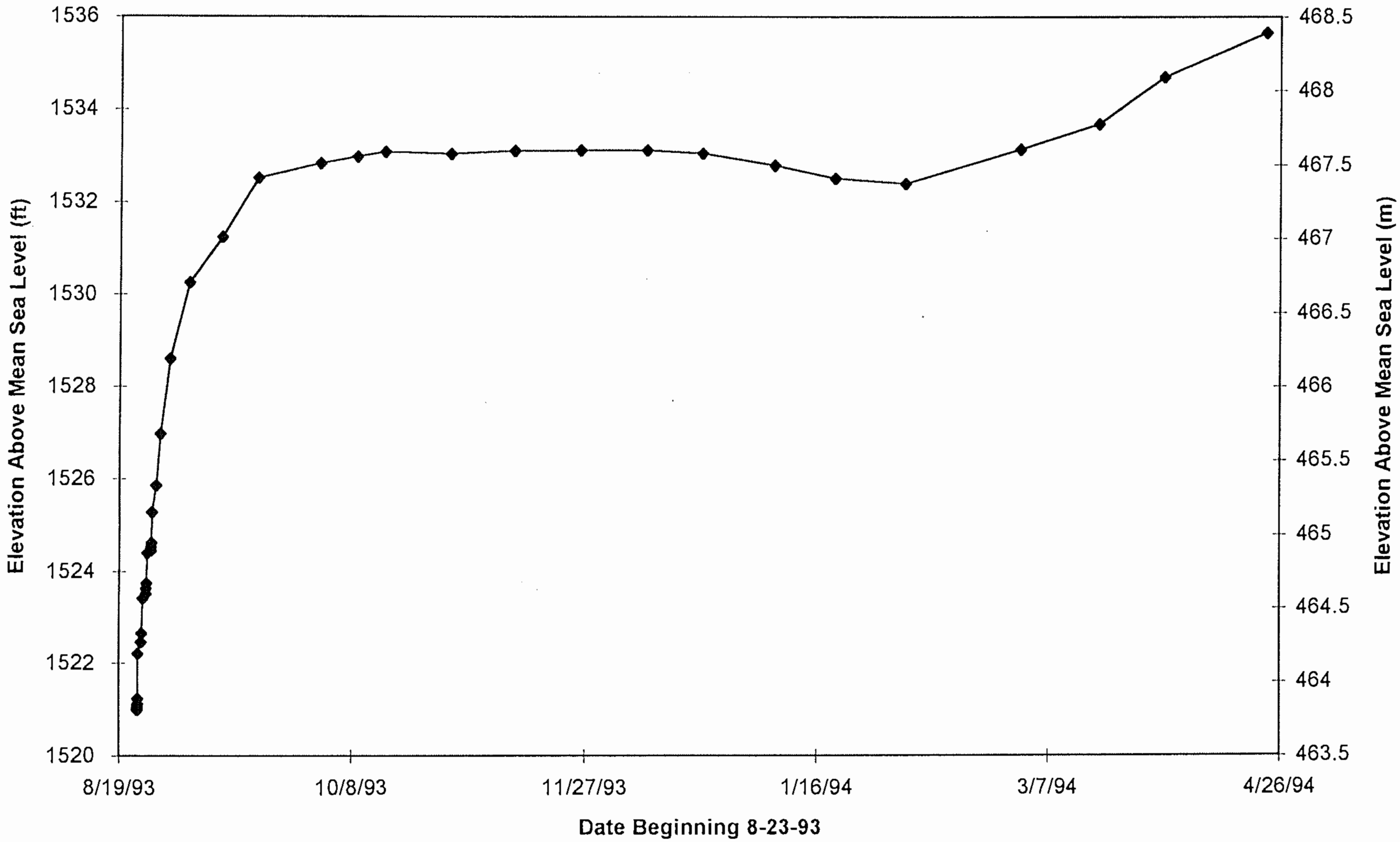


Figure 30 - Hydrograph R20-93-20
Weathered Zone - Cored 5.2m - 5.7m bls (17.2-18.7 ft)

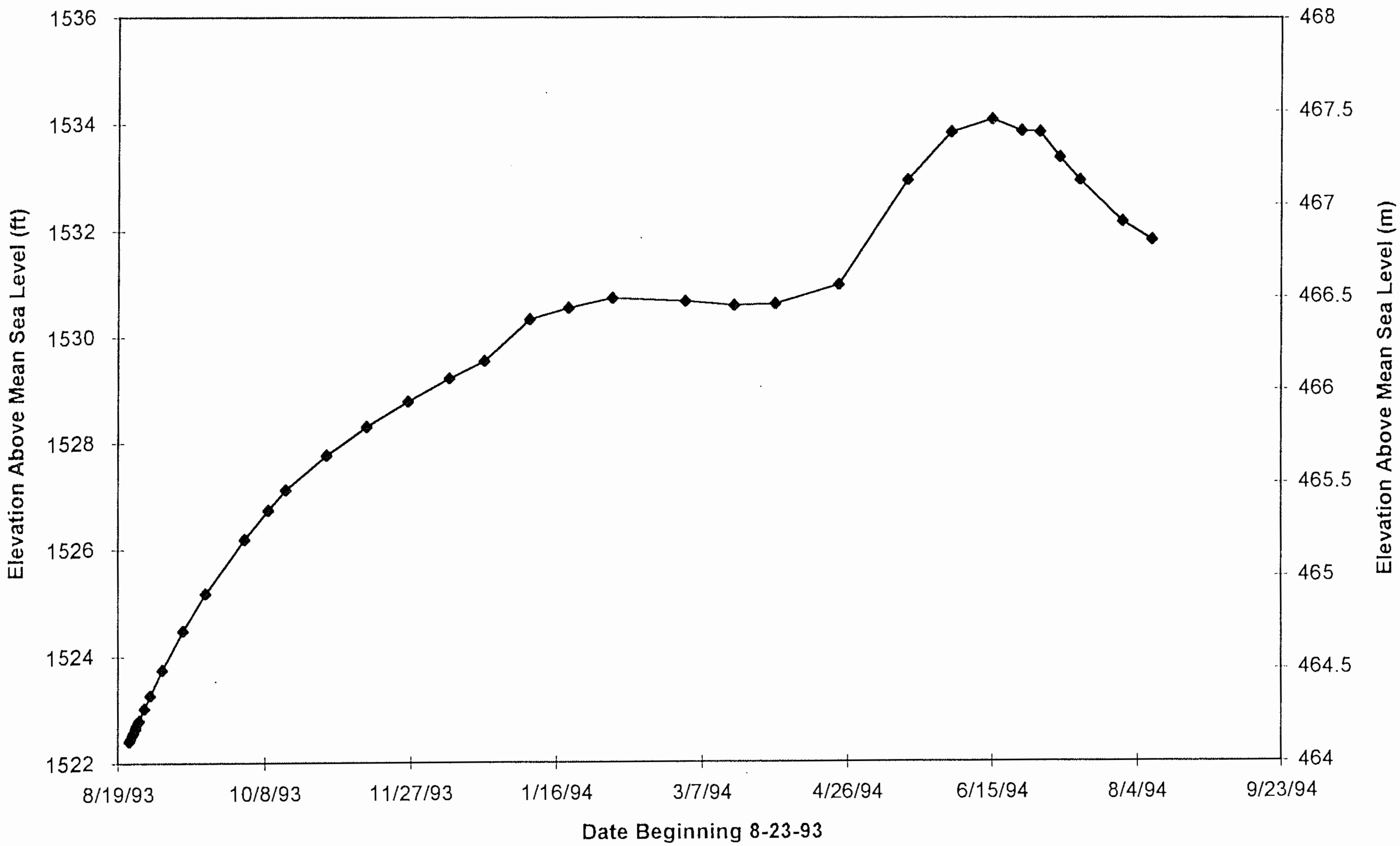


Figure 31 - Hydrograph R20-93-11
Transition Zone - Screened 7.3m - 8.9m bls (23.9-29.2 ft)

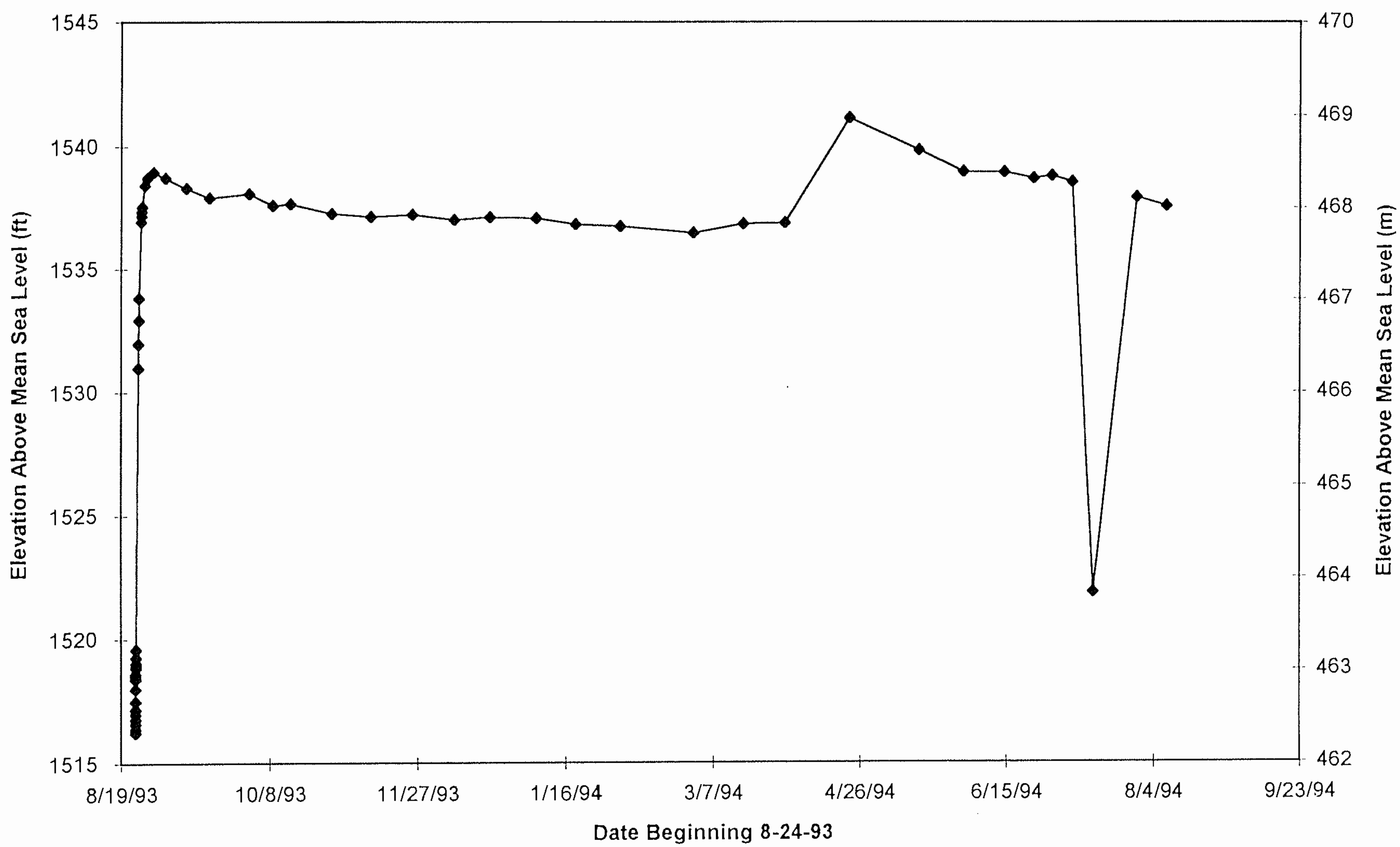


Figure 32 - Hydrograph R20-93-16
Transition Zone - Cored 7.1m - 8.7m bls (23.2-28.5 ft)

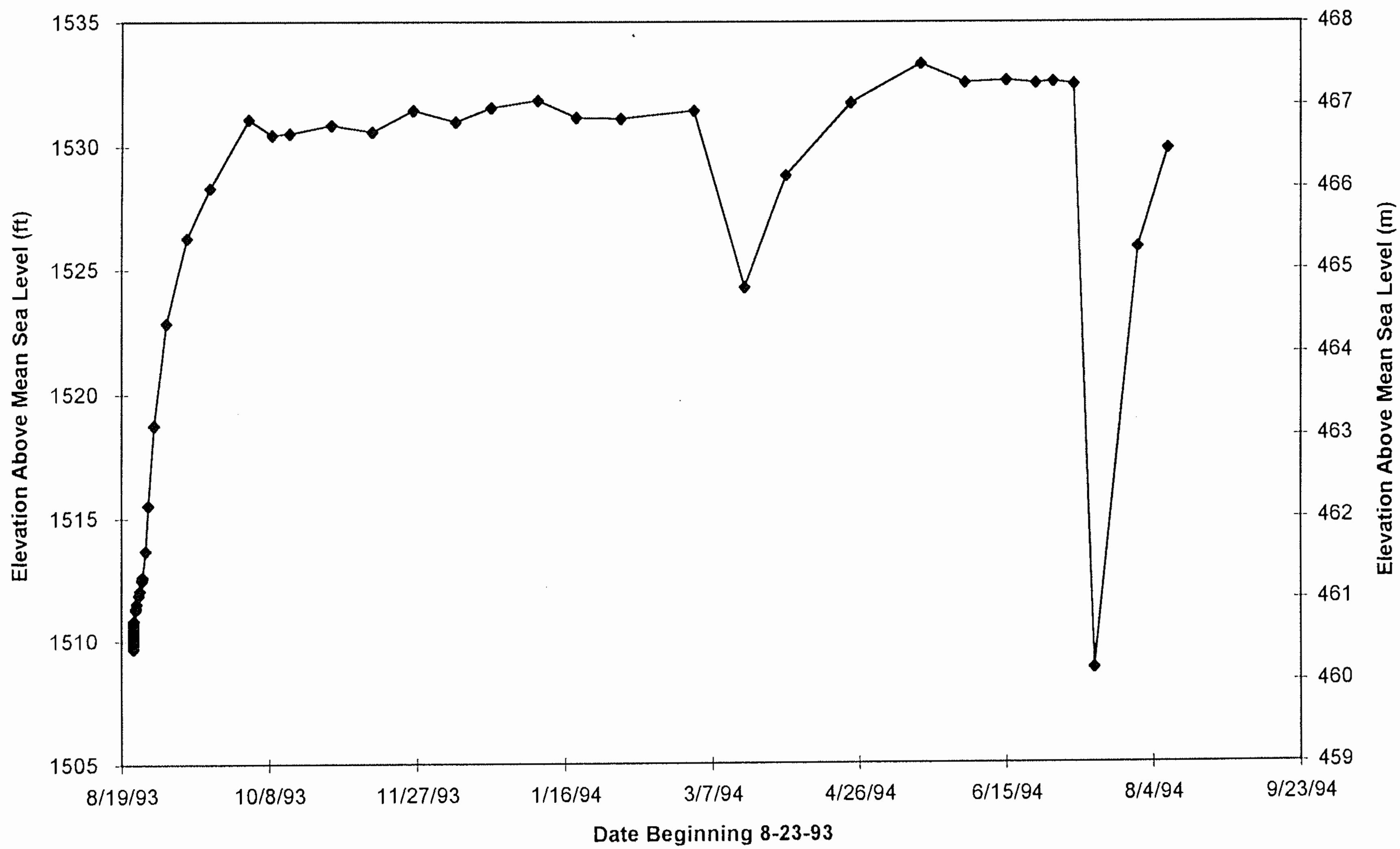
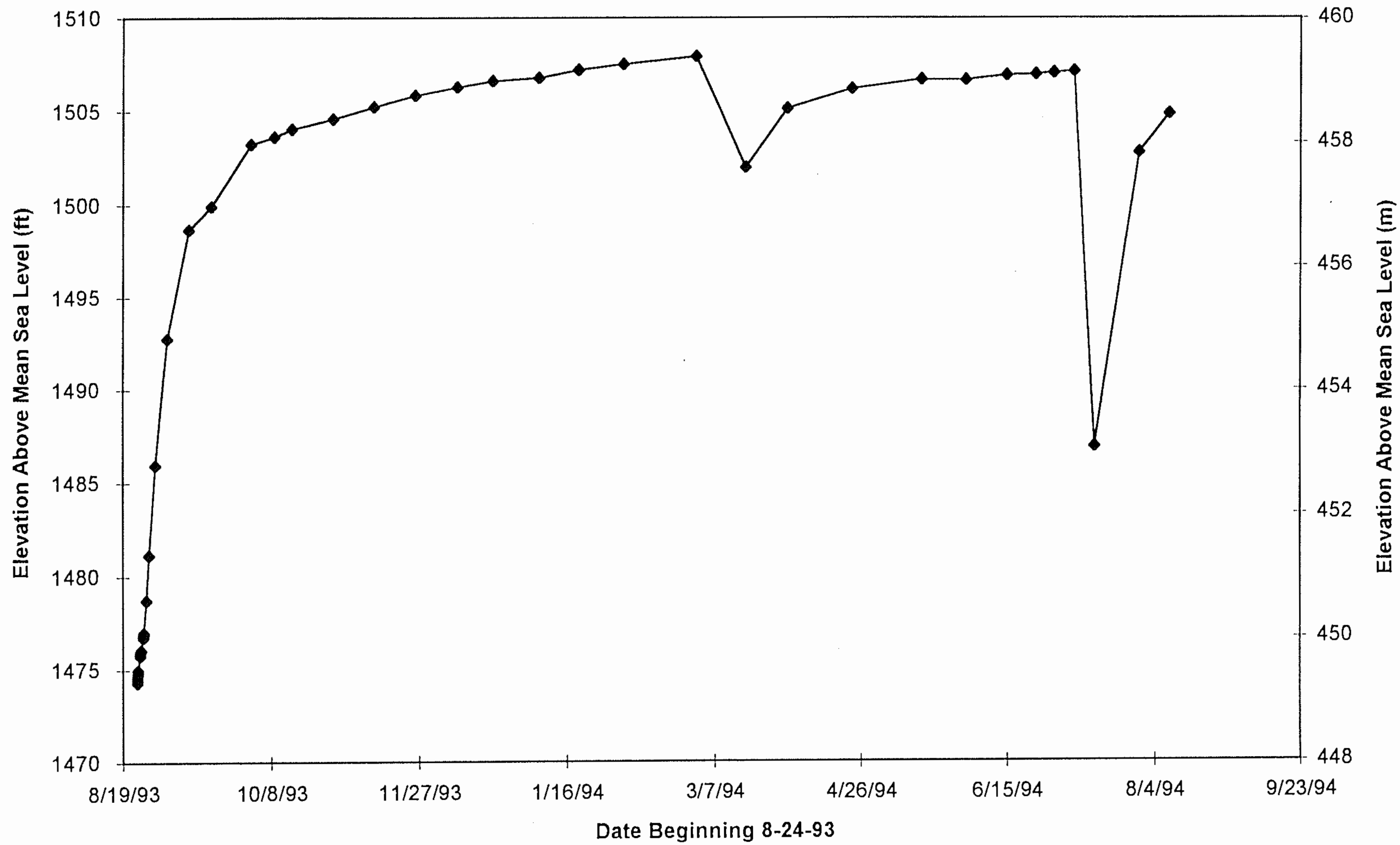


Figure 33 - Hydrograph R20-93-02
Unweathered Zone - Screened 20.2m - 21.9m bls(66.4-71.7 ft)



the shallow zone fluctuated by 1.2 m to 1.5 m (4 to 5 ft) for this same period. The two steep drops in water level in these two wells and well R20-93-02 resulted from bailing during sample collection.

Figure 33 is a hydrograph from the unweathered till at a depth of about 22.0 m (72 ft) bls. This hydrograph does not show any significant response to the recharge events that were observed in the shallow zone and the transition zone. The response of the hydrographs in the various zones within the till is very similar to the water-level fluctuations observed for weathered and unweathered till in the CENDAK study area (CENDAK, 1987).

Vertical hydraulic gradients were calculated for the unweathered till, across the unweathered-weathered till boundary and within the weathered till. The unweathered till had downward vertical hydraulic gradients that were calculated to be 0.89 (wells R20-93-03 and R20-93-02) and 0.25 (wells R20-93-15 and R20-93-14). The gradient of 0.25 must be viewed with skepticism since water levels in well R20-93-15, upon which the gradient was based, had not reached equilibrium. Disregarding the gradient calculated using data from well R20-93-15, the vertical gradient in the unweathered till is 0.89, which is generally similar to the 0.65 average vertical vertical hydraulic gradient determined for unweathered till in the CENDAK study area (CENDAK, 1987).

The vertical downward hydraulic gradient across the weathered-unweathered till boundary was calculated to be 0.68 (wells R20-93-11 and R20-93-02) and 0.76 (wells R20-93-16 and R20-93-14). The average was 0.72, which is similar to the average value reported for the unweathered till in the CENDAK study area.

In the weathered till, the vertical hydraulic gradient was calculated to be 0.041 upward (wells R20-93-07 and R20-93-11) and 0.042 downward (wells R20-93-18 and R20-93-16). CENDAK (1987) reported the vertical hydraulic gradients in the weathered till ranged from 1.196 downward to -0.928 upward, with an average of 0.065 downward.

The vertical hydraulic gradients for the weathered and unweathered till are also in close agreement to gradients reported by Craven and Ruedisili (1987) of 0.09 in the weathered till and 0.68 in the unweathered till. Desaulniers, et al. (1981) indicate vetical hydraulic gradients at three sites in southwestern Ontario ranged from 0.02 to 0.18 downward. A fourth site had an upward gradient that ranged from 0.03 to 0.21. These values are slightly lower than values determined for most South Dakota sites but do tend to show a similar trend. Comparisons to the results of CENDAK (1987) and Cravens and Ruedisili (1987) are important because they show that the results of this study can be used as a model for similar hydrogeologic settings in the glaciated areas of South Dakota.

The vertical hydraulic gradient in the upper zone is essentially zero. The vertical hydraulic gradient between the weathered and unweathered till and within the unweathered till may not be great enough to reach the threshold hydraulic gradient as described by Freeze and Cherry (1979). The threshold hydraulic gradient is described as the gradient that must be exceeded before ground-water flow begins. Hendry (1988) suggests that calculated average linear velocities may not be good indicators of ground water velocity if the threshold gradient is not exceeded.

CENDAK (1987) reported that a triaxial chamber test conducted by the Bureau of Reclamation on till from the CENDAK area produced no flow after 3 days at a constant gradient of 12. This is one indication that the gradient in the till at the landfill may not be high enough to exceed a threshold gradient and initiate ground-water flow. The actual threshold gradient for the till at the Sioux Falls landfill is unknown.

Hydraulic Conductivity of the Till

Results of Field Slug Tests

Slug-test data and charts showing compaison of these data for different completion zones, well diameters and completion methods are included as Appendix B. Table 2 lists values of K determined by both the Bouwer-Rice method and the Hvorslev method. These data are listed in both English and metric units. Values of K determined using the Hvorslev method were generally higher than K values determined using the Bouwer-Rice method. The actual difference is about 10^{-9} m/s (10^{-7} ft/min) or smaller. Therefore, either method will provide acceptable and reliable data.

Hydraulic conductivity determined by these methods ranged from 5.63×10^{-11} m/s (1.10×10^{-9} ft/min) to 9.56×10^{-8} m/s (1.88×10^{-5} ft/min). Figure 34 shows a graph of slug test derived K versus depth. There is a pattern of lower K with greater depth in the till. Values of K in the weathered zone ranged from 10^{-10} to 10^{-8} m/s (10^{-8} to 10^{-5} ft/min). In the transition zone K values range from 10^{-11} to 10^{-9} m/s (10^{-9} to 10^{-6} ft/min). In the unweathered zone K values range from 10^{-11} to 10^{-10} m/s (about 10^{-9} to 10^{-8} ft/min). This trend is consistent with the oxidation and fracturing within the three till zones at the landfill.

Hydraulic conductivity determined by field slug test methods at the Sioux Falls landfill compare very well with K values obtained by other investigators using similar methods (Hendry, 1983; Cravens and Ruedisili, 1987; D'Astous et al., 1988; CENDAK, 1987). Jones et al. (1992) conducted pumping tests in the weathered till zone in Iowa and found a mean K value of 5.22×10^{-6} m/s (1.03×10^{-3} ft/min), slightly higher than K values reported by other investigators. Jones (1993) conducted pumping and slug tests in the unweathered till in Iowa. Hydraulic conductivity determined for the Iowa site was comparable to K values reported for this and other studies, although slightly on the high end at about 10^{-9} to 10^{-8} m/s (10^{-7} to 10^{-6} ft/min).

One objective of this project was to compare K data from slug tests of wells of different diameter and different construction. These comparisons are based on the data calculated using the Bouwer-Rice method. Four-inch diameter wells were completed in the shallow zone with cored intakes and screened intervals. These were compared to 50 mm (2-inch) diameter wells with similar completions. Hydraulic conductivity calculated for the 100 mm (4-inch) cored wells ranged from 5.03×10^{-10} to 1.28×10^{-8} m/s (9.90×10^{-8} to 2.52×10^{-6} ft/min), compared to 7.21×10^{-10} to 2.28×10^{-9} m/s (1.42×10^{-7} to 4.48×10^{-7} ft/min) for the 50 mm (2-inch) cored wells. There is no

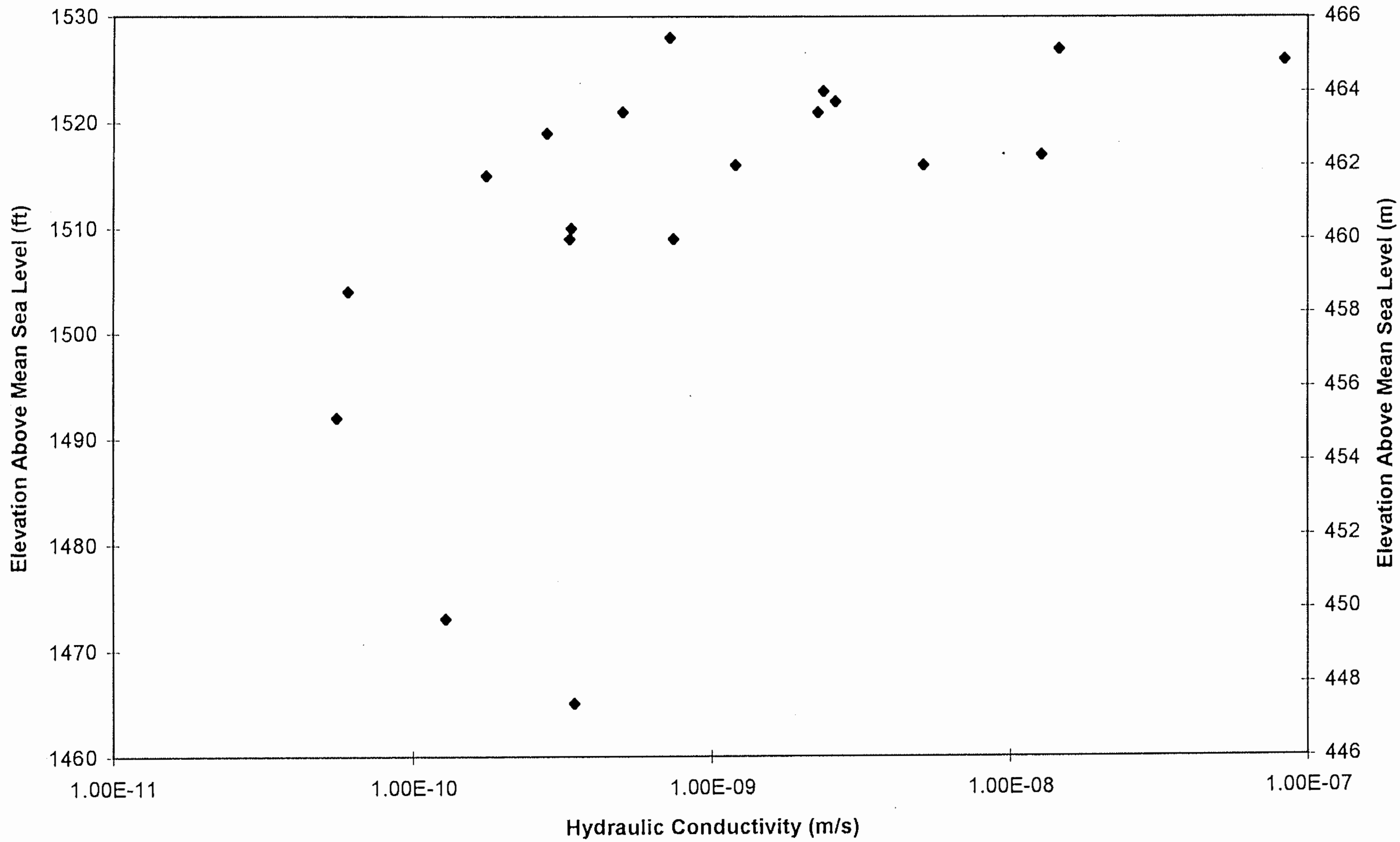
Table 2: Results of Field Slug Tests

Well Number	Hvorslev Method (m/s)	Hvorslev Method (ft/min)	Bouwer-Rice Method (m/s)	Bouwer-Rice Method (ft/min)	Till Zone
R20-93-07	1.90E-08	3.75E-06	1.46E-08	2.88E-06	Weathered
R20-93-08	3.91E-09	7.70E-07	2.37E-09	4.67E-07	Weathered
R20-93-09	6.64E-10	1.70E-07	7.21E-10	1.42E-07	Weathered
R20-93-13	2.97E-09	5.84E-07	2.28E-09	4.48E-07	Weathered
R20-93-18	1.96E-09	3.85E-07	1.20E-09	2.37E-07	Weathered
R20-93-19	4.04E-09	7.96E-07	2.61E-09	5.13E-07	Weathered
R20-93-20	6.10E-10	1.20E-07	5.03E-10	9.90E-08	Weathered
R20-93-21	3.35E-10	6.60E-08	2.82E-10	5.54E-08	Weathered
R20-93-22	9.56E-08	1.88E-05	8.38E-08	1.65E-05	Weathered
R20-93-23	1.75E-08	3.44E-06	1.28E-08	2.52E-06	Weathered
R20-93-05	7.82E-10	1.54E-07	7.47E-10	1.47E-07	Weathered
R20-93-06	1.80E-10	3.55E-08	1.76E-10	3.47E-08	Weathered
R20-93-11	7.01E-09	1.38E-06	5.18E-09	1.02E-06	Transition
R20-93-12	1.00E-10	1.97E-08	6.07E-11	1.19E-08	Transition
R20-93-16	3.93E-10	7.73E-08	3.35E-10	6.60E-08	Transition
R20-93-17	3.76E-10	7.40E-08	3.39E-10	6.68E-08	Transition
R20-93-02	1.63E-10	3.20E-08	1.30E-10	2.55E-08	Unweathered
R20-93-03	6.10E-11	1.20E-08	5.63E-11	1.11E-08	Unweathered
R20-93-14	3.30E-10	6.50E-08	3.49E-10	6.86E-08	Unweathered

definite difference apparent in these data. The 100 mm (4-inch) screened wells ranged from 2.82 x 10^{-10} to 1.28 x 10^{-8} m/s (5.55 x 10^{-8} to 2.52 x 10^{-6} ft/min) compared to 2.6 x 10^{-9} to 1.46 x 10^{-8} m/s (5.12 x 10^{-7} to 2.87 x 10^{-6} ft/min) for the 50 mm (2-inch) screened wells.

Comparing the 100 mm (4-inch) cored wells with the 100 mm (4-inch) screened wells shows that K for the cored wells is higher by 0.22 to 0.70 orders of magnitude. However, similar comparison of the 50 mm (2-inch) cored wells shows K to be lower for the cored wells by about

Figure 34 - Hydraulic Conductivity From Field Slug Tests



0.02 to 0.5 orders of magnitude. It was anticipated that the cored wells would yield a lower K since the open length is not as great and would not intersect as many fractures. Yet, both of the 100 mm (4-inch) wells deviated from this pattern.

Screen length did appear to have an impact on calculated K values. Wells completed with 3 m (10 ft) screened intervals had lower K by about 0.13 orders of magnitude. This is attributed to the screened section reaching deeper into the formation where there are less fractures to intersect.

In general, any trends observed between K values calculated from wells with various completions were weak, at best. This suggests that any of the well completion methods should produce data that are acceptable. In terms of ease of data reduction, the cored intake wells tended to produce relatively straight lines for the Bouwer-Rice and Hvorslev plots. Early data for the screened wells showed the effects of sand pack drainage and the curves also were not linear at longer time periods for most of the screened wells. The data from the cored wells are also more likely to be comparable to K values determined in the laboratory. However, the wells completed with 1.5 m (5ft) screens seem to provide accurate data and have the least problems associated with well installation and completion.

<u>Results of Laboratory Tests of Cores</u>

Hydraulic Conductivity for Shelby-Tube and 0.3 m (12-Inch) Diameter Till Cores

Tables 3 and 4 list K values determined for till cores collected by both the Shelby-tube method and with the 0.3 m (12-inch) diameter PVC device previously described. Values of K were determined for 49 Shelby-tube sections. The K data for the Shelby-tube cores are plotted against elevation in Figure 35. With the exception of one core from a depth of about 5.5 m (18 ft) bls, the K values for the Shelby-tube samples were below the U.S. EPA solid waste landfill liner criteria of 1×10^{-9} m/s (1.97×10^{-7} ft/min). Hydraulic conductivity ranged from 3.8×10^{-11} to 1.9×10^{-9} m/s (7.48×10^{-9} to 3.74×10^{-7} ft/min). This is generally one to two orders of magnitude lower than K values determined by field slug test methods.

Values of K determined for the Shelby-tube cores also show a pattern of decreasing K with depth, although not nearly as pronounced as that observed for K values determined utilizing the field slug-test data. Two outliers (R20-93-03 and R20-93-14), 15.8 m (52 ft) bls and 22.0 m (72 ft) bls, can probably be attributed to side-wall leakage between the core and the Shelby-tube. However, a vertical, iron stained fracture was observed in the core sample from 15.9 m (52 ft) bls.

Nine 0.3 m (12-inch) diameter cores were analyzed by constant-head methods. Figure 36 shows a plot of K versus depth bls for these larger diameter cores. Values of K for these samples ranged from 5.0×10^{-10} to 2.0×10^{-6} m/s (9.84×10^{-8} to 3.94×10^{-4} ft/min). The higher K values were obtained from samples that had significant fracturing of the till. Two samples from elevations of 460.4 m (1510.6 ft) and 459.9 m (1508.7 ft) exhibited high K values because single and

Table 3: Hydraulic Conductivity (K) of Shelby-Tube Cores - continued

Well Number	Shelby Depth m (ft)	Sample Depth m (ft)	Falling-Head Lab Results m/s (ft/min)
R20-93-02	21.3-22.0 (70-72)	21.6-21.7 (70.8-71.2)	7.0E-11 (1.38E-08)
		21.8-21.9 (71.4-71.7)	7.3E-11 (1.44E-08)
R20-93-02	22.0-22.6 (72-74)	22.3-22.4 (73.3-73.5)	9.3E-11 (1.83E-08)
		22.4-22.5 (73.5-73.8)	8.0E-11 (1.58E-08)
R20-93-03	14.6-15.2 (48-50)	14.9-14.9 (48.8-49.0)	6.5E-11 (1.28E-08)
		15.1-15.2 (49.5-49.8)	9.5E-11 (1.87E-08)
R20-93-03	15.2-15.9 (50-52)	15.6-15.7 (51.3-51.5)	9.5E-11 (1.87E-08)
		15.7-15.8 (51.5-51.8)	6.0E-10 (1.18E-07)
R20-93-05	7.6-8.2 (25-27)	7.9-8.0 (25.9-26.2)	4.5E-11 (8.86E-09)
		8.1-8.2 (26.4-26.7)	6.0E-11 (1.18E-08)
R20-93-05	8.2-8.8 (27-29)	8.6-8.7 (28.3-28.5)	2.5E-10 (4.92E-08)
		8.7-8.8 (28.5-28.8)	9.5E-11 (1.87E-08)
R20-93-05	8.8-9.5 (29-31)	9.2-9.3 (30.3-30.5)	6.5E-11 (1.28E-08)
		9.3-9.4 (30.5-30.8)	9.0E-11 (1.77E-08)
R20-93-07	4.3-4.9 (14-16)	4.6-4.7 (15.3-15.5)	7.8E-11 (1.54E-08)
		4.7-4.8 (15.5-15.8)	7.0E-11 (1.38E-08)
R20-93-08	4.3-4.9 (14-16)	4.5-4.7 (14.9-15.5)	3.9E-10 (7.68E-08)
		4.7-4.8 (15.4-15.7)	3.8E-11 (7.48E-09)
R20-93-08	4.9-5.5 (16-18)	5.2-5.2 (16.9-17.2)	3.5E-10 (6.89E-08)
		5.3-5.4 (17.4-17.7)	1.7E-10 (3.35E-08)
R20-93-08	5.5-6.1 (18-20)	5.8-5.9 (19.2-19.4)	6.0E-11 (1.18E-08)
		5.9-6.0 (19.4-19.7)	5.2E-11 (1.02E-08)
R20-93-11	7.3-7.9 (24-26)	7.6-7.7 (25.0-25.3)	1.3E-10 (2.56E-08)
		7.8-7.9 (25.5-25.8)	9.6E-11 (1.89E-08)
R20-93-12	7.6-8.2 (25-27)	8.0-8.1 (26.3-26.5)	1.6E-10 (3.15E-08)

Table 3: Hydraulic Conductivity (K) of Shelby-Tube Cores - continued

Well Number	Shelby Depth m (ft)	Sample Depth m (ft)	Falling-Head Lab Results m/s (ft/min)
		8.1-8.2 (26.5-26.8)	3.3E-10 (6.50E-08)
R20-93-12	8.2-8.8 (27-29)	8.5-8.6 (28.0-28.3)	1.0E-10 (1.97E-08)
		8.7-8.8 (28.5-28.8)	5.7E-11 (1.12E-08)
R20-93-12	8.8-9.5 (29-31)	9.2-9.3 (30.3-30.5)	1.1E-10 (2.17E-08)
		9.3-9.4 (30.5-30.8)	1.1E-10 (2.17E-08)
R20-93-14	21.3-22.0 (70-72)	21.6-21.7 (71.0-71.3)	2.8E-10 (5.51E-08)
		21.8-21.9 (71.5-71.8)	4.6E-11 (9.06E-09)
R20-93-15	14.9-15.5 (49-51)	15.2-15.3 (50.0-50.3)	4.5E-11 (8.86E-09)
		15.4-15.5 (50.5-50.8)	4.3E-11 (8.47E-09)
R20-93-16	8.0-8.6 (26.2-28.2)	8.2-8.3 (27.0-27.3)	8.1E-11 (1.60E-08)
		8.4-8.5 (27.8-28.0)	4.8E-11 (9.45E-09)
R20-93-18	4.3-4.9 (14-16)	4.4-4.5 (14.7-14.9)	9.0E-11 (1.77E-08)
		4.6-4.7 (15.3-15.5)	1.6E-10 (3.15E-08)
R20-93-18	5.5-6.1 (18-20)	5.9-6.0 (19.3-19.5)	1.8E-10 (3.54E-08)
		6.0-6.1 (19.5-19.8)	9.0E-11 (1.77E-08)
R20-93-19	4.3-4.9 (14-16)	4.6-4.7 (15.0-15.3)	3.8E-10 (7.48E-08)
		4.7-4.8 (15.5-15.8)	2.0E-10 (3.94E-08)
R20-93-20	5.3-5.9 (17.4-19.4)	5.7-5.8 (18.8-19.0)	5.5E-11 (1.08E-08)
		5.8-5.9 (19.0-19.3)	5.5E-11 (1.08E-08)
R20-93-21	6.1-6.7 (20-22)	6.2-6.3 (20.5-20.7)	7.0E-11 (1.38E-08)
		6.3-6.4 (20.7-20.9)	5.9E-11 (1.16E-08)
R20-93-22	5.3-5.8 (17.4-19.1)	5.6-5.7 (18.4-18.7)	1.9E-09 (3.74E-07)
R20-93-23	5.5-6.1 (18-20)	5.6-5.7 (18.5-18.8)	8.5E-11 (1.67E-08)
		5.7-5.8 (18.8-19.0)	8.5E-11 (1.67E-08)

Table 4: Hydraulic Conductivity (K) of 0.3 m (12-inch) Diameter Cores

Elevation of Sample in Trench m (ft)	Depth of Sample bls m (ft)	Constant Head Lab Results m/s (ft/min)
464.8 (1525.0)	5.8 (18.9)	4.5E-08 (8.86E-06)
464.3 (1523.3)	6.3 (20.6)	4.3E-08 (8.47E-06)
463.1 (1519.2)	7.5 (24.7)	4.9E-09 (9.65E-07)
462.4 (1517.0)	8.2 (26.9)	5.4E-07 (1.06E-04)
461.7 (1514.8)	8.9 (29.1)	5.0E-09 (9.84E-07)
461.1 (1512.7)	9.5 (31.2)	4.8E-09 (9.44E-07)
460.4 (1510.6)	10.2 (33.3)	3.2E-06 (6.30E-04)
459.9 (1508.7)	10.7 (35.2)	2.0E-06 (3.94E-04)
458.9 (1505.5)	11.7 (38.4)	5.0E-10 (9.84E-08)

double fractures were purposely sampled. Flow through these samples was dominated by fractures. The K value of 5 x 10^{-10} m/s (9.84 x 10^{-8} ft/min) was from a sample of unfractured, unweathered till. Data from these larger diameter cores suggest decreasing K with decreasing fracture density. No distinct correlation of K versus depth is apparent for these samples, although if the two high K samples are disregarded there is a trend of decreasing K with increasing depth. With so few samples the trend is not statistically defensible. Every effort was made to minimize sample disturbance and side-wall leakage, and this did not appear to be a problem for the samples for which data are reported. However, the potential exists for core disturbance during the sample collection procedure that could result in opening of fractures or side-wall leakage. Some samples were discarded due to obvious disturbance and side-wall leakage. Refinement of the field sample collection procedure will help reduce this concern for future studies. The method does appear to more readily encompass a REV than the Shelby-tube cores, and appears to provide values of K that are on the same order of magnitude as the field slug tests.

Hydraulic conductivity determined from cores is comparable to K values determined on cores by other investigators for clayey weathered and unweathered till. Other investigators have observed that field derived K values are one to over two orders of magnitude greater than laboratory determined K values, which is the case for the Sioux Falls landfill site. This is particularly true for the weathered till where it is more difficult to encompass a REV with the small diameter core (Desaulniers, 1981; Prudic, 1982; Hendry, 1982; Fredericia, 1993; CENDAK, 1987).

Figure 35 - Hydraulic Conductivity From Laboratory Cores

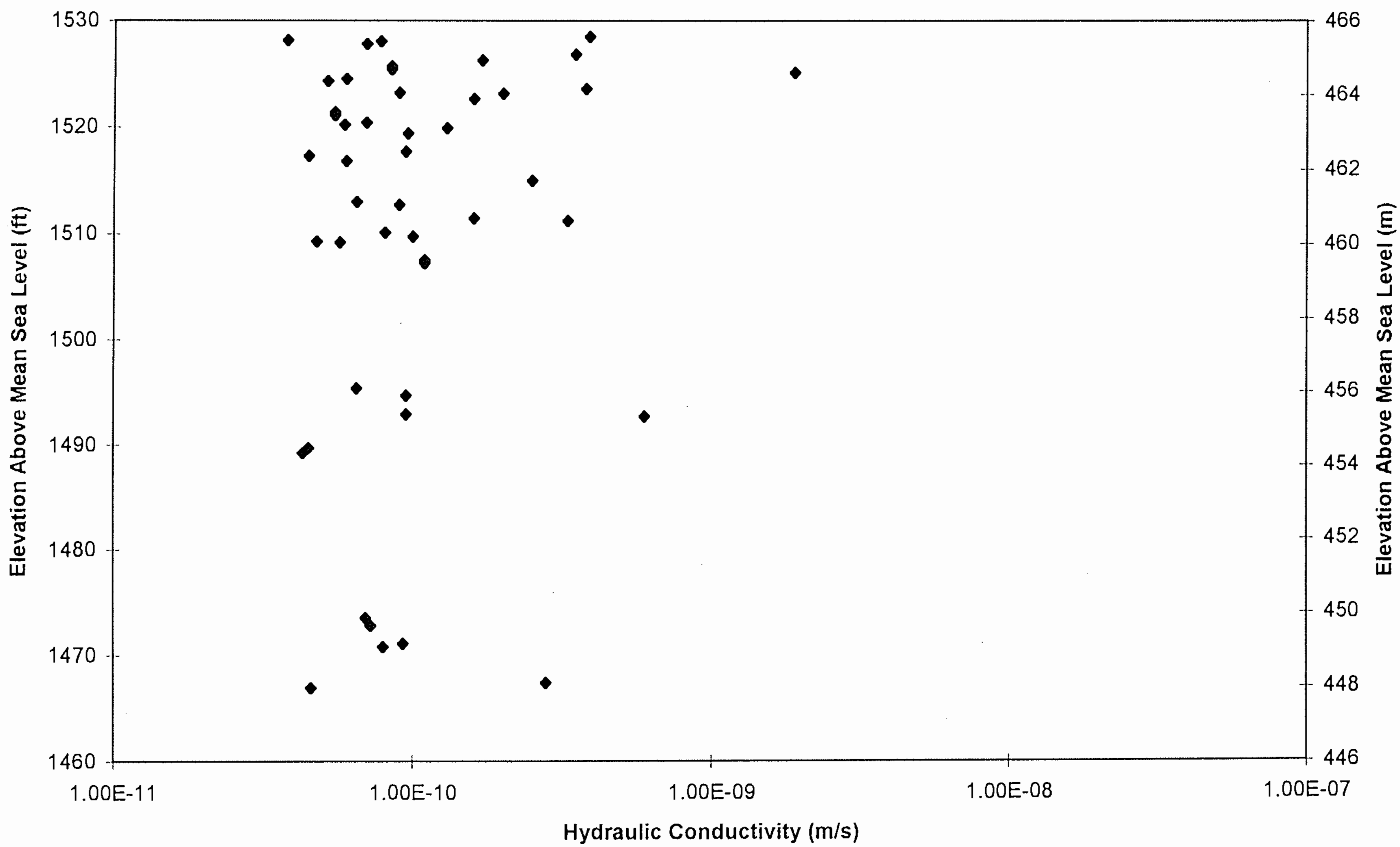
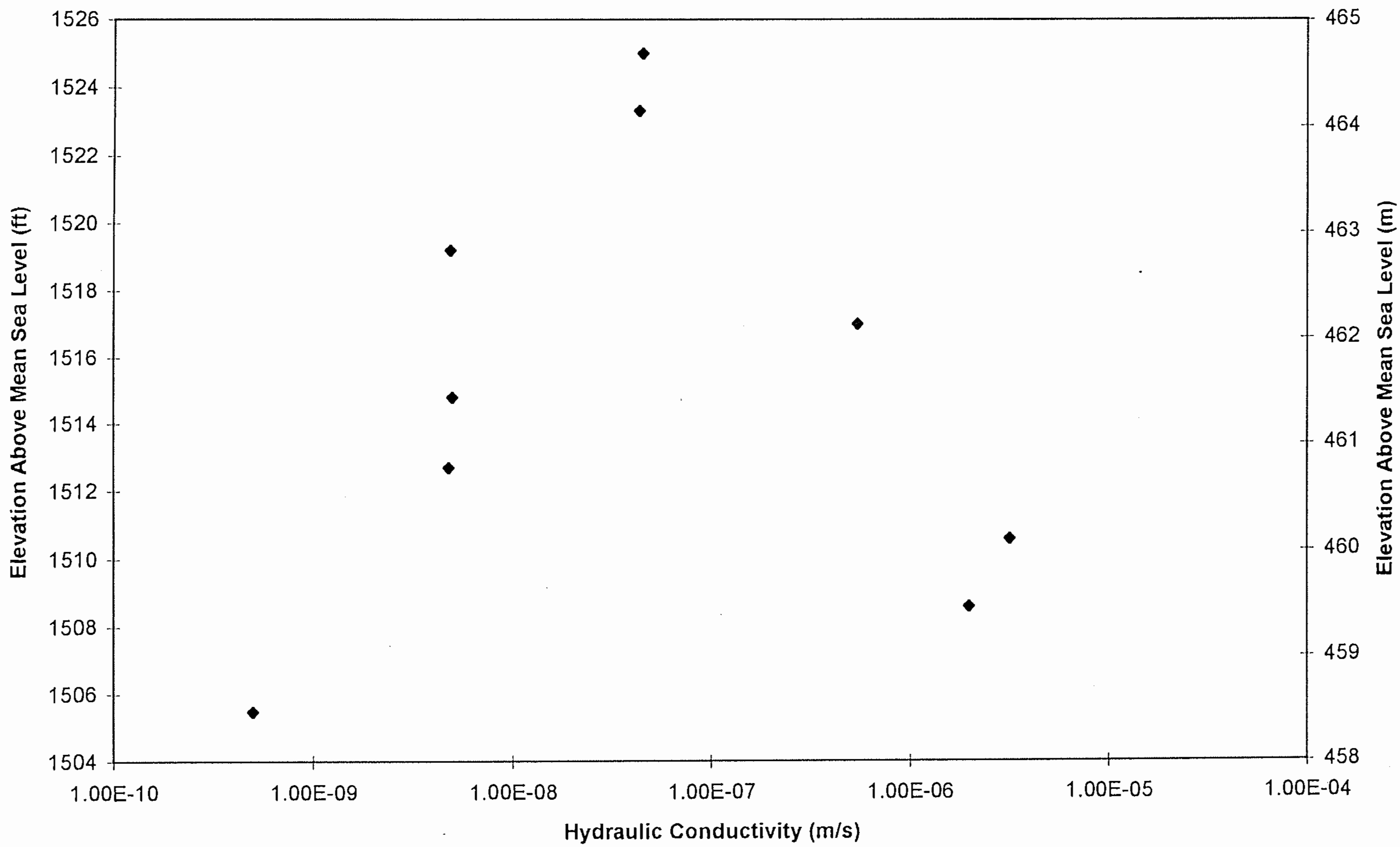


Figure 36 - Hydraulic Conductivity From Large Diameter Cores



Hydrochemistry

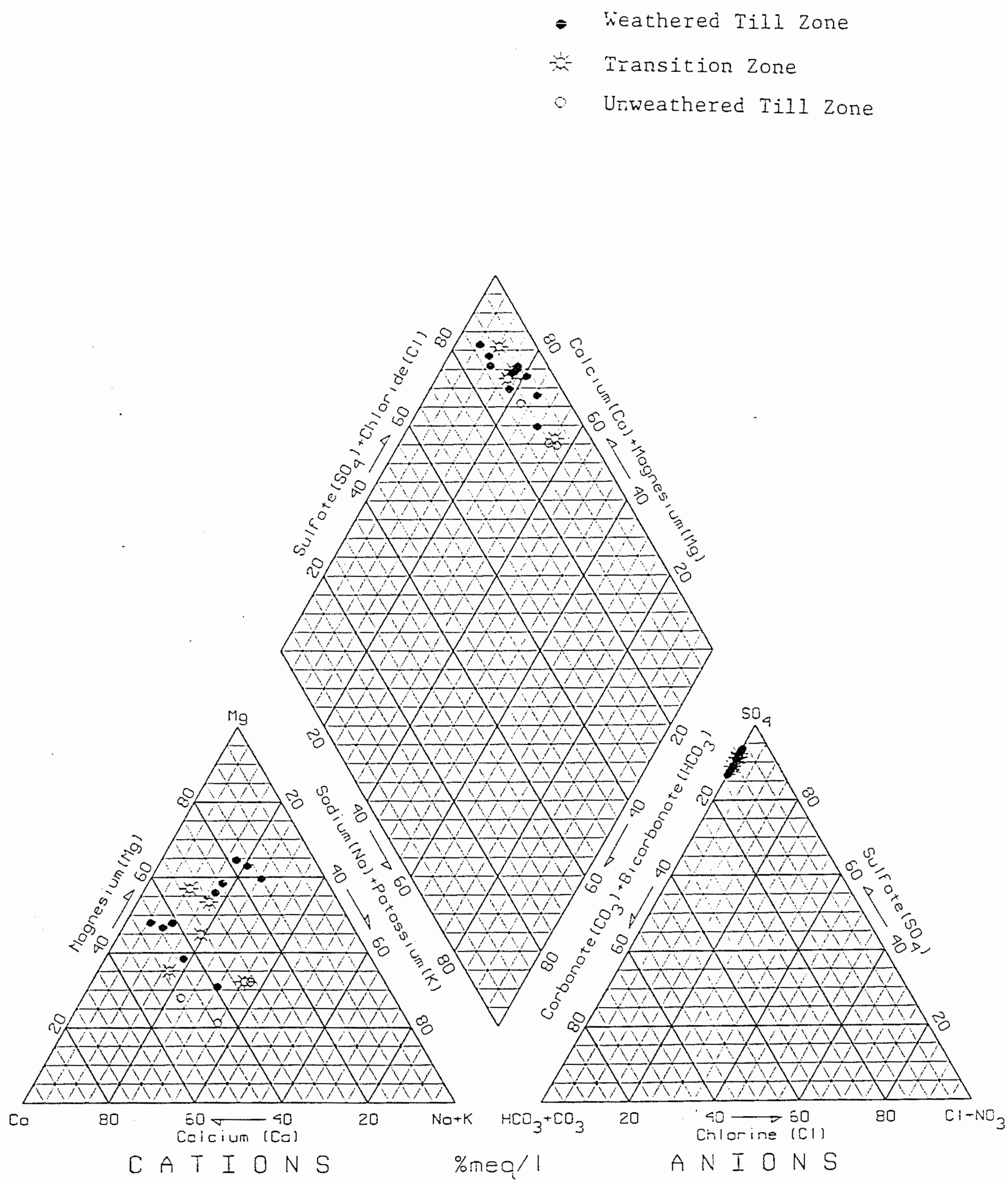
Inorganic Water Quality

Samples from 18 of the 20 monitoring wells were analyzed for major inorganic chemistry. The ground water in the till has very high total dissolved solids (TDS) and is extremely hard. Figure 37 is a trilinear diagram of these water quality data. The water is a Mg-Ca-Na-SO_4-HCO_3 type. The calcium concentration ranged from 412 to 562 mg/L. Magnesium ranged from 141 to 997 mg/L and sodium concentration ranged from 62 to 796 mg/L. The predominant anion was sulfate. Concentrations of sulfate were extremely high ranging from 2320 to 6360 mg/L. Bicarbonate, the second most prevalent anion ranged from 335 to 557 mg/L. Chloride concentrations are very low ranging from 2.5 to 23 mg/L.

Some differences in sulfate concentration were noted as related to depth but a trend that was consistent between the two well nests used in this study was not identified. In the north well nest, 5 shallow wells ranging in depth from about 5.2 to 7 m (17 to 23 ft) had sulfate concentrations ranging from 2320 to 2550 mg/L. These five wells are completed in the weathered till. Two slightly deeper wells at depths of about 8.8 and 10.7 m (29 and 35 ft) had sulfate concentrations of 3250 to 3520 mg/L, respectively. These two wells are completed in a transition zone of weathered and unweathered till. Two wells at depths of about 15.9 and 22.0 m (52 and 72 ft) had concentrations of 2430 and 2320 mg/L, respectively. These wells are completed in unweathered till. Ground water in this well nest has the highest concentrations of sulfate in the transition zone, between weathered and unweathered till. Concentrations of sulfate are very similar in the weathered till and the unweathered till.

Sulfate concentrations in the southern well nest did not exhibit the highest concentrations of sulfate in the transition zone. Five wells completed at depths ranging from about 5.2 to 6.7 m (17 to 22 ft) had sulfate concentrations ranging from 3610 to 6360 mg/L. These five wells are completed in weathered till. Three deeper wells completed at depths of about 8.5, 8.8, and 10.4 m (28, 29, and 34 ft) had sulfate concentrations of 2460, 3220, and 3180 mg/L, respectively. One well completed at a depth of about 22.6 m (74 ft) had a sulfate concentration of 2960 mg/L. Ground water in the southern well nest exhibited the highest sulfate concentrations in the weathered till, in contrast to the northern nest where the highest concentrations were observed in the transition zone. In the southern well nest, concentrations of sulfate were very similar in the transition and unweathered zones.

Figures 38 through 44 show concentrations of major inorganic cations and anions versus depth bls for ground water at the Sioux Falls landfill. Figure 38 shows no significant difference in the concentration of calcium with depth. Figures 39 and 40, sodium and potassium, also show no trend with depth. Figure 41 shows that the concentration of magnesium decreased with depth, which is comparable to the findings of Cravens and Ruedisili (1987). There is also a weak trend of bicarbonate and sulfate concentrations decreasing with depth bls, especially for the southern well nest (Figures 42 and 43). The concentrations of chloride were less than 15 mg/L in the weathered zone and the transition zone but were greater than 15 mg/L in the deeper unweathered till.



Fiugre 37 - Trilinear Diagram of Ground Water in Till

Figure 38 - Calcium Concentrations of Ground Water

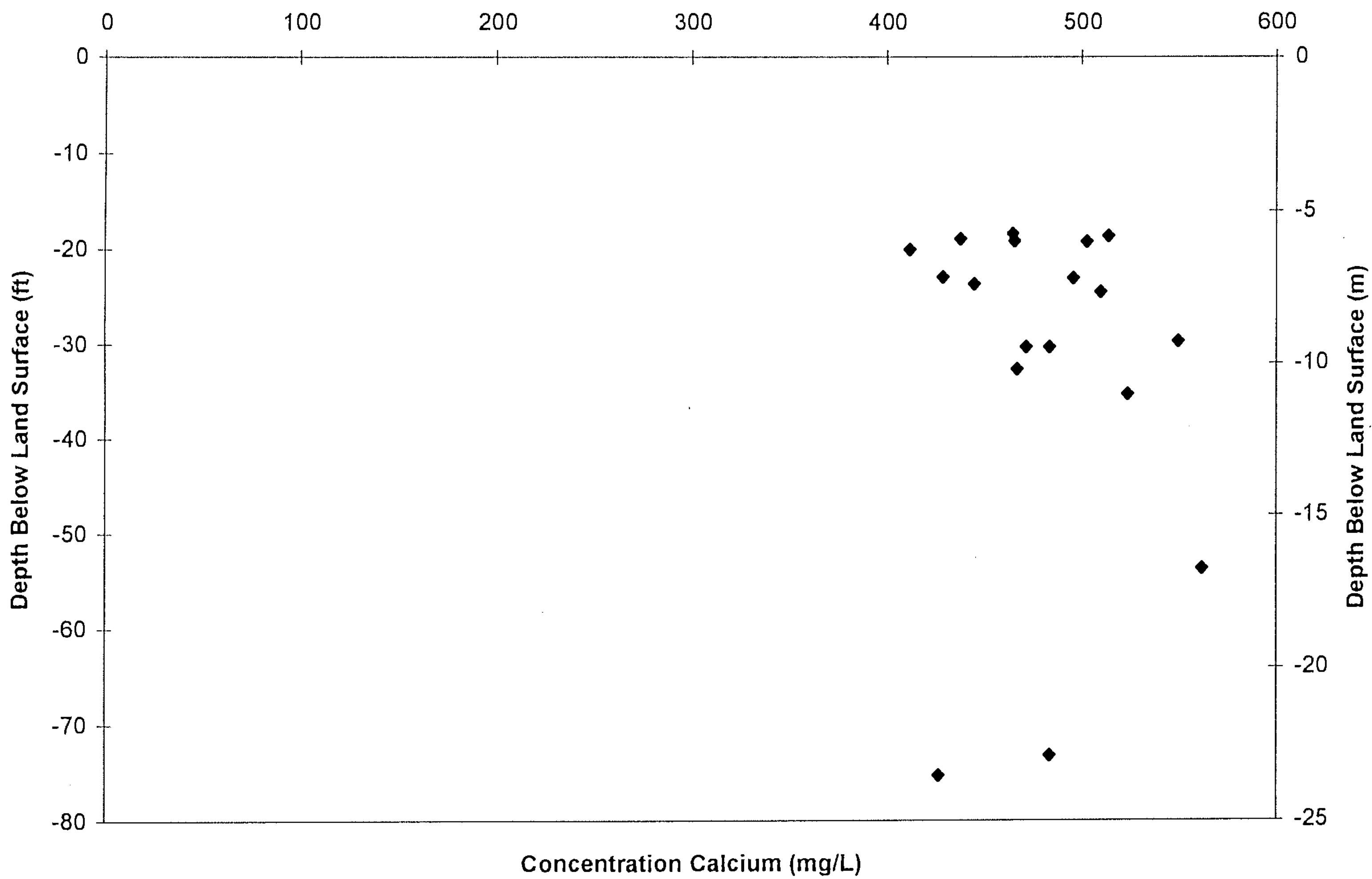


Figure 39 - Sodium Concentrations of Ground Water

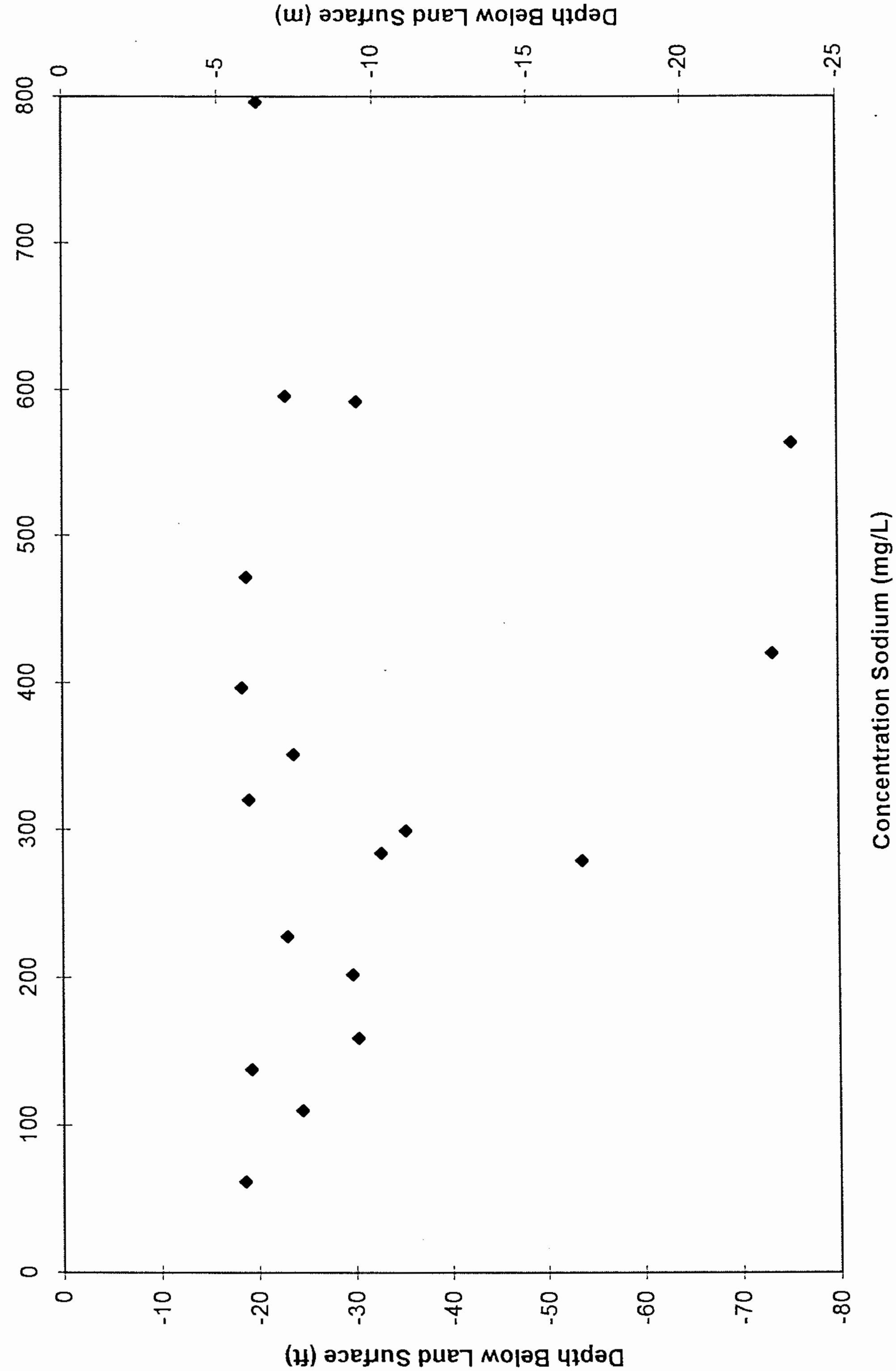


Figure 40 - Potassium Concentrations of Ground Water

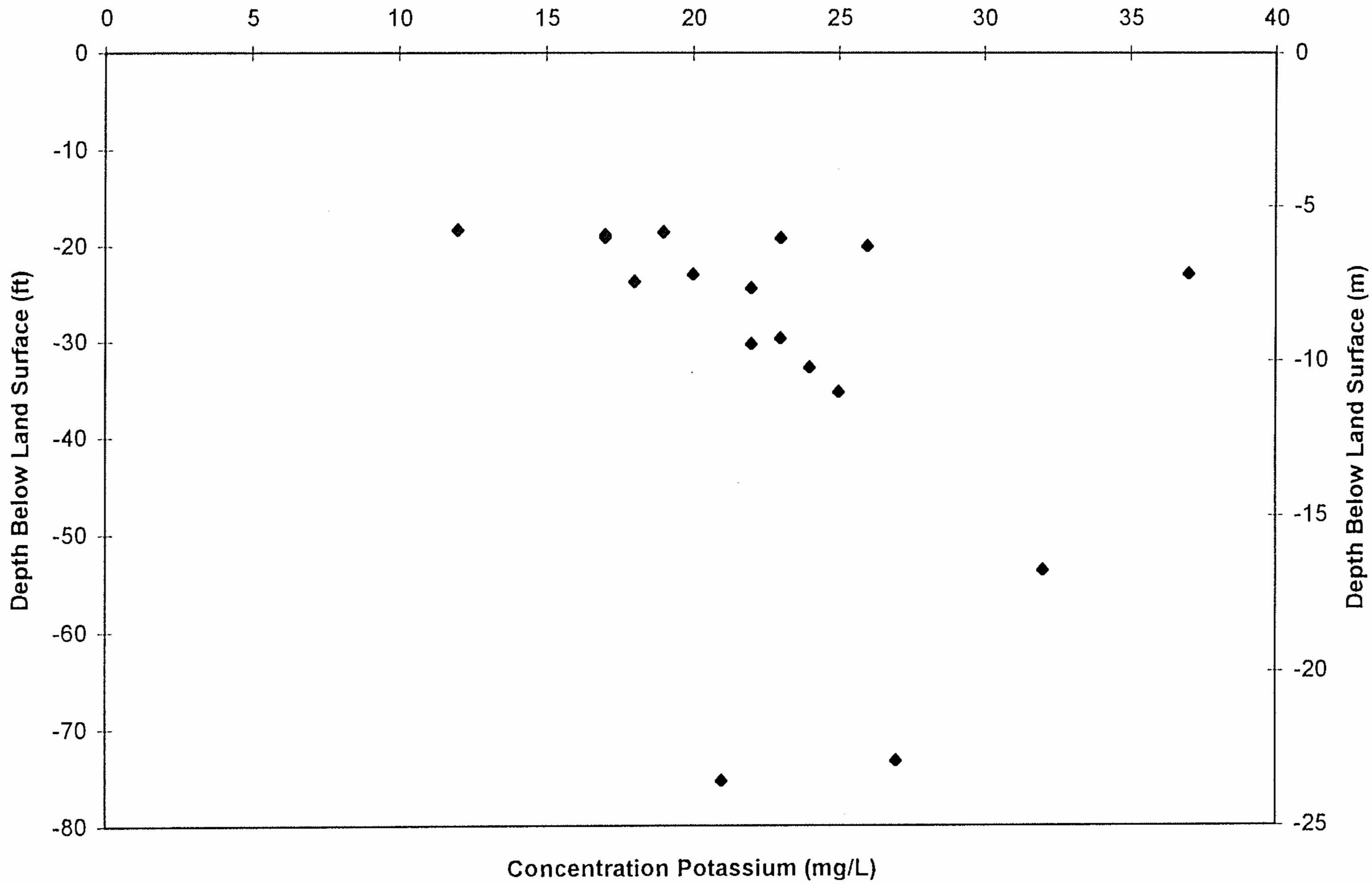


Figure 41 - Magnesium Concentrations of Ground Water

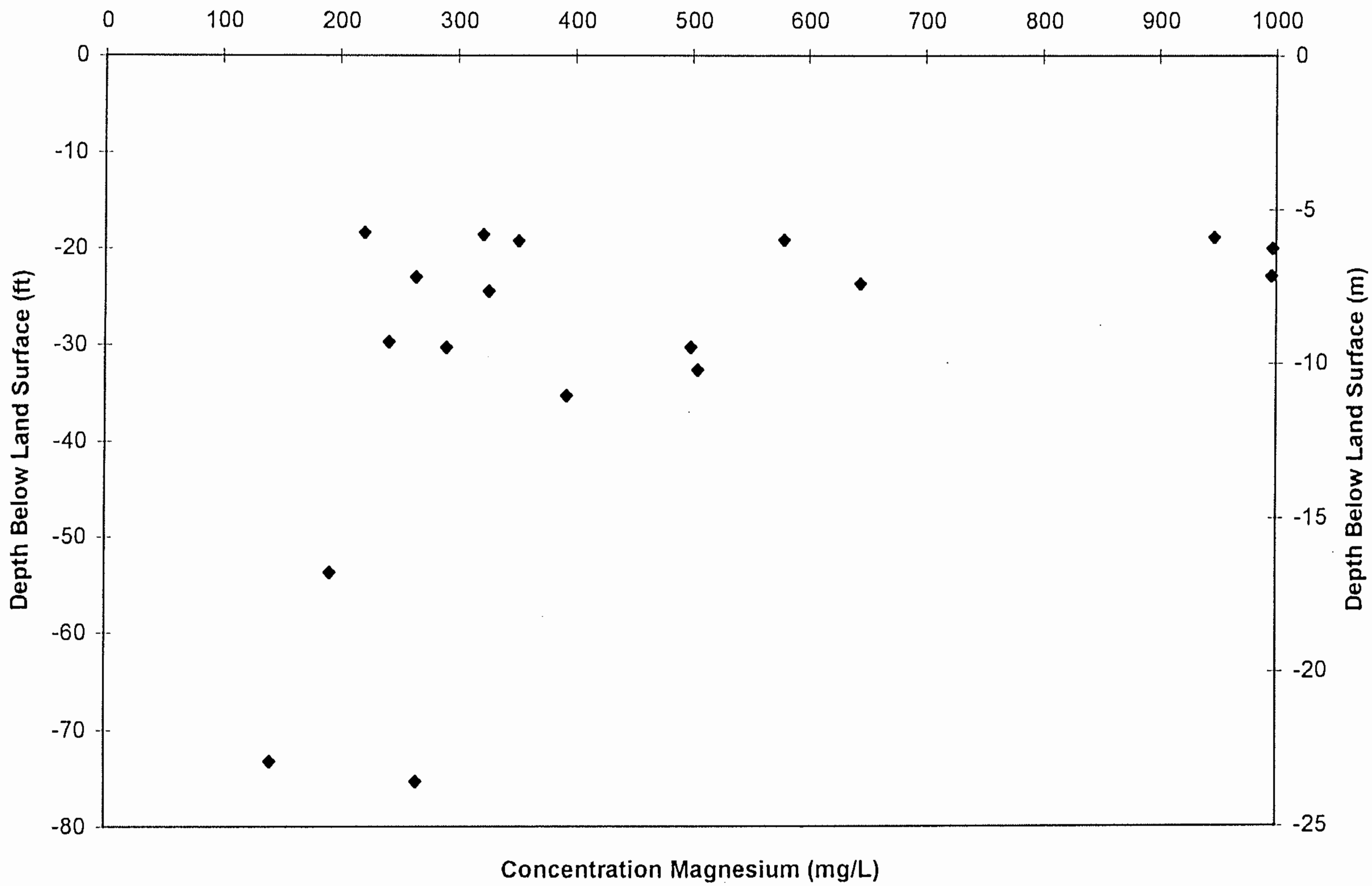


Figure 42 - Bicarbonate Concentraitons of Ground Water

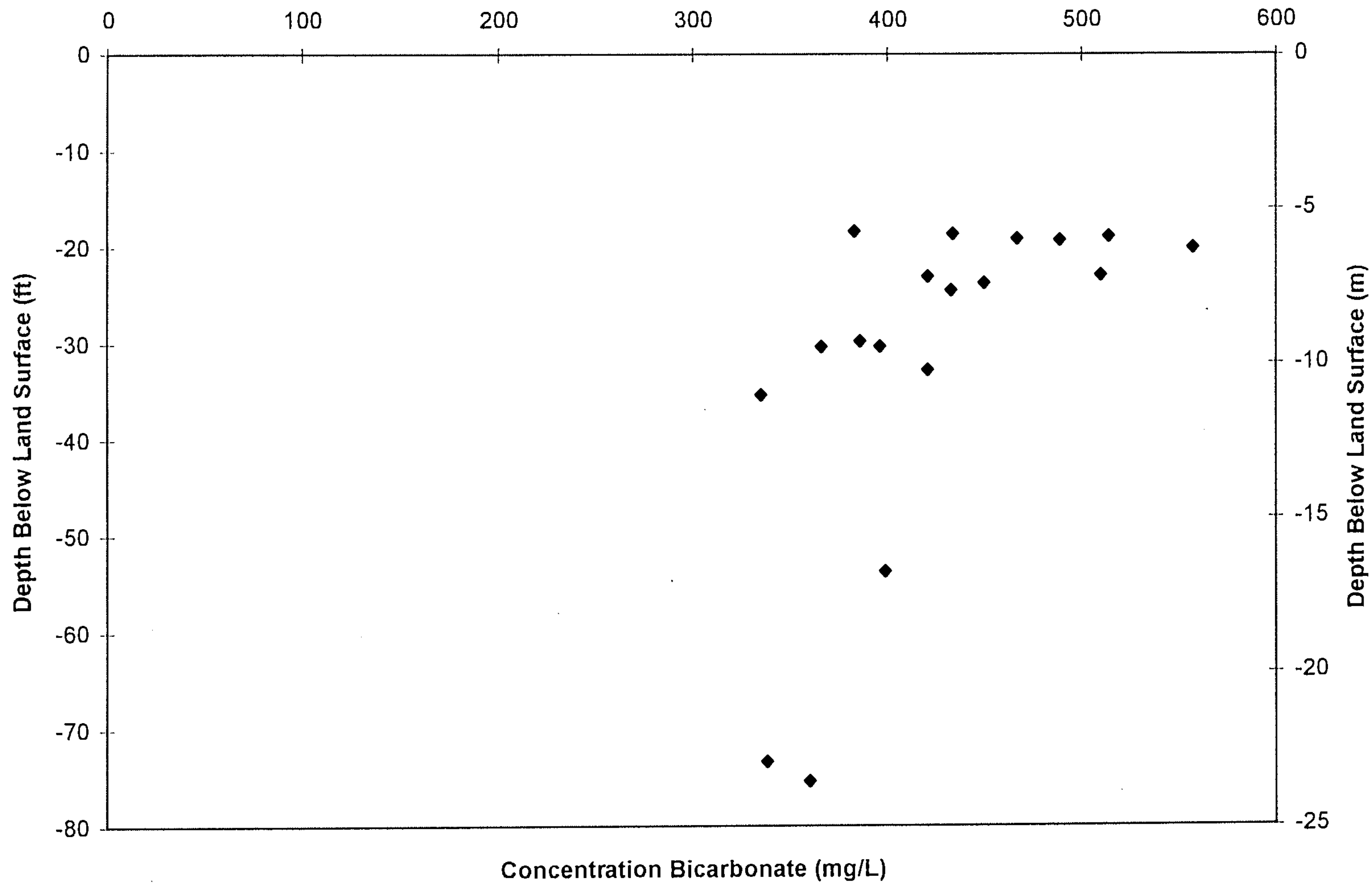


Figure 43 - Sulfate Concentrations of Ground Water

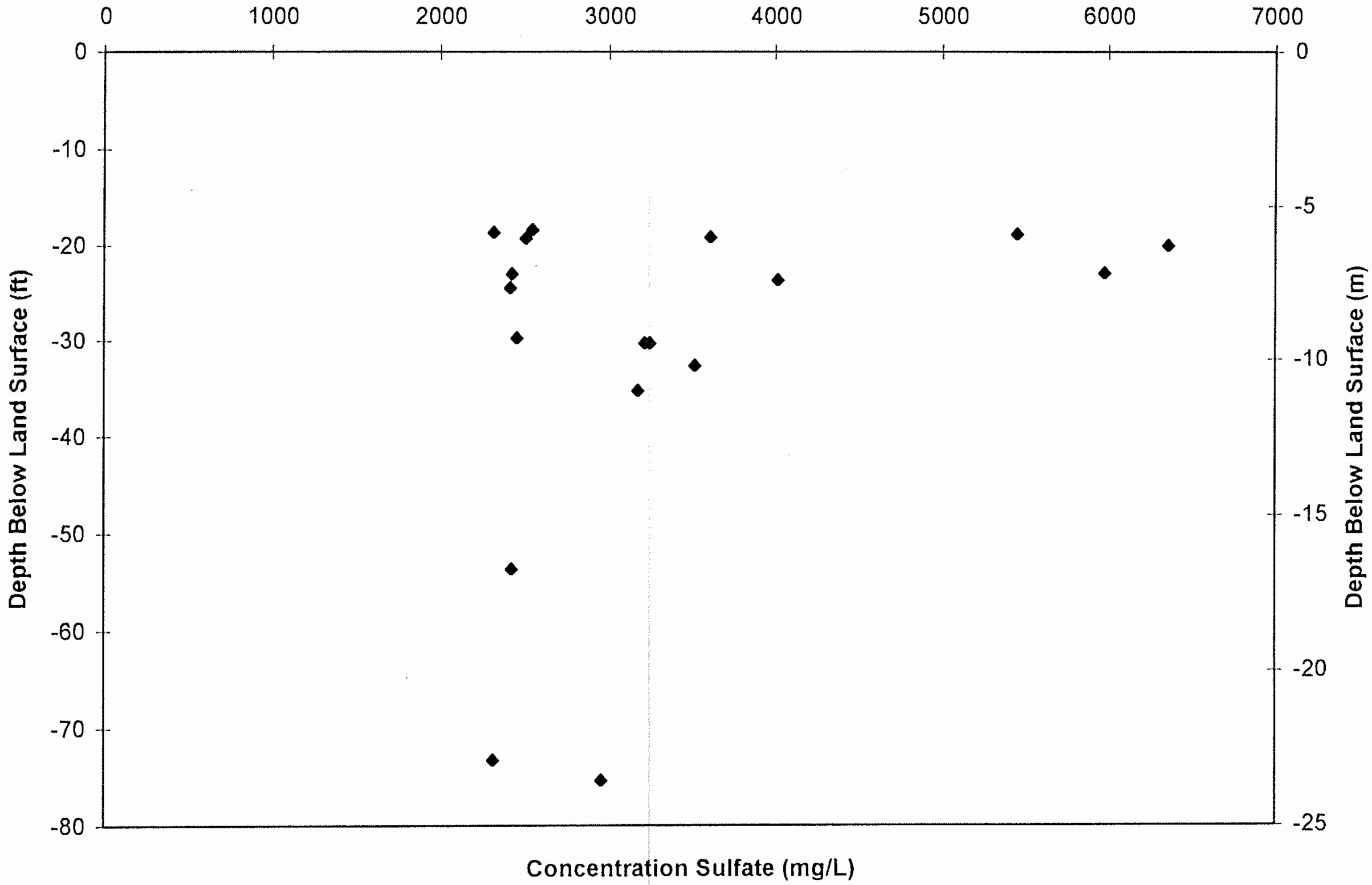
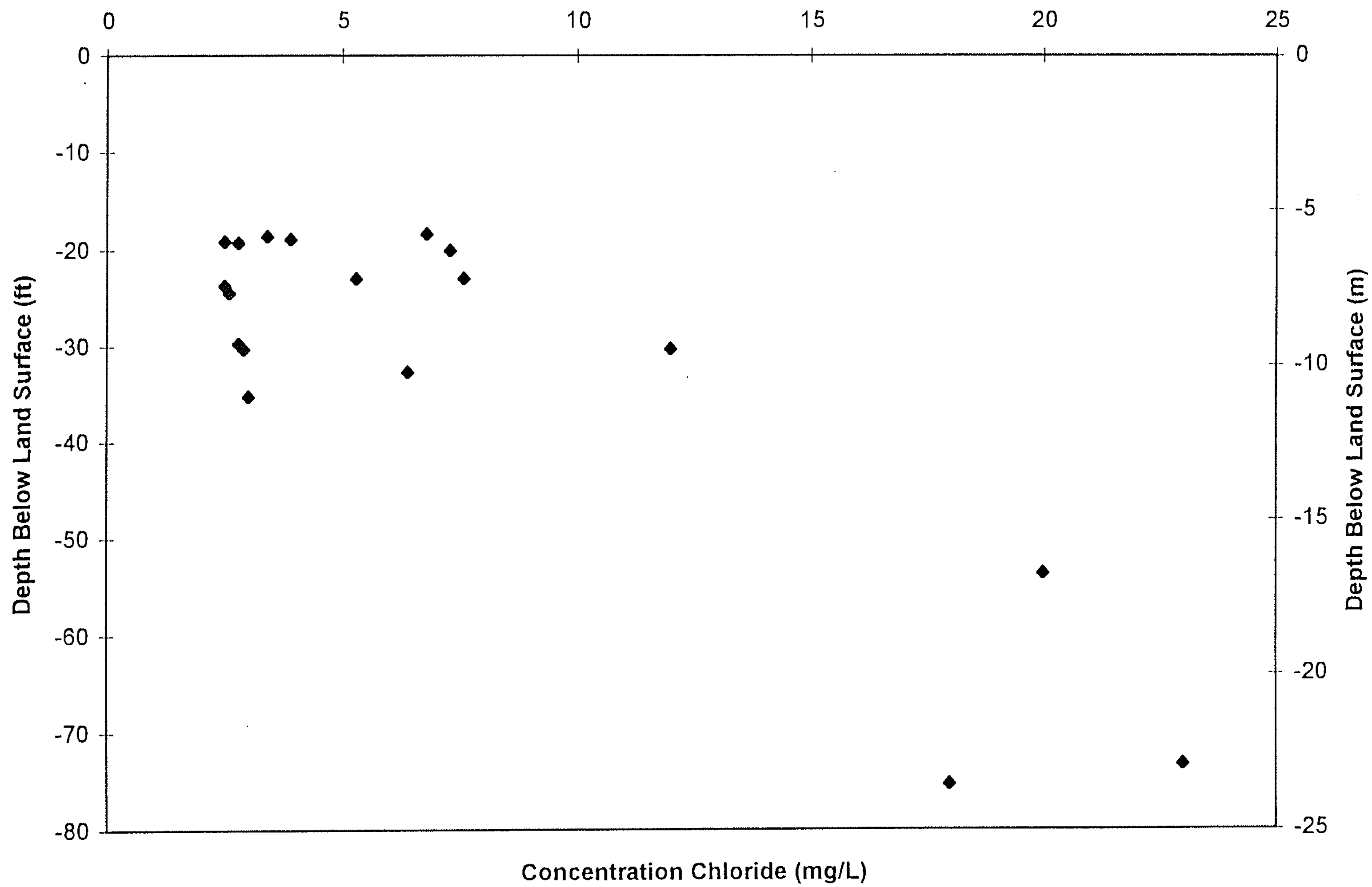


Figure 44 - Chloride Concentratons of Ground Water



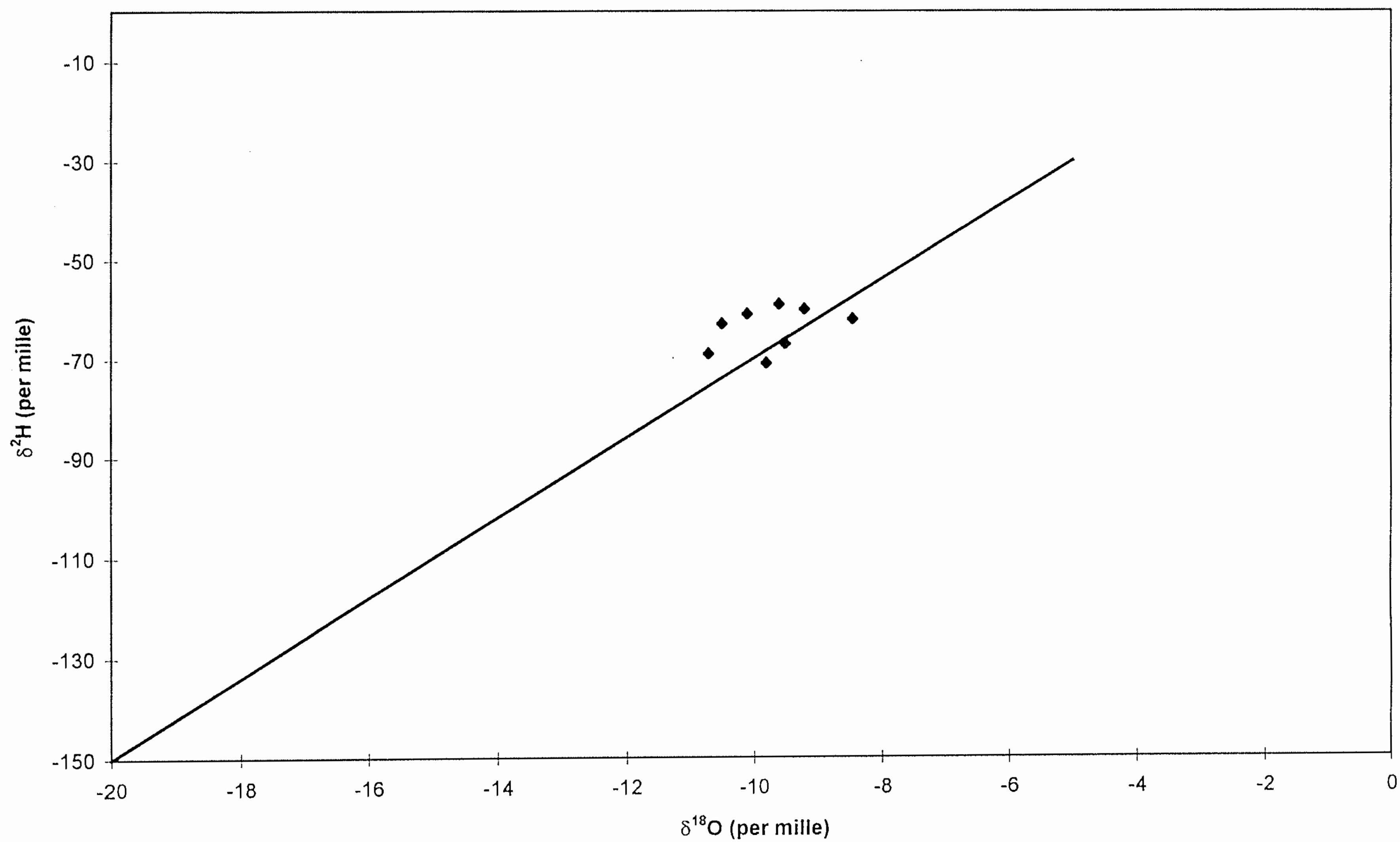
The southern nest of wells is in a topographic depression (slough) while the northern nest is topographically higher. The general direction of potential ground-water flow is to the south-southwest. The significantly higher concentration of sulfate in the shallow zone in the southern nest of wells may be a result of a local flow system.

The high concentrations of total dissolved solids and sulfate indicate that little flushing, if any, of the ground water is occurring. If significant flushing of the shallow ground water were occurring due to ground water moving laterally or vertically to discharge zones, lower concentrations of total dissolved solids and sulfates should be evident in the shallow ground water. This is in accordance with the results of Hendry et al. (1986). They concluded that no losses of sulfate were occurring at their study site in Canada, where the sulfate was redistributed locally but was not removed from the system.

$\delta^{18}O$ and $\delta^{2}H$ Data

Figure 45 is a plot of $\delta^{18}O$ versus $\delta^{2}H$ for 8 samples. All of the samples plot relatively close to the meteoric water line. However, a pattern is apparent. With the exception of well R20-93-15, which plots essentially on the meteoric water line, all other wells, for which isotopic analyses were made, and which are completed in the deep unweathered till and in the transition zone, plot above the meteoric water line. This may indicate H_2S exchange, CO_2 exchange or silicate hydration (Domenico and Schwartz, 1990). Two wells in the shallow zone that were sampled and analyzed for isotopes (R20-93-07 and R20-93-21) plot slightly below the meteoric water line. This may indicate evaporative concentration within the shallow ground water zone at this site. Hendry (1986) indicates that high concentrations of sulfate in the weathered till at their site cannot be attributed to evaporation because there is no enrichment of chloride in the porewater of the weathered till over that of the porewater in the nonweathered till. This is true for the Sioux Falls landfill site also where the chloride concentrations are actually lower in the weathered till than in the unweathered till. Hendry (1988) indicated that $\delta^{18}O$ and $\delta^{2}H$ data for the nonweathered till at their site does not indicate evaporative concentration but their isotopic data for the weathered till does indicate that evaporative concentration is occurring and may be a dominant mechanism of water removal from weathered till zones. Hendry (1988) plotted $\delta^{18}O$ and $\delta^{2}H$ data for the weathered till and nonweathered till at their site in Canada and performed regression analysis of these data. The equation for the standard meteoric water line is $\delta^{2}H = 8\ \delta^{18}O + 10$. Hendry's regression line for the nonweathered till produced an equation of $\delta^{2}H = 8.1\ \delta^{18}O + 7.4$ (r^2=0.96). The equation of the line for the weathered till at Hendry's site was $\delta^{2}H = 5.7\ \delta^{18}O - 44.1$ (r^2=0.95). The slope of 5.7 indicates evaporation from this zone. A similar analysis of the isotopic data from the Sioux Falls landfill, plus some additional isotopic data from Lincoln County, South Dakota (about 32 km; 20 miles to the south of the Sioux Falls landfill) yields similar lines (Iles et al., 1996). For the unweathered till, the equation is $\delta^{2}H = 8.34\ \delta^{18}O + 17.97$ (r^2=0.93). For the weathered till, the equation is $\delta^{2}H = 4.95\ \delta^{18}O - 21.05$ (r^2=0.83). The slope of 4.95 indicates evaporative enrichment in the weathered till zone.

Figure 45 - Isottope Ratios



Tritium and ^{14}C Data

Table 5 lists the tritium and ^{14}C concentrations of ground water from the various wells within the site. Tritium concentrations were determined for ground-water samples from 8 wells including wells in the shallow, fractured, weathered zone, the transition zone and the deeper unfractured, unweathered till. The results of the ground-water tritium analyses were used as a guide to determine which wells to sample and analyze the ground water for ^{14}C age determinations. Tritium concentrations ranged from -0.03 to 6.05 tritium unit (TU). A tritium concentration of 1 TU or less was assumed to indicate no recent addition of recharge. Wells with ground-water tritium concentrations of 1 TU or less were selected for ^{14}C age determination. Figure 46 shows a plot of tritium concentrations versus depth bls. Ground water in the upper weathered zone, above about 7.9 m (26 ft) bls has had recent addition of tritium. Ground water in the

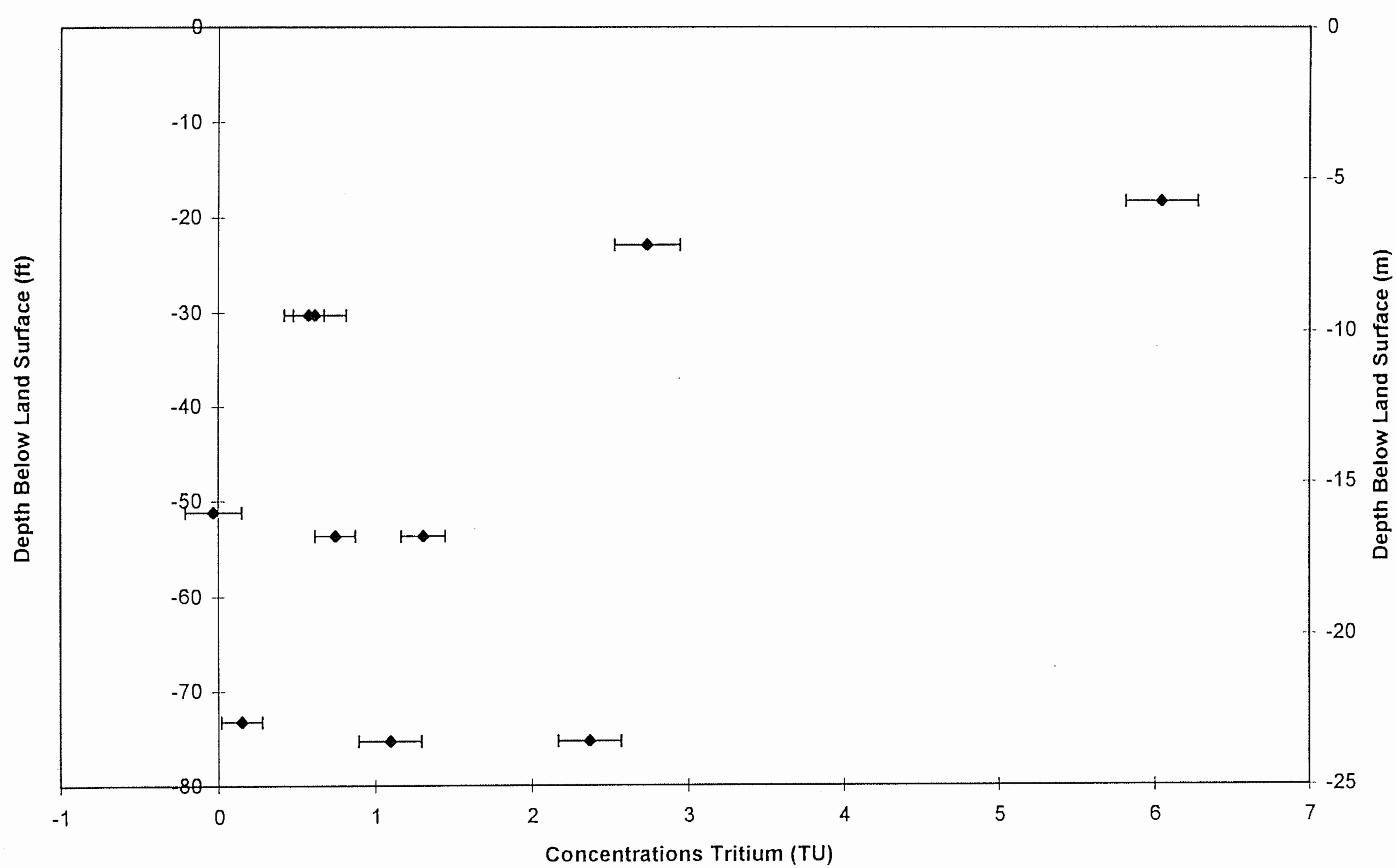
Table 5: Tritium, ^{14}C, $\delta^{18}O$ and $\delta^{2}H$ Data

Well #	Till Zone*	Date Tritium Samples Collected	Tritium (TU)	Date C^{14} Samples Collected	C^{14} Years BP	$\delta^{18}O$ (‰) Samples Collected 07/14/94	δD (‰) Samples Collected 07/14/94
R20-93-07	Shal	03/01/94	6.05			-9.8	-71
R20-93-21	Shal	03/01/94	2.74			-8.4	-62
R20-93-11	Tran	03/01/94	0.58	07/14/94	12,082	-9.2	-60
R20-93-16	Tran	03/01/94	0.62	07/14/94	9,299	-9.6	-59
R20-93-02	Deep	03/01/94	0.15	07/14/94	21,829	-10.7	-69
R20-93-03	Deep	03/01/94	1.31**	10/28/94	17,880	-10.1	-69
R20-93-03	Deep	06/30/94	0.75**				
R20-93-14	Deep	03/01/94	2.37**	10/28/94	10,933	-10.5	-63
R20-93-14	Deep	06/30/94	1.10**				
R20-93-15	Deep	03/08/94	-0.03	07/14/94	19,085	-9.5	-67

*Zones = Shallow Weathered (Shal), Transition Between Weathered and Unweathered (Tran), and Deep Unweathered (Deep)
**Well was resampled on June 30, 1994

transition zone, 6.3 to 12.2 m (22 to 40 ft) bls, and ground water in the unweathered zone, below about 12.2 m (40 ft) bls, had tritium concentrations that ranged from -0.03 to 2.37 TU. Ground

Figure 46 - Tritium Concentrations of Ground Water



water from wells R20-93-03 and R20-93-14 (15.9 and 22.6 m (52 and 74 ft) bls) had tritium concentrations of 1.31 and 2.37 TU. These wells were resampled in June 1994. The tritium concentrations for wells R20-93-03 and R20-93-14 at the time of resampling in June was 0.75 and 1.10 TU, respectively. It is proposed that the somewhat higher tritium concentrations in these wells, from the initial sampling, were a result of water moving down from the upper zone during well installation and completion. These wells recover very slowly. Every effort was made to develop the wells prior to sampling. However, some ground water from the shallow zone may have impacted these initial samples, and may still be impacting the data from well R20-93-14 to some extent. Another possible explanation is that ground water is moving to these depths naturally via downward vertical flow. There are three significant results that do not support this conclusion. First, tritium concentrations in the transition zone, at about 9.1 m (30 ft) bls, are below 1 TU. Secondly, ground water from the other wells at 15.2 and 22.0 m (50 and 72 ft) bls are -0.03 and 0.15 TU, respectively. Thirdly, the ^{14}C age determination for ground water from the wells clearly indicates a very old age for the water.

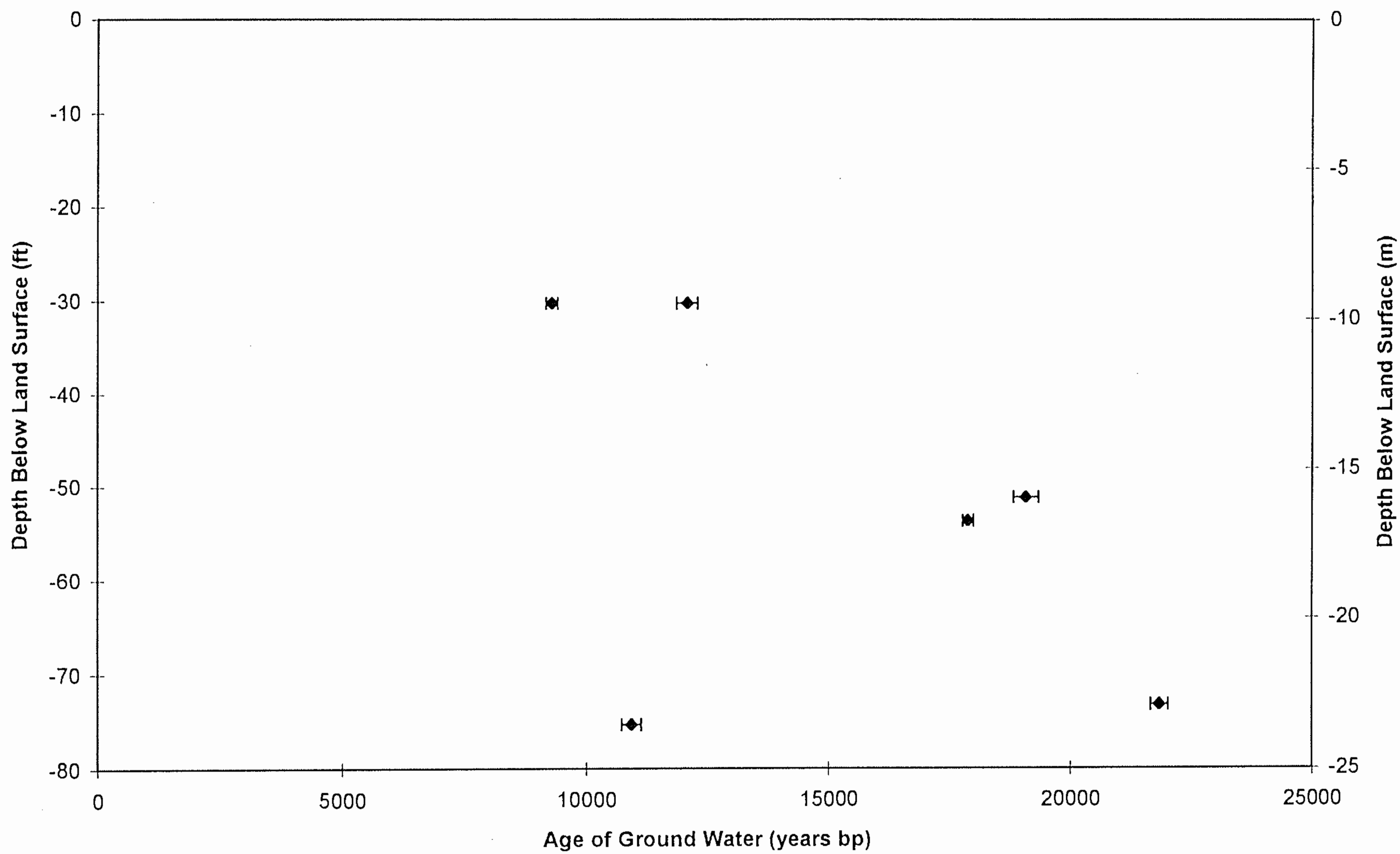
Carbon-14 age determinations were made for ground water from six wells; two wells in the transition zone at about 8.8 m (29 ft) bls, two wells in the unweathered till at about 15.2 and 15.8 m (50 and 52 ft) bls and two deeper wells at about 22.0 and 22.6 m (72 and 74 ft) bls. These data indicate increasing age of ground water with increasing depth bls, exclusive of the well at about 22.6 m (74 ft) (Figure 47). The age of the ground water in the transition zone ranged from about 9,300 years b.p. to about 12,100 years b.p.. In the wells at about 15.2 and 15.8 m (50 and 52 ft), the age of the ground water ranged from near 17,900 years b.p. to about 19,100 years b.p.. The ground-water age determinations from the wells at about 22.0 and 22.6 m (72 and 74 ft) had a wider range of about 10,900 years b.p. to about 21,800 years b.p.. The younger age at this depth was from ground water from well R20-93-14. This was a well that had an initial elevated tritium concentration. Even after resampling in June 1994, ground water from this well still had a tritium concentration of 1.10 TU. It is believed that this well is still showing an influence of ground water that moved down from shallower zones during the well installation process.

The ground water from well R20-93-14, and the other wells for which ^{14}C determinations were made, was still over 9,000 years old and is generally consistent with the age of the glacial sediments in the vicinity of the landfill. These data, in combination with the tritium data, indicate that there is no significant downward vertical movement of ground water within the till at this site.

Discussion

Till at the Sioux Falls landfill can be divided into three distinct zones including a highly fractured, weathered upper zone, extending to a depth of about 6.3 m (22 ft) below land surface, a transition zone from about 6.3 to 12.2 m (22 to 40 ft) below land surface, in which the fracture density decreases with depth, and an unfractured, unweathered zone below about 12.2 m (40ft) below land surface. An attempt was made to follow individual fractures from land surface to total depth as a new landfill trench was excavated. However, the upper zone was so highly fractured and weathered that this was not possible. Even in the transition zone, it was difficult to trace a

Figure 47 - ^{14}C Age Dates For Ground Water



single fracture for more than about two layers, about 1.2 m (4 ft). The fractures within the transition zone do extend vertically and decreasing fracture density with increasing depth is very apparent in this zone. Individual fractures in the transition zone narrow to a "v" where they terminate.

Vertical movement of water in the shallow, fractured, weathered till is occurring. Rapid response of the water table to precipitation events is evidence of this. The water table is generally from 0.6 to 4.6 m (2 to 15 ft) below land surface at the study site. The slightly tritiated water that was found at a depth of 6.3 m (22 ft) may have been emplaced at an earlier time when the water table was near that depth or it may be a result of mixing of tritiated and untritiated water in the fractures.

The quantification of lateral movement of water in the shallow, fractured, weathered till was not directly addressed in this investigation. However, observations of a very shallow water table within a few feet of 12.2 m (40 ft) deep trenches qualitatively indicates that little lateral movement is occurring. This empirical evidence is supported by the inorganic water chemistry, specifically the total dissolved solids and sulfate data. The sulfate and total dissolved solids concentrations in shallow till water indicate that little or no lateral flushing of the ground water in this zone is occurring. It is the opinion of the authors that a water balance study of the site would further support the interpretation of no significant lateral flow in the weathered till.

Evidence indicates that movement of ground water in the transition zone between the weathered and unweathered till is insignificant, even though fractures are present in the transition zone and a subdued response of water levels to precipitation events was observed. This interpretation is supported by the inorganic water quality, isotopic and ^{14}C age dating information, and hydraulic conductivity data. The rise of water levels in wells completed in this zone in response to precipitation events does not reflect the actual movement of water into this zone. Rather, it reflects an increase in pressure due to accumulation of precipitation (recharge) in the upper portions of fractures. Collectively, the data indicate that no significant amount of water is moving vertically downward from the weathered zone through the transition zone.

Ground-water movement through the unweathered till at this site is interpreted to be insignificant or nonexistent. This interpretation is supported by the inorganic water quality, isotopic and ^{14}C age dating information, hydraulic conductivity data, and unfractured nature of this zone in the till.

Three working hypotheses were presented early in this report. Of these, the third is supported by the results of this research. That hypothesis is that the major component of water dissipation from the till is by upward movement (dissipation by evapotranspiration). This is consistent with other research performed in South Dakota in similar sediments (Barari and Hedges, 1985; CENDAK, 1987; CENDAK, 1988: Cravens and Ruedisili, 1987). This is also consistent with most other contemporary research of a similar nature (Cherry et al., 1973; Grisak and Cherry, 1975; Hendry, 1988). The impact that the results of this study has on the issues of liners and monitoring is significant. Results will help guide decisions regarding the necessity for liners and regarding the suitability of conventional monitoring techniques at the landfill.

Combining the interpretations regarding water movement in the weathered till, the transition zone, and the unweathered till leads to the following conclusions related to the need for ground-water monitoring at the landfill. Little or no monitoring of the transition zone and unweathered till is needed. This is because of the lack of water movement through these zones. Monitoring of water in the weathered till is probably warranted until further studies effectively quantify lateral ground-water movement, even though little lateral movement is interpreted to occur in this zone.

The findings of this research are consistent with the conclusions arrived at by the South Dakota Geological Survey (Barari and Hedges, 1985). Their conclusions were that the major portion of water recharged to the weathered till is dissipated by upward movement, that ground-water movement through the unweathered clayey till is insignificant, and that lateral ground-water movement in weathered till is small under natural conditions.

Conclusions and Recommendations

- Till at the Sioux Falls landfill is greatly fractured and weathered to about 6.3 m (22 ft) below land surface and somewhat fractured and weathered to about 12.2 m (40 ft) below land surface.

- Fracture density and spacing decrease with increasing depth.

- Below about 12.2 m (40 ft) below land surface, the till is unweathered and unfractured.

- Fracture surfaces are coated with mineralization including gypsum crystals.

- Hydrographs indicate rapid recharge to the water table in the weathered till, and a more subdued response in the transition zone, which is presumed to be a pressure response rather actual movement of water into this zone.

- Hydraulic conductivity in weathered till ranges from about 10^{-10} to 10^{-7} m/s, as determined using slug test methods..

- Hydraulic conductivity in the transition zone and in the unweathered till ranges from 10^{-11} to 10^{-10} m/s, as determined using slug test methods.

- Analysis of Shelby-tube cores indicates hydraulic conductivity values that are one to two orders of magnitude lower than hydraulic conductivity values determined by field slug-test methods.

- Sulfate and total dissolved solids concentrations are evidence that indicate that if any lateral flow is occurring in the weathered till that it is very slow and very local.

- Tritium and ^{14}C data indicate that ground water in the transition zone and in the deeper unweathered till are about the same age as glacial deposits in the vicinity of the landfill. The shallow, weathered zone has had recent additions of water via rapid infiltration into the fractures.

- Vertical downward flow is insignificant in the transition zone and in the deeper unweathered till.

- The primary mode of ground-water discharge is via evapotranspiration.

- There is no need to install a bottom liner in this type of hydrogeologic setting assuming that the bottom of the excavated waste disposal trench is in the unweathered till.

- Side-wall liners in the unweathered till, and in the transition zone between the unweathered till and the highly weathered near-surface till, will provide little to no protection beyond what nature is presently providing.

- A side-wall liner is probably not needed in the highly weathered near-surface till but current regulatory concerns may dictate the use of such a liner in this zone until lateral ground-water movement can be quantified.

- Additional research is needed to define horizontal ground-water flow in the weathered till.

- Additional research is needed to quantify the vertical upward movement of ground-water from the till via evapotranspiration.

- Finally, if additional quantification of water discharge from clayey till proves that the dissipation is predominantly upward and the lateral movement is insignificant, then the need for leachate collection systems as a safeguard against contaminant movement has to be evaluated.

References Cited

Bagchi, A., 1990, Design, construction and monitoring of sanitary landfill. John Wiley and Sons, New York. Chpt. 2, 9.7, 9.8 and 10.

Barari, A., L.S. Hedges, 1985, Movement of water in glacial till. International Association of Hydrogeologists Memories, hydrogeology of rocks of low permeability, v. XVII, part 1 proceedings, Tucson, Arizona, Congress, United States of America, pp. 129-136.

Barari,. A., D. Iles and C. Cowman, 1992, Ground-water movement in clayey till. 37th Annual Midwest Ground Water Conference, Program with Abstracts, p. 18.

Bouwer, H. and Rice, R.C., 1976, A slug test for determining hydraulic conductivity of unconfined aquifers with completely or partially penetrating wells. Water Resources Research, v. 12, pp. 423-428.

CENDAK, 1987, Comparison of irrigated land in southern Alberta, Canada, with CENDAK area, South Dakota. Compiled for the CENDAK Drainage Steering Committee, by the South Dakota Department of Water and Natural Resources, Division of Geological Survey, Vermillion, SD.

CENDAK, 1988, Concluding report of CENDAK drainage investigations. CENDAK Drainage Steering Committee. United States Bureau of Reclamation, Missouri Regional Office, Billings, MT.

Cherry, J.A., G.E. Grisak and W.E. Clister, 1973, Hydrogeologic studies at a subsurface radioactive-waste-management site in west-central Canada. In: International Symposium on Underground Waste Management and Artificial Recharge, AAPS-USGS. Edited by J. Braunstein, September 26-30, v. 1, pp. 436-467.

Cravens, S.J. and L.C. Ruedisili, 1987, Water movement in till of east-central South Dakota. Ground Water, v. 25, no. 5, pp. 555-561.

Daniels, D.P. , S.J. Fritz and D.I. Leap, 1991, Estimating recharge rates through unsaturated glacial till by tritium tracing. Ground Water, v. 29, no. 1, pp. 26-34.

D'Astous, A.Y., W.W. Ruland, J.R.G. Bruce, J.A. Cherry and R.W. Gillham, 1989, Fracture effects in the shallow groundwater zone in weathered Sarina-area clay. Can, Geotech, J., v. 26, pp. 43-56.

Davis, R.K., D.L. Iles and V.R. Schaefer, 1993, Adequacy of ground water monitoring requirements for facilities constructed in clayey till. Geological Society of America, Abstracts with programs, v. 25, no. 6, p. A425.

Davis, R.K., D.L. Iles and V.R. Schaefer, 1995, Ground water movement in fractured clayey till at the Runge Landfill, Sioux Falls, South Dakota. Geological Society of America, Abstracts with Programs, v. 27, no. 3, p. A46.

Desaulniers, D.E., J.A. Cherry and P. Fritz, 1981, Origin, age and movement of pore water in argillaceous Quaternary deposits at four sites in southwestern Ontario. Journal of Hydrology, v. 50, pp. 231-257.

Domenico P. A. and F.W. Schwartz, 1990, Physical and chemical hydrogeology. John Wiley and Sons, Inc., pp. 465-467.

Federal Register, 1988, Proposed RCRA subtitle D regulations 40 CFR, Part 258, criteria for municipal solid waste landfills, v. 53, no. 168, pp. 33405-33422.

Fredericia, J., 1993, Fractures in clayey till in Denmark: occurrence, genesis and hydrological significance. Geological Society of America, Abstracts with Program, v. 25, no. 6, p. 426.

Freeze, R.A. and J.A. Cherry, 1979, Groundwater. Prentice-Hall, Inc. Englewood Cliffs, NJ p. 72.

Grisak, G.E., 1975, The fracture porosity of glacial till. Can. J. Earth Sci., v. 12, pp. 513-515

Grisak, G.E. and Cherry, J.A., 1975, Hydrologic characteristics and response of fractured till and clay confining a shallow aquifer. Canadian Geotechnical Journal, v. 12, no. 1 pp. 23-43.

Hendry, M.J., 1982, Hydraulic conductivity of a glacial till in Alberta. Groundwater, v. 20, no. 2, pp. 162-169.

Hendry, M.J., 1983, Groundwater recharge through heavy-textured soil. Journal of Hydrology, v. 63, pp. 201-209.

Hendry, M.J., J.A. Cherry and E.I. Wallick, 1986, Origin and distribution of sulfate in fractured till in southern Alberta, Canada. Water Resources Research, v. 22, no. 1, pp. 45-61.

Hendry, M.J., 1988, Hydrogeology of clay till in a prairie region Canada. Ground Water, v. 26, no. 5, pp. 607-614.

Hvorslev, M.J., 1951, Time lag and soil permeability in groundwater observations. Waterways Experiment Station Bulletin 36, U.S. Army Corps of Engineers, Vicksburg, MS.

Iles, D.L., 1989, Investigation of the Sioux Falls sanitary landfill. South Dakota Department of Water and Natural Resources, Division of Geological Survey, Open-File Report 58-UR, 69p.

Iles, D.L., A. Barari, and L.S. Hedges, 1996, Ground water movement within till in Lincoln County, South Dakota. South Dakota Department of Environment and Natural Resources, Geological Survey Program Open-File Report 4-BAS, 82p.

Jones, L., 1993, A comparison of pumping and slug tests for estimating the hydraulic conductivity of weathered Wisconsin age till in Iowa. Ground Water, v. 31, no. 6, pp. 896-904.

Jones, L., T. Lemar and C. Tsai, 1992, Results of two pumping tests in Wisconsin age weathered till in Iowa. Ground Water, v. 30, no. 4, pp. 529-538.

Kortran, J.M., 1995, Effects of fractures and sample size on the hydraulic conductivity of glacial till. M.S. Thesis, Department of Civil Engineering, South Dakota State University, 109p.

Lindgren, R.J. and C.A. Niehus, 1992, Water resources of Minnehaha County, South Dakota. U.S. Geological Survey, Water-Resources Investigations Report 91-4101, 80p.

McKay, L.D., R.W. Gillham and J.A. Cherry, 1993, Field experiments in fractured clay till, 2. solute and colloid transport. Water Resources research, v. 29, no. 12, pp. 3879-3890.

Prudic, D.E., 1982, Hydraulic conductivity of a fine-grained till, Cattaraugus County, New York. Groundwater, v. 20, no. 2, pp. 194-204.

Prudic, D.E., 1986, Ground-water hydrology and subsurface migration of radionuclides at a commercial radioactive-waste burial site, West Valley, Cattaraugus County, New York. U.S. Geological Survey Professional Paper 1325, 83p.

Simpkins, W.W. and T.B. Parkin, 1993, Hydrogeology and redox geochemistry of CH_4 in a late Wisconsin till and loess sequence in central Iowa. Water Resources Research, v. 29, no. 11, pp. 3643-3657.

TCT, 1988, Subsurface exploration program, proposed sanitary land fill southwest of Sioux Falls, South Dakota, logs of boreholes. On file with the City of Sioux Falls, Health Department.

TCT, 1991, Potential liner evaluation Runge Landfill, Sioux Falls, South Dakota. On file with the City of Sioux Falls, Health Department.

TCT, 1992, Monitoring well installation and groundwater analysis Runge Landfill, Sioux Falls, South Dakota. Sioux Falls Health Department Sioux Falls, South Dakota.

Tomhave, D.W., 1994, Geology of Minnehaha County, South Dakota. South Dakota Department of Environment and Natural Resources, Division of Geological Survey, Bulletin 37, 53p.

Appendix A

Logs of Boreholes

County: MINNEHAHA
Legal Location: NE NW SE SW sec. 35, T. 101 N., R. 51 W.
Latitude: 43.3007
Land Owner: SIOUX FALLS
Project: RUNGE LANDFILL (GRPEP)
Drilling Company: SDGS
Driller: D. IVERSON
Geologist: D. ILES
Date Drilled: 05-25-1993
Ground Surface Elevation: 1541.01 I
Total Drill Hole Depth: 50.0
USGS Hydrologic Unit Code: 10170203
Electric Log Information:
Spontaneous Potential:
Natural Gamma:
Samples: X

Location: 101N-51W-35CDBA 1
Longitude: 96.5523
Driller's Log:
Geologist's Log: X
Drilling Method: HOLLOWSTEM
Test Hole Number: R20-93-01
Single Point Resistivity:
Extra:

After completion of drilling, the hole was pressure grouted from bottom to top with bentonite grout. This hole was used to repeatedly locate the same X-Y coordinate as a trench was excavated for the landfill.

1541.01 - 1540.81	0 - 0.2	Clay, black, silty, pebbly, sandy
1540.81 - 1539.81	0.2 - 1.2	Clay, yellowish-brown, silty, sandy, pebbly
1539.81 - 1539.01	1.2 - 2.0	Clay, yellowish-brown with some gray, silty, sandy, pebbly
1539.01 - 1538.61	2.0 - 2.4	Sand, gray-brown, medium, silty
1538.61 - 1537.71	2.4 - 3.3	Clay, gray with some reddish-brown, very silty; some fine sand
1537.71 - 1537.01	3.3 - 4.0	Sand, reddish-brown, fine to medium
1537.01 - 1536.91	4.0 - 4.1	Silt, gray, sandy
1536.91 - 1536.81	4.1 - 4.2	Sand, yellowish-brown, fine
1536.81 - 1536.51	4.2 - 4.5	Silt, gray, sandy
1536.51 - 1536.31	4.5 - 4.7	Sand, yellowish-brown, fine
1536.31 - 1535.91	4.7 - 5.1	Silt, gray with some yellowish-brown, sandy, clayey
1535.91 - 1535.81	5.1 - 5.2	Sand, yellowish-brown, fine
1535.81 - 1535.51	5.2 - 5.5	Silt, gray with some yellowish-brown, very sandy
1535.51 - 1535.21	5.5 - 5.8	Clay, gray, silty, sandy
1535.21 - 1535.11	5.8 - 5.9	Sand, yellowish-brown, fine
1535.11 - 1535.01	5.9 - 6.0	Clay, yellowish-brown with some gray, silty, sandy
1535.01 - 1533.31	6.0 - 7.7	Clay, yellowish-brown, silty, sandy, pebbly
1533.31 - 1533.01	7.7 - 8.0	Unknown; no sample recovery
1533.01 - 1532.11	8.0 - 8.9	Clay, yellowish-brown, silty, pebbly, very sandy
1532.11 - 1531.01	8.9 - 10.0	Unknown; no sample recovery
1531.01 - 1527.01	10.0 - 14.0	Clay, yellowish-brown with some gray, silty, sandy, pebbly; some black organic-like material
1527.01 - 1525.01	14.0 - 16.0	Unknown; no sample recovery, the lead auger became plugged
1525.01 - 1523.91	16.0 - 17.1	Clay, greenish-brown, pebbly, slightly sandy, very silty
1523.91 - 1521.01	17.1 - 20.0	Clay, greenish-brown with some gray, sandy, pebbly; unoxidized sand seam at 17.7 feet
1521.01 - 1517.01	20.0 - 24.0	Clay, gray with some brown, silty, sandy, pebbly; horizontal and vertical fractures evident with mineralization
1517.01 - 1515.01	24.0 - 26.0	Clay, gray and brown, silty, sandy, pebbly; plastic-like; very fractured
1515.01 - 1513.01	26.0 - 28.0	Clay, gray, silty, sandy, pebbly; plastic-like; a single oxidized fracture was observed
1513.01 - 1511.01	28.0 - 30.0	Clay, gray, silty, sandy, pebbly; plastic-like; no fractures
1511.01 - 1509.01	30.0 - 32.0	Clay, gray, silty, sandy, pebbly; plastic-like; two fractures containing reddish-brown sand and silt were observed

1509.01 - 1507.51	32.0 - 33.5	Clay, gray, silty, sandy, pebbly; plastic-like; a few fractures were observed
1507.51 - 1507.01	33.5 - 34.0	Clay, gray, very silty; no fractures
1507.01 - 1505.01	34.0 - 36.0	Clay, gray, silty, sandy, pebbly; no fractures
1505.01 - 1503.01	36.0 - 38.0	Clay, gray, sandy, pebbly, very silty; no fractures
1503.01 - 1499.31	38.0 - 41.7	Clay, gray, silty, sandy, pebbly; no fractures
1499.31 - 1499.01	41.7 - 42.0	Unknown; no sample recovery
1499.01 - 1491.01	42.0 - 50.0	Clay, gray, silty, sandy, pebbly, very sandy from 43.4 to 43.6 feet; two thin horizontal unoxidized sand seams between 44 and 46 feet; less silty between 46 and 48 feet; no fractures

Continuous split-spoon samples were collected from this hole except where noted otherwise.

County: MINNEHAHA
Location: 101N-51W-35CCBD 1
Legal Location: SE NW SW SW sec. 35, T. 101 N., R. 51 W.
Latitude: 43.3008
Longitude: 96.5529
Land Owner: SIOUX FALLS
Project: RUNGE LANDFILL (GRPEP)
Drilling Company: SDGS
Driller: D. IVERSON
Driller's Log:
Geologist: D. ILES
Geologist's Log: X
Date Drilled: 05-26-1993
Drilling Method: HOLLOWSTEM
Ground Surface Elevation: 1544.53 I
Total Drill Hole Depth: 74.0
Test Hole Number: R20-93-02
Water Rights Well:
SDGS Well Name: R20-93-02
Other Well Name:
Basin: BIG SIOUX
Aquifer: TILL
Management Unit:
Screen Type: PVC, MFG., 0.010 SLOT, FLUSH
Screen Length: 5.3
Casing Type: PVC, SCH. 40, FLUSH
Casing Diameter: 2.0
Casing Top Elevation: 1545.93 I
Casing Stick-up: 1.40
Total Casing and Screen: 73.2
Well Maintenance Date:
USGS Hydrologic Unit Code: 10170203
Electric Log Information:
Spontaneous Potential:
Single Point Resistivity:
Natural Gamma:
Extra:
Samples: X

Well centralizers: 27, 47, and 67 feet. Filter pack (0.65-0.75 mm quartz sand): 74-63 feet. Bentonite grout 63-2.5 feet. Cement: 2.5-0 feet. Steel well protector. Leveling of cuttings added 0.6 feet to ground surface.

1544.53 - 1543.63	0 - 0.9	Clay, yellowish-brown, silty, sandy, pebbly
1543.63 - 1543.53	0.9 - 1.0	Sand, brown, medium to very coarse; with some grass at base
1543.53 - 1542.53	1.0 - 2.0	Clay, black, silty
1542.53 - 1541.73	2.0 - 2.8	Clay, yellowish-brown with some gray mottling, silty
1541.73 - 1540.53	2.8 - 4.0	Sand, yellowish-brown and gray mottled, fine to medium, silty, clayey; with some fine to coarse gravel
1540.53 - 1536.53	4.0 - 8.0	Clay, yellowish-brown with some gray mottling, silty, sandy, pebbly; a horizontal sand seam at 6.2 feet; fractures evident
1536.53 - 1534.53	8.0 - 10.0	Unknown; no recovery, the lead auger became plugged
1534.53 - 1532.53	10.0 - 12.0	Clay, greenish-brown and gray mottled, silty, pebbly, very sandy; with a horizontal sand filled fracture
1532.53 - 1530.53	12.0 - 14.0	Clay, greenish-gray and brown mottled, silty, sandy, pebbly; there was only 0.7 feet of recovery in this interval; the lead auger became plugged

1530.53 - 1528.53	14.0 - 16.0	Clay, greenish-gray with some brown mottling, silty, sandy, pebbly; with an approximately 2-inch diameter rock in the split spoon
1528.53 - 1526.03	16.0 - 18.5	Clay, greenish-gray and brown mottled, silty, sandy, pebbly; dark-brown and reddish-brown oxidation along vertical fractures
1526.03 - 1525.73	18.5 - 18.8	Silt, yellowish-brown with some gray, sandy
1525.73 - 1525.23	18.8 - 19.3	Clay, gray and brown mottled, silty, sandy, pebbly
1525.23 - 1524.53	19.3 - 20.0	Unknown; no sample recovery
1524.53 - 1522.93	20.0 - 21.6	Clay, gray, silty, sandy, pebbly; very stiff
1522.93 - 1522.53	21.6 - 22.0	Clay, greenish-gray, and brown mottled, silty, sandy, pebbly; with a horizontal fracture with many small gypsum crystals
1522.53 - 1520.53	22.0 - 24.0	Clay, yellowish-brown and greenish-gray mottled, silty, sandy, pebbly; with three horizontal fractures with sand and relatively large gypsum crystals; also several vertical unoxidized fractures
1520.53 - 1520.33	24.0 - 24.2	Sand, brown, medium to very coarse
1520.33 - 1518.53	24.2 - 26.0	Clay, yellowish-brown, silty, sandy, pebbly; this whole interval contained a vertical fracture with relatively large gypsum crystals
1518.53 - 1516.53	26.0 - 28.0	Clay, gray with some brown, silty, sandy, pebbly; with a vertical unoxidized fracture
1516.53 - 1514.53	28.0 - 30.0	Clay, gray with some brown, sandy, pebbly, very silty; with some vertical oxidized fractures; also some thin unoxidized fractures in an oxidized matrix
1514.53 - 1493.43	30.0 - 51.1	Clay, gray, silty, sandy, pebbly; plastic-like; a horizontal reddish-brown sand seam at 30.6 feet; horizontal gray silt seams at 44.5, 44.6 and 44.9 feet
1493.43 - 1492.83	51.1 - 51.7	Silt, gray, clayey, slightly sandy
1492.83 - 1478.33	51.7 - 66.2	Clay, gray, silty, sandy, pebbly; plastic-like; a horizontal fine to coarse sand seam at 52.2 feet; an approximately 2-inch diameter rock at 56.6 feet; a horizontal coarse sand seam at 61.8 feet; horizontal silt seams at 65.3 and 66.2 feet
1478.33 - 1477.33	66.2 - 67.2	Clay, gray, silty, sandy, pebbly; a horizontal sand seam at 66.5 feet
1477.33 - 1477.03	67.2 - 67.5	Silt, gray, clayey, very sandy
1477.03 - 1474.53	67.5 - 70.0	Clay, gray, silty, sandy, pebbly; a horizontal sand seam at 67.7 feet
1474.53 - 1470.53	70.0 - 74.0	Unknown; shelby-tube samples taken from 70 to 72 and 72 to 74 feet; sediment in the bottoms of the shelby tubes appeared to be a silty, sandy, pebbly, gray clay

Continuous split-spoon samples were collected from this hole except where noted otherwise. Shelby-tube samples were collected from 70-74 feet, left in the tubes, sealed, and transported to South Dakota State University for analysis.

County: MINNEHAHA
Location: 101N-51W-35CCBD 2
Legal Location: SE NW SW SW sec. 35, T. 101 N., R. 51 W.
Latitude: 43.3008
Longitude: 96.5529
Land Owner: SIOUX FALLS
Project: RUNGE LANDFILL (GRPEP)
Drilling Company: SDGS
Driller: D. IVERSON
Driller's Log:
Geologist: D. ILES
Geologist's Log: X
Date Drilled: 05-27-1993
Drilling Method: HOLLOWSTEM
Ground Surface Elevation: 1544.30 I
Total Drill Hole Depth: 52.0
Test Hole Number: R20-93-03
Water Rights Well:
SDGS Well Name: R20-93-03
Other Well Name:
Basin: BIG SIOUX
Aquifer: TILL
Management Unit:

Screen Type: PVC, MFG., 0.010 SLOT, FLUSH — Screen Length: 5.3
Casing Type: PVC, SCH. 40, FLUSH — Casing Diameter: 2.0
Casing Top Elevation: 1545.55 I
Casing Stick-up: 1.25 — Total Casing and Screen: 53.6
Well Maintenance Date:
USGS Hydrologic Unit Code: 10170203
Electric Log Information:
Spontaneous Potential: — Single Point Resistivity:
Natural Gamma: — Extra:
Samples:

Casing installed through inside of auger. Filter pack (0.65-0.75 mm quartz sand): 52-45 feet. Bentonite grout: 45-2.5 feet. Cement: 2.5-0 feet. Steel well protector. Leveling of cuttings added 0.8 feet to ground surface.

1544.30 - 1538.30	0 - 6.0	Clay, yellowish-brown, silty, sandy, pebbly
1538.30 - 1537.80	6.0 - 6.5	Sand, yellowish-brown, fine to medium; with some fine to coarse gravel
1537.80 - 1537.30	6.5 - 7.0	Clay, yellowish-brown, silty, sandy, pebbly; with some rocks
1537.30 - 1530.30	7.0 - 14.0	Clay, yellowish-brown, silty, sandy, pebbly
1530.30 - 1528.30	14.0 - 16.0	Clay, yellowish-brown, sandy, pebbly, siltier than interval from 7 to 14 feet
1528.30 - 1520.30	16.0 - 24.0	Clay, yellowish-brown, silty, sandy, pebbly
1520.30 - 1517.70	24.0 - 26.6	Clay, yellowish-brown and gray mottled, silty, sandy, pebbly; unoxidized vertical fracture with large gypsum crystals
1517.70 - 1516.30	26.6 - 28.0	Clay, gray, silty, sandy, pebbly; some oxidation along fractures; an unoxidized horizontal sand seam with large gypsum crystals at 27.7 feet
1516.30 - 1496.30	28.0 - 48.0	Clay, gray, silty, sandy, pebbly
1496.30 - 1492.30	48.0 - 52.0	Unknown; shelby-tube samples taken from 48 to 50 and 50 to 52 feet; sediment in the bottom of the shelby tube was similar to the interval from 28-48 feet

Split-spoon samples were collected from 24-28 feet. Shelby-tube samples were collected from 48-52 feet, left in the tubes, sealed, and transported to South Dakota State University for analysis. See log for R20-93-02 for descriptions of continuous split-spoon samples to a depth of 70 feet near this location.

County: MINNEHAHA — Location: 101N-51W-35CCBD 3
Legal Location: SE NW SW SW sec. 35, T. 101 N., R. 51 W.
Latitude: 43.3007 — Longitude: 96.5529
Land Owner: SIOUX FALLS
Project: RUNGE LANDFILL (GRPEP)
Drilling Company: SDGS
Driller: D. IVERSON — Driller's Log:
Geologist: D. ILES — Geologist's Log: X
Date Drilled: 06-01-1993 — Drilling Method: AUGER
Ground Surface Elevation: 1542.17 I
Total Drill Hole Depth: 30.0 — Test Hole Number: R20-93-04
USGS Hydrologic Unit Code: 10170203
Electric Log Information:
Spontaneous Potential: — Single Point Resistivity:
Natural Gamma: — Extra:
Samples:

This hole was abandoned because of runny sediment continually entering the hole. Bentonite grout: 30-2 feet. Cuttings: 2-0 feet.

1542.17 - 1530.17	0 - 12.0	Clay, yellowish-brown, silty, sandy, pebbly

1530.17 - 1527.17	12.0 - 15.0	Sand, yellowish-brown
1527.17 - 1524.17	15.0 - 18.0	Clay, yellowish-brown, silty, sandy, pebbly
1524.17 - 1523.17	18.0 - 19.0	Sand, yellowish-brown
1523.17 - 1518.17	19.0 - 24.0	Clay, yellowish-brown, silty, sandy, pebbly
1518.17 - 1512.17	24.0 - 30.0	Clay, gray, silty, sandy, pebbly

See log for R20-93-02 for descriptions of continuous split-spoon samples to a depth of 70 feet near this location.

County: MINNEHAHA
Location: 101N-51W-35CCBD 4
Legal Location: SE NW SW SW sec. 35, T. 101 N., R. 51 W.
Latitude: 43.3007
Longitude: 96.5529
Land Owner: SIOUX FALLS
Project: RUNGE LANDFILL (GRPEP)
Drilling Company: SDGS
Driller: D. IVERSON
Driller's Log:
Geologist: D. ILES
Geologist's Log: X
Date Drilled: 06-02-1993
Drilling Method: AUGER
Ground Surface Elevation: 1543.39 I
Total Drill Hole Depth: 34.0
Test Hole Number: R20-93-05
Water Rights Well:
SDGS Well Name: R20-93-05
Other Well Name:
Basin: BIG SIOUX
Aquifer: TILL
Management Unit:
Screen Type: PVC, MFG., 0.010 SLOT, FLUSH
Screen Length: 10.3
Casing Type: PVC, SCH. 40, FLUSH
Casing Diameter: 2.0
Casing Top Elevation: 1543.99 I
Casing Stick-up: 0.60
Total Casing and Screen: 35.3
Well Maintenance Date:
USGS Hydrologic Unit Code: 10170203
Electric Log Information:
Spontaneous Potential:
Single Point Resistivity:
Natural Gamma:
Extra:
Samples:

Casing installed through inside of auger. Filter pack (0.65-0.75 mm quartz sand): 34-19 feet. Bentonite grout: 19-2.5 feet. Cement: 2.5-0 feet. Steel well protector. Leveling of cuttings added 0.7 feet to ground surface.

1543.39 - 1542.39	0 - 1.0	Topsoil, black
1542.39 - 1535.39	1.0 - 8.0	Clay, yellowish-brown, silty, sandy, pebbly
1535.39 - 1531.39	8.0 - 12.0	Clay, yellowish-brown, sandy, pebbly, very silty
1531.39 - 1529.39	12.0 - 14.0	Sand, yellowish-brown, clayey
1529.39 - 1519.39	14.0 - 24.0	Clay, yellowish-brown, silty, sandy, pebbly
1519.39 - 1512.39	24.0 - 31.0	Unknown; shelby-tube samples taken from 25 to 27, 27 to 29, and 29 to 31 feet
1512.39 - 1509.39	31.0 - 34.0	Clay, gray, silty, sandy, pebbly

Shelby-tube samples were collected from 25-31 feet, left in the tubes, sealed, and transported to South Dakota State University for analysis. See log for R20-93-02 for descriptions of continuous split-spoon samples to a depth of 70 feet near this location.

County: MINNEHAHA
Location: 101N-51W-35CDBC 3
Legal Location: SW NW SE SW sec. 35, T. 101 N., R. 51 W.
Latitude: 43.3007
Longitude: 96.5529

Land Owner: SIOUX FALLS
Project: RUNGE LANDFILL (GRPEP)
Drilling Company: SDGS
Driller: D. IVERSON
Geologist: D. ILES
Date Drilled: 06-02-1993
Ground Surface Elevation: 1543.04 I
Total Drill Hole Depth: 28.3
Water Rights Well:
Other Well Name:
Basin: BIG SIOUX
Management Unit:
Screen Type: OPEN CORE HOLE BELOW CASING
Casing Type: PVC, SCH. 80, FLUSH
Casing Top Elevation: 1544.64 I
Casing Stick-up: 1.60
Well Maintenance Date:
USGS Hydrologic Unit Code: 10170203
Electric Log Information:
Spontaneous Potential:
Natural Gamma:
Samples:

Driller's Log:
Geologist's Log: X
Drilling Method: AUGER

Test Hole Number: R20-93-06
SDGS Well Name: R20-93-06

Aquifer: TILL

Screen Length: 0.8
Casing Diameter: 2.0

Total Casing and Screen: 29.5

Single Point Resistivity:
Extra:

Casing installed through inside of auger and pushed into hole bottom from 27-27.5 feet. A shelby-tube sample was collected through the casing from 27-28.3 feet to create a water-intake area. Bentonite grout: 27-3 feet. Cement: 3-0 feet. Steel well protector. Leveling of cuttings added 0.4 feet to ground surface.

1543.04 - 1542.04	0 - 1.0	Topsoil, black
1542.04 - 1536.04	1.0 - 7.0	Clay, yellowish-brown, sandy, pebbly, very silty
1536.04 - 1534.04	7.0 - 9.0	Clay, yellowish-brown, pebbly, very silty and sandy
1534.04 - 1531.04	9.0 - 12.0	Clay, yellowish-brown, silty, sandy, pebbly
1531.04 - 1530.04	12.0 - 13.0	Sand, yellowish-brown, clayey
1530.04 - 1522.04	13.0 - 21.0	Clay, yellowish-brown, silty, sandy, pebbly
1522.04 - 1520.04	21.0 - 23.0	Clay, yellowish-brown with some gray, silty, sandy, pebbly
1520.04 - 1514.74	23.0 - 28.3	Clay, gray, silty, sandy, pebbly

Shelby-tube sample collected from 27-28.3 feet. Sample was extruded and described. See log for R20-93-02 for descriptions of continuous split-spoon samples to a depth of 70 feet near this location.

County: MINNEHAHA
Location: 101N-51W-35CDBC 4
Legal Location: SW NW SE SW sec. 35, T. 101 N., R. 51 W.
Latitude: 43.3007
Longitude: 96.5529
Land Owner: SIOUX FALLS
Project: RUNGE LANDFILL (GRPEP)
Drilling Company: SDGS
Driller: D. IVERSON
Geologist: D. ILES
Date Drilled: 06-03-1993
Ground Surface Elevation: 1543.47 I
Total Drill Hole Depth: 17.0
Water Rights Well:
Other Well Name:
Basin: BIG SIOUX
Management Unit:
Screen Type: PVC, MFG., 0.010 SLOT, FLUSH

Driller's Log:
Geologist's Log: X
Drilling Method: AUGER

Test Hole Number: R20-93-07
SDGS Well Name: R20-93-07

Aquifer: TILL

Screen Length: 5.3

Casing Type: PVC, SCH. 40, FLUSH
Casing Diameter: 2.0
Casing Top Elevation: 1544.97 I
Casing Stick-up: 1.50
Total Casing and Screen: 18.4
Well Maintenance Date:
USGS Hydrologic Unit Code: 10170203
Electric Log Information:
Spontaneous Potential:
Single Point Resistivity:
Natural Gamma:
Extra:
Samples:

Well centralizer: 9 feet. The hole collapsed around the screen from 17-16.4 feet. Filter pack (0.65-0.75 mm quartz sand): 16.4-9 feet. Bentonite grout: 9-2.5 feet. Cement: 2.5-0 feet. Steel well protector. Leveling of cuttings added 0.5 feet to ground surface.

1543.47 - 1539.47	0 - 4.0	Clay, yellowish-brown, sandy, pebbly, very silty
1539.47 - 1535.47	4.0 - 8.0	Clay, yellowish-brown, silty, sandy, pebbly
1535.47 - 1531.47	8.0 - 12.0	Clay, yellowish-brown, silty, pebbly, very sandy
1531.47 - 1529.47	12.0 - 14.0	Clay, yellowish-brown, silty, sandy, pebbly
1529.47 - 1527.47	14.0 - 16.0	Unknown; a shelby-tube sample taken from 14 to 16 feet
1527.47 - 1526.47	16.0 - 17.0	Clay, yellowish-brown, silty, sandy, pebbly

A shelby-tube sample was collected from 14-16 feet, left in the tube, sealed, and transported to South Dakota State University for analysis. See log for R20-93-02 for descriptions of continuous split-spoon samples to a depth of 70 feet near this location.

County: MINNEHAHA
Location: 101N-51W-35CDBC 5
Legal Location: SW NW SE SW sec. 35, T. 101 N., R. 51 W.
Latitude: 43.3008
Longitude: 96.5529
Land Owner: SIOUX FALLS
Project: RUNGE LANDFILL (GRPEP)
Drilling Company: SDGS
Driller: D. IVERSON
Driller's Log:
Geologist: D. ILES
Geologist's Log: X
Date Drilled: 06-03-1993
Drilling Method: AUGER
Ground Surface Elevation: 1543.84 I
Total Drill Hole Depth: 22.0
Test Hole Number: R20-93-08
Water Rights Well:
SDGS Well Name: R20-93-08
Other Well Name:
Basin: BIG SIOUX
Aquifer: TILL
Management Unit:
Screen Type: PVC, MFG., 0.010 SLOT, FLUSH
Screen Length: 10.3
Casing Type: PVC, SCH. 40, FLUSH
Casing Diameter: 2.0
Casing Top Elevation: 1545.44 I
Casing Stick-up: 1.60
Total Casing and Screen: 23.0
Well Maintenance Date:
USGS Hydrologic Unit Code: 10170203
Electric Log Information:
Spontaneous Potential:
Single Point Resistivity:
Natural Gamma:
Extra:
Samples:

Well centralizer: 9 feet. The hole collapsed from 22-21 feet. Filter pack (0.65-0.75 mm quartz sand): 21-9 feet. Bentonite grout: 9-2.5 feet. Cement: 2.5-0 feet. Steel well protector. Leveling of cuttings added 0.4 feet to ground surface.

1543.84 - 1539.84	0 - 4.0	Clay, yellowish-brown, sandy, pebbly, very silty
1539.84 - 1537.84	4.0 - 6.0	Clay, yellowish-brown, silty, sandy, pebbly
1537.84 - 1535.84	6.0 - 8.0	Clay, yellowish-brown, silty, pebbly, very sandy
1535.84 - 1529.84	8.0 - 14.0	Clay, yellowish-brown, silty, sandy, pebbly
1529.84 - 1523.84	14.0 - 20.0	Unknown; shelby-tube samples were taken from 14 to 16, 16 to 18, and 18 to 20 feet
1523.84 - 1521.84	20.0 - 22.0	Clay, yellowish-brown with some gray, silty, sandy, pebbly

Shelby-tube samples were collected from 14-20 feet, left in the tubes, sealed, and transported to South Dakota State University for analysis. See log for R20-93-02 for descriptions of continuous split-spoon samples to a depth of 70 feet near this location.

County: MINNEHAHA
Location: 101N-51W-35CDBC 6
Legal Location: SW NW SE SW sec. 35, T. 101 N., R. 51 W.
Latitude: 43.3008
Longitude: 96.5529
Land Owner: SIOUX FALLS
Project: RUNGE LANDFILL (GRPEP)
Drilling Company: SDGS
Driller: D. IVERSON
Driller's Log:
Geologist: D. ILES
Geologist's Log: X
Date Drilled: 06-03-1993
Drilling Method: AUGER
Ground Surface Elevation: 1544.78 I
Total Drill Hole Depth: 16.8
Test Hole Number: R20-93-09
Water Rights Well:
SDGS Well Name: R20-93-09
Other Well Name:
Basin: BIG SIOUX
Aquifer: TILL
Management Unit:
Screen Type: OPEN CORE HOLE BELOW CASING
Screen Length: 0.3
Casing Type: PVC, SCH. 80, FLUSH
Casing Diameter: 2.0
Casing Top Elevation: 1546.08 I
Casing Stick-up: 1.30
Total Casing and Screen: 18.7
Well Maintenance Date:
USGS Hydrologic Unit Code: 10170203
Electric Log Information:
Spontaneous Potential:
Single Point Resistivity:
Natural Gamma:
Extra:
Samples:

Casing installed through inside of auger and pushed into hole bottom from 16-16.5 feet. A shelby-tube sample was collected through the casing from 16-16.8 feet to create a water-in-take area. Bentonite grout: 16-2.5 feet. Cement: 2.5-0 feet. Steel well protector. Leveling of cuttings added 0.9 feet to ground surface.

1544.78 - 1540.78	0 - 4.0	Clay, yellowish-brown, sandy, pebbly, very silty
1540.78 - 1538.78	4.0 - 6.0	Clay, yellowish-brown, silty, pebbly, very sandy; with some rocks
1538.78 - 1532.78	6.0 - 12.0	Clay, yellowish-brown, silty, sandy, pebbly
1532.78 - 1530.78	12.0 - 14.0	Clay, yellowish-brown, silty, pebbly, very sandy; with some rocks
1530.78 - 1528.78	14.0 - 16.0	Clay, yellowish-brown, silty, sandy, pebbly
1528.78 - 1527.98	16.0 - 16.8	Clay, yellowish-brown, silty, sandy, pebbly; with some gypsum crystals

Shelby-tube sample collected from 16-16.8 feet. Sample was extruded and described. See log for R20-93-02 for descriptions of continuous split-spoon samples to a depth of 70 feet near this location.

County: MINNEHAHA
Location: 101N-51W-35CCBD 5
Legal Location: SE NW SW SW sec. 35, T. 101 N., R. 51 W.

Latitude: 43.3008 Longitude: 96.5529
Land Owner: SIOUX FALLS
Project: RUNGE LANDFILL (GRPEP)
Drilling Company: SDGS
Driller: D. IVERSON Driller's Log:
Geologist: D. ILES Geologist's Log: X
Date Drilled: 06-03-1993 Drilling Method: AUGER
Ground Surface Elevation: 1542.52 I
Total Drill Hole Depth: 29.0 Test Hole Number: R20-93-10
USGS Hydrologic Unit Code: 10170203
Electric Log Information:
Spontaneous Potential: Single Point Resistivity:
Natural Gamma: Extra:
Samples:

A shelby-tube sample was collected from 27-29 feet but the tube became detached in the hole. The damaged tube was recovered and auger was removed from the hole. Sandy material collapsed and prevented insertion of well into the hole. The hole was abandoned. Bentonite grout: 29-2 feet. Cuttings: 2-0 feet.

1542.52 - 1538.52	0 - 4.0	Clay, yellowish-brown, silty, sandy, pebbly
1538.52 - 1534.52	4.0 - 8.0	Clay, yellowish-brown, silty, pebbly, very sandy
1534.52 - 1530.52	8.0 - 12.0	Clay, yellowish-brown, silty, sandy, pebbly
1530.52 - 1528.52	12.0 - 14.0	Sand, yellowish-brown, clayey
1528.52 - 1525.52	14.0 - 17.0	Clay, yellowish-brown, silty, pebbly, very sandy
1525.52 - 1523.52	17.0 - 19.0	Sand and gravel, clayey
1523.52 - 1518.52	19.0 - 24.0	Clay, yellowish-brown, silty, sandy, pebbly; a rock from 23.5 to 24 feet
1518.52 - 1515.52	24.0 - 27.0	Clay, yellowish-brown with some light-gray, silty, sandy, pebbly
1515.52 - 1513.52	27.0 - 29.0	Clay, light-gray and dark-brown, silty, sandy, pebbly

County: MINNEHAHA Location: 101N-51W-35CCBD 6
Legal Location: SE NW SW SW sec. 35, T. 101 N., R. 51 W.
Latitude: 43.3008 Longitude: 96.5529
Land Owner: SIOUX FALLS
Project: RUNGE LANDFILL (GRPEP)
Drilling Company: SDGS
Driller: D. IVERSON Driller's Log:
Geologist: D. ILES Geologist's Log: X
Date Drilled: 06-07-1993 Drilling Method: AUGER
Ground Surface Elevation: 1545.00 I
Total Drill Hole Depth: 29.0 Test Hole Number: R20-93-11
Water Rights Well: SDGS Well Name: R20-93-11
Other Well Name:
Basin: BIG SIOUX Aquifer: TILL
Management Unit:
Screen Type: PVC, MFG., 0.010 SLOT, FLUSH Screen Length: 5.3
Casing Type: PVC, SCH. 40, FLUSH Casing Diameter: 2.0
Casing Top Elevation: 1546.00 I
Casing Stick-up: 1.00 Total Casing and Screen: 30.3
Well Maintenance Date:
USGS Hydrologic Unit Code: 10170203
Electric Log Information:
Spontaneous Potential: Single Point Resistivity:
Natural Gamma: Extra:
Samples:

Well centralizer: 17 feet. The hole collapsed from 29-28.5 feet. Filter pack (0.65-0.75 mm quartz sand): 28.5-20.5 feet. Granular bentonite: 20.5-18.5 feet. Bentonite grout: 18.5-2.5 feet. Cement: 2.5-0 feet. Steel well protector. Leveling of cuttings added 0.5 feet to ground surface.

1545.00 - 1541.00	0 - 4.0	Clay, yellowish-brown, silty, sandy, pebbly
1541.00 - 1538.00	4.0 - 7.0	Clay, yellowish-brown, silty, pebbly, very sandy
1538.00 - 1532.00	7.0 - 13.0	Clay, yellowish-brown to brown, silty, sandy, pebbly
1532.00 - 1530.00	13.0 - 15.0	Clay, yellowish-brown to brown, silty, pebbly, some of it very sandy; rock at 14 feet
1530.00 - 1522.00	15.0 - 23.0	Clay, yellowish-brown to brown, silty, sandy, pebbly
1522.00 - 1521.00	23.0 - 24.0	Clay, light-gray to gray, silty, sandy, pebbly
1521.00 - 1519.00	24.0 - 26.0	Unknown; shelby-tube sample taken from 24 to 26 feet
1519.00 - 1516.00	26.0 - 29.0	Clay, gray, silty, sandy, pebbly

A shelby-tube sample was collected from 24-26 feet, left in the tube, sealed, and transported to South Dakota State University for analysis. See log form R20-93-02 for descriptions of continuous split-spoon samples to a depth of 70 feet near this location.

County: MINNEHAHA
Location: 101N-51W-35CCDA 1
Legal Location: NE SE SW SW sec. 35, T. 101 N., R. 51 W.
Latitude: 43.3004
Longitude: 96.5531
Land Owner: SIOUX FALLS
Project: RUNGE LANDFILL (GRPEP)
Drilling Company: SDGS
Driller: D. IVERSON
Driller's Log:
Geologist: D. ILES
Geologist's Log: X
Date Drilled: 06-07-1993
Drilling Method: AUGER
Ground Surface Elevation: 1537.86 I
Total Drill Hole Depth: 33.0
Test Hole Number: R20-93-12
Water Rights Well:
SDGS Well Name: R20-93-12
Other Well Name:
Basin: BIG SIOUX
Aquifer: TILL
Management Unit:
Screen Type: PVC, MFG., 0.010 SLOT, FLUSH
Screen Length: 10.3
Casing Type: PVC, SCH. 40, FLUSH
Casing Diameter: 2.0
Casing Top Elevation: 1539.06 I
Casing Stick-up: 1.20
Total Casing and Screen: 35.3
Well Maintenance Date:
USGS Hydrologic Unit Code: 10170203
Electric Log Information:
Spontaneous Potential:
Single Point Resistivity:
Natural Gamma:
Extra:
Samples:

Well centralizer: 17 feet. Filter pack (0.65-0.75 mm quartz sand): 33-21 feet. Granular bentonite: 21-20 feet. Bentonite grout: 20-2.5 feet. Cement: 2.5-0 feet. Steel well protector. Leveling of cuttings added 1.1 feet to ground surface.

1537.86 - 1536.86	0 - 1.0	Topsoil, black
1536.86 - 1532.86	1.0 - 5.0	Clay, yellowish-brown
1532.86 - 1530.86	5.0 - 7.0	Clay, yellowish-brown, very sandy
1530.86 - 1529.86	7.0 - 8.0	Clay, light-tan to yellowish-brown, silty, sandy, pebbly
1529.86 - 1523.86	8.0 - 14.0	Clay, yellowish-brown, silty, pebbly, slightly sandy
1523.86 - 1516.86	14.0 - 21.0	Clay, gray, silty, sandy, pebbly; mixed with reddish-brown sand
1516.86 - 1512.86	21.0 - 25.0	Clay, gray, silty, sandy, pebbly

1512.86 - 1506.86	25.0 - 31.0	Unknown; shelby-tube samples were taken from 25-27, 27-29, and 29-31 feet
1506.86 - 1504.86	31.0 - 33.0	Clay, gray, silty, sandy, pebbly

Shelby-tube samples were collected from 25-31 feet, left in the tubes, sealed, and transported to South Dakota State University for analysis. See log form R20-93-14 for descriptions of continuous split-spoon samples to a depth of 64 feet near this location.

County: MINNEHAHA
Location: 101N-51W-35CCDA 2
Legal Location: NE SE SW SW sec. 35, T. 101 N., R. 51 W.
Latitude: 43.3004
Longitude: 96.5530
Land Owner: SIOUX FALLS
Project: RUNGE LANDFILL (GRPEP)
Drilling Company: SDGS
Driller: D. IVERSON
Driller's Log:
Geologist: D. ILES
Geologist's Log: X
Date Drilled: 06-07-1993
Drilling Method: AUGER
Ground Surface Elevation: 1538.24 I
Total Drill Hole Depth: 17.3
Test Hole Number: R20-93-13
Water Rights Well:
SDGS Well Name: R20-93-13
Other Well Name:
Basin: BIG SIOUX
Aquifer: TILL
Management Unit:
Screen Type: OPEN CORE HOLE BELOW CASING
Screen Length: 0.8
Casing Type: PVC, SCH. 80, FLUSH
Casing Diameter: 2.0
Casing Top Elevation: 1540.04 I
Casing Stick-up: 1.80
Total Casing and Screen: 19.5
Well Maintenance Date:
USGS Hydrologic Unit Code: 10170203
Electric Log Information:
Spontaneous Potential:
Single Point Resistivity:
Natural Gamma:
Extra:
Samples:

Casing installed through inside of auger & pushed into hole bottom from 16-16.5 feet. A shelby-tube sample was collected through the casing from 16-17.3 feet to create a water-intake area. Bentonite grout: 16-2.5 feet. Cement: 2.5-0 feet. Steel well protector. Leveling of cuttings added 1.2 feet to ground surface.

1538.24 - 1537.24	0 - 1.0	Topsoil, black
1537.24 - 1535.24	1.0 - 3.0	Clay, yellowish-brown
1535.24 - 1533.24	3.0 - 5.0	Clay, yellowish-brown, very sandy
1533.24 - 1529.24	5.0 - 9.0	Clay, yellowish-brown, silty, sandy, pebbly
1529.24 - 1527.24	9.0 - 11.0	Clay, yellowish-brown, silty, pebbly, very sandy
1527.24 - 1522.24	11.0 - 16.0	Clay, yellowish-brown, silty, sandy, pebbly
1522.24 - 1520.94	16.0 - 17.3	Clay, yellowish-brown with a little gray, silty, sandy, pebbly; with many gypsum crystals

Shelby-tube sample collected from 16-17.3 feet. Sample was extruded and described. See log for R20-93-14 for descriptions of continuous split-spoon samples to a depth of 64 feet near this location.

County: MINNEHAHA
Location: 101N-51W-35CCDA 3
Legal Location: NE SE SW SW sec. 35, T. 101 N., R. 51 W.
Latitude: 43.3005
Longitude: 96.5530
Land Owner: SIOUX FALLS

Project: RUNGE LANDFILL (GRPEP)
Drilling Company: SDGS
Driller: D. IVERSON
Geologist: D. ILES
Date Drilled: 06-08-1993
Ground Surface Elevation: 1538.58 I
Total Drill Hole Depth: 74.0
Water Rights Well:
Other Well Name:
Basin: BIG SIOUX
Management Unit:
Screen Type: PVC, MFG., 0.010 SLOT, FLUSH
Casing Type: PVC, SCH. 40, FLUSH
Casing Top Elevation: 1540.38 I
Casing Stick-up: 1.80
Well Maintenance Date:
USGS Hydrologic Unit Code: 10170203
Electric Log Information:
Spontaneous Potential:
Natural Gamma:
Samples: X

Driller's Log:
Geologist's Log: X
Drilling Method: HOLLOWSTEM

Test Hole Number: R20-93-14
SDGS Well Name: R20-93-14

Aquifer:

Screen Length: 5.3
Casing Diameter: 2.0

Total Casing and Screen: 75.3

Single Point Resistivity:
Extra:

Well centralizers: 15, 25, 55, and 65 feet. The hole collapsed from 74-72.8 feet. Filter pack (0.65-0.75 mm quartz sand): 72.8-60 feet. Bentonite grout: 60-2.5 feet. Cement: 2.5-0 feet. Steel well protector. Leveling of cuttings added 0.7 feet to ground surface.

1538.58 - 1536.18	0 - 2.4	Clay, black, very silty
1536.18 - 1535.28	2.4 - 3.3	Clay, olive-brown with some gray mottling grading to more gray than olive-brown, very silty; some gray fractures evident in the lower portion of this interval
1535.28 - 1533.38	3.3 - 5.2	Clay, gray with brown mottling
1533.38 - 1533.28	5.2 - 5.3	Sand, reddish-brown, medium to coarse
1533.28 - 1532.78	5.3 - 5.8	Clay, gray with brown mottling
1532.78 - 1532.18	5.8 - 6.4	Sand, reddish-brown, medium to coarse
1532.18 - 1530.58	6.4 - 8.0	Clay, gray, silty, sandy, pebbly; many reddish-brown vertical fractures; a horizontal oxidized sand seam at 7.6 feet
1530.58 - 1530.38	8.0 - 8.2	Sand, brown with some gray, medium to coarse
1530.38 - 1528.58	8.2 - 10.0	Clay, olive-brown with gray mottling, silty, sandy, pebbly
1528.58 - 1526.58	10.0 - 12.0	Clay, olive-brown with gray mottling, silty, sandy, pebbly; there was a swirl pattern to the mottling and some gypsum crystals in the swirl pattern
1526.58 - 1524.58	12.0 - 14.0	Clay, olive-brown, silty, sandy, pebbly; large vertical fracture from 12-12.6 feet; several oxidized and unoxidized fractures; very sandy from 13.5-13.7 feet
1524.58 - 1523.98	14.0 - 14.6	Sand, reddish-brown, fine
1523.98 - 1521.48	14.6 - 17.1	Clay, olive-brown and gray, silty, sandy, pebbly; very sandy from 15.8-16 feet; fractures evident
1521.48 - 1520.58	17.1 - 18.0	Clay, gray, with some brown; oxidized and unoxidized fractures evident
1520.58 - 1519.48	18.0 - 19.1	Clay, gray, silty, sandy, pebbly; with some oxidized fractures
1519.48 - 1518.58	19.1 - 20.0	Clay, gray, silty, sandy, pebbly
1518.58 - 1516.58	20.0 - 22.0	Clay, gray, silty, sandy, pebbly; oxidized vertical fractures evident; unoxidized horizontal coarse sand seam at 20.7 feet
1516.58 - 1512.58	22.0 - 26.0	Clay, gray, silty, sandy, pebbly; plastic-like; a few vertical oxidized fractures
1512.58 - 1506.58	26.0 - 32.0	Clay, gray, silty, sandy, pebbly; plastic-like; oxidized horizontal sand

		seams at 26.1 and 30.2 feet; the sand seam at 30.2 feet seems relatively dry; some oxidation at 28.3 feet
1506.58 - 1506.38	32.0 - 32.2	Silt, gray; some reddish-brown oxidation
1506.38 - 1504.68	32.2 - 33.9	Clay, gray, sandy, pebbly, very silty
1504.68 - 1504.38	33.9 - 34.2	Sand, gray, fine, very silty
1504.38 - 1503.78	34.2 - 34.8	Clay, gray, very silty
1503.78 - 1503.48	34.8 - 35.1	Silt, gray
1503.48 - 1502.88	35.1 - 35.7	Clay, gray, very silty
1502.88 - 1486.78	35.7 - 51.8	Clay, gray, silty, sandy, pebbly; an unoxidized wet sand seam at 36.6 feet; an unoxidized silt seam at 45.2 feet; an unoxidized fine sand seam at 51 feet
1486.78 - 1486.18	51.8 - 52.4	Sand, gray, fine to medium, silty, clayey
1486.18 - 1474.58	52.4 - 64.0	Clay, gray, silty, sandy, pebbly; unoxidized sand seams at 57.2, 58.7, and 61.5 feet
1474.58 - 1464.58	64.0 - 74.0	Unknown; attempts were made to collect shelby-tube samples from 64-74 feet but the lead auger repeatedly became plugged; only one shelby-tube sample was collected from 70-72 feet; the sediment at 74 feet was a silty, sandy, and pebbly, gray clay

Continuous split-spoon samples were collected from this hole except where noted otherwise. A shelby-tube sample was collected from 70-72 feet, left in the tube, sealed, and transported to South Dakota State University for analysis.

County: MINNEHAHA | Location: 101N-51W-35CCDA 4
Legal Location: NE SE SW SW sec. 35, T. 101 N., R. 51 W.
Latitude: 43.3005 | Longitude: 96.5530
Land Owner: SIOUX FALLS
Project: RUNGE LANDFILL (GRPEP)
Drilling Company: SDGS
Driller: D. IVERSON | Driller's Log:
Geologist: D. ILES | Geologist's Log: X
Date Drilled: 06-09-1993 | Drilling Method: AUGER
Ground Surface Elevation: 1539.89 I
Total Drill Hole Depth: 51.0 | Test Hole Number: R20-93-15
Water Rights Well: | SDGS Well Name: R20-93-15
Other Well Name:
Basin: BIG SIOUX | Aquifer: TILL
Management Unit:
Screen Type: PVC, MFG., 0.010 SLOT, FLUSH | Screen Length: 5.3
Casing Type: PVC, SCH. 40, FLUSH | Casing Diameter: 2.0
Casing Top Elevation: 1541.39 I
Casing Stick-up: 1.50 | Total Casing and Screen: 51.2
Well Maintenance Date:
USGS Hydrologic Unit Code: 10170203
Electric Log Information:
Spontaneous Potential: | Single Point Resistivity:
Natural Gamma: | Extra:
Samples:

Well centralizers: 6, 16, 26, and 36 feet. The hole collapsed from 51-49.7 feet. Filter pack (0.65-0.75 mm quartz sand): 49.7-41.5 feet. Granular bentonite: 41.5-40.5 feet. Bentonite grout: 40.5-2.5 feet. Cement: 2.5-0 feet. Steel well protector.

1539.89 - 1538.89	0 - 1.0	Topsoil, black
1538.89 - 1535.89	1.0 - 4.0	Clay, yellowish-brown

1535.89 - 1533.89	4.0 - 6.0	Clay, tan, silty
1533.89 - 1532.89	6.0 - 7.0	Clay, yellowish-brown
1532.89 - 1531.39	7.0 - 8.5	Sand, brown, medium, clayey
1531.39 - 1523.89	8.5 - 16.0	Clay, yellowish-brown, silty, sandy, pebbly; a rock at 14 feet
1523.89 - 1521.89	16.0 - 18.0	Clay, tan to dark-tan, silty, sandy, pebbly
1521.89 - 1519.89	18.0 - 20.0	Clay, dark-tan to gray, silty, sandy, pebbly
1519.89 - 1515.89	20.0 - 24.0	Clay, dark-tan, light-gray, and brown, silty, sandy, pebbly; a rock at 24 feet
1515.89 - 1514.89	24.0 - 25.0	Clay, light-gray, dark-brown, and gray, silty, sandy, pebbly
1514.89 - 1508.89	25.0 - 31.0	Clay, gray and dark-brown, silty, sandy, pebbly
1508.89 - 1490.89	31.0 - 49.0	Clay, gray, silty, sandy, pebbly
1490.89 - 1488.89	49.0 - 51.0	Unknown; a shelby-tube sample was taken from 49-51 feet; sediment in the bottom of the shelby tube was a silty, sandy, and pebbly, gray clay

A shelby-tube sample was collected from 49-51 feet, left in the tube, sealed, and transported to South Dakota State University for analysis. See log for R20-93-14 for descriptions of continuous split-spoon samples to a depth of 64 feet near this location.

County: MINNEHAHA
Location: 101N-51W-35CCDA 5
Legal Location: NE SE SW SW sec. 35, T. 101 N., R. 51 W.
Latitude: 43.3004
Longitude: 96.5530
Land Owner: SIOUX FALLS
Project: RUNGE LANDFILL (GRPEP)
Drilling Company: SDGS
Driller: D. IVERSON
Driller's Log:
Geologist: D. ILES
Geologist's Log: X
Date Drilled: 06-10-1993
Drilling Method: AUGER
Ground Surface Elevation: 1537.24 I
Total Drill Hole Depth: 29.0
Test Hole Number: R20-93-16
Water Rights Well:
SDGS Well Name: R20-93-16
Other Well Name:
Basin: BIG SIOUX
Aquifer: TILL
Management Unit:
Screen Type: PVC, MFG., 0.010 SLOT, FLUSH
Screen Length: 5.3
Casing Type: PVC, SCH. 40, FLUSH
Casing Diameter: 2.0
Casing Top Elevation: 1538.94 I
Casing Stick-up: 1.70
Total Casing and Screen: 30.3
Well Maintenance Date:
USGS Hydrologic Unit Code: 10170203
Electric Log Information:
Spontaneous Potential:
Single Point Resistivity:
Natural Gamma:
Extra:
Samples:

Well centralizers: 6 and 12 feet. Filter pack (0.65-0.75 mm quartz sand): 29-20.5 feet. Granular bentonite: 20.5-19.5 feet. Bentonite grout: 19.5-2.5 feet. Cement: 2.5-0 feet. Steel well protector.

1537.24 - 1536.24	0 - 1.0	Topsoil, black
1536.24 - 1525.24	1.0 - 12.0	Clay, yellowish-brown
1525.24 - 1523.24	12.0 - 14.0	Clay, yellowish-brown, silty, sandy, pebbly; with some rocks
1523.24 - 1522.24	14.0 - 15.0	Clay, yellowish-brown to tan, silty, sandy, pebbly
1522.24 - 1520.24	15.0 - 17.0	Clay, tan, light-gray, and yellowish-brown, silty, sandy, pebbly
1520.24 - 1517.24	17.0 - 20.0	Clay, gray and tan, silty, sandy, pebbly
1517.24 - 1511.04	20.0 - 26.2	Clay, gray, silty, sandy, pebbly
1511.04 - 1509.04	26.2 - 28.2	Unknown; a shelby-tube sample was taken from 26.2-28.2 feet

1509.04 - 1508.24	28.2 - 29.0	Clay, gray, silty, sandy, pebbly

A shelby-tube sample was collected from 26.2-28.2 feet, left in the tube, sealed, and transported to South Dakota State University for analysis. See log for R20-93-14 for descriptions of continuous split-spoon samples to a depth of 64 feet near this location.

County: MINNEHAHA
Location: 101N-51W-35CCDA 6
Legal Location: NE SE SW SW sec. 35, T. 101 N., R. 51 W.
Latitude: 43.3004
Longitude: 96.5530
Land Owner: SIOUX FALLS
Project: RUNGE LANDFILL (GRPEP)
Drilling Company: SDGS
Driller: D. IVERSON
Driller's Log:
Geologist: D. ILES
Geologist's Log: X
Date Drilled: 06-10-1993
Drilling Method: AUGER
Ground Surface Elevation: 1537.58 I
Total Drill Hole Depth: 28.0
Test Hole Number: R20-93-17
Water Rights Well:
SDGS Well Name: R20-93-17
Other Well Name:
Basin: BIG SIOUX
Aquifer: TILL
Management Unit:
Screen Type: OPEN CORE HOLE BELOW CASING
Screen Length: 0.5
Casing Type: PVC, SCH. 80, FLUSH
Casing Diameter: 2.0
Casing Top Elevation: 1539.18 I
Casing Stick-up: 1.60
Total Casing and Screen: 29.5
Well Maintenance Date:
USGS Hydrologic Unit Code: 10170203
Electric Log Information:
Spontaneous Potential:
Single Point Resistivity:
Natural Gamma:
Extra:
Samples:

Casing installed through inside of auger and pushed into hole bottom from 27-27.5 feet. A shelby-tube sample was collected through the casing from 27-28 feet to create a water-intake area. Bentonite grout: 27-2.5 feet. cement: 2.5-0 feet. Steel well protector. Leveling of cuttings added 0.4 feet to ground surface.

1537.58 - 1536.58	0 - 1.0	Topsoil, black
1536.58 - 1534.58	1.0 - 3.0	Clay, yellowish-brown
1534.58 - 1530.58	3.0 - 7.0	Clay, yellowish-brown, silty
1530.58 - 1526.58	7.0 - 11.0	Clay, yellowish-brown, silty, sandy, pebbly
1526.58 - 1523.58	11.0 - 14.0	Clay, yellowish-brown, silty, pebbly, very sandy; some rocks from 11-13 feet
1523.58 - 1520.58	14.0 - 17.0	Clay, yellowish-brown, tan, and light-gray, silty, sandy, pebbly
1520.58 - 1518.58	17.0 - 19.0	Clay, dark-brown, light-gray, and reddish-brown, silty, sandy, pebbly
1518.58 - 1516.58	19.0 - 21.0	Clay, brown and yellowish-brown, silty, sandy, pebbly; soft
1516.58 - 1510.58	21.0 - 27.0	Clay, gray with some yellowish-brown to brown, silty, sandy, pebbly
1510.58 - 1509.58	27.0 - 28.0	Clay, gray with some reddish-brown, silty, sandy, pebbly; horizontal oxidized fractures evident

Shelby-tube sample collected from 27-28 feet. Sample was extruded and described. See log R20-93-14 for descriptions of continuous split-spoon samples to a depth of 64 feet near this location.

County: MINNEHAHA
Location: 101N-51W-35CCDA 7
Legal Location: NE SE SW SW sec. 35, T. 101 N., R. 51 W.
Latitude: 43.3005
Longitude: 96.5530

Land Owner: SIOUX FALLS
Project: RUNGE LANDFILL (GRPEP)
Drilling Company: SDGS
Driller: D. IVERSON
Geologist: D. ILES
Date Drilled: 06-13-1993
Ground Surface Elevation: 1537.99 I
Total Drill Hole Depth: 22.0
Water Rights Well:
Other Well Name:
Basin: BIG SIOUX
Management Unit:
Screen Type: PVC, MFG., 0.010 SLOT, FLUSH
Casing Type: PVC, SCH. 40, FLUSH
Casing Top Elevation: 1539.89 I
Casing Stick-up: 1.90
Well Maintenance Date:
USGS Hydrologic Unit Code: 10170203
Electric Log Information:
Spontaneous Potential:
Natural Gamma:
Samples:

Driller's Log:
Geologist's Log: X
Drilling Method: AUGER

Test Hole Number: R20-93-18
SDGS Well Name: R20-93-18

Aquifer: TILL

Screen Length: 10.3
Casing Diameter: 2.0

Total Casing and Screen: 23.7

Single Point Resistivity:
Extra:

Well centralizer: 10.5 feet. The hole collapsed from 22-21.5 feet. Filter pack (0.65-0.75 mm quartz sand): 21.5-8.5 feet. Granular bentonite: 8.5-7.0 feet. Bentonite grout: 7.0-2.5 feet. Cement: 2.5-0 feet. Steel well protector.

1537.99 - 1536.99	0 - 1.0	Topsoil, black
1536.99 - 1534.99	1.0 - 3.0	Clay, yellowish-brown
1534.99 - 1532.99	3.0 - 5.0	Clay, yellowish-brown and tan, silty
1532.99 - 1523.99	5.0 - 14.0	Clay, yellowish-brown, silty, sandy, pebbly
1523.99 - 1521.99	14.0 - 16.0	Unknown; a shelby-tube sample was taken from 14-16 feet
1521.99 - 1519.99	16.0 - 18.0	Clay, yellowish-brown, silty, sandy, pebbly
1519.99 - 1517.99	18.0 - 20.0	Unknown; a shelby-tube sample was taken from 18-20 feet
1517.99 - 1515.99	20.0 - 22.0	Clay, yellowish-brown, silty, sandy, pebbly

Shelby-tube samples were collected from 14-16 and 18-20 feet, left in the tubes, sealed, and transported to South Dakota State University for analysis. See log for R20-93-14 for descriptions of continuous split-spoon samples to a depth of 64 feet near this location.

County: MINNEHAHA
Location: 101N-51W-35CCDA 8
Legal Location: NE SE SW SW sec. 35, T. 101 N., R. 51 W.
Latitude: 43.3005
Longitude: 96.5530
Land Owner: SIOUX FALLS
Project: RUNGE LANDFILL (GRPEP)
Drilling Company: SDGS
Driller: D. IVERSON
Geologist: D. ILES
Date Drilled: 06-13-1993
Ground Surface Elevation: 1538.77 I
Total Drill Hole Depth: 17.0
Water Rights Well:
Other Well Name:
Basin: BIG SIOUX

Driller's Log:
Geologist's Log: X
Drilling Method: AUGER

Test Hole Number: R20-93-19
SDGS Well Name: R20-93-19

Aquifer: TILL

Management Unit:
Screen Type: PVC, MFG., 0.010 SLOT, FLUSH — Screen Length: 5.3
Casing Type: PVC, SCH. 40, FLUSH — Casing Diameter: 2.0
Casing Top Elevation: 1540.57 I
Casing Stick-up: 1.80 — Total Casing and Screen: 18.9
Well Maintenance Date:
USGS Hydrologic Unit Code: 10170203
Electric Log Information:
Spontaneous Potential: — Single Point Resistivity:
Natural Gamma: — Extra:
Samples:

Well centralizer: 10.5 feet. The hole collapsed from 17-16.5 feet. Filter pack (0.65-0.75 mm quartz sand): 16.5-9 feet. Bentonite grout: 9-2.5 feet. Cement: 2.5-0 feet. Steel well protector. Leveling of cuttings added 0.2 feet to ground surface.

1538.77 - 1537.77	0 - 1.0	Topsoil, black
1537.77 - 1535.77	1.0 - 3.0	Clay, yellowish-brown, silty
1535.77 - 1534.77	3.0 - 4.0	Clay, yellowish-brown and tan
1534.77 - 1524.77	4.0 - 14.0	Clay, yellowish-brown, silty, sandy, pebbly
1524.77 - 1522.77	14.0 - 16.0	Unknown; a shelby-tube sample was taken from 14-16 feet
1522.77 - 1521.77	16.0 - 17.0	Clay, yellowish-brown, silty, sandy, pebbly

A shelby-tube sample was collected from 14-16 feet, left in the tube, sealed, and transported to South Dakota State University for analysis. See log for R20-93-14 for descriptions of continuous split-spoon samples to a depth of 64 feet near this location.

County: MINNEHAHA — Location: 101N-51W-35CCDA 9
Legal Location: NE SE SW SW sec. 35, T. 101 N., R. 51 W.
Latitude: 43.3005 — Longitude: 96.5530
Land Owner: SIOUX FALLS
Project: RUNGE LANDFILL (GRPEP)
Drilling Company: SDGS
Driller: D. IVERSON — Driller's Log:
Geologist: D. ILES — Geologist's Log: X
Date Drilled: 06-13-1993 — Drilling Method: AUGER
Ground Surface Elevation: 1540.26 I
Total Drill Hole Depth: 19.5 — Test Hole Number: R20-93-20
Water Rights Well: — SDGS Well Name: R20-93-20
Other Well Name:
Basin: BIG SIOUX — Aquifer: TILL
Management Unit:
Screen Type: OPEN CORE HOLE BELOW CASING — Screen Length: 1.5
Casing Type: PVC, SCH. 40, FLUSH — Casing Diameter: 4.0
Casing Top Elevation: 1541.56 I
Casing Stick-up: 1.30 — Total Casing and Screen: 20.0
Well Maintenance Date:
USGS Hydrologic Unit Code: 10170203
Electric Log Information:
Spontaneous Potential: — Single Point Resistivity:
Natural Gamma: — Extra:
Samples:

Casing installed through auger & pushed into hole bottom from 17.5-18 ft. A shelby-tube sample collected through casing from 17.5-19.5 ft to create a water-intake area. Granular bentonite: 17.5-16.5

ft. Bentonite grout: 16.5-2.5 ft. Cement: 2.5-0 ft. Steel well protector. Leveling of cuttings added 0.7 ft to ground surface.

1540.26 - 1539.26	0 - 1.0	Topsoil, black
1539.26 - 1536.26	1.0 - 4.0	Clay, yellowish-brown
1536.26 - 1534.26	4.0 - 6.0	Clay, yellowish-brown and tan, silty
1534.26 - 1522.76	6.0 - 17.5	Clay, yellowish-brown, silty, sandy, pebbly
1522.76 - 1520.76	17.5 - 19.5	Unknown; a shelby-tube sample was taken from 17.5-19.5 feet; sediment in the bottom of the shelby tube looked similar to the interval from 6-17.5 feet

A shelby-tube sample was collected from 17.5-19.5 feet, left in the tube, sealed, and transported to South Dakota State University for analysis. See log for R20-93-14 for descriptions of continuous split-spoon samples to a depth of 64 feet near this location.

County: MINNEHAHA
Location: 101N-51W-35CCDA10
Legal Location: NE SE SW SW sec. 35, T. 101 N., R. 51 W.
Latitude: 43.3005
Longitude: 96.5530
Land Owner: SIOUX FALLS
Project: RUNGE LANDFILL (GRPEP)
Drilling Company: SDGS
Driller: D. IVERSON
Driller's Log:
Geologist: D. ILES
Geologist's Log: X
Date Drilled: 06-15-1993
Drilling Method: AUGER
Ground Surface Elevation: 1540.96 I
Total Drill Hole Depth: 23.5
Test Hole Number: R20-93-21
Water Rights Well:
SDGS Well Name: R20-93-21
Other Well Name:
Basin: BIG SIOUX
Aquifer: TILL
Management Unit:
Screen Type: PVC, MFG., 0.010 SLOT, FLUSH
Screen Length: 4.7
Casing Type: PVC, SCH. 40, FLUSH
Casing Diameter: 4.0
Casing Top Elevation: 1542.36 I
Casing Stick-up: 1.40
Total Casing and Screen: 23.0
Well Maintenance Date:
USGS Hydrologic Unit Code: 10170203
Electric Log Information:
Spontaneous Potential:
Single Point Resistivity:
Natural Gamma:
Extra:
Samples:

Well centralizer: 11.5 feet. The hole collapsed from 23.5-21 feet. Filter pack (0.65-0.75 mm quartz sand): 21-14.5 feet. Granular bentonite: 14.5-14 feet. Bentonite grout: 14-2.5 feet. Cement: 2.5-0 feet. Steel well protector. Leveling of cuttings added 0.6 feet to ground surface.

1540.96 - 1539.96	0 - 1.0	Topsoil, black
1539.96 - 1537.96	1.0 - 3.0	Clay, yellowish-brown
1537.96 - 1535.96	3.0 - 5.0	Clay, yellowish-brown, silty
1535.96 - 1522.96	5.0 - 18.0	Clay, yellowish-brown, silty, sandy, pebbly
1522.96 - 1520.96	18.0 - 20.0	Clay, yellowish-brown, tan, and gray, silty, sandy, pebbly
1520.96 - 1518.96	20.0 - 22.0	Unknown; a shelby-tube sample was taken from 20-22 feet; sediment at the bottom of the shelby tube was similar to the interval from 18-20 feet except with more gray coloration
1518.96 - 1517.46	22.0 - 23.5	Clay, gray, silty, sandy, pebbly

A shelby-tube sample was collected from 20-22 feet, left in the tube, sealed, and transported to South Dakota State University for analysis. See log for R20-93-14 for descriptions of continuous split-spoon samples to a depth of 64 feet near this location.

County: MINNEHAHA
Location: 101N-51W-35CDBC 7
Legal Location: SW NW SE SW sec. 35, T. 101 N., R. 51 W.
Latitude: 43.3008
Longitude: 96.5528
Land Owner: SIOUX FALLS
Project: RUNGE LANDFILL (GRPEP)
Drilling Company: SDGS
Driller: D. IVERSON
Driller's Log:
Geologist: D. ILES
Geologist's Log: X
Date Drilled: 06-15-1993
Drilling Method: AUGER
Ground Surface Elevation: 1543.68 I
Total Drill Hole Depth: 19.1
Test Hole Number: R20-93-22
Water Rights Well:
SDGS Well Name: R20-93-22
Other Well Name:
Basin: BIG SIOUX
Aquifer: TILL
Management Unit:
Screen Type: OPEN CORE HOLE BELOW CASING
Screen Length: 1.1
Casing Type: PVC, SCH. 40, FLUSH
Casing Diameter: 4.0
Casing Top Elevation: 1545.18 I
Casing Stick-up: 1.50
Total Casing and Screen: 20.0
Well Maintenance Date:
USGS Hydrologic Unit Code: 10170203
Electric Log Information:
Spontaneous Potential:
Single Point Resistivity:
Natural Gamma:
Extra:
Samples:

Casing installed through auger & pushed into hole bottom from 17.5-18 ft. A shelby-tube sample was collected through the casing from 17.5-19.1 ft to create a water-intake area. Hole collapsed from 17.5-16 ft. Granular bentonite: 16-14 ft. Bentonite grout: 14-2.5 ft. Cement: 2.5-0 ft. See lithology notes for additional information.

1543.68 - 1542.68	0 - 1.0	Topsoil, black
1542.68 - 1540.68	1.0 - 3.0	Clay, yellowish-brown, silty, sandy, pebbly
1540.68 - 1539.68	3.0 - 4.0	Clay, yellowish-brown, sandy, pebbly, very silty
1539.68 - 1529.68	4.0 - 14.0	Clay, yellowish-brown, silty, sandy, pebbly
1529.68 - 1526.18	14.0 - 17.5	Clay, yellowish-brown and tan, silty, sandy, pebbly
1526.18 - 1524.58	17.5 - 19.1	Unknown; shelby-tube sample taken from 17.5-19.1 feet

Steel well protector installed. Leveling of cuttings added 0.5 ft to ground surface. A shelby-tube sample was collected from 17.5-19.1 ft, left in the tube, sealed, and transported to South Dakota State University for analysis. See log for R20-93-02 for descriptions of continuous split-spoon samples to a depth of 70 ft near this location.

County: MINNEHAHA
Location: 101N-51W-35CDBC 8
Legal Location: SW NW SE SW sec. 35, T. 101 N., R. 51 W.
Latitude: 43.3008
Longitude: 96.5528
Land Owner: SIOUX FALLS
Project: RUNGE LANDFILL (GRPEP)
Drilling Company: SDGS
Driller: D. IVERSON
Driller's Log:
Geologist: D. ILES
Geologist's Log: X

Date Drilled: 06-15-1993
Ground Surface Elevation: 1544.31 I
Total Drill Hole Depth: 23.0
Water Rights Well:
Other Well Name:
Basin: BIG SIOUX
Management Unit:
Screen Type: PVC, MFG., 0.010 SLOT, FLUSH
Casing Type: PVC, SCH. 40, FLUSH
Casing Top Elevation: 1545.51 I
Casing Stick-up: 1.20
Well Maintenance Date:
USGS Hydrologic Unit Code: 10170203
Electric Log Information:
Spontaneous Potential:
Natural Gamma:
Samples:

Drilling Method: AUGER

Test Hole Number: R20-93-23
SDGS Well Name: R20-93-23

Aquifer: TILL

Screen Length: 4.7
Casing Diameter: 4.0

Total Casing and Screen: 24.5

Single Point Resistivity:
Extra:

Casing installed through inside of auger. The hole collapsed from 23-22.5 feet. Filter pack (0.65-0.75 mm quartz sand): 22.5-16 feet. Granular bentonite: 16-15 feet. Bentonite grout: 15-2.5 feet. Cement: 2.5-0 feet. Steel well protector. Leveling of cuttings added 0.8 feet to ground surface.

1544.31 - 1543.31	0 - 1.0	Topsoil, black
1543.31 - 1540.31	1.0 - 4.0	Clay, yellowish-brown and tan, silty, sandy, pebbly
1540.31 - 1537.31	4.0 - 7.0	Clay, yellowish-brown, sandy, pebbly, very silty
1537.31 - 1534.31	7.0 - 10.0	Clay, yellowish-brown, silty, sandy, pebbly
1534.31 - 1532.31	10.0 - 12.0	Clay, yellowish-brown, sandy, pebbly, very silty
1532.31 - 1526.31	12.0 - 18.0	Clay, yellowish-brown, silty, sandy, pebbly
1526.31 - 1524.31	18.0 - 20.0	Unknown; a shelby-tube sample was taken from 18-20 feet; sediment at the bottom of the shelby tube was similar to the interval from 12-18 feet
1524.31 - 1521.31	20.0 - 23.0	Clay, yellowish-brown and gray, silty, sandy, pebbly

A shelby-tube sample was collected from 18-20 feet, left in the tube, sealed, and transported to South Dakota State University for analysis. See log for R20-93-02 for descriptions of continuous split-spoon samples to a depth of 70 feet near this location.

Appendix B

Comparison of Slug Test Results

Appendix B. Comparison of slug test results.

Slug test resultls are arranged according to the weathering zone in the till, and in ascending order within each zone.

Results from the Bouwer and Rice (1976) and Hvorslev (1951) methods of analysis are included for each well.

Weathered zone		
Well	K m/sec	K ft/min
R20-93-21	2.82E-10	5.55E-08
R20-93-21	3.35E-10	6.59E-08
R20-93-20	5.03E-10	9.90E-08
R20-93-20	6.10E-10	1.20E-07
R20-93-09	6.64E-10	1.31E-07
R20-93-09	7.21E-10	1.42E-07
R20-93-18	1.20E-09	2.36E-07
R20-93-18	1.96E-09	3.86E-07
R20-93-13	2.28E-09	4.49E-07
R20-93-08	2.37E-09	4.67E-07
R20-93-19	2.61E-09	5.14E-07
R20-93-13	2.97E-09	5.85E-07
R20-93-08	3.91E-09	7.70E-07
R20-93-19	4.04E-09	7.95E-07
R20-93-23	1.28E-08	2.52E-06
R20-93-07	1.46E-08	2.87E-06
R20-93-23	1.75E-08	3.44E-06
R20-93-07	1.90E-08	3.74E-06
R20-93-22	8.38E-08	1.65E-05
R20-93-22	9.56E-08	1.88E-05
minimum	2.82E-10	5.55E-08
maximum	9.56E-08	1.88E-05
average	1.34E-08	2.64E-06

Transition zone		
Well	K m/sec	K ft/min
R20-93-12	6.07E-11	1.19E-08
R20-93-12	1.00E-10	1.97E-08
R20-93-06	1.76E-10	3.46E-08
R20-93-06	1.80E-10	3.54E-08
R20-93-16	3.35E-10	6.59E-08
R20-93-17	3.39E-10	6.67E-08
R20-93-17	3.76E-10	7.40E-08
R20-93-16	3.93E-10	7.74E-08
R20-93-05	7.47E-10	1.47E-07
R20-93-05	7.82E-10	1.54E-07
R20-93-11	5.18E-09	1.02E-06
R20-93-11	7.01E-09	1.38E-06
minimum	6.07E-11	1.19E-08
maximum	7.01E-09	1.38E-06
average	1.31E-09	2.57E-07

Unweathered zone		
Well	K m/sec	K ft/min
R20-93-03	5.63E-11	1.11E-08
R20-93-03	6.10E-11	1.20E-08
R20-93-02	1.30E-10	2.56E-08
R20-93-02	1.63E-10	3.21E-08
R20-93-14	3.30E-10	6.50E-08
R20-93-14	3.49E-10	6.87E-08
minimum	5.63E-11	1.11E-08
maximum	3.49E-10	6.87E-08
average	1.82E-10	3.57E-08

Appendix B continued.

Slug test results are arranged according to well diameter, then according to the length of the well screen, and in ascending order within each category.

Results from the Bouwer and Rice (1976) and Hvorslev (1951) methods of analysis are included for each well.

2-inch diameter

Well	Screen length (ft)	K m/sec	K ft/min
R20-93-02	5.3	1.30E-10	2.56E-08
R20-93-02	5.3	1.63E-10	3.21E-08
R20-93-03	5.3	5.63E-11	1.11E-08
R20-93-03	5.3	6.10E-11	1.20E-08
R20-93-07	5.3	1.46E-08	2.87E-06
R20-93-07	5.3	1.90E-08	3.74E-06
R20-93-11	5.3	5.18E-09	1.02E-06
R20-93-11	5.3	7.01E-09	1.38E-06
R20-93-14	5.3	3.30E-10	6.50E-08
R20-93-14	5.3	3.49E-10	6.87E-08
R20-93-16	5.3	3.35E-10	6.59E-08
R20-93-16	5.3	3.93E-10	7.74E-08
R20-93-19	5.3	2.61E-09	5.14E-07
R20-93-19	5.3	4.04E-09	7.95E-07
	minimum	5.63E-11	1.11E-08
	maximum	1.90E-08	3.74E-06
	average	3.88E-09	7.63E-07

Well	Screen length (ft)	K m/sec	K ft/min
R20-93-05	10.3	7.47E-10	1.47E-07
R20-93-05	10.3	7.82E-10	1.54E-07
R20-93-08	10.3	2.37E-09	4.67E-07
R20-93-08	10.3	3.91E-09	7.70E-07
R20-93-12	10.3	6.07E-11	1.19E-08
R20-93-12	10.3	1.00E-10	1.97E-08
R20-93-18	10.3	1.20E-09	2.36E-07
R20-93-18	10.3	1.96E-09	3.86E-07
	minimum	6.07E-11	1.19E-08
	maximum	3.91E-09	7.70E-07
	average	1.39E-09	2.74E-07

4-inch diameter

Well	Screen length (ft)	K m/sec	K ft/min
R20-93-21	4.7	2.82E-10	5.55E-08
R20-93-21	4.7	3.35E-10	6.59E-08
R20-93-23	4.7	1.28E-08	2.52E-06
R20-93-23	4.7	1.75E-08	3.44E-06
	minimum	2.82E-10	5.55E-08
	maximum	1.75E-08	3.44E-06
	average	7.73E-09	1.52E-06

Appendix B continued.

Slug test results are arranged according to well diameter, then according to the type of water intake, and in ascending order within each category.

Results from the Bouwer and Rice (1976) and Hvorslev (1951) methods of analysis are included for each well.

2-inch diameter

wells with screens

Well	K m/sec	K ft/min
R20-93-03	5.63E-11	1.11E-08
R20-93-12	6.07E-11	1.19E-08
R20-93-03	6.10E-11	1.20E-08
R20-93-12	1.00E-10	1.97E-08
R20-93-02	1.30E-10	2.56E-08
R20-93-02	1.63E-10	3.21E-08
R20-93-14	3.30E-10	6.50E-08
R20-93-16	3.35E-10	6.59E-08
R20-93-14	3.49E-10	6.87E-08
R20-93-16	3.93E-10	7.74E-08
R20-93-05	7.47E-10	1.47E-07
R20-93-05	7.82E-10	1.54E-07
R20-93-18	1.20E-09	2.36E-07
R20-93-18	1.96E-09	3.86E-07
R20-93-08	2.37E-09	4.67E-07
R20-93-19	2.61E-09	5.14E-07
R20-93-08	3.91E-09	7.70E-07
R20-93-19	4.04E-09	7.95E-07
R20-93-11	5.18E-09	1.02E-06
R20-93-11	7.01E-09	1.38E-06
R20-93-07	1.46E-08	2.87E-06
R20-93-07	1.90E-08	3.74E-06
minimum	5.63E-11	1.11E-08
maximum	1.90E-08	3.74E-06
average	2.97E-09	5.85E-07

wells with cored intakes

Well	K m/sec	K ft/min
R20-93-06	1.76E-10	3.46E-08
R20-93-06	1.80E-10	3.54E-08
R20-93-17	3.39E-10	6.67E-08
R20-93-17	3.76E-10	7.40E-08
R20-93-09	6.64E-10	1.31E-07
R20-93-09	7.21E-10	1.42E-07
R20-93-13	2.28E-09	4.49E-07
R20-93-13	2.97E-09	5.85E-07
minimum	1.76E-10	3.46E-08
maximum	2.97E-09	5.85E-07
average	9.63E-10	1.90E-07

4-inch diameter

wells with cored intakes

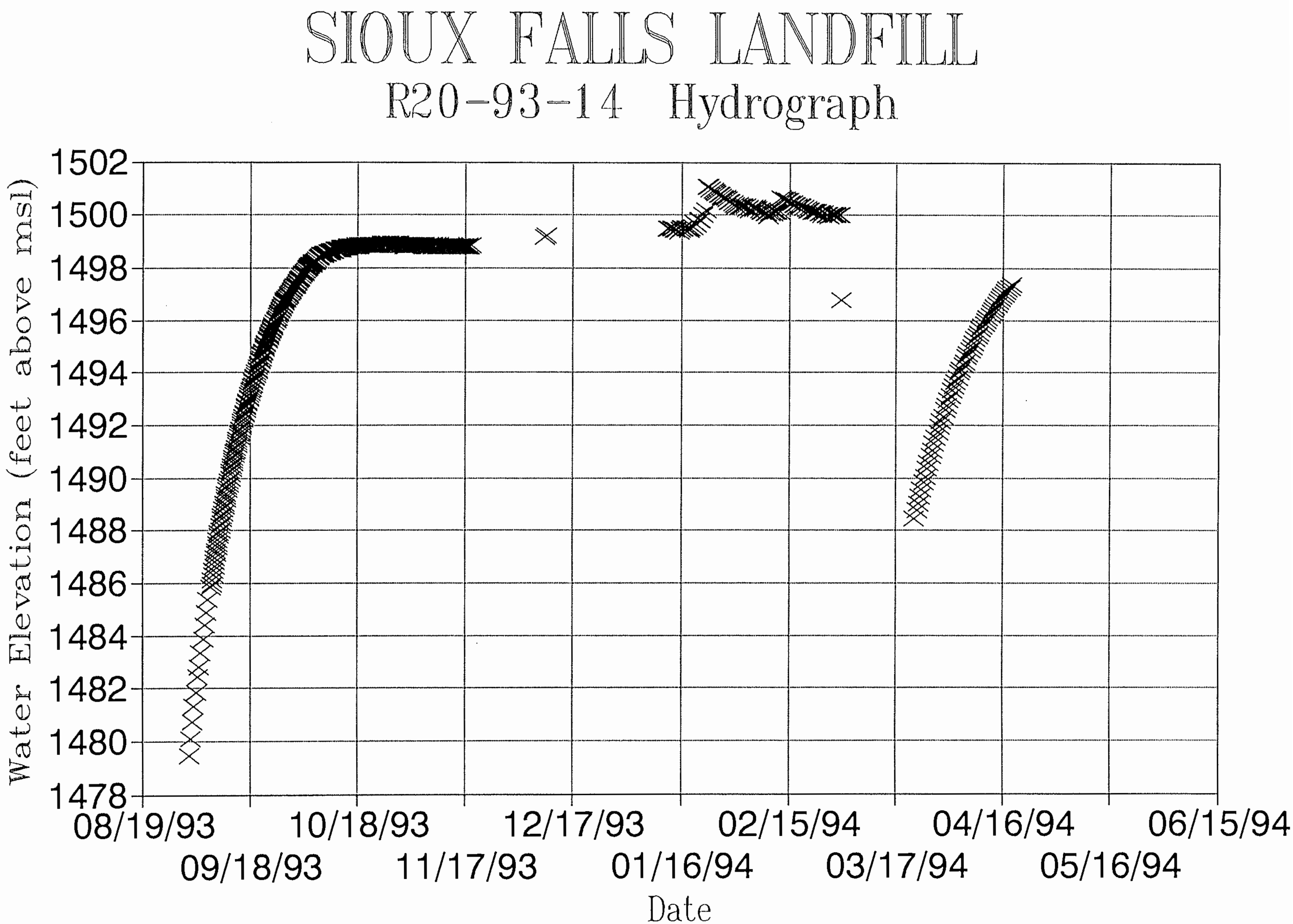
Well	K m/sec	K ft/min
R20-93-20	5.03E-10	9.90E-08
R20-93-20	6.10E-10	1.20E-07
R20-93-22	8.38E-08	1.65E-05
R20-93-22	9.56E-08	1.88E-05
minimum	5.03E-10	9.90E-08
maximum	9.56E-08	1.88E-05
average	4.51E-08	8.88E-06

wells with screens

Well	K m/sec	K ft/min
R20-93-21	2.82E-10	5.55E-08
R20-93-21	3.35E-10	6.59E-08
R20-93-23	1.28E-08	2.52E-06
R20-93-23	1.75E-08	3.44E-06
minimum	2.82E-10	5.55E-08
maximum	1.75E-08	3.44E-06
average	7.73E-09	1.52E-06

Appendix C

Water-Level Data and Hydrographs


SIOUX FALLS LANDFILL
R20-93-14 Hydrograph
Water Elevation (feet above msl)
1502
1500
1498
1496
1494
1492
1490
1488
1486
1484
1482
1480
1478
08/19/93
09/18/93
10/18/93
11/17/93
12/17/93
01/16/94
02/15/94
03/17/94
04/16/94
05/16/94
06/15/94
Date

DATE	TIME	STATIO	Pres.Head	Ser.Date	Wat.Elev.	
09/01/93	00:00:00	R20-93-14	8.31	34213.00	1479.47	
09/01/93	12:00:00	77	8.94	34213.50	1480.10	
09/02/93	00:00:00	77	9.55	34214.00	1480.71	
09/02/93	12:00:00	77	10.14	34214.50	1481.30	
09/03/93	00:00:00	77	10.69	34215.00	1481.85	
09/03/93	12:00:00	77	11.25	34215.50	1482.41	
09/04/93	00:00:00	77	1.42	34216.00	1482.80	Approx.
09/04/93	12:00:00	77	1.97	34216.50	1483.35	Approx.
09/05/93	00:00:00	77	2.49	34217.00	1483.87	Approx.
09/05/93	12:00:00	77	3.00	34217.50	1484.38	Approx.
09/06/93	00:00:00	77	3.49	34218.00	1484.87	Approx.
09/06/93	12:00:00	77	3.98	34218.50	1485.36	Approx.
09/07/93	00:00:00	77	4.44	34219.00	1485.82	Approx.
09/07/93	10:00:00	77	0.18	34219.42	1485.94	
09/07/93	14:00:00	77	0.36	34219.58	1486.12	
09/07/93	18:00:00	77	0.54	34219.75	1486.30	
09/07/93	22:00:00	77	0.71	34219.92	1486.47	
09/08/93	02:00:00	77	0.87	34220.08	1486.63	
09/08/93	06:00:00	77	1.02	34220.25	1486.78	
09/08/93	10:00:00	77	1.17	34220.42	1486.93	
09/08/93	14:00:00	77	1.32	34220.58	1487.08	
09/08/93	18:00:00	77	1.46	34220.75	1487.22	
09/08/93	22:00:00	77	1.61	34220.92	1487.37	
09/09/93	02:00:00	77	1.74	34221.08	1487.50	
09/09/93	06:00:00	77	1.89	34221.25	1487.65	
09/09/93	10:00:00	77	2.03	34221.42	1487.77	
09/09/93	14:00:00	77	2.16	34221.58	1487.90	
09/09/93	18:00:00	77	2.29	34221.75	1488.03	
09/09/93	22:00:00	77	2.42	34221.92	1488.16	
09/10/93	02:00:00	77	2.55	34222.08	1488.29	
09/10/93	06:00:00	77	2.68	34222.25	1488.42	
09/10/93	10:00:00	77	2.81	34222.42	1488.55	
09/10/93	14:00:00	77	2.93	34222.58	1488.67	
09/10/93	18:00:00	77	3.06	34222.75	1488.80	
09/10/93	22:00:00	77	3.18	34222.92	1488.92	
09/11/93	02:00:00	77	3.30	34223.08	1489.04	
09/11/93	06:00:00	77	3.42	34223.25	1489.16	
09/11/93	10:00:00	77	3.55	34223.42	1489.29	
09/11/93	14:00:00	77	3.67	34223.58	1489.41	
09/11/93	18:00:00	77	3.79	34223.75	1489.53	
09/11/93	22:00:00	77	3.91	34223.92	1489.65	
09/12/93	02:00:00	77	4.02	34224.08	1489.76	
09/12/93	06:00:00	77	4.14	34224.25	1489.88	
09/12/93	10:00:00	77	4.25	34224.42	1489.99	
09/12/93	14:00:00	77	4.37	34224.58	1490.11	
09/12/93	18:00:00	77	4.48	34224.75	1490.22	
09/12/93	22:00:00	77	4.59	34224.92	1490.33	
09/13/93	02:00:00	77	4.70	34225.08	1490.44	

09/13/93	06:00:00	77	4.80	34225.25	1490.54
09/13/93	10:00:00	77	4.91	34225.42	1490.65
09/13/93	14:00:00	77	5.01	34225.58	1490.75
09/13/93	18:00:00	77	5.12	34225.75	1490.86
09/13/93	22:00:00	77	5.22	34225.92	1490.96
09/14/93	02:00:00	77	5.32	34226.08	1491.06
09/14/93	06:00:00	77	5.42	34226.25	1491.16
09/14/93	10:00:00	77	5.52	34226.42	1491.26
09/14/93	14:00:00	77	5.63	34226.58	1491.37
09/14/93	18:00:00	77	5.73	34226.75	1491.47
09/14/93	22:00:00	77	5.82	34226.92	1491.56
09/15/93	02:00:00	77	5.91	34227.08	1491.65
09/15/93	06:00:00	77	6.00	34227.25	1491.74
09/15/93	10:00:00	77	6.11	34227.42	1491.85
09/15/93	14:00:00	77	6.21	34227.58	1491.95
09/15/93	18:00:00	77	6.30	34227.75	1492.04
09/15/93	22:00:00	77	6.39	34227.92	1492.13
09/16/93	02:00:00	77	6.48	34228.08	1492.22
09/16/93	06:00:00	77	6.56	34228.25	1492.30
09/16/93	10:00:00	77	6.66	34228.42	1492.40
09/16/93	14:00:00	77	6.75	34228.58	1492.49
09/16/93	18:00:00	77	6.84	34228.75	1492.58
09/16/93	22:00:00	77	6.92	34228.92	1492.66
09/17/93	02:00:00	77	7.00	34229.08	1492.74
09/17/93	06:00:00	77	7.08	34229.25	1492.82
09/17/93	10:00:00	77	7.17	34229.42	1492.91
09/17/93	14:00:00	77	7.25	34229.58	1492.99
09/17/93	18:00:00	77	7.33	34229.75	1493.07
09/17/93	22:00:00	77	7.41	34229.92	1493.15
09/18/93	02:00:00	77	7.49	34230.08	1493.23
09/18/93	06:00:00	77	7.57	34230.25	1493.31
09/18/93	10:00:00	77	7.65	34230.42	1493.39
09/18/93	14:00:00	77	7.73	34230.58	1493.47
09/18/93	18:00:00	77	7.81	34230.75	1493.55
09/18/93	22:00:00	77	7.88	34230.92	1493.62
09/19/93	02:00:00	77	7.96	34231.08	1493.70
09/19/93	06:00:00	77	8.03	34231.25	1493.77
09/19/93	10:00:00	77	8.11	34231.42	1493.85
09/19/93	14:00:00	77	8.18	34231.58	1493.92
09/19/93	18:00:00	77	8.26	34231.75	1494.00
09/19/93	22:00:00	77	8.33	34231.92	1494.07
09/20/93	02:00:00	77	8.40	34232.08	1494.14
09/20/93	06:00:00	77	8.47	34232.25	1494.21
09/20/93	10:00:00	77	8.54	34232.42	1494.28
09/20/93	14:00:00	77	8.61	34232.58	1494.35
09/20/93	18:00:00	77	8.68	34232.75	1494.42
09/20/93	22:00:00	77	8.75	34232.92	1494.49
09/21/93	02:00:00	77	8.82	34233.08	1494.56
09/21/93	06:00:00	77	8.88	34233.25	1494.62
09/21/93	10:00:00	77	8.95	34233.42	1494.69

09/21/93	14:00:00	77	9.02	34233.58	1494.76
09/21/93	18:00:00	77	9.09	34233.75	1494.83
09/21/93	22:00:00	77	9.15	34233.92	1494.89
09/22/93	02:00:00	77	9.22	34234.08	1494.96
09/22/93	06:00:00	77	9.28	34234.25	1495.02
09/22/93	10:00:00	77	9.34	34234.42	1495.08
09/22/93	14:00:00	77	9.40	34234.58	1495.14
09/22/93	18:00:00	77	9.47	34234.75	1495.21
09/22/93	22:00:00	77	9.52	34234.92	1495.26
09/23/93	02:00:00	77	9.57	34235.08	1495.31
09/23/93	06:00:00	77	9.63	34235.25	1495.37
09/23/93	10:00:00	77	9.70	34235.42	1495.44
09/23/93	14:00:00	77	9.76	34235.58	1495.50
09/23/93	18:00:00	77	9.82	34235.75	1495.56
09/23/93	22:00:00	77	9.87	34235.92	1495.61
09/24/93	02:00:00	77	9.92	34236.08	1495.66
09/24/93	06:00:00	77	9.98	34236.25	1495.72
09/24/93	10:00:00	77	10.04	34236.42	1495.78
09/24/93	14:00:00	77	10.10	34236.58	1495.84
09/24/93	18:00:00	77	10.16	34236.75	1495.90
09/24/93	22:00:00	77	10.20	34236.92	1495.94
09/25/93	02:00:00	77	10.25	34237.08	1495.99
09/25/93	06:00:00	77	10.30	34237.25	1496.04
09/25/93	10:00:00	77	10.36	34237.42	1496.10
09/25/93	14:00:00	77	10.42	34237.58	1496.16
09/25/93	18:00:00	77	10.47	34237.75	1496.21
09/25/93	22:00:00	77	10.51	34237.92	1496.25
09/26/93	02:00:00	77	10.56	34238.08	1496.30
09/26/93	06:00:00	77	10.61	34238.25	1496.35
09/26/93	10:00:00	77	10.66	34238.42	1496.40
09/26/93	14:00:00	77	10.70	34238.58	1496.44
09/26/93	18:00:00	77	10.74	34238.75	1496.48
09/26/93	22:00:00	77	10.78	34238.92	1496.52
09/27/93	02:00:00	77	10.81	34239.08	1496.55
09/27/93	06:00:00	77	10.86	34239.25	1496.60
09/27/93	10:00:00	77	10.91	34239.42	1496.65
09/27/93	14:00:00	77	10.97	34239.58	1496.71
09/27/93	18:00:00	77	11.01	34239.75	1496.75
09/27/93	22:00:00	77	11.04	34239.92	1496.78
09/28/93	02:00:00	77	11.08	34240.08	1496.82
09/28/93	06:00:00	77	11.12	34240.25	1496.86
09/28/93	10:00:00	77	11.16	34240.42	1496.90
09/28/93	14:00:00	77	11.20	34240.58	1496.94
09/28/93	18:00:00	77	11.24	34240.75	1496.98
09/28/93	22:00:00	77	11.26	34240.92	1497.00
09/29/93	02:00:00	77	11.29	34241.08	1497.03
09/29/93	06:00:00	77	11.32	34241.25	1497.06
09/29/93	10:00:00	77	11.37	34241.42	1497.11
09/29/93	14:00:00	77	11.41	34241.58	1497.15
09/29/93	18:00:00	77	11.44	34241.75	1497.18

09/29/93	22:00:00	77	11.47	34241.92	1497.21
09/30/93	02:00:00	77	11.50	34242.08	1497.24
09/30/93	06:00:00	77	11.54	34242.25	1497.28
09/30/93	10:00:00	77	11.58	34242.42	1497.32
09/30/93	14:00:00	77	0.53	34242.58	1497.29
09/30/93	18:00:00	77	0.61	34242.75	1497.37
09/30/93	22:00:00	77	0.65	34242.92	1497.41
10/01/93	02:00:00	77	0.69	34243.08	1497.45
10/01/93	06:00:00	77	0.72	34243.25	1497.48
10/01/93	10:00:00	77	0.76	34243.42	1497.52
10/01/93	14:00:00	77	0.80	34243.58	1497.56
10/01/93	18:00:00	77	0.83	34243.75	1497.59
10/01/93	22:00:00	77	0.85	34243.92	1497.61
10/02/93	02:00:00	77	0.87	34244.08	1497.63
10/02/93	06:00:00	77	0.90	34244.25	1497.66
10/02/93	10:00:00	77	0.93	34244.42	1497.69
10/02/93	14:00:00	77	0.97	34244.58	1497.73
10/02/93	18:00:00	77	1.00	34244.75	1497.76
10/02/93	22:00:00	77	1.01	34244.92	1497.77
10/03/93	02:00:00	77	1.04	34245.08	1497.80
10/03/93	06:00:00	77	1.07	34245.25	1497.83
10/03/93	10:00:00	77	1.10	34245.42	1497.86
10/03/93	14:00:00	77	1.14	34245.58	1497.90
10/03/93	18:00:00	77	1.19	34245.75	1497.95
10/03/93	22:00:00	77	1.21	34245.92	1497.97
10/04/93	02:00:00	77	1.23	34246.08	1497.99
10/04/93	06:00:00	77	1.26	34246.25	1498.02
10/04/93	10:00:00	77	1.28	34246.42	1498.04
10/04/93	14:00:00	77	1.30	34246.58	1498.06
10/04/93	18:00:00	77	1.32	34246.75	1498.08
10/04/93	22:00:00	77	1.33	34246.92	1498.09
10/05/93	02:00:00	77	1.35	34247.08	1498.11
10/05/93	06:00:00	77	1.36	34247.25	1498.12
10/05/93	10:00:00	77	1.39	34247.42	1498.15
10/05/93	14:00:00	77	1.42	34247.58	1498.18
10/05/93	18:00:00	77	1.44	34247.75	1498.20
10/05/93	22:00:00	77	1.45	34247.92	1498.21
10/06/93	02:00:00	77	1.47	34248.08	1498.23
10/06/93	06:00:00	77	1.49	34248.25	1498.25
10/06/93	10:00:00	77	1.52	34248.42	1498.28
10/06/93	14:00:00	77	1.55	34248.58	1498.31
10/06/93	18:00:00	77	1.57	34248.75	1498.33
10/06/93	22:00:00	77	1.59	34248.92	1498.35
10/07/93	02:00:00	77	1.61	34249.08	1498.37
10/07/93	06:00:00	77	1.62	34249.25	1498.38
10/07/93	10:00:00	77	1.64	34249.42	1498.40
10/07/93	14:00:00	77	1.67	34249.58	1498.43
10/07/93	18:00:00	77	1.69	34249.75	1498.45
10/07/93	22:00:00	77	1.70	34249.92	1498.46
10/08/93	02:00:00	77	1.71	34250.08	1498.47

10/08/93	06:00:00	77	1.72	34250.25	1498.48
10/08/93	10:00:00	77	1.72	34250.42	1498.48
10/08/93	14:00:00	77	1.74	34250.58	1498.50
10/08/93	18:00:00	77	1.74	34250.75	1498.50
10/08/93	22:00:00	77	1.75	34250.92	1498.51
10/09/93	02:00:00	77	1.75	34251.08	1498.51
10/09/93	06:00:00	77	1.76	34251.25	1498.52
10/09/93	10:00:00	77	1.77	34251.42	1498.53
10/09/93	14:00:00	77	1.79	34251.58	1498.55
10/09/93	18:00:00	77	1.80	34251.75	1498.56
10/09/93	22:00:00	77	1.79	34251.92	1498.55
10/10/93	02:00:00	77	1.79	34252.08	1498.55
10/10/93	06:00:00	77	1.80	34252.25	1498.56
10/10/93	10:00:00	77	1.82	34252.42	1498.58
10/10/93	14:00:00	77	1.85	34252.58	1498.61
10/10/93	18:00:00	77	1.85	34252.75	1498.61
10/10/93	22:00:00	77	1.85	34252.92	1498.61
10/11/93	02:00:00	77	1.85	34253.08	1498.61
10/11/93	06:00:00	77	1.86	34253.25	1498.62
10/11/93	10:00:00	77	1.88	34253.42	1498.64
10/11/93	14:00:00	77	1.90	34253.58	1498.66
10/11/93	18:00:00	77	1.91	34253.75	1498.67
10/11/93	22:00:00	77	1.90	34253.92	1498.66
10/12/93	02:00:00	77	1.91	34254.08	1498.67
10/12/93	06:00:00	77	1.90	34254.25	1498.66
10/12/93	10:00:00	77	1.92	34254.42	1498.68
10/12/93	14:00:00	77	1.93	34254.58	1498.69
10/12/93	18:00:00	77	1.94	34254.75	1498.70
10/12/93	22:00:00	77	1.93	34254.92	1498.69
10/13/93	02:00:00	77	1.93	34255.08	1498.69
10/13/93	06:00:00	77	1.93	34255.25	1498.69
10/13/93	10:00:00	77	1.95	34255.42	1498.71
10/13/93	14:00:00	77	1.96	34255.58	1498.72
10/13/93	18:00:00	77	1.97	34255.75	1498.73
10/13/93	22:00:00	77	1.96	34255.92	1498.72
10/14/93	02:00:00	77	1.96	34256.08	1498.72
10/14/93	06:00:00	77	1.97	34256.25	1498.73
10/14/93	10:00:00	77	1.98	34256.42	1498.74
10/14/93	14:00:00	77	1.99	34256.58	1498.75
10/14/93	18:00:00	77	2.00	34256.75	1498.76
10/14/93	22:00:00	77	2.00	34256.92	1498.76
10/15/93	02:00:00	77	2.00	34257.08	1498.76
10/15/93	06:00:00	77	2.00	34257.25	1498.76
10/15/93	10:00:00	77	2.01	34257.42	1498.77
10/15/93	14:00:00	77	2.02	34257.58	1498.78
10/15/93	18:00:00	77	2.02	34257.75	1498.78
10/15/93	22:00:00	77	2.02	34257.92	1498.78
10/16/93	02:00:00	77	2.02	34258.08	1498.78
10/16/93	06:00:00	77	2.03	34258.25	1498.79
10/16/93	10:00:00	77	2.03	34258.42	1498.79

10/16/93	14:00:00	77	2.04	34258.58	1498.80
10/16/93	18:00:00	77	2.04	34258.75	1498.80
10/16/93	22:00:00	77	2.04	34258.92	1498.80
10/17/93	02:00:00	77	2.04	34259.08	1498.80
10/17/93	06:00:00	77	2.04	34259.25	1498.80
10/17/93	10:00:00	77	2.04	34259.42	1498.80
10/17/93	14:00:00	77	2.05	34259.58	1498.81
10/17/93	18:00:00	77	2.06	34259.75	1498.82
10/17/93	22:00:00	77	2.05	34259.92	1498.81
10/18/93	02:00:00	77	2.05	34260.08	1498.81
10/18/93	06:00:00	77	2.05	34260.25	1498.81
10/18/93	10:00:00	77	2.06	34260.42	1498.82
10/18/93	14:00:00	77	2.07	34260.58	1498.83
10/18/93	18:00:00	77	2.07	34260.75	1498.83
10/18/93	22:00:00	77	2.06	34260.92	1498.82
10/19/93	02:00:00	77	2.06	34261.08	1498.82
10/19/93	06:00:00	77	2.06	34261.25	1498.82
10/19/93	10:00:00	77	2.06	34261.42	1498.82
10/19/93	14:00:00	77	2.07	34261.58	1498.83
10/19/93	18:00:00	77	2.08	34261.75	1498.84
10/19/93	22:00:00	77	2.07	34261.92	1498.83
10/20/93	02:00:00	77	2.07	34262.08	1498.83
10/20/93	06:00:00	77	2.07	34262.25	1498.83
10/20/93	10:00:00	77	2.07	34262.42	1498.83
10/20/93	14:00:00	77	2.08	34262.58	1498.84
10/20/93	18:00:00	77	2.08	34262.75	1498.84
10/20/93	22:00:00	77	2.07	34262.92	1498.83
10/21/93	02:00:00	77	2.06	34263.08	1498.82
10/21/93	06:00:00	77	2.06	34263.25	1498.82
10/21/93	10:00:00	77	2.07	34263.42	1498.83
10/21/93	14:00:00	77	2.08	34263.58	1498.84
10/21/93	18:00:00	77	2.08	34263.75	1498.84
10/21/93	22:00:00	77	2.06	34263.92	1498.82
10/22/93	02:00:00	77	2.06	34264.08	1498.82
10/22/93	06:00:00	77	2.06	34264.25	1498.82
10/22/93	10:00:00	77	2.08	34264.42	1498.84
10/22/93	14:00:00	77	2.09	34264.58	1498.85
10/22/93	18:00:00	77	2.09	34264.75	1498.85
10/22/93	22:00:00	77	2.08	34264.92	1498.84
10/23/93	02:00:00	77	2.08	34265.08	1498.84
10/23/93	06:00:00	77	2.08	34265.25	1498.84
10/23/93	10:00:00	77	2.09	34265.42	1498.85
10/23/93	14:00:00	77	2.10	34265.58	1498.86
10/23/93	18:00:00	77	2.10	34265.75	1498.86
10/23/93	22:00:00	77	2.10	34265.92	1498.86
10/24/93	02:00:00	77	2.10	34266.08	1498.86
10/24/93	06:00:00	77	2.10	34266.25	1498.86
10/24/93	10:00:00	77	2.10	34266.42	1498.86
10/24/93	14:00:00	77	2.11	34266.58	1498.87
10/24/93	18:00:00	77	2.11	34266.75	1498.87

10/24/93	22:00:00	77	2.11	34266.92	1498.87
10/25/93	02:00:00	77	2.11	34267.08	1498.87
10/25/93	06:00:00	77	2.11	34267.25	1498.87
10/25/93	10:00:00	77	2.12	34267.42	1498.88
10/25/93	14:00:00	77	2.12	34267.58	1498.88
10/25/93	18:00:00	77	2.12	34267.75	1498.88
10/25/93	22:00:00	77	2.12	34267.92	1498.88
10/26/93	02:00:00	77	2.12	34268.08	1498.88
10/26/93	06:00:00	77	2.11	34268.25	1498.87
10/26/93	10:00:00	77	2.11	34268.42	1498.87
10/26/93	14:00:00	77	2.11	34268.58	1498.87
10/26/93	18:00:00	77	2.11	34268.75	1498.87
10/26/93	22:00:00	77	2.10	34268.92	1498.86
10/27/93	02:00:00	77	2.10	34269.08	1498.86
10/27/93	06:00:00	77	2.08	34269.25	1498.84
10/27/93	10:00:00	77	2.09	34269.42	1498.85
10/27/93	14:00:00	77	2.12	34269.58	1498.88
10/27/93	18:00:00	77	2.12	34269.75	1498.88
10/27/93	22:00:00	77	2.12	34269.92	1498.88
10/28/93	02:00:00	77	2.12	34270.08	1498.88
10/28/93	06:00:00	77	2.13	34270.25	1498.89
10/28/93	10:00:00	77	2.12	34270.42	1498.88
10/28/93	14:00:00	77	2.14	34270.58	1498.90
10/28/93	18:00:00	77	2.13	34270.75	1498.89
10/28/93	22:00:00	77	2.11	34270.92	1498.87
10/29/93	02:00:00	77	2.11	34271.08	1498.87
10/29/93	06:00:00	77	2.10	34271.25	1498.86
10/29/93	10:00:00	77	2.11	34271.42	1498.87
10/29/93	14:00:00	77	2.11	34271.58	1498.87
10/29/93	18:00:00	77	2.10	34271.75	1498.86
10/29/93	22:00:00	77	2.09	34271.92	1498.85
10/30/93	02:00:00	77	2.09	34272.08	1498.85
10/30/93	06:00:00	77	2.08	34272.25	1498.84
10/30/93	10:00:00	77	2.08	34272.42	1498.84
10/30/93	14:00:00	77	2.09	34272.58	1498.85
10/30/93	18:00:00	77	2.10	34272.75	1498.86
10/30/93	22:00:00	77	2.06	34272.92	1498.82
10/31/93	02:00:00	77	2.04	34273.08	1498.80
10/31/93	06:00:00	77	2.04	34273.25	1498.80
10/31/93	10:00:00	77	2.08	34273.42	1498.84
10/31/93	14:00:00	77	2.10	34273.58	1498.86
10/31/93	18:00:00	77	2.10	34273.75	1498.86
10/31/93	22:00:00	77	2.08	34273.92	1498.84
11/01/93	02:00:00	77	2.08	34274.08	1498.84
11/01/93	06:00:00	77	2.08	34274.25	1498.84
11/01/93	10:00:00	77	2.09	34274.42	1498.85
11/01/93	14:00:00	77	2.10	34274.58	1498.86
11/01/93	18:00:00	77	2.10	34274.75	1498.86
11/01/93	22:00:00	77	2.09	34274.92	1498.85
11/02/93	02:00:00	77	2.09	34275.08	1498.85

11/02/93	06:00:00	77	2.08	34275.25	1498.84
11/02/93	10:00:00	77	2.09	34275.42	1498.85
11/02/93	14:00:00	77	2.10	34275.58	1498.86
11/02/93	18:00:00	77	2.10	34275.75	1498.86
11/02/93	22:00:00	77	2.08	34275.92	1498.84
11/03/93	02:00:00	77	2.08	34276.08	1498.84
11/03/93	06:00:00	77	2.08	34276.25	1498.84
11/03/93	10:00:00	77	2.09	34276.42	1498.85
11/03/93	14:00:00	77	2.10	34276.58	1498.86
11/03/93	18:00:00	77	2.10	34276.75	1498.86
11/03/93	22:00:00	77	2.10	34276.92	1498.86
11/04/93	02:00:00	77	2.09	34277.08	1498.85
11/04/93	06:00:00	77	2.10	34277.25	1498.86
11/04/93	10:00:00	77	2.10	34277.42	1498.86
11/04/93	14:00:00	77	2.10	34277.58	1498.86
11/04/93	18:00:00	77	2.09	34277.75	1498.85
11/04/93	22:00:00	77	2.09	34277.92	1498.85
11/05/93	02:00:00	77	2.08	34278.08	1498.84
11/05/93	06:00:00	77	2.07	34278.25	1498.83
11/05/93	10:00:00	77	2.06	34278.42	1498.82
11/05/93	14:00:00	77	2.06	34278.58	1498.82
11/05/93	18:00:00	77	2.05	34278.75	1498.81
11/05/93	22:00:00	77	2.05	34278.92	1498.81
11/06/93	02:00:00	77	2.03	34279.08	1498.79
11/06/93	06:00:00	77	2.02	34279.25	1498.78
11/06/93	10:00:00	77	2.03	34279.42	1498.79
11/06/93	14:00:00	77	2.07	34279.58	1498.83
11/06/93	18:00:00	77	2.06	34279.75	1498.82
11/06/93	22:00:00	77	2.03	34279.92	1498.79
11/07/93	02:00:00	77	2.04	34280.08	1498.80
11/07/93	06:00:00	77	2.04	34280.25	1498.80
11/07/93	10:00:00	77	2.06	34280.42	1498.82
11/07/93	14:00:00	77	2.08	34280.58	1498.84
11/07/93	18:00:00	77	2.07	34280.75	1498.83
11/07/93	22:00:00	77	2.05	34280.92	1498.81
11/08/93	02:00:00	77	2.05	34281.08	1498.81
11/08/93	06:00:00	77	2.05	34281.25	1498.81
11/08/93	10:00:00	77	2.04	34281.42	1498.80
11/08/93	14:00:00	77	2.06	34281.58	1498.82
11/08/93	18:00:00	77	2.06	34281.75	1498.82
11/08/93	22:00:00	77	2.03	34281.92	1498.79
11/09/93	02:00:00	77	2.03	34282.08	1498.79
11/09/93	06:00:00	77	2.03	34282.25	1498.79
11/09/93	10:00:00	77	2.04	34282.42	1498.80
11/09/93	14:00:00	77	2.06	34282.58	1498.82
11/09/93	18:00:00	77	2.05	34282.75	1498.81
11/09/93	22:00:00	77	2.03	34282.92	1498.79
11/10/93	02:00:00	77	2.03	34283.08	1498.79
11/10/93	06:00:00	77	2.02	34283.25	1498.78
11/10/93	10:00:00	77	2.02	34283.42	1498.78

11/10/93	14:00:00	77	2.04	34283.58	1498.80
11/10/93	18:00:00	77	2.04	34283.75	1498.80
11/10/93	22:00:00	77	2.04	34283.92	1498.80
11/11/93	02:00:00	77	2.04	34284.08	1498.80
11/11/93	06:00:00	77	2.03	34284.25	1498.79
11/11/93	10:00:00	77	2.03	34284.42	1498.79
11/11/93	14:00:00	77	2.05	34284.58	1498.81
11/11/93	18:00:00	77	2.04	34284.75	1498.80
11/11/93	22:00:00	77	2.03	34284.92	1498.79
11/12/93	02:00:00	77	2.02	34285.08	1498.78
11/12/93	06:00:00	77	2.02	34285.25	1498.78
11/12/93	10:00:00	77	2.03	34285.42	1498.79
11/12/93	14:00:00	77	2.03	34285.58	1498.79
11/12/93	18:00:00	77	2.04	34285.75	1498.80
11/12/93	22:00:00	77	2.04	34285.92	1498.80
11/13/93	02:00:00	77	2.05	34286.08	1498.81
11/13/93	06:00:00	77	2.04	34286.25	1498.80
11/13/93	10:00:00	77	2.04	34286.42	1498.80
11/13/93	14:00:00	77	2.05	34286.58	1498.81
11/13/93	18:00:00	77	2.05	34286.75	1498.81
11/13/93	22:00:00	77	2.04	34286.92	1498.80
11/14/93	02:00:00	77	2.04	34287.08	1498.80
11/14/93	06:00:00	77	2.04	34287.25	1498.80
11/14/93	10:00:00	77	2.04	34287.42	1498.80
11/14/93	14:00:00	77	2.04	34287.58	1498.80
11/14/93	18:00:00	77	2.03	34287.75	1498.79
11/14/93	22:00:00	77	2.03	34287.92	1498.79
11/15/93	02:00:00	77	2.02	34288.08	1498.78
11/15/93	06:00:00	77	2.02	34288.25	1498.78
11/15/93	10:00:00	77	2.02	34288.42	1498.78
11/15/93	14:00:00	77	2.04	34288.58	1498.80
11/15/93	18:00:00	77	2.04	34288.75	1498.80
11/15/93	22:00:00	77	2.03	34288.92	1498.79
11/16/93	02:00:00	77	2.03	34289.08	1498.79
11/16/93	06:00:00	77	2.03	34289.25	1498.79
11/16/93	10:00:00	77	2.04	34289.42	1498.80
11/16/93	14:00:00	77	2.05	34289.58	1498.81
11/16/93	18:00:00	77	2.05	34289.75	1498.81
11/16/93	22:00:00	77	2.03	34289.92	1498.79
11/17/93	02:00:00	77	2.04	34290.08	1498.80
11/17/93	06:00:00	77	2.03	34290.25	1498.79
11/17/93	10:00:00	77	2.04	34290.42	1498.80
11/17/93	14:00:00	77	2.06	34290.58	1498.82
11/17/93	18:00:00	77	2.05	34290.75	1498.81
11/17/93	22:00:00	77	2.04	34290.92	1498.80
11/18/93	02:00:00	77	2.04	34291.08	1498.80
11/18/93	06:00:00	77	2.05	34291.25	1498.81
11/18/93	10:00:00	77	2.06	34291.42	1498.82
12/09/93	00:00:00	77	2.39	34312.00	1499.15

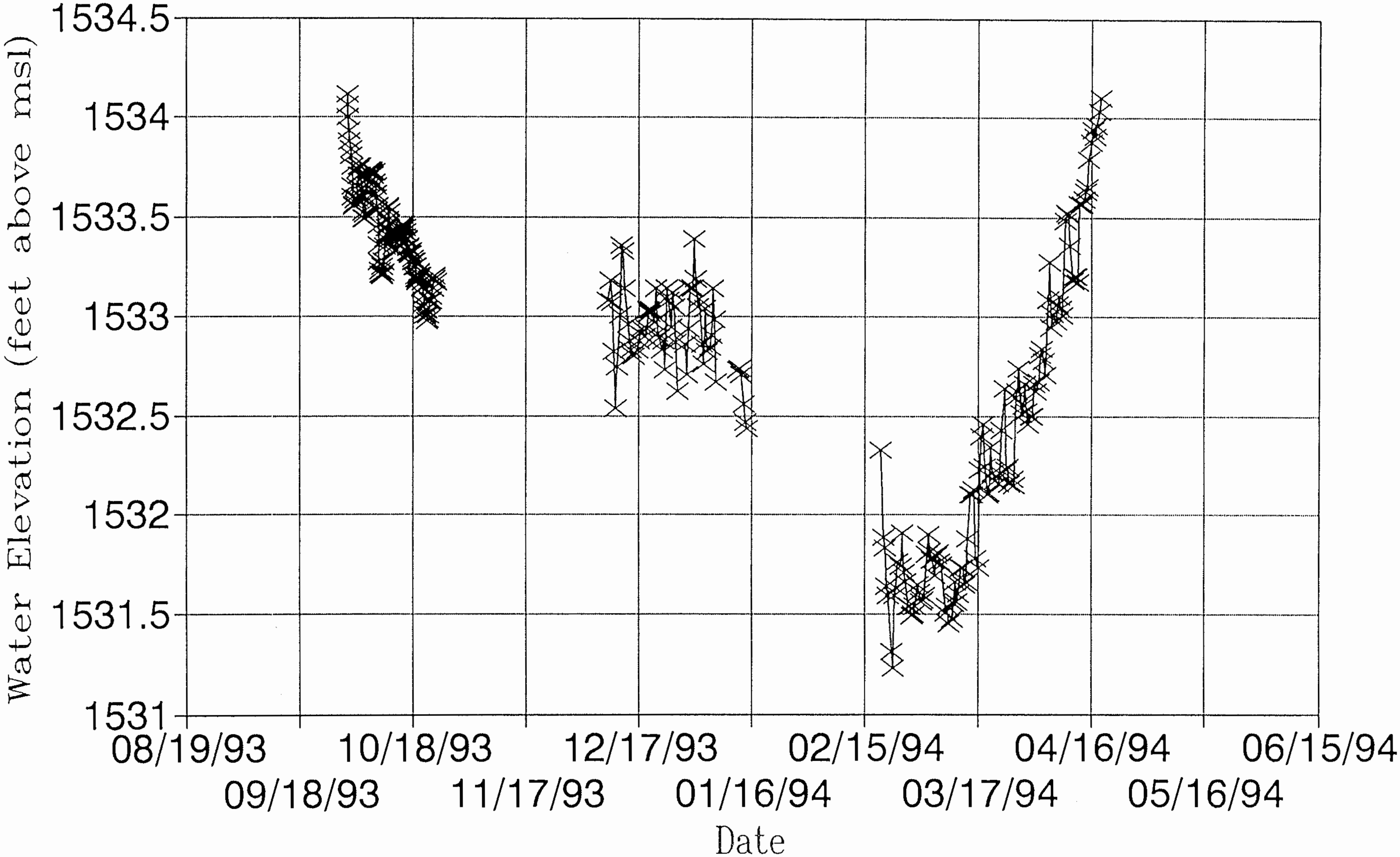
12/09/93	12:00:00	77	2.43	34312.50	1499.19
01/12/94	06:00:00	77	2.72	34346.25	1499.48
01/12/94	18:00:00	77	2.74	34346.75	1499.50
01/13/94	06:00:00	77	2.71	34347.25	1499.47
01/13/94	18:00:00	77	2.71	34347.75	1499.47
01/14/94	06:00:00	77	2.68	34348.25	1499.44
01/14/94	18:00:00	77	2.66	34348.75	1499.42
01/15/94	06:00:00	77	2.62	34349.25	1499.38
01/15/94	18:00:00	77	2.66	34349.75	1499.42
01/16/94	06:00:00	77	2.74	34350.25	1499.50
01/16/94	18:00:00	77	2.71	34350.75	1499.47
01/17/94	06:00:00	77	2.70	34351.25	1499.46
01/17/94	18:00:00	77	2.70	34351.75	1499.46
01/18/94	06:00:00	77	2.68	34352.25	1499.44
01/18/94	18:00:00	77	2.74	34352.75	1499.50
01/19/94	06:00:00	77	2.77	34353.25	1499.53
01/19/94	18:00:00	77	2.94	34353.75	1499.70
01/20/94	06:00:00	77	2.88	34354.25	1499.64
01/20/94	18:00:00	77	3.03	34354.75	1499.79
01/21/94	06:00:00	77	3.04	34355.25	1499.80
01/22/94	06:00:00	77	3.27	34356.25	1500.03
01/22/94	18:00:00	77	3.39	34356.75	1500.15
01/23/94	06:00:00	77	4.30	34357.25	1501.06
01/23/94	18:00:00	77	4.29	34357.75	1501.05
01/24/94	06:00:00	77	4.22	34358.25	1500.98
01/24/94	18:00:00	77	4.17	34358.75	1500.93
01/25/94	06:00:00	77	4.11	34359.25	1500.87
01/25/94	18:00:00	77	4.06	34359.75	1500.82
01/26/94	06:00:00	77	4.01	34360.25	1500.77
01/26/94	18:00:00	77	3.97	34360.75	1500.73
01/27/94	06:00:00	77	3.94	34361.25	1500.70
01/27/94	18:00:00	77	3.90	34361.75	1500.66
01/28/94	06:00:00	77	3.87	34362.25	1500.63
01/28/94	18:00:00	77	3.85	34362.75	1500.61
01/29/94	06:00:00	77	3.75	34363.25	1500.51
01/29/94	18:00:00	77	3.74	34363.75	1500.50
01/30/94	06:00:00	77	3.65	34364.25	1500.41
01/30/94	18:00:00	77	3.63	34364.75	1500.39
01/31/94	06:00:00	77	3.57	34365.25	1500.33
01/31/94	18:00:00	77	3.63	34365.75	1500.39
02/01/94	06:00:00	77	3.55	34366.25	1500.31
02/01/94	18:00:00	77	3.59	34366.75	1500.35
02/02/94	06:00:00	77	3.55	34367.25	1500.31
02/02/94	18:00:00	77	3.56	34367.75	1500.32
02/03/94	06:00:00	77	3.47	34368.25	1500.23
02/03/94	18:00:00	77	3.53	34368.75	1500.29
02/04/94	06:00:00	77	3.43	34369.25	1500.19
02/04/94	18:00:00	77	3.52	34369.75	1500.28
02/05/94	06:00:00	77	3.47	34370.25	1500.23

02/05/94	18:00:00	77	3.51	34370.75	1500.27
02/06/94	06:00:00	77	3.47	34371.25	1500.23
02/06/94	18:00:00	77	3.41	34371.75	1500.17
02/07/94	06:00:00	77	3.35	34372.25	1500.11
02/07/94	18:00:00	77	3.34	34372.75	1500.10
02/08/94	06:00:00	77	3.31	34373.25	1500.07
02/08/94	18:00:00	77	3.32	34373.75	1500.08
02/09/94	06:00:00	77	3.19	34374.25	1499.95
02/09/94	18:00:00	77	3.30	34374.75	1500.06
02/10/94	06:00:00	77	3.32	34375.25	1500.08
02/10/94	18:00:00	77	3.37	34375.75	1500.13
02/11/94	06:00:00	77	3.33	34376.25	1500.09
02/11/94	18:00:00	77	3.37	34376.75	1500.13
02/12/94	06:00:00	77	3.38	34377.25	1500.14
02/12/94	18:00:00	77	3.86	34377.75	1500.62
02/13/94	06:00:00	77	3.81	34378.25	1500.57
02/13/94	18:00:00	77	3.82	34378.75	1500.58
02/14/94	06:00:00	77	3.76	34379.25	1500.52
02/14/94	18:00:00	77	3.76	34379.75	1500.52
02/15/94	06:00:00	77	3.69	34380.25	1500.45
02/15/94	18:00:00	77	3.68	34380.75	1500.44
02/16/94	06:00:00	77	3.64	34381.25	1500.40
02/16/94	18:00:00	77	3.62	34381.75	1500.38
02/17/94	06:00:00	77	3.56	34382.25	1500.32
02/17/94	18:00:00	77	3.56	34382.75	1500.32
02/18/94	06:00:00	77	3.55	34383.25	1500.31
02/19/94	06:00:00	77	3.51	34384.25	1500.27
02/19/94	18:00:00	77	3.47	34384.75	1500.23
02/20/94	06:00:00	77	3.41	34385.25	1500.17
02/20/94	18:00:00	77	3.41	34385.75	1500.17
02/21/94	06:00:00	77	3.36	34386.25	1500.12
02/21/94	18:00:00	77	3.36	34386.75	1500.12
02/22/94	06:00:00	77	3.33	34387.25	1500.09
02/22/94	18:00:00	77	3.33	34387.75	1500.09
02/23/94	06:00:00	77	3.31	34388.25	1500.07
02/23/94	18:00:00	77	3.32	34388.75	1500.08
02/24/94	06:00:00	77	3.26	34389.25	1500.02
02/24/94	18:00:00	77	3.31	34389.75	1500.07
02/25/94	06:00:00	77	3.24	34390.25	1500.00
02/25/94	18:00:00	77	3.27	34390.75	1500.03
02/26/94	06:00:00	77	3.21	34391.25	1499.97
02/26/94	18:00:00	77	3.25	34391.75	1500.01
02/27/94	06:00:00	77	3.23	34392.25	1499.99
02/27/94	18:00:00	77	3.24	34392.75	1500.00
02/28/94	06:00:00	77	3.24	34393.25	1500.00
02/28/94	18:00:00	77	3.26	34393.75	1500.02
03/01/94	06:00:00	77	3.24	34394.25	1500.00
03/01/94	18:00:00	77	0.00	34394.75	1496.76
03/22/94	06:00:00	77	1.01	34415.25	1488.41

03/22/94	18:00:00	77	1.33	34415.75	1488.73
03/23/94	06:00:00	77	1.61	34416.25	1489.01
03/23/94	18:00:00	77	1.89	34416.75	1489.29
03/24/94	06:00:00	77	2.15	34417.25	1489.55
03/24/94	18:00:00	77	2.44	34417.75	1489.84
03/25/94	06:00:00	77	2.65	34418.25	1490.05
03/25/94	18:00:00	77	2.94	34418.75	1490.34
03/26/94	06:00:00	77	3.17	34419.25	1490.57
03/26/94	18:00:00	77	3.44	34419.75	1490.84
03/27/94	06:00:00	77	3.66	34420.25	1491.06
03/27/94	18:00:00	77	3.89	34420.75	1491.29
03/28/94	06:00:00	77	4.11	34421.25	1491.51
03/28/94	18:00:00	77	4.34	34421.75	1491.74
03/29/94	06:00:00	77	4.53	34422.25	1491.93
03/29/94	18:00:00	77	4.74	34422.75	1492.14
03/30/94	06:00:00	77	4.90	34423.25	1492.30
03/30/94	18:00:00	77	5.16	34423.75	1492.56
03/31/94	06:00:00	77	5.32	34424.25	1492.72
03/31/94	18:00:00	77	5.54	34424.75	1492.94
04/01/94	06:00:00	77	5.69	34425.25	1493.09
04/01/94	18:00:00	77	5.92	34425.75	1493.32
04/02/94	06:00:00	77	6.07	34426.25	1493.47
04/02/94	18:00:00	77	6.25	34426.75	1493.65
04/03/94	06:00:00	77	6.38	34427.25	1493.78
04/03/94	18:00:00	77	6.59	34427.75	1493.99
04/04/94	06:00:00	77	6.74	34428.25	1494.14
04/04/94	18:00:00	77	6.88	34428.75	1494.28
04/05/94	06:00:00	77	7.00	34429.25	1494.40
04/05/94	18:00:00	77	7.18	34429.75	1494.58
04/06/94	06:00:00	77	7.29	34430.25	1494.69
04/06/94	18:00:00	77	7.47	34430.75	1494.87
04/07/94	06:00:00	77	7.59	34431.25	1494.99
04/07/94	18:00:00	77	7.74	34431.75	1495.14
04/08/94	06:00:00	77	7.87	34432.25	1495.27
04/08/94	18:00:00	77	8.01	34432.75	1495.41
04/09/94	06:00:00	77	8.11	34433.25	1495.51
04/09/94	18:00:00	77	8.25	34433.75	1495.65
04/10/94	06:00:00	77	8.34	34434.25	1495.74
04/10/94	18:00:00	77	8.48	34434.75	1495.88
04/11/94	06:00:00	77	8.57	34435.25	1495.97
04/11/94	18:00:00	77	8.69	34435.75	1496.09
04/12/94	06:00:00	77	8.80	34436.25	1496.20
04/12/94	18:00:00	77	8.91	34436.75	1496.31
04/13/94	06:00:00	77	9.00	34437.25	1496.40
04/13/94	18:00:00	77	9.13	34437.75	1496.53
04/14/94	06:00:00	77	9.22	34438.25	1496.62
04/14/94	18:00:00	77	9.33	34438.75	1496.73
04/15/94	06:00:00	77	9.42	34439.25	1496.82
04/15/94	18:00:00	77	9.52	34439.75	1496.92
04/16/94	06:00:00	77	9.59	34440.25	1496.99

04/16/94	18:00:00	77	9.69	34440.75	1497.09
04/17/94	06:00:00	77	9.77	34441.25	1497.17
04/17/94	18:00:00	77	9.87	34441.75	1497.27
04/18/94	06:00:00	77	9.94	34442.25	1497.34

SIOUX FALLS LANDFILL
R20-93-19 Hydrograph



DATE	TIME	STATION	Pres.Head	Ser.Date	Wat.Elev.
09/30/93	18:00:00	R20-93-19	11.46	34242.75	1534.12
09/30/93	22:00:00	3	11.40	34242.92	1534.06
10/01/93	02:00:00	3	11.34	34243.08	1534.00
10/01/93	06:00:00	3	11.27	34243.25	1533.93
10/01/93	10:00:00	3	11.22	34243.42	1533.88
10/01/93	14:00:00	3	11.18	34243.58	1533.84
10/01/93	18:00:00	3	11.15	34243.75	1533.81
10/01/93	22:00:00	3	11.09	34243.92	1533.75
10/02/93	02:00:00	3	10.99	34244.08	1533.65
10/02/93	06:00:00	3	10.94	34244.25	1533.60
10/02/93	10:00:00	3	10.89	34244.42	1533.55
10/02/93	14:00:00	3	10.90	34244.58	1533.56
10/02/93	18:00:00	3	10.92	34244.75	1533.58
10/02/93	22:00:00	3	10.91	34244.92	1533.57
10/03/93	02:00:00	3	10.92	34245.08	1533.58
10/03/93	06:00:00	3	10.93	34245.25	1533.59
10/03/93	10:00:00	3	10.99	34245.42	1533.65
10/03/93	14:00:00	3	11.05	34245.58	1533.71
10/03/93	18:00:00	3	11.08	34245.75	1533.74
10/03/93	22:00:00	3	11.09	34245.92	1533.75
10/04/93	02:00:00	3	11.09	34246.08	1533.75
10/04/93	06:00:00	3	11.05	34246.25	1533.71
10/04/93	10:00:00	3	10.98	34246.42	1533.64
10/04/93	14:00:00	3	10.94	34246.58	1533.60
10/04/93	18:00:00	3	10.93	34246.75	1533.59
10/04/93	22:00:00	3	10.86	34246.92	1533.52
10/05/93	02:00:00	3	10.83	34247.08	1533.49
10/05/93	06:00:00	3	10.83	34247.25	1533.49
10/05/93	10:00:00	3	10.85	34247.42	1533.51
10/05/93	14:00:00	3	10.92	34247.58	1533.58
10/05/93	18:00:00	3	10.98	34247.75	1533.64
10/05/93	22:00:00	3	11.00	34247.92	1533.66
10/06/93	02:00:00	3	11.01	34248.08	1533.67
10/06/93	06:00:00	3	11.02	34248.25	1533.68
10/06/93	10:00:00	3	11.02	34248.42	1533.68
10/06/93	14:00:00	3	11.04	34248.58	1533.70
10/06/93	18:00:00	3	11.07	34248.75	1533.73
10/06/93	22:00:00	3	11.06	34248.92	1533.72
10/07/93	02:00:00	3	11.07	34249.08	1533.73
10/07/93	06:00:00	3	11.05	34249.25	1533.71
10/07/93	10:00:00	3	11.05	34249.42	1533.71
10/07/93	14:00:00	3	11.05	34249.58	1533.71
10/07/93	18:00:00	3	11.06	34249.75	1533.72
10/07/93	22:00:00	3	11.01	34249.92	1533.67
10/08/93	02:00:00	3	10.99	34250.08	1533.65
10/08/93	06:00:00	3	10.95	34250.25	1533.61
10/08/93	10:00:00	3	10.93	34250.42	1533.59
10/08/93	14:00:00	3	10.89	34250.58	1533.55

10/08/93	18:00:00	3	10.87	34250.75	1533.53
10/08/93	22:00:00	3	10.80	34250.92	1533.46
10/09/93	02:00:00	3	10.70	34251.08	1533.36
10/09/93	06:00:00	3	10.61	34251.25	1533.27
10/09/93	10:00:00	3	10.55	34251.42	1533.21
10/09/93	14:00:00	3	10.57	34251.58	1533.23
10/09/93	18:00:00	3	10.59	34251.75	1533.25
10/09/93	22:00:00	3	10.55	34251.92	1533.21
10/10/93	02:00:00	3	10.54	34252.08	1533.20
10/10/93	06:00:00	3	10.56	34252.25	1533.22
10/10/93	10:00:00	3	10.61	34252.42	1533.27
10/10/93	14:00:00	3	10.69	34252.58	1533.35
10/10/93	18:00:00	3	10.73	34252.75	1533.39
10/10/93	22:00:00	3	10.73	34252.92	1533.39
10/11/93	02:00:00	3	10.75	34253.08	1533.41
10/11/93	06:00:00	3	10.78	34253.25	1533.44
10/11/93	10:00:00	3	10.82	34253.42	1533.48
10/11/93	14:00:00	3	10.88	34253.58	1533.54
10/11/93	18:00:00	3	10.89	34253.75	1533.55
10/11/93	22:00:00	3	10.86	34253.92	1533.52
10/12/93	02:00:00	3	10.81	34254.08	1533.47
10/12/93	06:00:00	3	10.76	34254.25	1533.42
10/12/93	10:00:00	3	10.73	34254.42	1533.39
10/12/93	14:00:00	3	10.75	34254.58	1533.41
10/12/93	18:00:00	3	10.75	34254.75	1533.41
10/12/93	22:00:00	3	10.69	34254.92	1533.35
10/13/93	02:00:00	3	10.67	34255.08	1533.33
10/13/93	06:00:00	3	10.67	34255.25	1533.33
10/13/93	10:00:00	3	10.67	34255.42	1533.33
10/13/93	14:00:00	3	10.73	34255.58	1533.39
10/13/93	18:00:00	3	10.75	34255.75	1533.41
10/13/93	22:00:00	3	10.74	34255.92	1533.40
10/14/93	02:00:00	3	10.74	34256.08	1533.40
10/14/93	06:00:00	3	10.74	34256.25	1533.40
10/14/93	10:00:00	3	10.75	34256.42	1533.41
10/14/93	14:00:00	3	10.77	34256.58	1533.43
10/14/93	18:00:00	3	10.79	34256.75	1533.45
10/14/93	22:00:00	3	10.75	34256.92	1533.41
10/15/93	02:00:00	3	10.74	34257.08	1533.40
10/15/93	06:00:00	3	10.77	34257.25	1533.43
10/15/93	10:00:00	3	10.78	34257.42	1533.44
10/15/93	14:00:00	3	10.80	34257.58	1533.46
10/15/93	18:00:00	3	10.80	34257.75	1533.46
10/15/93	22:00:00	3	10.78	34257.92	1533.44
10/16/93	02:00:00	3	10.76	34258.08	1533.42
10/16/93	06:00:00	3	10.74	34258.25	1533.40
10/16/93	10:00:00	3	10.73	34258.42	1533.39
10/16/93	14:00:00	3	10.72	34258.58	1533.38
10/16/93	18:00:00	3	10.69	34258.75	1533.35
10/16/93	22:00:00	3	10.68	34258.92	1533.34

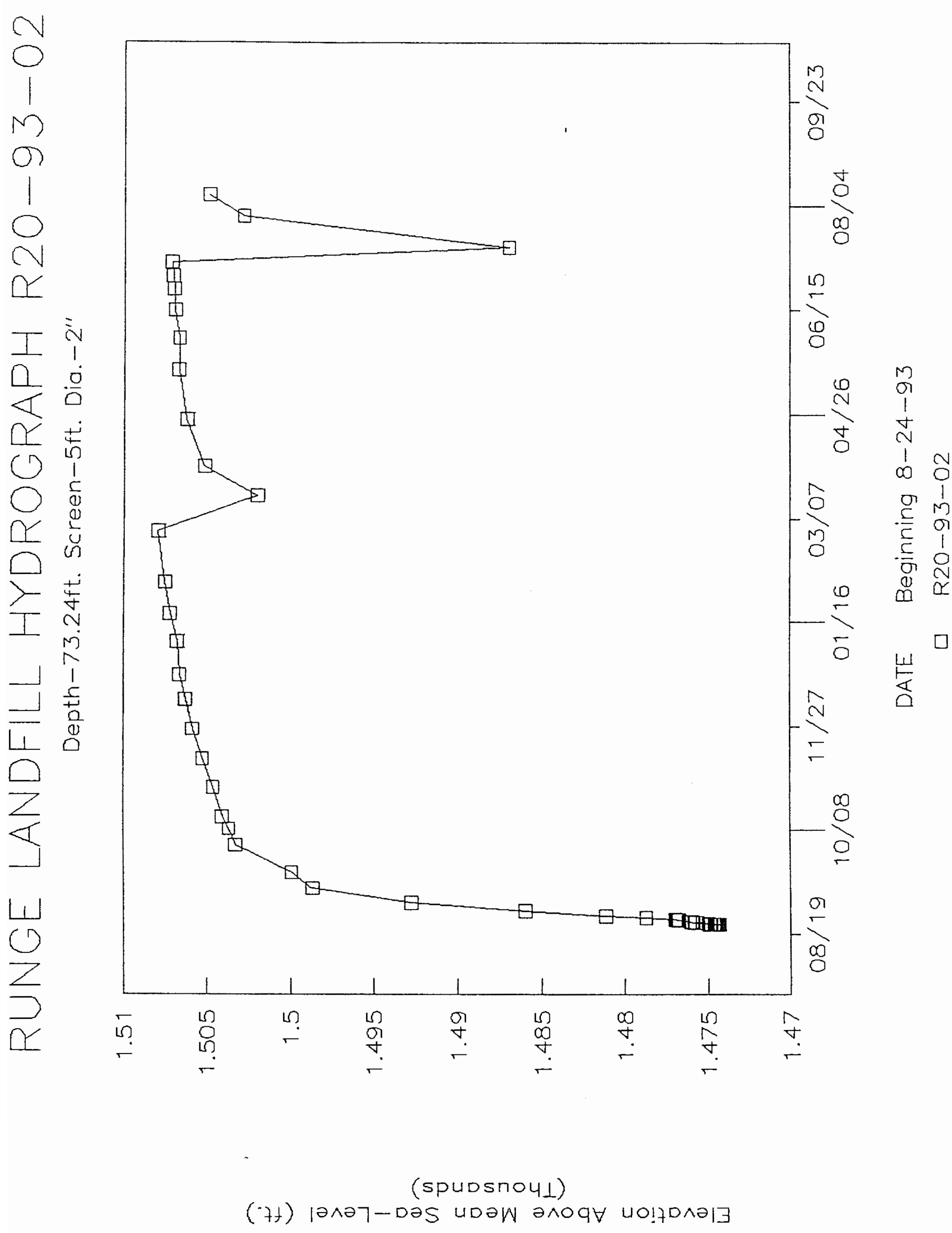
10/17/93	02:00:00	3	10.66	34259.08	1533.32
10/17/93	06:00:00	3	10.66	34259.25	1533.32
10/17/93	10:00:00	3	10.65	34259.42	1533.31
10/17/93	14:00:00	3	10.67	34259.58	1533.33
10/17/93	18:00:00	3	10.67	34259.75	1533.33
10/17/93	22:00:00	3	10.65	34259.92	1533.31
10/18/93	02:00:00	3	10.63	34260.08	1533.29
10/18/93	06:00:00	3	10.61	34260.25	1533.27
10/18/93	10:00:00	3	10.59	34260.42	1533.25
10/18/93	14:00:00	3	10.61	34260.58	1533.27
10/18/93	18:00:00	3	10.59	34260.75	1533.25
10/18/93	22:00:00	3	10.54	34260.92	1533.20
10/19/93	02:00:00	3	10.53	34261.08	1533.19
10/19/93	06:00:00	3	10.52	34261.25	1533.18
10/19/93	10:00:00	3	10.51	34261.42	1533.17
10/19/93	14:00:00	3	10.53	34261.58	1533.19
10/19/93	18:00:00	3	10.56	34261.75	1533.22
10/19/93	22:00:00	3	10.54	34261.92	1533.20
10/20/93	02:00:00	3	10.54	34262.08	1533.20
10/20/93	06:00:00	3	10.54	34262.25	1533.20
10/20/93	10:00:00	3	10.51	34262.42	1533.17
10/20/93	14:00:00	3	10.49	34262.58	1533.15
10/20/93	18:00:00	3	10.48	34262.75	1533.14
10/20/93	22:00:00	3	10.44	34262.92	1533.10
10/21/93	02:00:00	3	10.40	34263.08	1533.06
10/21/93	06:00:00	3	10.37	34263.25	1533.03
10/21/93	10:00:00	3	10.35	34263.42	1533.01
10/21/93	14:00:00	3	10.37	34263.58	1533.03
10/21/93	18:00:00	3	10.37	34263.75	1533.03
10/21/93	22:00:00	3	10.32	34263.92	1532.98
10/22/93	02:00:00	3	10.33	34264.08	1532.99
10/22/93	06:00:00	3	10.35	34264.25	1533.01
10/22/93	10:00:00	3	10.35	34264.42	1533.01
10/22/93	14:00:00	3	10.41	34264.58	1533.07
10/22/93	18:00:00	3	10.42	34264.75	1533.08
10/22/93	22:00:00	3	10.42	34264.92	1533.08
10/23/93	02:00:00	3	10.42	34265.08	1533.08
10/23/93	06:00:00	3	10.44	34265.25	1533.10
10/23/93	10:00:00	3	10.48	34265.42	1533.14
10/23/93	14:00:00	3	10.52	34265.58	1533.18
10/23/93	18:00:00	3	10.54	34265.75	1533.20
10/23/93	22:00:00	3	10.53	34265.92	1533.19
10/24/93	02:00:00	3	10.51	34266.08	1533.17
12/09/93	00:00:00	3	10.42	34312.00	1533.08
12/09/93	12:00:00	3	10.52	34312.50	1533.18
12/10/93	00:00:00	3	10.41	34313.00	1533.07
12/10/93	12:00:00	3	10.16	34313.50	1532.82
12/11/93	00:00:00	3	9.88	34314.00	1532.54
12/11/93	12:00:00	3	10.09	34314.50	1532.75

12/12/93	00:00:00	3	10.35	34315.00	1533.01
12/12/93	12:00:00	3	10.70	34315.50	1533.36
12/13/93	00:00:00	3	10.67	34316.00	1533.33
12/13/93	12:00:00	3	10.48	34316.50	1533.14
12/14/93	00:00:00	3	10.30	34317.00	1532.96
12/14/93	12:00:00	3	10.22	34317.50	1532.88
12/15/93	00:00:00	3	10.17	34318.00	1532.83
12/15/93	12:00:00	3	10.15	34318.50	1532.81
12/16/93	00:00:00	3	10.14	34319.00	1532.80
12/16/93	12:00:00	3	10.17	34319.50	1532.83
12/17/93	00:00:00	3	10.22	34320.00	1532.88
12/17/93	12:00:00	3	10.26	34320.50	1532.92
12/18/93	00:00:00	3	10.28	34321.00	1532.94
12/18/93	12:00:00	3	10.24	34321.50	1532.90
12/19/93	00:00:00	3	10.28	34322.00	1532.94
12/19/93	12:00:00	3	10.37	34322.50	1533.03
12/20/93	00:00:00	3	10.36	34323.00	1533.02
12/20/93	12:00:00	3	10.37	34323.50	1533.03
12/21/93	00:00:00	3	10.31	34324.00	1532.97
12/21/93	12:00:00	3	10.48	34324.50	1533.14
12/22/93	00:00:00	3	10.26	34325.00	1532.92
12/22/93	12:00:00	3	10.23	34325.50	1532.89
12/23/93	00:00:00	3	10.17	34326.00	1532.83
12/23/93	12:00:00	3	10.22	34326.50	1532.88
12/24/93	00:00:00	3	10.07	34327.00	1532.73
12/24/93	12:00:00	3	10.48	34327.50	1533.14
12/25/93	00:00:00	3	10.42	34328.00	1533.08
12/25/93	12:00:00	3	10.29	34328.50	1532.95
12/26/93	00:00:00	3	10.46	34329.00	1533.12
12/26/93	12:00:00	3	10.39	34329.50	1533.05
12/27/93	00:00:00	3	10.21	34330.00	1532.87
12/27/93	12:00:00	3	9.96	34330.50	1532.62
12/29/93	06:00:00	3	10.20	34332.25	1532.86
12/29/93	18:00:00	3	10.05	34332.75	1532.71
12/30/93	06:00:00	3	10.28	34333.25	1532.94
12/30/93	18:00:00	3	10.48	34333.75	1533.14
12/31/93	06:00:00	3	10.48	34334.25	1533.14
12/31/93	18:00:00	3	10.73	34334.75	1533.39
01/01/94	06:00:00	3	10.53	34335.25	1533.19
01/01/94	18:00:00	3	10.39	34335.75	1533.05
01/02/94	06:00:00	3	10.43	34336.25	1533.09
01/02/94	18:00:00	3	10.20	34336.75	1532.86
01/03/94	06:00:00	3	10.10	34337.25	1532.76
01/03/94	18:00:00	3	10.38	34337.75	1533.04
01/04/94	06:00:00	3	10.16	34338.25	1532.82
01/04/94	18:00:00	3	10.19	34338.75	1532.85
01/05/94	06:00:00	3	10.25	34339.25	1532.91
01/05/94	18:00:00	3	10.48	34339.75	1533.14
01/06/94	06:00:00	3	10.33	34340.25	1532.99

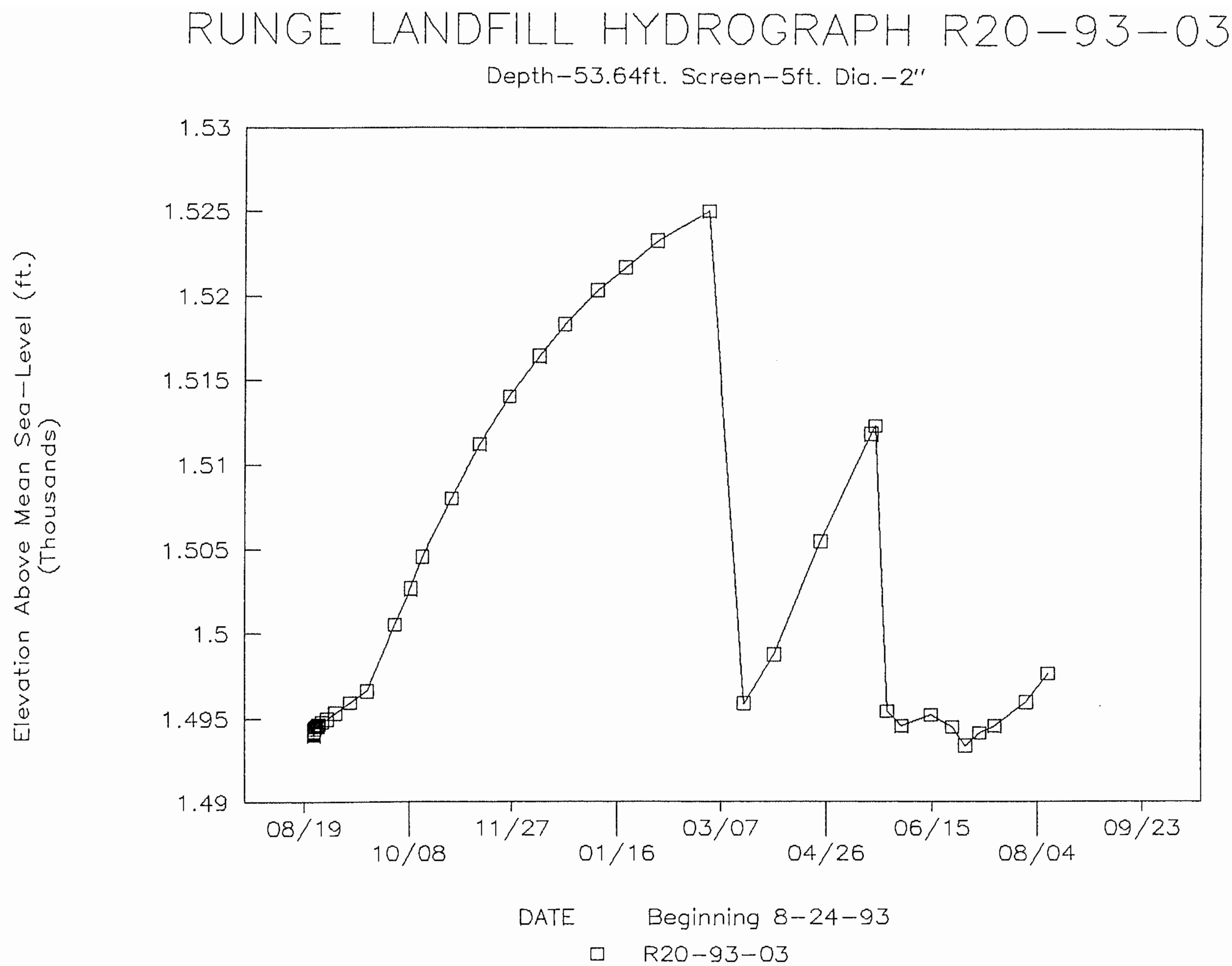
01/06/94	18:00:00	3	10.01	34340.75	1532.67
01/12/94	06:00:00	3	10.07	34346.25	1532.73
01/12/94	18:00:00	3	10.08	34346.75	1532.74
01/13/94	06:00:00	3	10.05	34347.25	1532.71
01/13/94	18:00:00	3	9.90	34347.75	1532.56
01/14/94	06:00:00	3	9.81	34348.25	1532.47
01/14/94	18:00:00	3	9.78	34348.75	1532.44
02/19/94	06:00:00	3	9.67	34384.25	1532.33
02/19/94	18:00:00	3	9.23	34384.75	1531.89
02/20/94	06:00:00	3	9.17	34385.25	1531.83
02/20/94	18:00:00	3	8.98	34385.75	1531.64
02/21/94	06:00:00	3	8.93	34386.25	1531.59
02/21/94	18:00:00	3	8.65	34386.75	1531.31
02/22/94	06:00:00	3	8.57	34387.25	1531.23
02/22/94	18:00:00	3	8.93	34387.75	1531.59
02/23/94	06:00:00	3	8.97	34388.25	1531.63
02/23/94	18:00:00	3	9.10	34388.75	1531.76
02/24/94	06:00:00	3	9.08	34389.25	1531.74
02/24/94	18:00:00	3	9.25	34389.75	1531.91
02/25/94	06:00:00	3	9.05	34390.25	1531.71
02/25/94	18:00:00	3	9.00	34390.75	1531.66
02/26/94	06:00:00	3	8.88	34391.25	1531.54
02/26/94	18:00:00	3	8.88	34391.75	1531.54
02/27/94	06:00:00	3	8.83	34392.25	1531.49
02/27/94	18:00:00	3	8.84	34392.75	1531.50
02/28/94	06:00:00	3	8.88	34393.25	1531.54
02/28/94	18:00:00	3	8.99	34393.75	1531.65
03/01/94	06:00:00	3	8.95	34394.25	1531.61
03/01/94	18:00:00	3	8.90	34394.75	1531.56
03/02/94	06:00:00	3	8.91	34395.25	1531.57
03/02/94	18:00:00	3	8.93	34395.75	1531.59
03/03/94	06:00:00	3	9.14	34396.25	1531.80
03/03/94	18:00:00	3	9.24	34396.75	1531.90
03/04/94	06:00:00	3	9.16	34397.25	1531.82
03/04/94	18:00:00	3	9.11	34397.75	1531.77
03/05/94	06:00:00	3	9.03	34398.25	1531.69
03/05/94	18:00:00	3	9.13	34398.75	1531.79
03/06/94	06:00:00	3	9.15	34399.25	1531.81
03/06/94	18:00:00	3	9.10	34399.75	1531.76
03/07/94	06:00:00	3	9.09	34400.25	1531.75
03/08/94	06:00:00	3	8.85	34401.25	1531.51
03/08/94	18:00:00	3	8.88	34401.75	1531.54
03/09/94	06:00:00	3	8.79	34402.25	1531.45
03/09/94	18:00:00	3	8.82	34402.75	1531.48
03/10/94	06:00:00	3	8.89	34403.25	1531.55
03/10/94	18:00:00	3	9.00	34403.75	1531.66
03/11/94	06:00:00	3	8.90	34404.25	1531.56
03/11/94	18:00:00	3	8.94	34404.75	1531.60

03/12/94	06:00:00	3	9.07	34405.25	1531.73
03/12/94	18:00:00	3	9.07	34405.75	1531.73
03/13/94	06:00:00	3	8.99	34406.25	1531.65
03/13/94	18:00:00	3	9.00	34406.75	1531.66
03/14/94	06:00:00	3	9.22	34407.25	1531.88
03/14/94	18:00:00	3	9.44	34407.75	1532.10
03/15/94	06:00:00	3	9.44	34408.25	1532.10
03/15/94	18:00:00	3	9.47	34408.75	1532.13
03/16/94	06:00:00	3	9.12	34409.25	1531.78
03/16/94	18:00:00	3	9.07	34409.75	1531.73
03/17/94	06:00:00	3	9.57	34410.25	1532.23
03/17/94	18:00:00	3	9.74	34410.75	1532.40
03/18/94	06:00:00	3	9.80	34411.25	1532.46
03/18/94	18:00:00	3	9.58	34411.75	1532.24
03/19/94	06:00:00	3	9.44	34412.25	1532.10
03/19/94	18:00:00	3	9.45	34412.75	1532.11
03/20/94	06:00:00	3	9.68	34413.25	1532.34
03/20/94	18:00:00	3	9.55	34413.75	1532.21
03/21/94	06:00:00	3	9.51	34414.25	1532.17
03/22/94	06:00:00	3	9.50	34415.25	1532.16
03/22/94	18:00:00	3	9.55	34415.75	1532.21
03/23/94	06:00:00	3	9.77	34416.25	1532.43
03/23/94	18:00:00	3	9.98	34416.75	1532.64
03/24/94	06:00:00	3	9.57	34417.25	1532.23
03/24/94	18:00:00	3	9.58	34417.75	1532.24
03/25/94	06:00:00	3	9.50	34418.25	1532.16
03/25/94	18:00:00	3	9.52	34418.75	1532.18
03/26/94	06:00:00	3	9.49	34419.25	1532.15
03/26/94	18:00:00	3	9.93	34419.75	1532.59
03/27/94	06:00:00	3	9.96	34420.25	1532.62
03/27/94	18:00:00	3	10.08	34420.75	1532.74
03/28/94	06:00:00	3	9.85	34421.25	1532.51
03/28/94	18:00:00	3	9.89	34421.75	1532.55
03/29/94	06:00:00	3	10.00	34422.25	1532.66
03/29/94	18:00:00	3	9.86	34422.75	1532.52
03/30/94	06:00:00	3	9.80	34423.25	1532.46
03/30/94	18:00:00	3	9.84	34423.75	1532.50
03/31/94	06:00:00	3	9.84	34424.25	1532.50
03/31/94	18:00:00	3	10.00	34424.75	1532.66
04/01/94	06:00:00	3	9.96	34425.25	1532.62
04/01/94	18:00:00	3	10.01	34425.75	1532.67
04/02/94	06:00:00	3	10.15	34426.25	1532.81
04/02/94	18:00:00	3	10.18	34426.75	1532.84
04/03/94	06:00:00	3	10.12	34427.25	1532.78
04/03/94	18:00:00	3	10.05	34427.75	1532.71
04/04/94	06:00:00	3	10.43	34428.25	1533.09
04/04/94	18:00:00	3	10.61	34428.75	1533.27
04/05/94	06:00:00	3	10.29	34429.25	1532.95
04/05/94	18:00:00	3	10.36	34429.75	1533.02
04/06/94	06:00:00	3	10.32	34430.25	1532.98

04/06/94	18:00:00	3	10.40	34430.75	1533.06
04/07/94	06:00:00	3	10.44	34431.25	1533.10
04/07/94	18:00:00	3	10.38	34431.75	1533.04
04/08/94	06:00:00	3	10.35	34432.25	1533.01
04/08/94	18:00:00	3	10.82	34432.75	1533.48
04/09/94	06:00:00	3	10.86	34433.25	1533.52
04/09/94	18:00:00	3	10.85	34433.75	1533.51
04/10/94	06:00:00	3	10.70	34434.25	1533.36
04/10/94	18:00:00	3	10.52	34434.75	1533.18
04/11/94	06:00:00	3	10.54	34435.25	1533.20
04/11/94	18:00:00	3	10.54	34435.75	1533.20
04/12/94	06:00:00	3	10.51	34436.25	1533.17
04/12/94	18:00:00	3	10.91	34436.75	1533.57
04/13/94	06:00:00	3	10.91	34437.25	1533.57
04/13/94	18:00:00	3	10.93	34437.75	1533.59
04/14/94	06:00:00	3	10.97	34438.25	1533.63
04/14/94	18:00:00	3	10.99	34438.75	1533.65
04/15/94	06:00:00	3	11.13	34439.25	1533.79
04/15/94	18:00:00	3	11.22	34439.75	1533.88
04/16/94	06:00:00	3	11.28	34440.25	1533.94
04/16/94	18:00:00	3	11.25	34440.75	1533.91
04/17/94	06:00:00	3	11.30	34441.25	1533.96
04/17/94	18:00:00	3	11.37	34441.75	1534.03
04/18/94	06:00:00	3	11.44	34442.25	1534.10


RUNGE LANDFILL HYDROGRAPH R20-93-02
Depth-73.24ft. Screen-5ft. Dia.-2"
1.51
1.505
1.5
1.495
1.49
1.485
1.48
1.475
1.47
Elevation Above Mean Sea-Level (ft.)
(Thousands)
08/19
10/08
11/27
01/16
03/07
04/26
06/15
08/04
09/23
DATE Beginning 8-24-93
R20-93-02

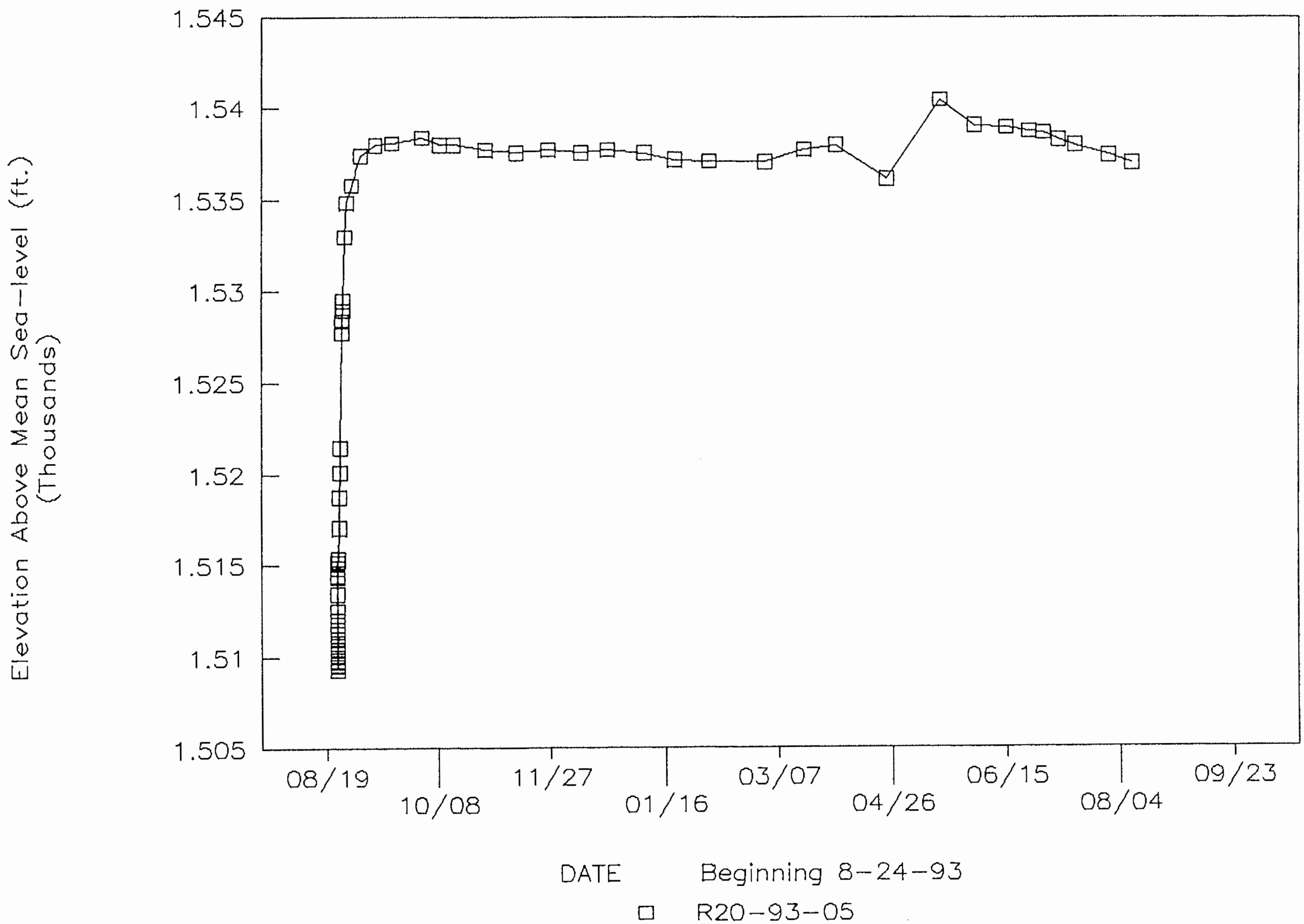
	ELEV.	HYDROGRAPHS		
R20-93-02	1545.93		1440	
WATER LEVEL	WATER LEVEL ELEVATION	TIME(min)	DAYS	DATE
				34205
71.62	1474.31	0	0	34205
71.6	1474.33	0.28	0.0001944	34205.00
71.55	1474.38	2.83	0.0019652	34205.00
71.5	1474.43	4.85	0.0033680	34205.00
71.45	1474.48	7	0.0048611	34205.00
71.4	1474.53	9.55	0.0066319	34205.00
71.35	1474.58	13.53	0.0093958	34205.00
71.3	1474.63	19.4	0.0134722	34205.01
71.14	1474.79	52.83	0.0366875	34205.03
71.1	1474.83	71.33	0.0495347	34205.04
71.05	1474.88	92.91	0.0645208	34205.06
70.96	1474.97	146.41	0.1016736	34205.10
70.18	1475.75	1095.33	0.7606458	34205.76
70.07	1475.86	1232.57	0.8559513	34205.85
69.96	1475.97	1390.57	0.9656736	34205.96
69.86	1476.07	1560.07	1.0833819	34206.08
69.19	1476.74	2585.57	1.7955347	34206.79
69.1	1476.83	2718.32	1.8877222	34206.88
69.03	1476.9	2854.32	1.9821666	34206.98
68.95	1476.98	2987.82	2.074875	34207.07
67.23	1478.7	4296.82	2.9839027	34207.98
64.8	1481.13	5568.82	3.8672361	34208.86
59.99	1485.94	8507.82	5.9082083	34210.90
53.18	1492.75	14461.32	10.042583	34215.04
47.27	1498.66	24637.32	17.10925	34222.10
46.02	1499.91	35774.32	24.843277	34229.84
42.69	1503.24	54878.32	38.109944	34243.10
42.29	1503.64	66291.82	46.035986	34251.03
41.88	1504.05	74969.57	52.062201	34257.06
41.36	1504.57	95057.82	66.012375	34271.01
40.71	1505.22	114859.82	79.763763	34284.76
40.09	1505.84	135135.32	93.843972	34298.84
39.67	1506.26	155627.32	108.07452	34313.07
39.32	1506.61	172919.32	120.08286	34325.08
39.17	1506.76	195549.32	135.79813	34340.79
38.74	1507.19	214407.32	148.89397	34353.89
38.42	1507.51	236257.32	164.06758	34369.06
38.01	1507.92	271951.32	188.85508	34393.85
43.95 Tritium	1501.98	296454.32	205.87105	34410.87
40.81	1505.12	316766.32	219.97661	34424.97
39.73	1506.2	348519.32	242.02730	34447.02
39.25	1506.68	382710.32	265.77105	34470.77
39.26	1506.67	404494.32	280.89883	34485.89
39.01	1506.92	424556.32	294.83077	34499.83
38.95	1506.98	439021.32	304.87591	34509.87
38.88	1507.05	447880.32	311.028	34516.02
38.8	1507.13	457686.32	317.83772	34522.83
59.02 O&H SAMPI	1486.91	467980.32	324.98633	34529.98
43.14	1502.79	489336.32	339.81688	34544.81
41.08	1504.85	504112.32	350.078	34555.07


RUNGE LANDFILL HYDROGRAPH R20—93—03
Depth—53.64ft. Screen—5ft. Dia.—2"
Elevation Above Mean Sea—Level (ft.)
(Thousands)
1.53
1.525
1.52
1.515
1.51
1.505
1.5
1.495
1.49
08/19
10/08
11/27
01/16
03/07
04/26
06/15
08/04
09/23
DATE
Beginning 8—24—93
R20—93—03

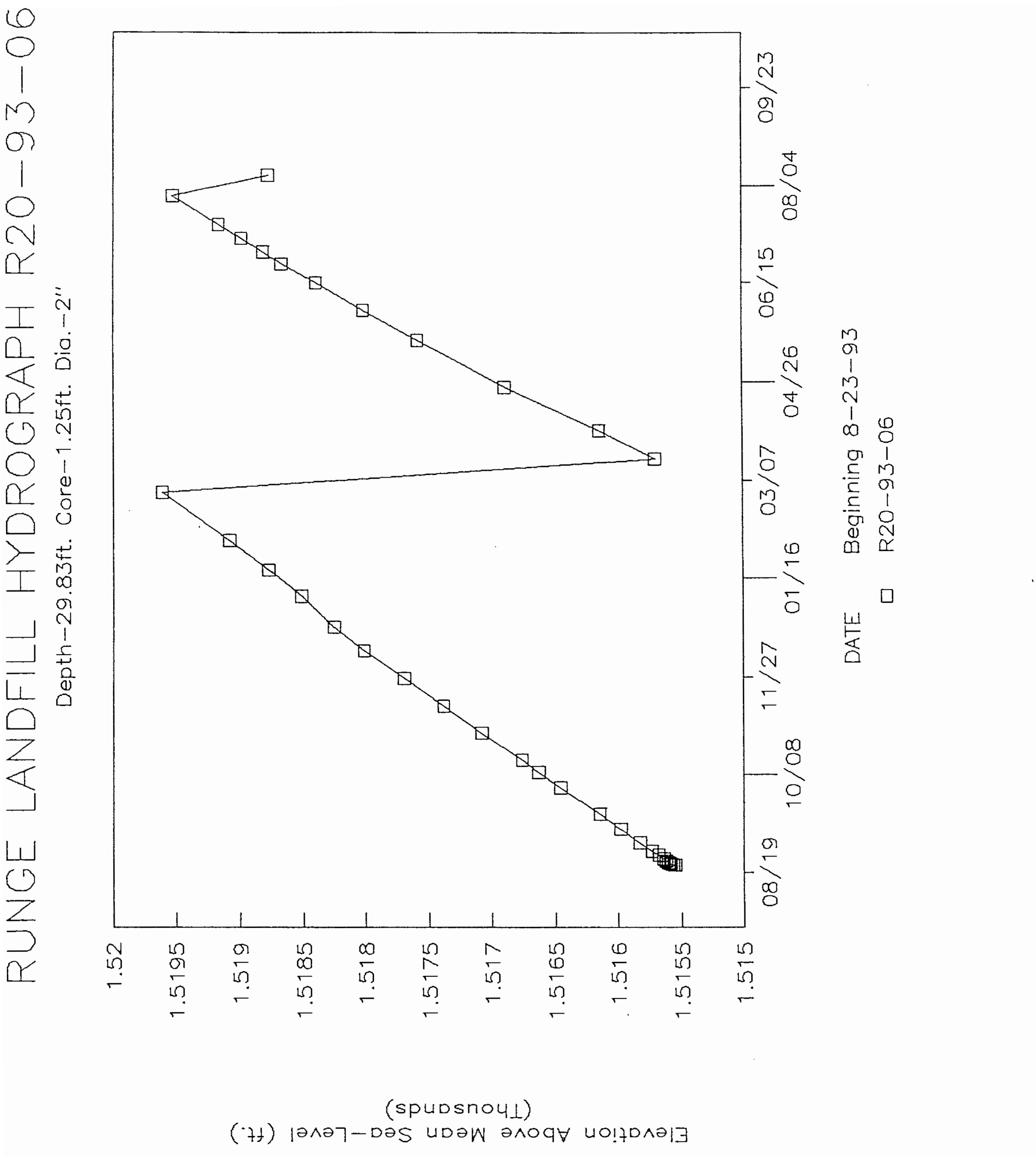
R20–93–03	ELEV. 1545.55	HYDROGRAPHS		1440	
WATER LEVEL		WATER LEVEL ELEVATION	TIME(min)	DAYS	DATE
					34205
51.53		1494.02	0	0	34205
51.5		1494.05	0.58	0.0004027	34205.00
51.45		1494.1	2.15	0.0014930	34205.00
51.4		1494.15	5.33	0.0037013	34205.00
51.3		1494.25	19.75	0.0137152	34205.01
51.21		1494.34	61.33	0.0425902	34205.04
51.18		1494.37	105.25	0.0730902	34205.07
51.16		1494.39	223.49	0.1552013	34205.15
51.15		1494.4	276.91	0.1922966	34205.19
51.08		1494.47	1225.56	0.8510833	34205.85
51.04		1494.51	1690.39	1.1738819	34206.17
50.97		1494.58	2716.14	1.8862083	34206.88
50.94		1494.61	3117.64	2.1650277	34207.16
50.77		1494.78	5698.89	3.9575625	34208.95
50.59		1494.96	8638.39	5.9988819	34210.99
50.24		1495.31	14592.39	10.133604	34215.13
49.61		1495.94	24768.39	17.200270	34222.20
48.94		1496.61	35904.89	24.933951	34229.93
45.02		1500.53	55008.89	38.200618	34243.20
42.91		1502.64	66418.89	46.124229	34251.12
41.04		1504.51	75100.39	52.153048	34257.15
37.56		1507.99	95188.39	66.103048	34271.10
34.34		1511.21	114990.89	79.854784	34284.85
31.53		1514.02	135264.89	93.933951	34298.93
29.13		1516.42	155754.89	108.16311	34313.16
27.27		1518.28	173048.89	120.17284	34325.17
25.25		1520.3	195672.89	135.88395	34340.88
23.89		1521.66	214541.89	148.98742	34353.98
22.33		1523.22	236387.89	164.15825	34369.15
20.56		1524.99	271973.89	188.87075	34393.87
49.66	Tritium	1495.89	296588.89	205.96450	34410.96
46.8		1498.75	316900.89	220.07006	34425.07
40.1		1505.45	348653.89	242.12075	34447.12
33.7		1511.85	382840.89	265.86172	34470.86
33.24	Bailing	1512.31	385647.89	267.81103	34472.81
50.13	Tritium	1495.42	394242.89	273.77978	34478.77
51.01	Bailing	1494.54	404367.89	280.81103	34485.81
50.36	Bailing	1495.19	424592.89	294.85617	34499.85
51.07	Bailing	1494.48	438987.89	304.85270	34509.85
52.18	After Sampl	1493.37	447864.89	311.01728	34516.01
51.43		1494.12	457675.89	317.83047	34522.83
50.97	O&HSAMPL	1494.58	467964.89	324.97561	34529.97
49.59		1495.96	489324.89	339.80895	34544.80
47.91		1497.64	504085.89	350.05964	34555.05
		1545.55		0	34205
		1545.55		0	34205
		1545.55		0	34205
		1545.55		0	34205
		1545.55		0	34205

RUNGE LANDFILL HYDROGRAPH R20—93—05

Depth—35.31ft. Screen—10ft. Dia.—2"



	ELEV.	HYDROGRAPHS		
R20-93-05	1543.99		1440	
WATER LEVEL	WATER LEVEL ELEVATION	TIME(min)	DAYS	DATE
				34205
34.68	1509.31	0	0	34205
34.5	1509.49	0.42	0.0002916	34205.00
34.4	1509.59	0.67	0.0004652	34205.00
34.3	1509.69	0.87	0.0006041	34205.00
34.2	1509.79	1.12	0.0007777	34205.00
34	1509.99	1.67	0.0011597	34205.00
33.8	1510.19	2.19	0.0015208	34205.00
33.6	1510.39	2.75	0.0019097	34205.00
33.4	1510.59	3.33	0.0023125	34205.00
33	1510.99	4.66	0.0032361	34205.00
32.5	1511.49	6.69	0.0046458	34205.00
32	1511.99	10.32	0.0071666	34205.00
31.5	1512.49	16.48	0.0114444	34205.01
30.61	1513.38	32.82	0.0227916	34205.02
29.69	1514.3	48.9	0.0339583	34205.03
29.65	1514.34	50.15	0.0348263	34205.03
29.6	1514.39	51.7	0.0359027	34205.03
29.15	1514.84	72.08	0.0500555	34205.05
28.87	1515.12	98.48	0.0683888	34205.06
28.65	1515.34	132.23	0.0918263	34205.09
26.94	1517.05	1062.98	0.7381805	34205.73
25.28	1518.71	1200.48	0.8336666	34205.83
23.92	1520.07	1357.98	0.9430416	34205.94
22.56	1521.43	1526.98	1.0604027	34206.06
16.27	1527.72	2553.48	1.77325	34206.77
15.63	1528.36	2685.23	1.8647430	34206.86
15.06	1528.93	2821.48	1.9593611	34206.95
14.51	1529.48	2955.48	2.0524166	34207.05
11.02	1532.97	4263.73	2.9609236	34207.96
9.15	1534.84	5525.98	3.8374861	34208.83
8.22	1535.77	8464.48	5.8781111	34210.87
6.62	1537.37	14419.23	10.013354	34215.01
6	1537.99	24594.23	17.079326	34222.07
5.94	1538.05	35730.98	24.813180	34229.81
5.62	1538.37	54834.98	38.079847	34243.07
6.02	1537.97	66246.48	46.0045	34251.00
6.01	1537.98	74926.48	52.032277	34257.03
6.29	1537.7	95008.48	65.978111	34270.97
6.44	1537.55	114810.98	79.729847	34284.72
6.3	1537.69	135086.48	93.810055	34298.81
6.43	1537.56	155578.48	108.04061	34313.04
6.26	1537.73	172870.48	120.04894	34325.04
6.47	1537.52	195500.48	135.76422	34340.76
6.81	1537.18	214360.48	148.86144	34353.86
6.93	1537.06	236211.48	164.03575	34369.03
6.94	1537.05	272103.48	188.96075	34393.96
6.26	1537.73	296409.48	205.83991	34410.83
6.03	1537.96	316721.48	219.94547	34424.94
7.89	1536.1	348472.48	241.99477	34446.99
3.56	1540.43	382661.48	265.73713	34470.73
4.94	1539.05	404445.48	280.86491	34485.86
5.06	1538.93	424507.48	294.79686	34499.79
5.29	1538.7	438977.48	304.84547	34509.84
5.36	1538.63	447833.48	310.99547	34515.99
5.73	1538.26	457640.48	317.80588	34522.80
6.03	1537.96	467933.48	324.95380	34529.95
6.6	1537.39	489289.48	339.78436	34544.78
7.03	1536.96	504063.48	350.04408	34555.04



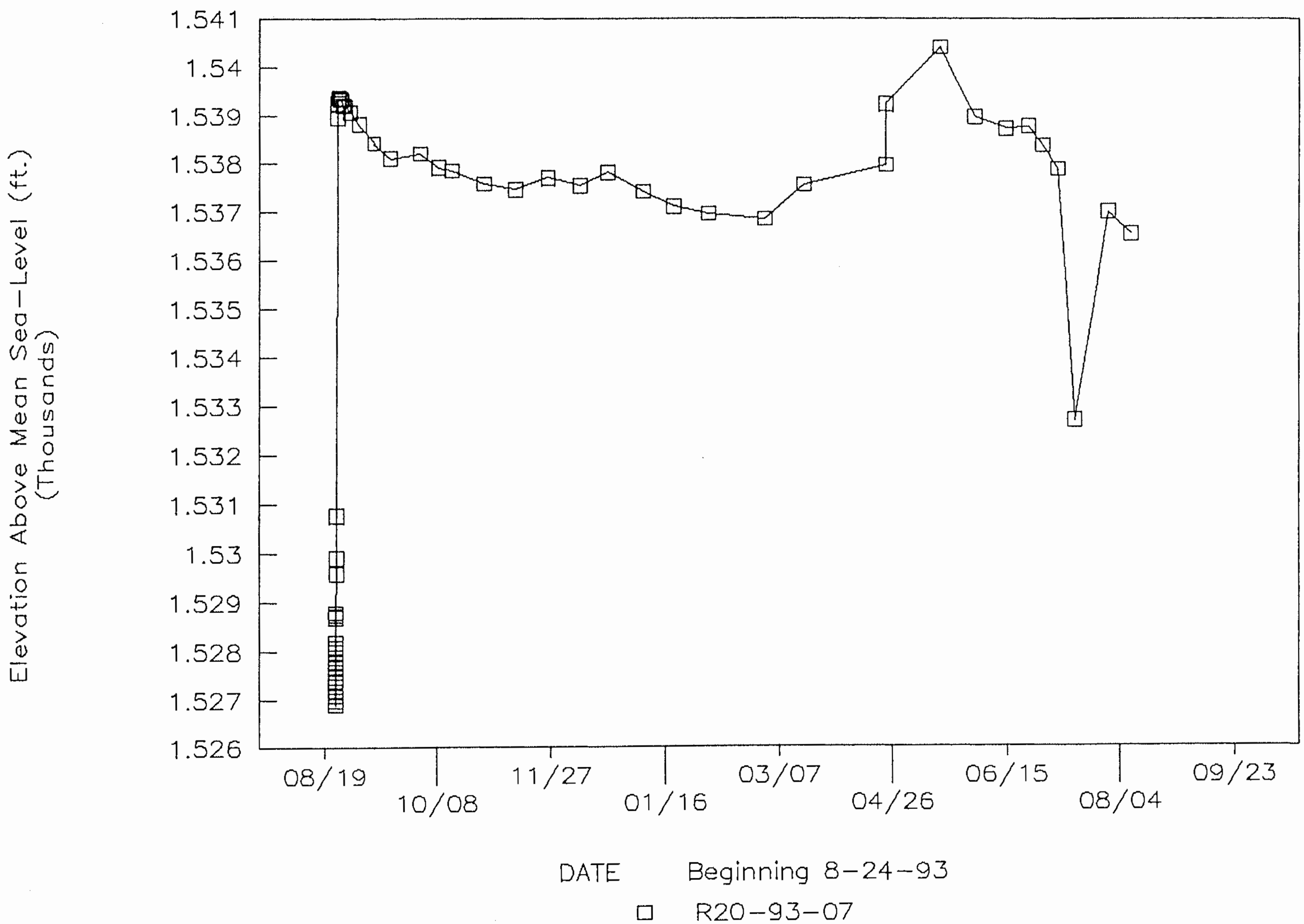
RUNGE LANDFILL HYDROGRAPH R20-93-06
Depth-29.83ft. Core-1.25ft. Dia.-2"
Elevation Above Mean Sea-Level (ft.)
(Thousands)
1.52
1.5195
1.519
1.5185
1.518
1.5175
1.517
1.5165
1.516
1.5155
1.515
08/19
10/08
11/27
01/16
03/07
04/26
06/15
08/04
09/23
DATE
Beginning 8-23-93
R20-93-06

	ELEV.	HYDROGRAPHS		
R20-93-06	1544.64		1440	

WATER LEVEL	WATER LEVEL ELEVATION	TIME(min)	DAYS	DATE
				34204
29.09	1515.55	0	0	34204
29.08	1515.56	81.75	0.0567708	34204.05
29.06	1515.58	419.3	0.2911805	34204.29
29.05	1515.59	1368.57	0.9503958	34204.95
29.04	1515.6	1867.5	1.296875	34205.29
29.02	1515.62	2809.67	1.9511597	34205.95
29.02	1515.62	3276.5	2.2753472	34206.27
29	1515.64	4300.25	2.9862847	34206.98
29	1515.64	4701	3.2645833	34207.26
28.96	1515.68	7283	5.0576388	34209.05
28.91	1515.73	10223	7.0993055	34211.09
28.81	1515.83	16179	11.235416	34215.23
28.66	1515.98	26354.5	18.301736	34222.30
28.49	1516.15	37474.5	26.023958	34230.02
28.18	1516.46	56581.5	39.292708	34243.29
28.01	1516.63	67998.5	47.221180	34251.22
27.88	1516.76	76677.5	53.248263	34257.24
27.56	1517.08	96763.5	67.196875	34271.19
27.26	1517.38	116564.5	80.947569	34284.94
26.95	1517.69	136837.5	95.026041	34299.02
26.63	1518.01	157331.5	109.25798	34313.25
26.39	1518.25	174621.5	121.26493	34325.26
26.13	1518.51	197251.5	136.98020	34340.98
25.87	1518.77	216111.5	150.07743	34354.07
25.56	1519.08	237961.5	165.25104	34369.25
25.03	1519.61	273547.5	189.96354	34393.96
28.94 Tritium	1515.7	298160.5	207.05590	34411.05
28.49	1516.15	318461.5	221.15381	34425.15
27.75	1516.89	350213.5	243.20381	34447.20
27.06	1517.58	384403.5	266.94687	34470.94
26.63	1518.01	406188.5	282.07534	34486.07
26.25	1518.39	426251.5	296.00798	34500.00
25.98	1518.66	440732.5	306.06423	34510.06
25.83	1518.81	449573.5	312.20381	34516.20
25.66	1518.98	459400.5	319.02812	34523.02
25.48	1519.16	469673.5	326.16215	34530.16
25.11	1519.53	491033.5	340.99548	34544.99
25.87	1518.77	505798.5	351.24895	34555.24

RUNGE LANDFILL HYDROGRAPH R20-93-07

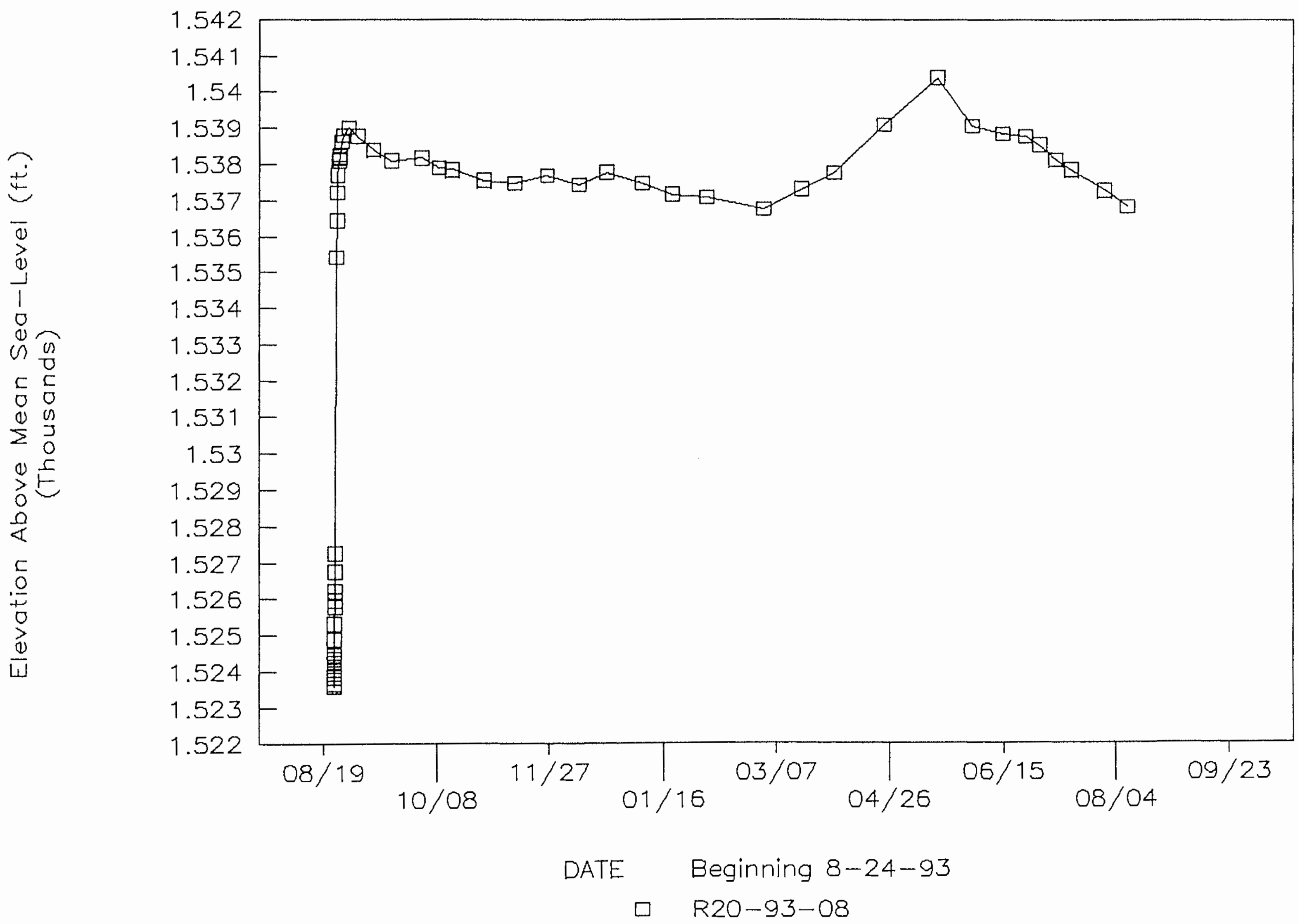
Depth-18.36ft. Screen-5ft. Dia.-2"



R20-93-07	ELEV. 1544.97	HYDROGRAPHS	1440	
WATER LEVEL	WATER LEVEL ELEVATION	TIME(min)	DAYS	DATE
				34205
18.09	1526.88	0	0	34205
18	1526.97	0.28	0.0001944	34205.00
17.9	1527.07	0.81	0.0005625	34205.00
17.8	1527.17	1.33	0.0009236	34205.00
17.7	1527.27	2.09	0.0014513	34205.00
17.6	1527.37	3.19	0.0022152	34205.00
17.5	1527.47	5.19	0.0036041	34205.00
17.4	1527.57	8.75	0.0060763	34205.00
17.3	1527.67	13.25	0.0092013	34205.00
17.2	1527.77	18.52	0.0128611	34205.01
17.1	1527.87	23.15	0.0160763	34205.01
17	1527.97	29.01	0.0201458	34205.02
16.9	1528.07	34.39	0.0238819	34205.02
16.8	1528.17	40.62	0.0282083	34205.02
16.28	1528.69	68.67	0.0476875	34205.04
16.25	1528.72	70.24	0.0487777	34205.04
16.2	1528.77	72.46	0.0503194	34205.05
15.4	1529.57	116.76	0.0810833	34205.08
15.07	1529.9	135.51	0.0941041	34205.09
14.2	1530.77	186.14	0.1292638	34205.12
6.04	1538.93	1136.67	0.7893541	34205.78
5.72	1539.25	1277.67	0.8872708	34205.88
5.63	1539.34	1435.92	0.9971666	34205.99
5.62	1539.35	1603.5	1.1135416	34206.11
5.65	1539.32	2628.67	1.8254652	34206.82
5.66	1539.31	3030.42	2.1044583	34207.10
5.77	1539.2	4342.17	3.0153958	34208.01
5.79	1539.18	5617.92	3.9013333	34208.90
5.91	1539.06	8557.92	5.943	34210.94
6.16	1538.81	14511.67	10.077548	34215.07
6.55	1538.42	24687.92	17.144388	34222.14
6.87	1538.1	35824.42	24.878069	34229.87
6.77	1538.2	54927.92	38.144388	34243.14
7.06	1537.91	66339.92	46.069388	34251.06
7.12	1537.85	75019.92	52.097166	34257.09
7.39	1537.58	95106.42	66.046125	34271.04
7.51	1537.46	114909.42	79.798208	34284.79
7.27	1537.7	135182.92	93.877027	34298.87
7.43	1537.54	155676.92	108.10897	34313.10
7.16	1537.81	172967.92	120.11661	34325.11
7.55	1537.42	195588.92	135.82563	34340.82
7.87	1537.1	214449.92	148.92355	34353.92
8.02	1536.95	236299.92	164.09716	34369.09
8.12	1536.85	272049.92	188.92355	34393.92
7.42 Tritium	1537.55	296498.92	205.90202	34410.90
7.01	1537.96	348561.92	242.05688	34447.05
5.75	1539.22	348516.92	242.02563	34447.02
4.58	1540.39	382759.92	265.8055	34470.80
6.02	1538.95	404543.92	280.93327	34485.93
6.27	1538.7	424607.92	294.86661	34499.86
6.22	1538.75	438979.92	304.84716	34509.84
6.61	1538.36	447927.92	311.06105	34516.06
7.09	1537.88	457748.92	317.88119	34522.88
12.28 O&HSAMPL	1532.69	468129.92	325.09022	34530.09
7.98	1536.99	489391.92	339.8555	34544.85
8.43	1536.54	504169.92	350.118	34555.11

RUNGE LANDFILL HYDROGRAPH R20—93—08

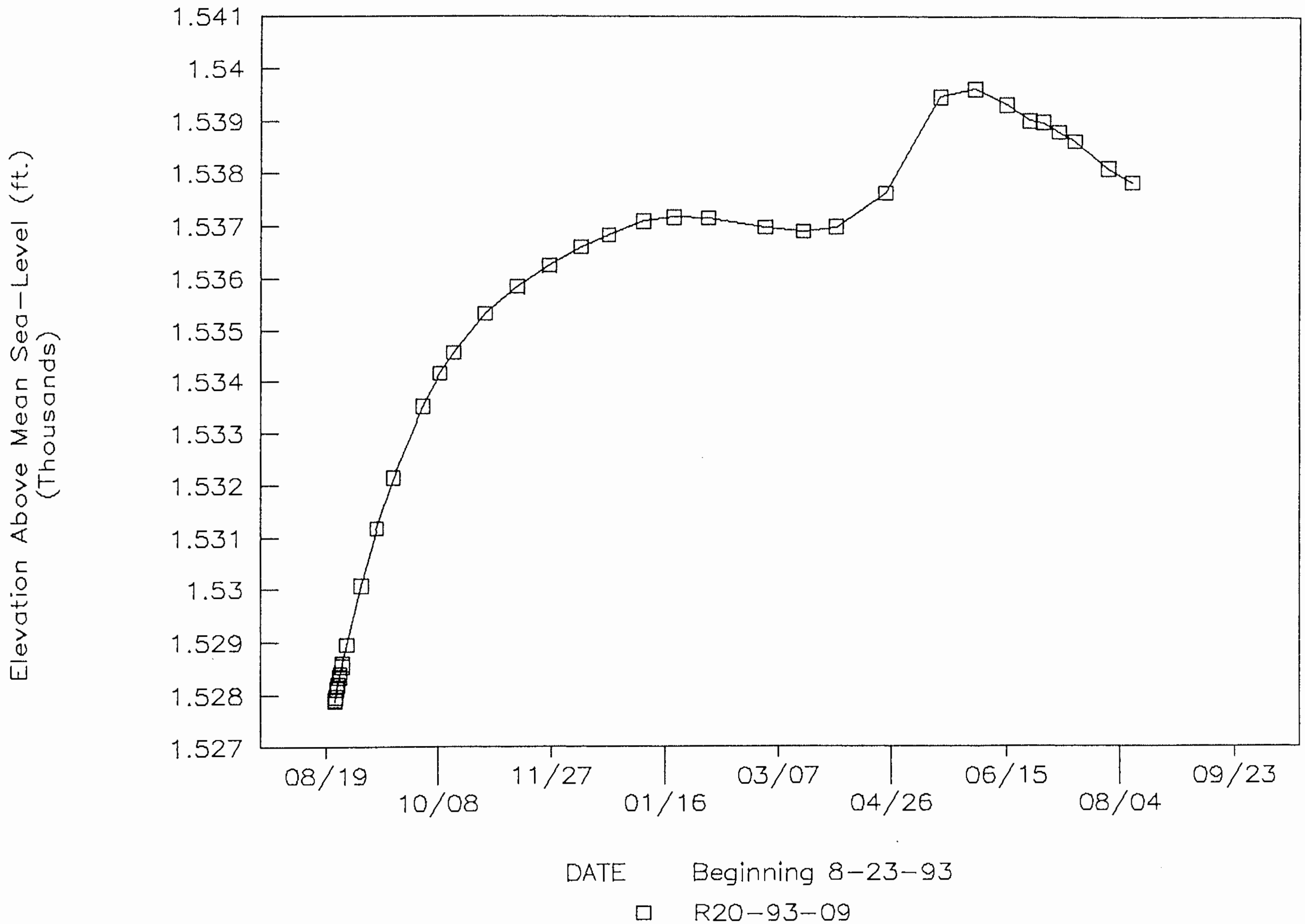
Depth—22.98ft. Screen—10ft. Dia.—2"



	ELEV.	HYDROGRAPHS		
R20-93-08	1545.44		1440	
WATER LEVEL	WATER LEVEL ELEVATION	TIME(min)	DAYS	DATE
				34205
21.88	1523.56	0	0	34205
21.8	1523.64	1.12	0.0007777	34205.00
21.6	1523.84	5.57	0.0038680	34205.00
21.5	1523.94	8.32	0.0057777	34205.00
21.4	1524.04	11.98	0.0083194	34205.00
21.3	1524.14	15.66	0.010875	34205.01
21.2	1524.24	19.98	0.013875	34205.01
21.1	1524.34	24.11	0.0167430	34205.01
21	1524.44	28.44	0.01975	34205.01
20.57	1524.87	53.56	0.0371944	34205.03
20.14	1525.3	92.14	0.0639861	34205.06
19.65	1525.79	139.56	0.0969166	34205.09
19.48	1525.96	159.64	0.1108611	34205.11
19.22	1526.22	191.39	0.1329097	34205.13
18.68	1526.76	254.56	0.1767777	34205.17
18.19	1527.25	302.64	0.2101666	34205.21
10.03	1535.41	1255.89	0.8721458	34205.87
9.01	1536.43	1393.81	0.9679236	34205.96
8.24	1537.2	1552.56	1.0781666	34206.07
7.75	1537.69	1720.31	1.1946597	34206.19
7.34	1538.1	2744.81	1.9061180	34206.90
7.29	1538.15	2880.56	2.0003888	34207.00
7.25	1538.19	3016.81	2.0950069	34207.09
7.19	1538.25	3147.31	2.1856319	34207.18
6.82	1538.62	4458.81	3.0963958	34208.09
6.64	1538.8	5728.31	3.9779930	34208.97
6.43	1539.01	8668.31	6.0196597	34211.01
6.67	1538.77	14622.56	10.154555	34215.15
7.04	1538.4	24798.56	17.221222	34222.22
7.35	1538.09	35935.06	24.954902	34229.95
7.27	1538.17	55038.81	38.221395	34243.22
7.56	1537.88	66451.81	46.147090	34251.14
7.59	1537.85	75130.81	52.174173	34257.17
7.9	1537.54	95219.31	66.124520	34271.12
7.99	1537.45	115019.81	79.874868	34284.87
7.77	1537.67	135293.81	93.954034	34298.95
8.01	1537.43	155787.81	108.18597	34313.18
7.68	1537.76	173077.81	120.19292	34325.19
7.97	1537.47	195702.81	135.90472	34340.90
8.29	1537.15	214563.81	149.00264	34354.00
8.38	1537.06	236413.81	164.17625	34369.17
8.69	1536.75	272316.81	189.10889	34394.10
8.15	1537.29	296611.81	205.98042	34410.98
7.69	1537.75	316923.81	220.08597	34425.08
6.36	1539.08	348675.81	242.13597	34447.13
5.05	1540.39	382869.81	265.88181	34470.88
6.4	1539.04	404653.81	281.00959	34486.00
6.62	1538.82	424717.81	294.94292	34499.94
6.68	1538.76	439179.81	304.98597	34509.98
6.92	1538.52	448037.81	311.13736	34516.13
7.33	1538.11	457862.81	317.96028	34522.96
7.61	1537.83	468141.81	325.09847	34530.09
8.18	1537.26	489495.81	339.92764	34544.92
8.63	1536.81	504272.81	350.18945	34555.18

RUNGE LANDFILL HYDROGRAPH R20-93-09

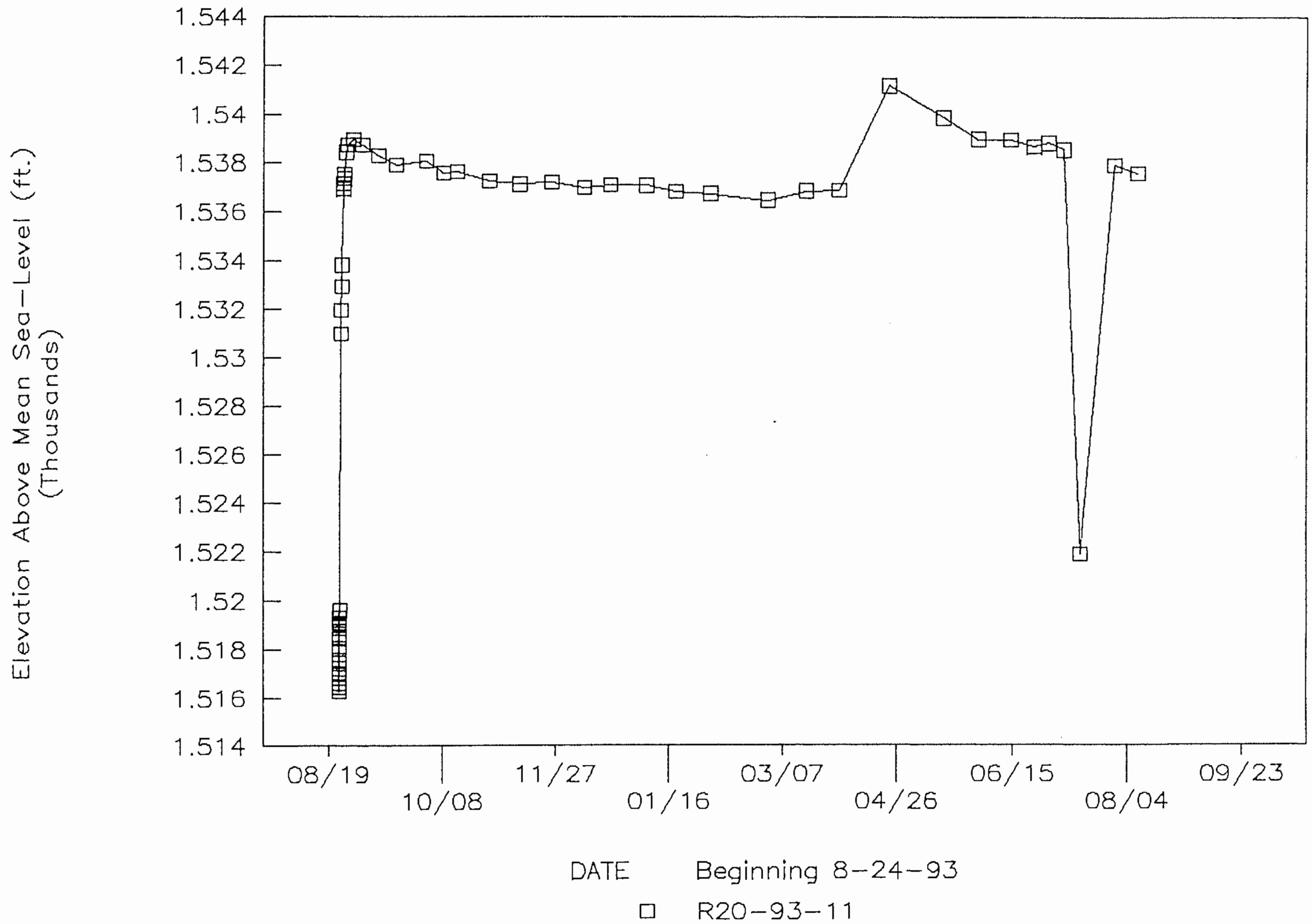
Depth-18.62ft. Core-0.8ft. Dia.-2"



	ELEV.	HYDROGRAPHS		
R20–93–09	1546.08		1440	
WATER LEVEL	WATER LEVEL ELEVATION	TIME(min)	DAYS	DATE
				34204
18.2	1527.88	0	0	34204
18.18	1527.9	74.17	0.0515069	34204.05
18.12	1527.96	411.87	0.2860208	34204.28
17.97	1528.11	1361.42	0.9454305	34204.94
17.89	1528.19	1860.09	1.2917291	34205.29
17.75	1528.33	2802.26	1.9460138	34205.94
17.69	1528.39	3268.76	2.2699722	34206.26
17.55	1528.53	4292.76	2.9810833	34206.98
17.5	1528.58	4693.26	3.2592083	34207.25
17.13	1528.95	7276.26	5.0529583	34209.05
16.01	1530.07	16171.76	11.230388	34215.23
14.92	1531.16	26347.26	18.296708	34222.29
13.95	1532.13	37467.26	26.018930	34230.01
12.57	1533.51	56573.76	39.287333	34243.28
11.92	1534.16	67979.26	47.207819	34251.20
11.51	1534.57	76659.76	53.235944	34257.23
10.76	1535.32	96746.26	67.184902	34271.18
10.23	1535.85	116607.76	80.977611	34284.97
9.83	1536.25	136890.26	95.062680	34299.06
9.48	1536.6	157384.26	109.29462	34313.29
9.26	1536.82	174674.26	121.30156	34325.30
8.98	1537.1	197306.26	137.01823	34341.01
8.91	1537.17	216168.26	150.11684	34354.11
8.92	1537.16	238018.26	165.29045	34369.29
9.11	1536.97	273920.26	190.22240	34394.22
9.18	1536.9	298216.26	207.09462	34411.09
9.09	1536.99	318528.26	221.20018	34425.20
8.44	1537.64	350278.26	243.24879	34447.24
6.62	1539.46	384466.26	266.99045	34470.99
6.47	1539.61	406251.26	282.11893	34486.11
6.77	1539.31	426319.26	296.05504	34500.05
7.07	1539.01	440784.26	306.10018	34510.10
7.11	1538.97	449641.26	312.25087	34516.25
7.28	1538.8	459472.26	319.07795	34523.07
7.46	1538.62	469741.26	326.20920	34530.20
7.98	1538.1	491101.26	341.04254	34545.04
8.25	1537.83	505856.26	351.28906	34555.28

RUNGE LANDFILL HYDROGRAPH R20-93-11

Depth-30.30ft. Screen-5ft. Dia.-2"

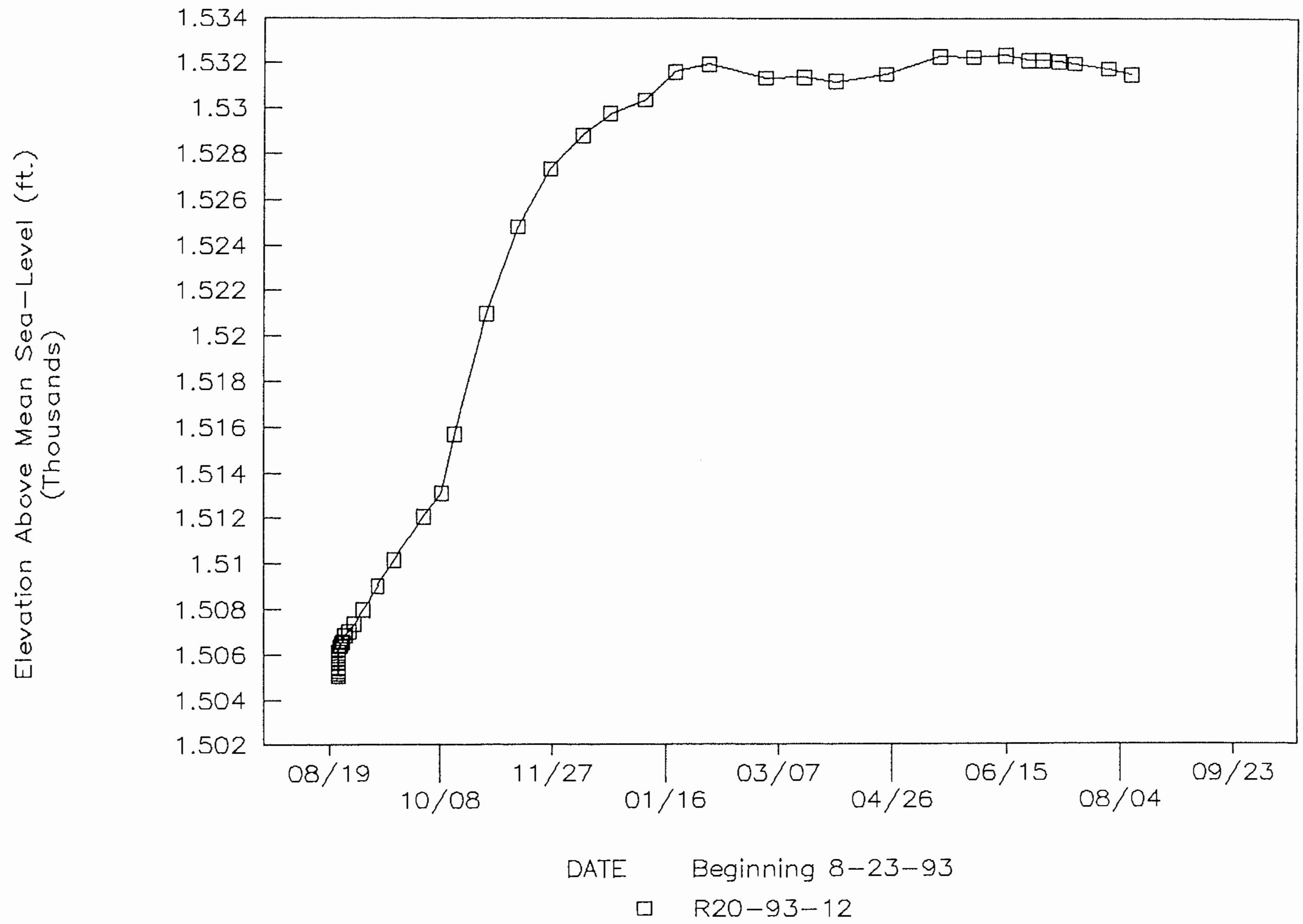


	ELEV.	HYDROGRAPHS		
R20−93−11	1546		1440	

WATER LEVEL	WATER LEVEL ELEVATION	TIME(min)	DAYS	DATE
				34205
29.75	1516.25	0	0	34205
29.6	1516.4	0.5	0.0003472	34205.00
29.4	1516.6	1.25	0.0008680	34205.00
29.2	1516.8	2.08	0.0014444	34205.00
29	1517	3.18	0.0022083	34205.00
28.8	1517.2	4.36	0.0030277	34205.00
28.5	1517.5	6.44	0.0044722	34205.00
28	1518	10.99	0.0076319	34205.00
27.6	1518.4	18.7	0.0129861	34205.01
27.5	1518.5	22.56	0.0156666	34205.01
27.4	1518.6	27.24	0.0189166	34205.01
27.15	1518.85	41.06	0.0285138	34205.02
27.05	1518.95	47.73	0.0331458	34205.03
26.95	1519.05	55.73	0.0387013	34205.03
26.73	1519.27	76.35	0.0530208	34205.05
26.41	1519.59	114.15	0.0792708	34205.07
15.02	1530.98	1044.48	0.7253333	34205.72
14.04	1531.96	1181.65	0.8205902	34205.82
13.07	1532.93	1339.4	0.9301388	34205.93
12.18	1533.82	1508.4	1.0475	34206.04
9.06	1536.94	2535.15	1.7605208	34206.76
8.83	1537.17	2666.4	1.8516666	34206.85
8.63	1537.37	2802.65	1.9462847	34206.94
8.45	1537.55	2937.4	2.0398611	34207.03
7.58	1538.42	4245.15	2.9480208	34207.94
7.28	1538.72	5517.9	3.831875	34208.83
7.04	1538.96	8455.9	5.8721527	34210.87
7.28	1538.72	14407.4	10.005138	34215.00
7.69	1538.31	24585.65	17.073368	34222.07
8.09	1537.91	35722.15	24.807048	34229.80
7.93	1538.07	54826.15	38.073715	34243.07
8.41	1537.59	66239.15	45.999409	34250.99
8.35	1537.65	74917.4	52.025972	34257.02
8.74	1537.26	95006.65	65.976840	34270.97
8.86	1537.14	114084.65	79.225451	34284.22
8.78	1537.22	134360.15	93.305659	34298.30
9	1537	154852.15	107.53621	34312.53
8.89	1537.11	172144.15	119.54454	34324.54
8.92	1537.08	194771.15	135.25774	34340.25
9.17	1536.83	213634.15	148.35704	34353.35
9.26	1536.74	235480.15	163.52788	34368.52
9.53	1536.47	271239.15	188.36052	34393.36
9.15 Tritium	1536.85	295669.15	205.32579	34410.32
9.12	1536.88	315981.15	219.43135	34424.43
4.86	1541.14	347736.15	241.48343	34446.48
6.15	1539.85	381925.15	265.22579	34470.22
7.03	1538.97	403709.15	280.35357	34485.35
7.05	1538.95	423771.15	294.28552	34499.28
7.31	1538.69	438228.15	304.32510	34509.32
7.19	1538.81	447097.15	310.48413	34515.48
7.44	1538.56	456912.15	317.30010	34522.30
24.11 O&HSAMPL	1521.89	467357.15	324.55357	34529.55
8.08	1537.92	488553.15	339.27302	34544.27
8.42	1537.58	503326.15	349.53204	34554.53

RUNGE LANDFILL HYDROGRAPH R20—93—12

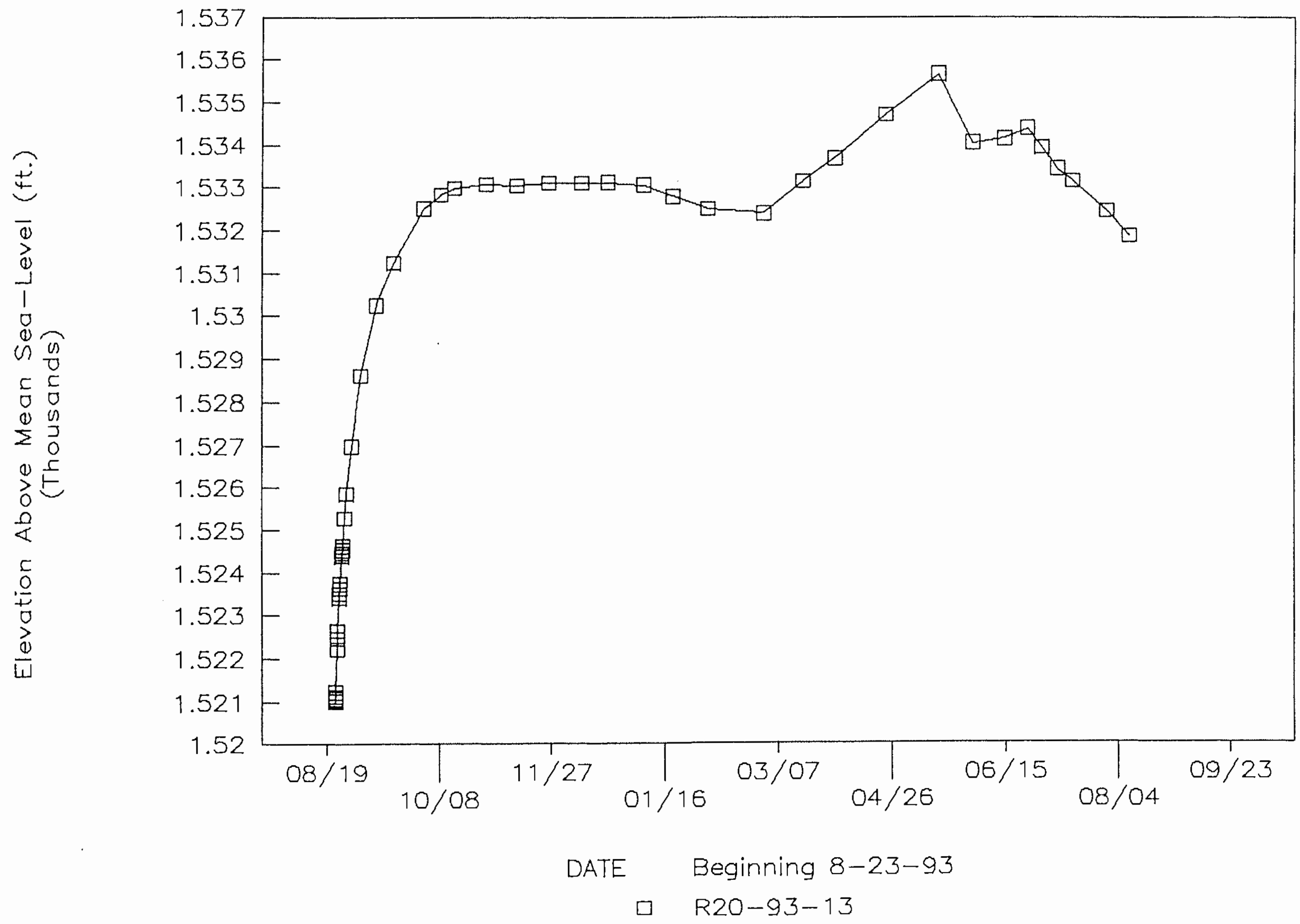
Depth—35.28ft. Screen10ft. Dia—2"



	ELEV.	HYDROGRAPHS		
R20-93-12	1539.06		1440	
WATER LEVEL	WATER LEVEL ELEVATION	TIME(min)	DAYS	DATE
				34204
34	1505.06	0	0	34204
33.9	1505.16	0.58	0.0004027	34204.00
33.8	1505.26	2.38	0.0016527	34204.00
33.7	1505.36	6.58	0.0045694	34204.00
33.6	1505.46	10.36	0.0071944	34204.00
33.48	1505.58	18.63	0.0129375	34204.01
33.4	1505.66	26.91	0.0186875	34204.01
33.29	1505.77	41.56	0.0288611	34204.02
33.1	1505.96	85.09	0.0590902	34204.05
32.98	1506.08	167.41	0.1162569	34204.11
32.73	1506.33	1109.28	0.7703333	34204.77
32.65	1506.41	1609.16	1.1174722	34205.11
32.55	1506.51	2563.41	1.7801458	34205.78
32.49	1506.57	3023.41	2.0995902	34206.09
32.26	1506.8	4056.41	2.8169513	34206.81
32.23	1506.83	4453.16	3.0924722	34207.09
32.05	1507.01	7037.91	4.8874375	34208.88
31.72	1507.34	9986.66	6.9351805	34210.93
31.1	1507.96	15934.66	11.065736	34215.06
30.04	1509.02	26112.66	18.133791	34222.13
28.89	1510.17	37220.16	25.847333	34229.84
26.99	1512.07	56325.16	39.114694	34243.11
25.96	1513.1	67769.41	47.062090	34251.06
23.39	1515.67	76433.66	53.078930	34257.07
18.1	1520.96	96553.66	67.051152	34271.05
14.27	1524.79	116330.66	80.785180	34284.78
11.75	1527.31	136604.66	94.864347	34298.86
10.27	1528.79	157094.66	109.09351	34313.09
9.33	1529.73	174396.66	121.10879	34325.10
8.71	1530.35	197018.66	136.81851	34340.81
7.46	1531.6	215878.66	149.91573	34353.91
7.12	1531.94	237731.66	165.09143	34369.09
7.73	1531.33	273616.66	190.01156	34394.01
7.69	1531.37	297927.66	206.89420	34410.89
7.89	1531.17	318242.66	221.00184	34425.00
7.57	1531.49	349991.66	243.04976	34447.04
6.78	1532.28	384182.66	266.79351	34470.79
6.79	1532.27	405898.66	281.87407	34485.87
6.71	1532.35	426030.66	295.85462	34499.85
6.93	1532.13	440496.66	305.90045	34509.90
6.94	1532.12	449304.66	312.01712	34516.01
6.99	1532.07	459420.66	319.04212	34523.04
7.11	1531.95	469449.66	326.00670	34530.00
7.32	1531.74	490807.66	340.83865	34544.83
7.59	1531.47	505544.66	351.07268	34555.07

RUNGE LANDFILL HYDROGRAPH R20-93-13

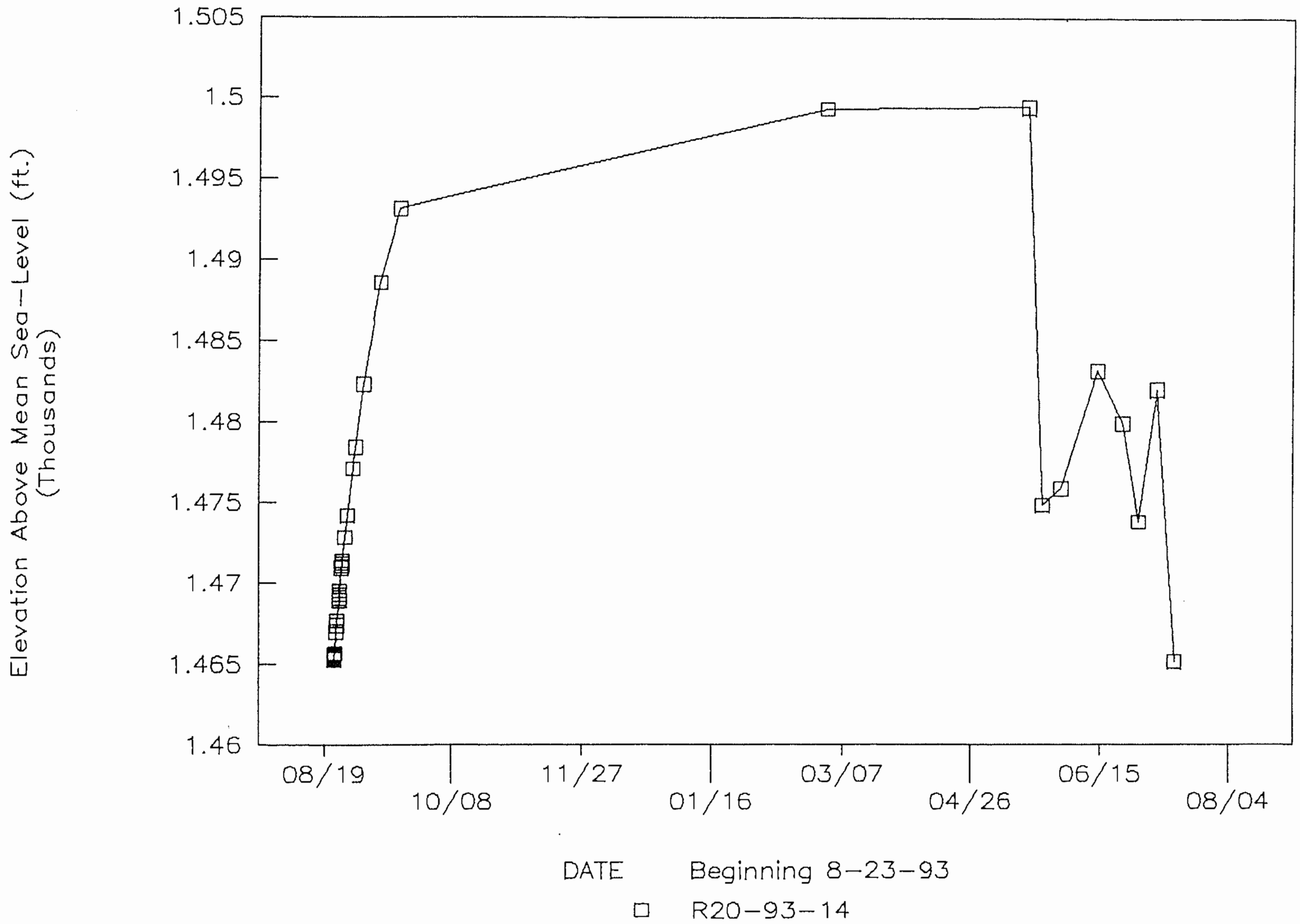
Depth-19.17ft. Core-1.25ft. Dia.-2"



	ELEV.	HYDROGRAPHS		
R20-93-13	1540.04		1440	
WATER LEVEL	WATER LEVEL ELEVATION	TIME(min)	DAYS	DATE
				34204
19.04	1521	0	0	34204
19.03	1521.01	0.7	0.0004861	34204.00
19.02	1521.02	2.58	0.0017916	34204.00
18.98	1521.06	25.08	0.0174166	34204.01
18.92	1521.12	70.58	0.0490138	34204.04
18.81	1521.23	75.66	0.0525416	34204.05
17.83	1522.21	1017.82	0.7068194	34204.70
17.58	1522.46	1296.57	0.9003958	34204.90
17.39	1522.65	1517.4	1.05375	34205.05
16.63	1523.41	2472.07	1.7167152	34205.71
16.53	1523.51	2598.9	1.8047916	34205.80
16.42	1523.62	2755.9	1.9138194	34205.91
16.31	1523.73	2931.4	2.0356944	34206.03
15.65	1524.39	3964.65	2.7532291	34206.75
15.59	1524.45	4081.65	2.8344791	34206.83
15.51	1524.53	4223.9	2.9332638	34206.93
15.42	1524.62	4361.65	3.0289236	34207.02
14.77	1525.27	5664.15	3.9334375	34207.93
14.19	1525.85	6946.15	4.8237152	34208.82
13.07	1526.97	9884.9	6.8645138	34210.86
11.44	1528.6	15832.65	10.994895	34214.99
9.79	1530.25	26010.65	18.062951	34222.06
8.8	1531.24	37118.15	25.776493	34229.77
7.53	1532.51	56223.4	39.044027	34243.04
7.21	1532.83	67666.4	46.990555	34250.99
7.06	1532.98	76342.4	53.015555	34257.01
6.96	1533.08	96462.4	66.987777	34270.98
7	1533.04	116239.4	80.721805	34284.72
6.94	1533.1	136511.4	94.799583	34298.79
6.93	1533.11	157001.4	109.02875	34313.02
6.92	1533.12	174303.4	121.04402	34325.04
6.99	1533.05	196926.4	136.75444	34340.75
7.25	1532.79	215785.4	149.85097	34353.85
7.54	1532.5	237640.4	165.02805	34369.02
7.65	1532.39	273524.4	189.9475	34393.94
6.9	1533.14	297836.4	206.83083	34410.83
6.36	1533.68	318151.4	220.93847	34424.93
5.34	1534.7	349900.4	242.98638	34446.98
4.38	1535.66	384091.4	266.73013	34470.73
6.01	1534.03	405809.4	281.81208	34485.81
5.91	1534.13	425939.4	295.79125	34499.79
5.67	1534.37	440396.4	305.83083	34509.83
6.1	1533.94	449213.4	311.95375	34515.95
6.62	1533.42	459329.4	318.97875	34522.97
6.91	1533.13	469359.4	325.94402	34529.94
7.61	1532.43	490716.4	340.77527	34544.77
8.19	1531.85	505453.4	351.00930	34555.00

RUNGE LANDFILL HYDROGRAPH R20—93—14

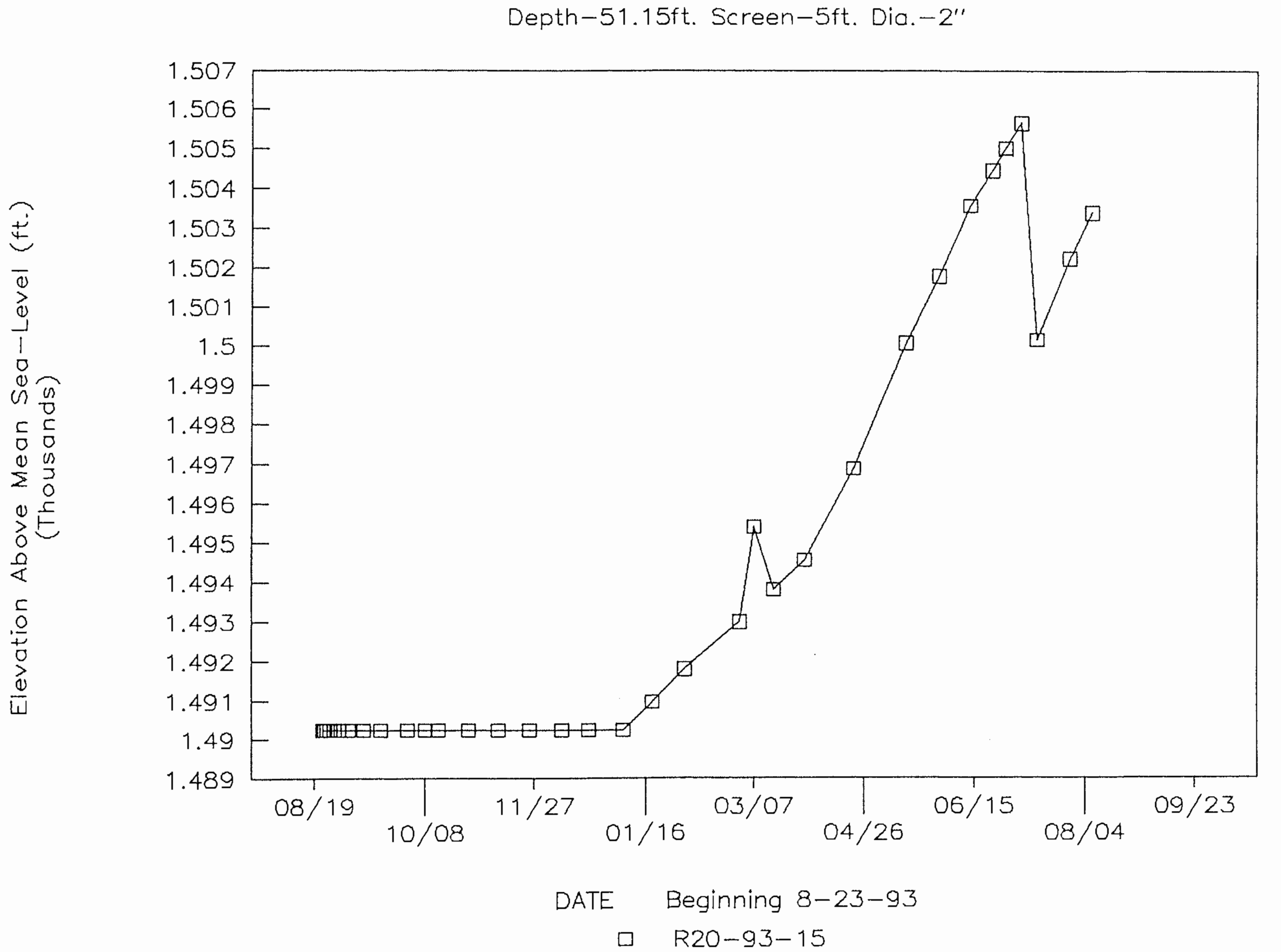
Depth—75.33ft. Screen—5ft. Dia.—2"



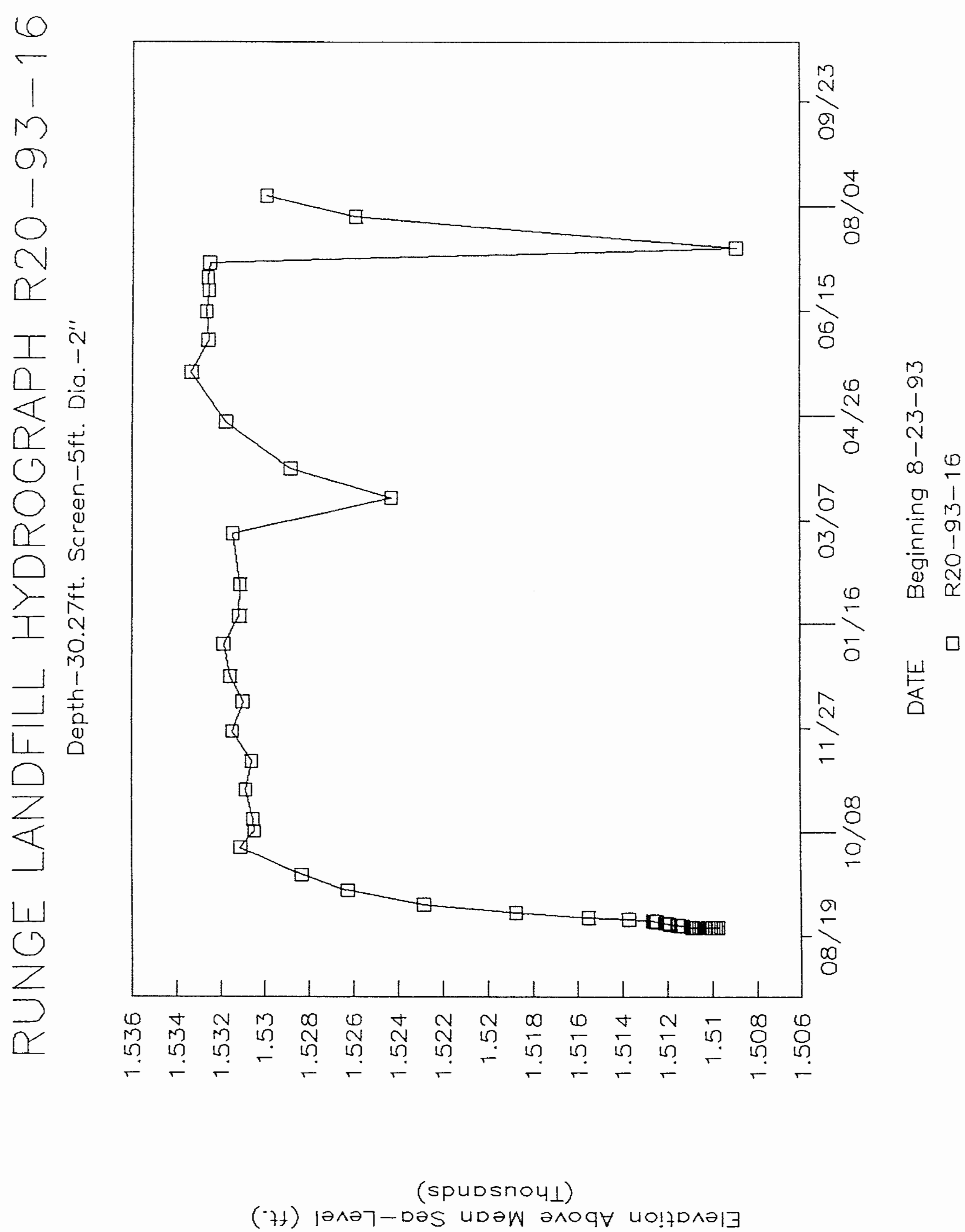
	ELEV.	HYDROGRAPHS		
R20-93-14	1540.38		1440	

WATER LEVEL	WATER LEVEL ELEVATION	TIME(min)	DAYS	DATE
				34204
75.14	1465.24	0	0	34204
75.1	1465.28	0.55	0.0003819	34204.00
75	1465.38	10.5	0.0072916	34204.00
74.95	1465.43	29.53	0.0205069	34204.02
74.9	1465.48	48.76	0.0338611	34204.03
74.85	1465.53	77.46	0.0537916	34204.05
74.77	1465.61	118.88	0.0825555	34204.08
73.41	1466.97	1061.63	0.7372430	34204.73
73.03	1467.35	1339.63	0.9302986	34204.93
72.74	1467.64	1559.96	1.0833055	34205.08
71.53	1468.85	2515.54	1.7469027	34205.74
71.36	1469.02	2641.79	1.8345763	34205.83
71.14	1469.24	2798.79	1.9436041	34205.94
70.89	1469.49	2973.79	2.0651319	34206.06
69.51	1470.87	4007.29	2.7828402	34206.78
69.37	1471.01	4120.79	2.8616597	34206.86
69.2	1471.18	4266.54	2.962875	34206.96
69.04	1471.34	4524.54	3.1420416	34207.14
67.56	1472.82	5826.79	4.0463819	34208.04
66.2	1474.18	7109.04	4.9368333	34208.93
63.31	1477.07	10047.79	6.9776319	34210.97
61.96	1478.42	11348.29	7.8807569	34211.88
58.08	1482.3	15995.54	11.108013	34215.10
51.84	1488.54	26174.04	18.176416	34222.17
47.25	1493.13	37280.79	25.889437	34229.88
41.08	1499.3	273501.04	189.93127	34393.93
40.95 Tritium	1499.43	386061.04	268.09794	34472.09
65.56 Bailing	1474.82	394511.04	273.966	34477.96
64.54 Tritium	1475.84	404606.04	280.97641	34484.97
57.25 Bailing	1483.13	424876.04	295.05280	34499.05
60.49 Bailing	1479.89	439241.04	305.0285	34509.02
66.59 AfterSample	1473.79	448031.04	311.13266	34515.13
58.41	1481.97	458011.04	318.06322	34522.06
75.25 O&HSAMPL	1465.13	468276.04	325.19169	34529.19

RUNGE LANDFILL HYDROGRAPH R20—93—15



	ELEV.	HYDROGRAPHS		
R20−93−15	1541.39		1440	
WATER LEVEL	WATER LEVEL ELEVATION	TIME(min)	DAYS	DATE
				34204
51.15	1490.24	0	0	34204
51.15	1490.24	1371.58	0.9524861	34204.95
51.15	1490.24	2806.42	1.9489027	34205.94
51.15	1490.24	4297.33	2.9842569	34206.98
51.15	1490.24	7281	5.05625	34209.05
51.15	1490.24	10219.5	7.096875	34211.09
51.15	1490.24	16170.5	11.229513	34215.22
51.15	1490.24	26347	18.296527	34222.29
51.15	1490.24	37455.5	26.010763	34230.01
51.15	1490.24	55122	38.279166	34242.27
51.15	1490.24	66565	46.225694	34250.22
51.15	1490.24	75240	52.25	34256.25
51.15	1490.24	95360	66.222222	34270.22
51.15	1490.24	115136	79.955555	34283.95
51.15	1490.24	135409	94.034027	34298.03
51.15	1490.24	155900	108.26388	34312.26
51.15	1490.24	173197	120.27569	34324.27
51.15	1490.24	195821	135.98680	34339.98
50.44	1490.95	214682	149.08472	34353.08
49.61	1491.78	236533	164.25902	34368.25
48.41	1492.98	272425	189.18402	34393.18
46.01	1495.38	282250	196.00694	34400.00
47.6 Tritium	1493.79	295290	205.0625	34409.06
46.85	1494.54	315606	219.17083	34423.17
44.51	1496.88	347356	241.21944	34445.21
41.35	1500.04	381545	264.96180	34468.96
39.62	1501.77	403260	280.04166	34484.04
37.83	1503.56	423390	294.02083	34498.02
36.94	1504.45	437860	304.06944	34508.06
36.38	1505.01	446668	310.18611	34514.18
35.74	1505.65	456775	317.20486	34521.20
41.25 O&HSAMPL	1500.14	466815	324.17708	34528.17
39.17	1502.22	488174	339.00972	34543.00
38	1503.39	502912	349.24444	34553.24


RUNGE LANDFILL HYDROGRAPH R20-93-16
Depth-30.27ft. Screen-5ft. Dia.-2"
Elevation Above Mean Sea-Level (ft.)
(Thousands)
1.536
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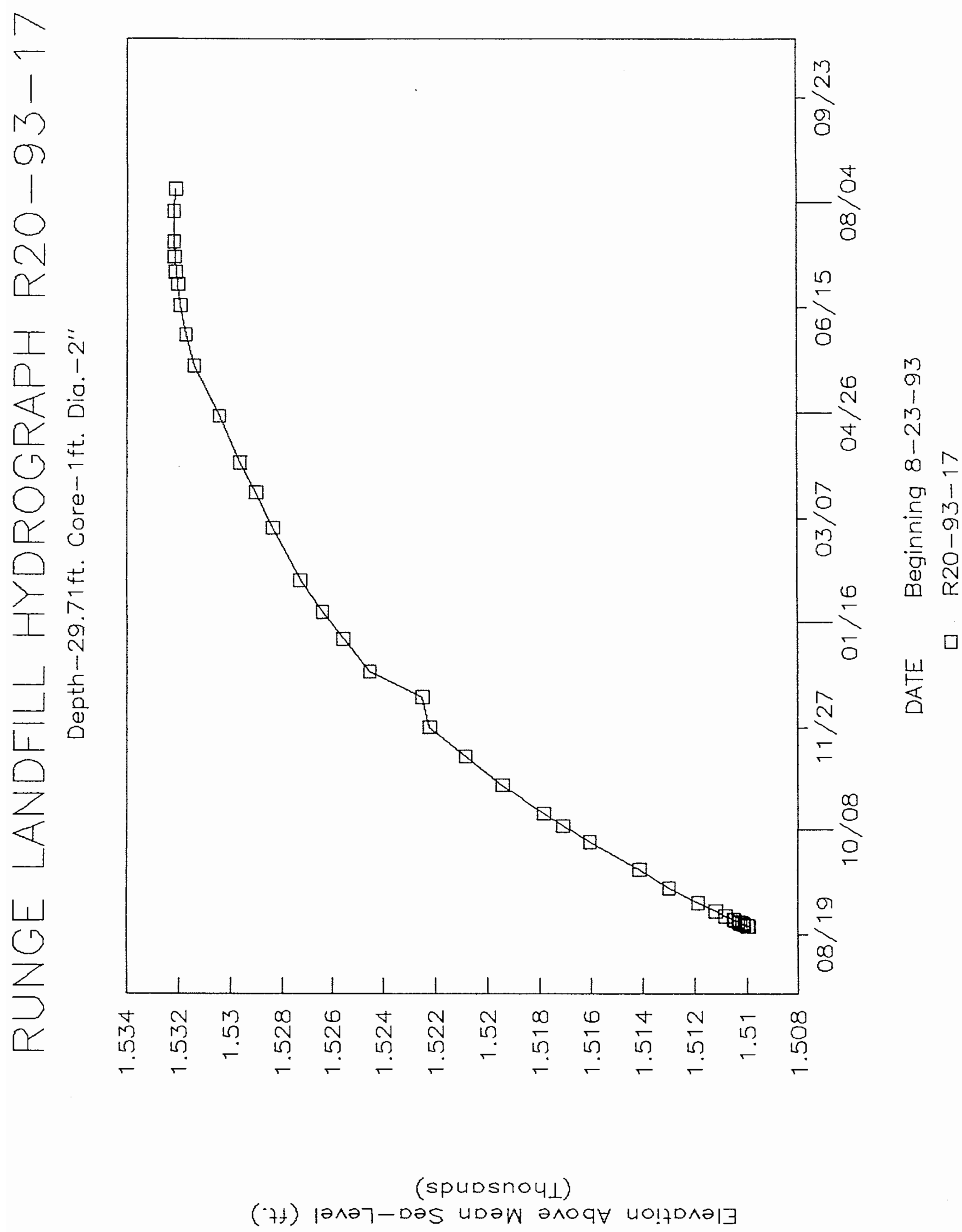
09/23
DATE
Beginning 8-23-93
R20-93-16

	ELEV.	HYDROGRAPHS		
R20-93-16	1538.94		1440	

WATER LEVEL	WATER LEVEL ELEVATION	TIME(min)	DAYS	DATE
				34204
29.25	1509.69	0	0	34204
29.1	1509.84	0.5	0.0003472	34204.00
29	1509.94	0.8	0.0005555	34204.00
28.9	1510.04	1.15	0.0007986	34204.00
28.8	1510.14	1.47	0.0010208	34204.00
28.7	1510.24	2.02	0.0014027	34204.00
28.6	1510.34	3.55	0.0024652	34204.00
28.5	1510.44	7.55	0.0052430	34204.00
28.4	1510.54	15.08	0.0104722	34204.01
28.3	1510.64	26	0.0180555	34204.01
28.26	1510.68	38.17	0.0265069	34204.02
28.19	1510.75	59.95	0.0416319	34204.04
28.17	1510.77	88.98	0.0617916	34204.06
28.12	1510.82	126.41	0.0877847	34204.08
28.09	1510.85	205.58	0.1427638	34204.14
27.67	1511.27	1146.33	0.7960625	34204.79
27.58	1511.36	1427	0.9909722	34204.99
27.42	1511.52	1646.83	1.1436319	34205.14
27.07	1511.87	2601.08	1.8063055	34205.80
26.88	1512.06	3061.58	2.1260972	34206.12
26.47	1512.47	4091	2.8409722	34206.84
26.43	1512.51	4216.58	2.9281805	34206.92
26.38	1512.56	4354.83	3.0241875	34207.02
26.33	1512.61	4490.58	3.1184583	34207.11
25.27	1513.67	5795.08	4.0243611	34208.02
23.43	1515.51	7075.83	4.9137708	34208.91
20.19	1518.75	10014.08	6.9542222	34210.95
16.08	1522.86	15963.33	11.085645	34215.08
12.67	1526.27	26140.83	18.153354	34222.15
10.63	1528.31	37248.58	25.867069	34229.86
7.86	1531.08	56353.83	39.134604	34243.13
8.49	1530.45	67796.83	47.081131	34251.08
8.43	1530.51	76471.83	53.105437	34257.10
8.1	1530.84	96591.83	67.077659	34271.07
8.36	1530.58	116368.33	80.811340	34284.81
7.51	1531.43	136642.33	94.890506	34298.89
7.96	1530.98	157132.33	109.11967	34313.11
7.4	1531.54	174434.33	121.13495	34325.13
7.12	1531.82	197055.33	136.84397	34340.84
7.8	1531.14	215916.33	149.94189	34353.94
7.84	1531.1	237769.33	165.11759	34369.11
7.52	1531.42	273404.33	189.86411	34393.86
14.66 Tritium	1524.28	297965.33	206.92036	34410.92
10.13	1528.81	318280.33	221.02800	34425.02
7.21	1531.73	350029.33	243.07592	34447.07
5.63	1533.31	384220.33	266.81967	34470.81
6.41	1532.53	405936.33	281.90022	34485.90
6.31	1532.63	426066.33	295.87939	34499.87
6.43	1532.51	440534.33	305.92661	34509.92
6.37	1532.57	449342.33	312.04328	34516.04
6.47	1532.47	459332.33	318.98078	34522.98
30.09 O&HSAMPL	1508.85	469669.33	326.15925	34530.15
13.03	1525.91	490846.33	340.86550	34544.86
9.03	1529.91	505583.33	351.09953	34555.09


RUNGE LANDFILL HYDROGRAPH R20-93-17
Depth-29.71ft. Core-1ft. Dia.-2"
Elevation Above Mean Sea-Level (ft.)
(Thousands)
1.534
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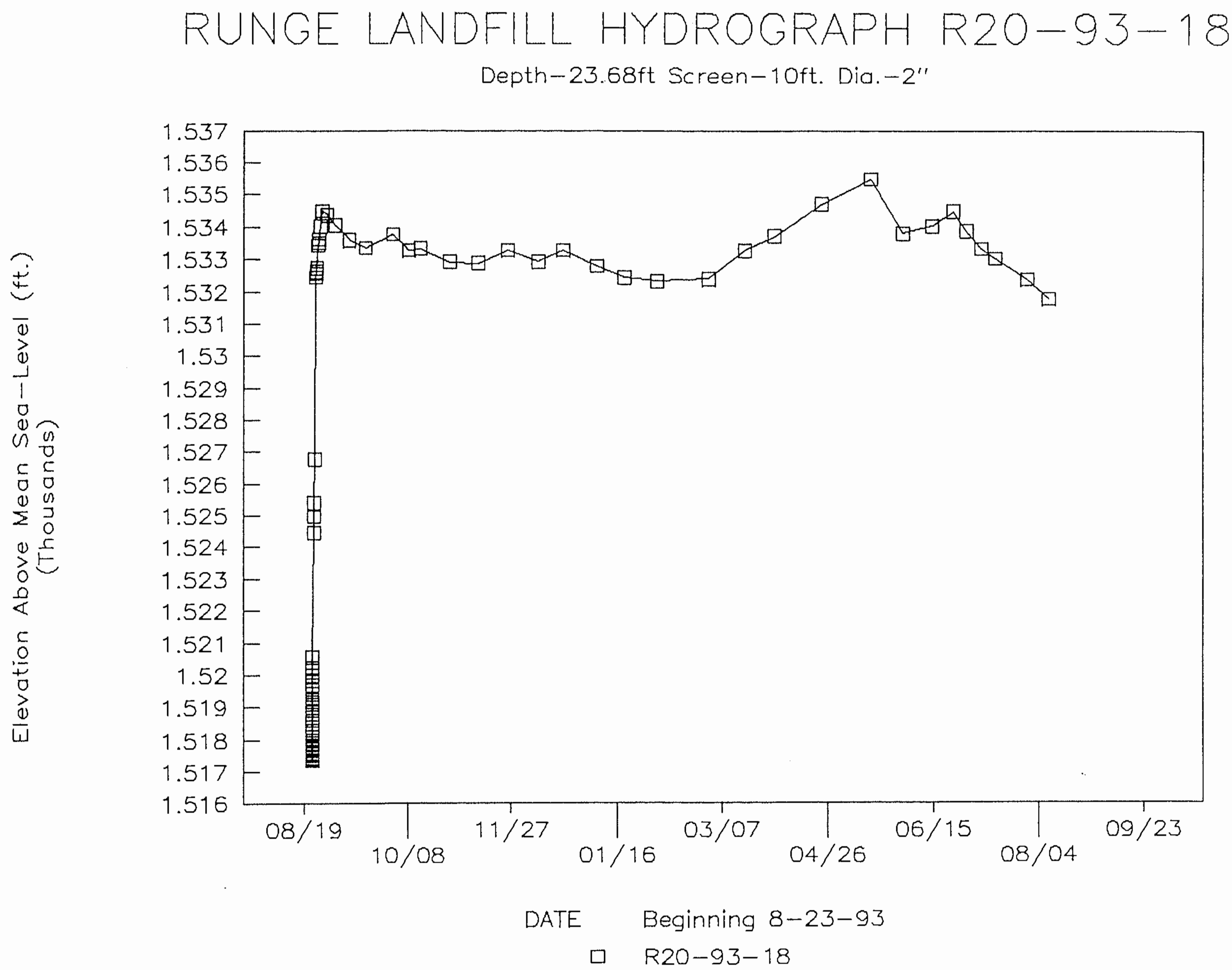
09/23
DATE
Beginning 8-23-93
R20-93-17

	ELEV.	HYDROGRAPHS		
R20-93-17	1539.18		1440	
WATER LEVEL	WATER LEVEL ELEVATION	TIME(min)	DAYS	DATE
				34204
29.28	1509.9	0	0	34204
29.25	1509.93	91.25	0.0633680	34204.06
29.24	1509.94	164.25	0.1140625	34204.11
29.23	1509.95	233.83	0.1623819	34204.16
29.11	1510.07	1173.83	0.8151597	34204.81
29.04	1510.14	1675	1.1631944	34205.16
28.93	1510.25	2628.83	1.8255763	34205.82
28.87	1510.31	3090	2.1458333	34206.14
28.74	1510.44	4120.25	2.8612847	34206.86
28.69	1510.49	4518.5	3.1378472	34207.13
28.37	1510.81	7103.75	4.9331597	34208.93
28.02	1511.16	10042	6.9736111	34210.97
27.34	1511.84	15992.25	11.105729	34215.10
26.22	1512.96	26169.25	18.173090	34222.17
25.07	1514.11	38717.5	26.887152	34230.88
23.15	1516.03	57822.25	40.154340	34244.15
22.1	1517.08	69265.25	48.100868	34252.10
21.35	1517.83	77940.25	54.125173	34258.12
19.76	1519.42	98058.75	68.096354	34272.09
18.33	1520.85	117835.25	81.830034	34285.83
16.95	1522.23	138109.25	95.909201	34299.90
16.67	1522.51	158599.25	110.13836	34314.13
14.66	1524.52	175900.25	122.15295	34326.15
13.61	1525.57	198520.25	137.86128	34341.86
12.79	1526.39	217383.25	150.96059	34354.96
11.93	1527.25	239236.25	166.13628	34370.13
10.85	1528.33	275124.25	191.05850	34395.05
10.2	1528.98	299432.25	207.93906	34411.93
9.58	1529.6	319747.25	222.04670	34426.04
8.77	1530.41	351496.25	244.09461	34448.09
7.81	1531.37	385687.25	267.83836	34471.83
7.47	1531.71	407403.25	282.91892	34486.91
7.26	1531.92	427533.25	296.89809	34500.89
7.16	1532.02	442001.25	306.94531	34510.94
7.08	1532.1	450809.25	313.06197	34517.06
7.03	1532.15	460927.25	320.08836	34524.08
7.01	1532.17	470957.25	327.05364	34531.05
7.01	1532.17	492313.25	341.88420	34545.88
7.06	1532.12	507051.25	352.11892	34556.11


RUNGE LANDFILL HYDROGRAPH R20-93-18
Depth-23.68ft Screen-10ft. Dia.-2"
Elevation Above Mean Sea-Level (ft.)
(Thousands)
1.537
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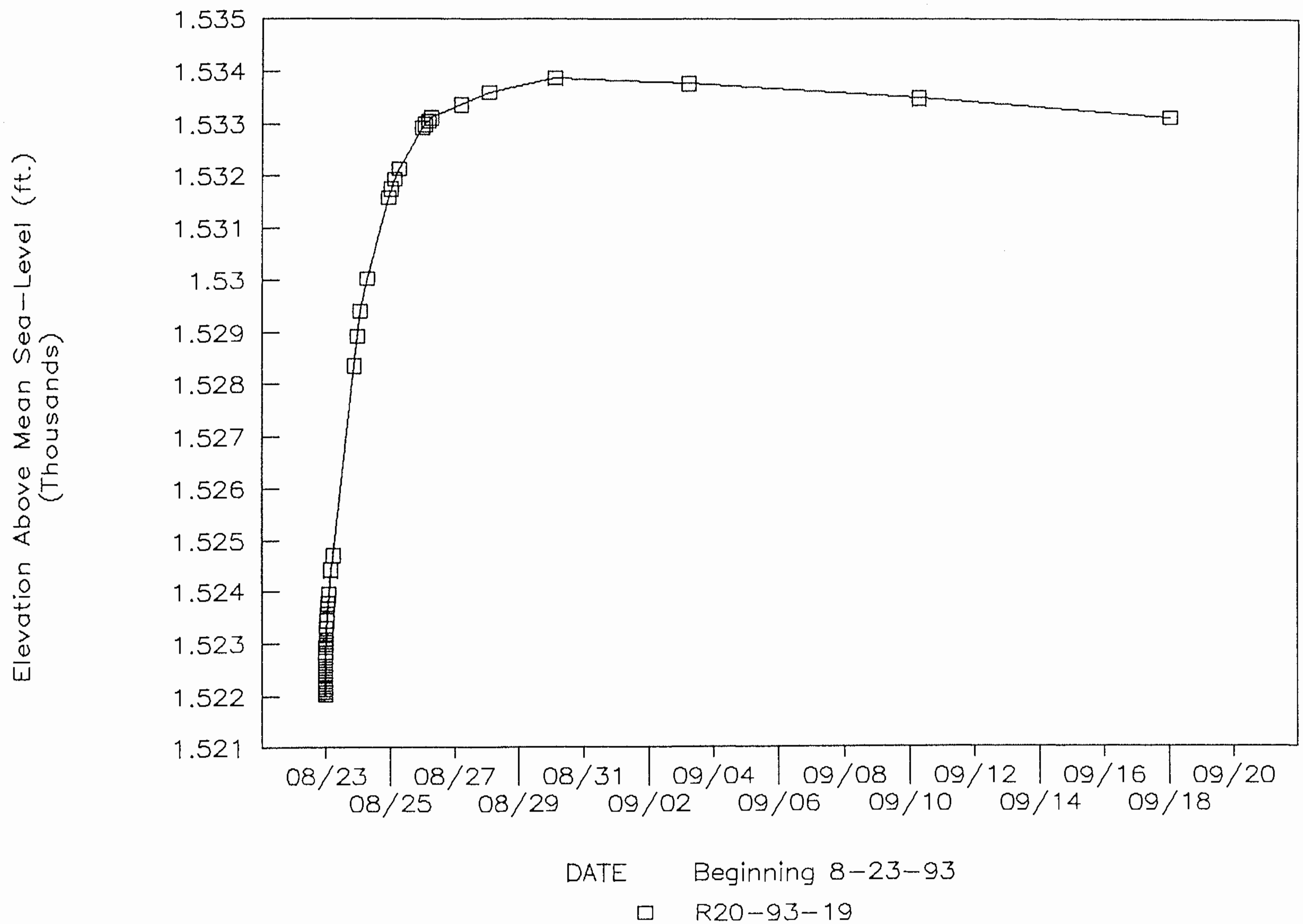
09/23
DATE Beginning 8-23-93
R20-93-18

	ELEV.	HYDROGRAPHS		
R20-93-18	1539.89		1440	
WATER LEVEL	WATER LEVEL ELEVATION	TIME (min)	DAYS	DATE
				34204
22.55	1517.34	0	0	34204
22.5	1517.39	0.37	0.0002569	34204.00
22.45	1517.44	0.97	0.0006736	34204.00
22.4	1517.49	1.57	0.0010902	34204.00
22.35	1517.54	2.17	0.0015069	34204.00
22.3	1517.59	2.79	0.0019375	34204.00
22.25	1517.64	3.51	0.0024375	34204.00
22.2	1517.69	4.23	0.0029375	34204.00
22.15	1517.74	5.01	0.0034791	34204.00
22.1	1517.79	5.84	0.0040555	34204.00
22.05	1517.84	6.71	0.0046597	34204.00
22	1517.89	7.68	0.0053333	34204.00
21.9	1517.99	9.76	0.0067777	34204.00
21.8	1518.09	12.18	0.0084583	34204.00
21.7	1518.19	14.93	0.0103680	34204.01
21.6	1518.29	18	0.0125	34204.01
21.5	1518.39	21.5	0.0149305	34204.01
21.4	1518.49	25.55	0.0177430	34204.01
21.3	1518.59	30.08	0.0208888	34204.02
21.2	1518.69	35.08	0.0243611	34204.02
21.1	1518.79	40.51	0.0281319	34204.02
21	1518.89	46.89	0.0325625	34204.03
20.9	1518.99	54.66	0.0379583	34204.03
20.8	1519.09	63.57	0.0441458	34204.04
20.65	1519.24	77.1	0.0535416	34204.05
20.34	1519.55	114.85	0.0797569	34204.07
20.23	1519.66	131.07	0.0910208	34204.09
20.06	1519.83	157.95	0.1096875	34204.10
19.91	1519.98	185.65	0.1289236	34204.12
19.69	1520.2	224.47	0.1558819	34204.15
19.34	1520.55	297.15	0.2063541	34204.20
15.44	1524.45	1236.9	0.8589583	34204.85
14.93	1524.96	1380.07	0.9583819	34204.95
14.49	1525.4	1520.24	1.0557222	34205.05
13.13	1526.76	1738.91	1.2075763	34205.20
7.45	1532.44	2692.83	1.8700208	34205.87
7.34	1532.55	2825.33	1.9620347	34205.96
7.28	1532.61	2982.83	2.0714097	34206.07
7.17	1532.72	3154.08	2.1903333	34206.19
6.46	1533.43	4183.83	2.9054375	34206.90
6.39	1533.5	4313.08	2.9951944	34206.99
6.28	1533.61	4582.08	3.182	34207.18
5.88	1534.01	5888.58	4.0892916	34208.08
5.41	1534.48	7167.58	4.9774861	34208.97
5.53	1534.36	10096.08	7.0111666	34211.01
5.84	1534.05	16046.33	11.143284	34215.14
6.29	1533.6	26223.08	18.210472	34222.21
6.55	1533.34	37331.58	25.924708	34229.92
6.13	1533.76	56436.58	39.192069	34243.19
6.62	1533.27	67878.83	47.138076	34251.13
6.57	1533.32	76554.08	53.162555	34257.16
6.99	1532.9	96673.58	67.134430	34271.13
7.02	1532.87	116450.08	80.868111	34284.86
6.61	1533.28	136495.58	94.788597	34298.78
6.97	1532.92	156980.58	109.01429	34313.01
6.61	1533.28	174286.58	121.03234	34325.03
7.12	1532.77	196906.58	136.74068	34340.74
7.46	1532.43	215769.58	149.83998	34353.83
7.59	1532.3	237622.58	165.01568	34369.01
7.5	1532.39	273510.58	189.93790	34393.93
6.63	1533.26	297818.58	206.81845	34410.81
6.19	1533.7	318133.58	220.92609	34424.92
5.2	1534.69	349883.58	242.97470	34446.97
4.41	1535.48	384073.58	266.71776	34470.71
6.1	1533.79	405787.58	281.79693	34485.79
5.88	1534.01	425919.58	295.77748	34499.77
5.43	1534.46	440384.58	305.82262	34509.82
6.04	1533.85	449195.58	311.94137	34515.94
6.59	1533.3	459307.58	318.96359	34522.96
6.88	1533.01	469337.58	325.92887	34529.92
7.53	1532.36	490694.58	340.76012	34544.76
8.15	1531.74	505433.58	350.99554	34554.99

RUNGE LANDFILL HYDROGRAPH R20−93−19

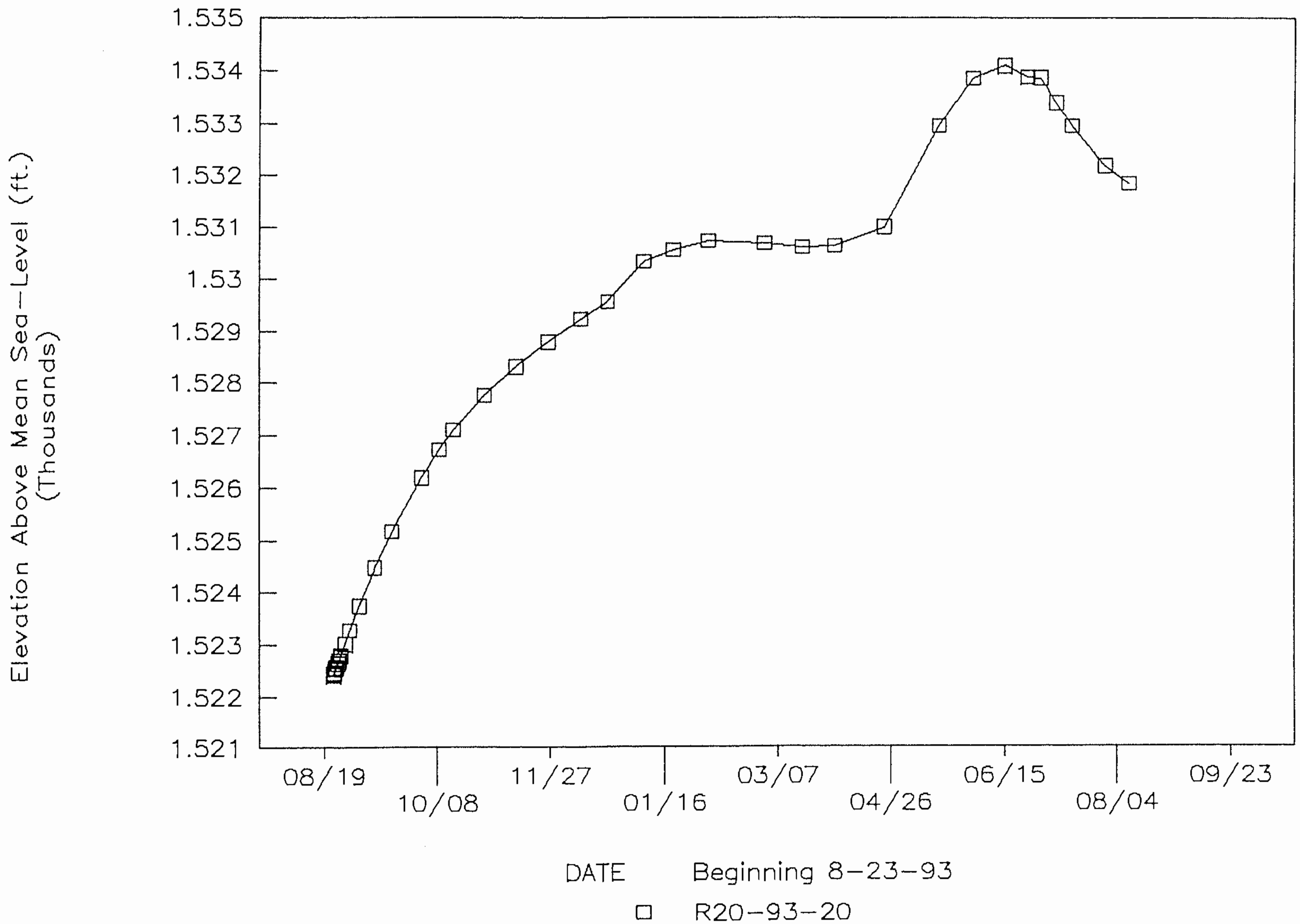
Depth−18.92ft. Screen−5ft. Dia.−2″



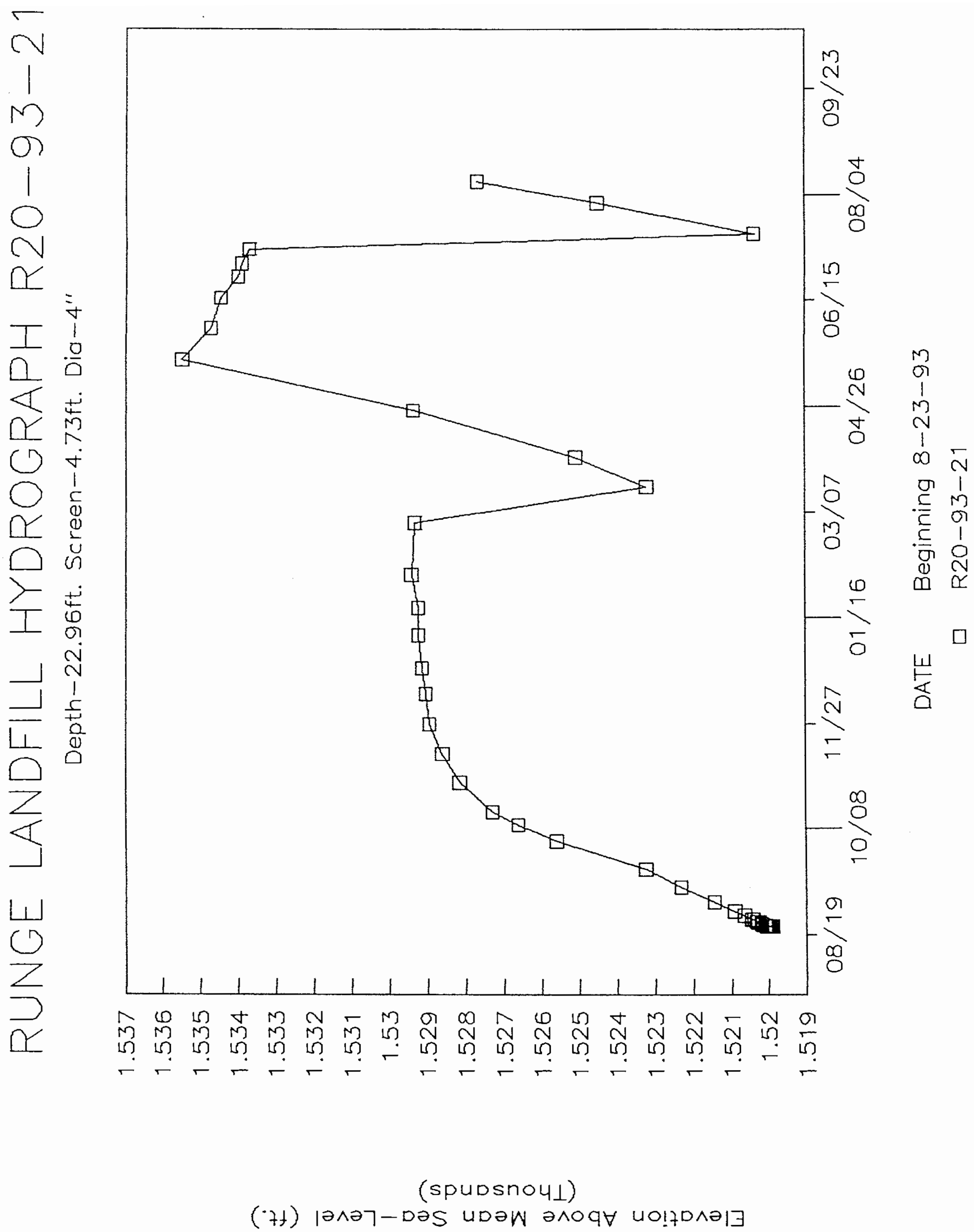
	ELEV.	HYDROGRAPHS		
R20-93-19	1540.57		1440	
WATER LEVEL	WATER LEVEL ELEVATION	TIME(min)	DAYS	DATE
				34204
18.55	1522.02	0	0	34204
18.5	1522.07	0.42	0.0002916	34204.00
18.45	1522.12	0.83	0.0005763	34204.00
18.4	1522.17	1.5	0.0010416	34204.00
18.35	1522.22	2.37	0.0016458	34204.00
18.3	1522.27	3.5	0.0024305	34204.00
18.25	1522.32	4.67	0.0032430	34204.00
18.2	1522.37	5.92	0.0041111	34204.00
18.15	1522.42	7.42	0.0051527	34204.00
18.1	1522.47	8.92	0.0061944	34204.00
18.05	1522.52	10.59	0.0073541	34204.00
18	1522.57	12.34	0.0085694	34204.00
17.9	1522.67	16.09	0.0111736	34204.01
17.8	1522.77	20.76	0.0144166	34204.01
17.65	1522.92	28.68	0.0199166	34204.01
17.6	1522.97	32.1	0.0222916	34204.02
17.5	1523.07	40.68	0.02825	34204.02
17.4	1523.17	50.76	0.03525	34204.03
17.29	1523.28	64.18	0.0445694	34204.04
17.14	1523.43	82.18	0.0570694	34204.05
17	1523.57	103.18	0.0716527	34204.07
16.81	1523.76	134.26	0.0932361	34204.09
16.63	1523.94	171.51	0.1191041	34204.11
16.15	1524.42	281.37	0.1953958	34204.19
15.87	1524.7	351.37	0.2440069	34204.24
12.22	1528.35	1290.42	0.896125	34204.89
11.66	1528.91	1434.5	0.9961805	34204.99
11.18	1529.39	1574.25	1.0932291	34205.09
10.54	1530.03	1853.08	1.2868611	34205.28
8.99	1531.58	2807	1.9493055	34205.94
8.83	1531.74	2938.67	2.0407430	34206.04
8.63	1531.94	3096.92	2.1506388	34206.15
8.43	1532.14	3268.42	2.2697361	34206.26
7.66	1532.91	4297.42	2.9843194	34206.98
7.59	1532.98	4429.67	3.0761597	34207.07
7.53	1533.04	4562.67	3.1685208	34207.16
7.46	1533.11	4696.67	3.2615763	34207.26
7.21	1533.36	6002.42	4.1683472	34208.16
6.97	1533.6	7281.67	5.0567152	34209.05
6.69	1533.88	10220.17	7.0973402	34211.09
6.81	1533.76	16169.92	11.229111	34215.22
7.08	1533.49	26347.17	18.296645	34222.29
7.45	1533.12	37455.17	26.010534	34230.01

RUNGE LANDFILL HYDROGRAPH R20-93-20

Depth-20.74ft. Core-2ft. Dia.-4"



	ELEV.	HYDROGRAPHS		
R20-93-20	1541.56		1440	
WATER LEVEL	WATER LEVEL ELEVATION	TIME(min)	DAYS	DATE
				34204
19.15	1522.41	0	0	34204
19.14	1522.42	55	0.0381944	34204.03
19.13	1522.43	192.33	0.1335625	34204.13
19.11	1522.45	399.58	0.2774861	34204.27
19.11	1522.45	466.58	0.3240138	34204.32
19.03	1522.53	1415.58	0.9830416	34204.98
19	1522.56	1917	1.33125	34205.33
18.92	1522.64	2870.25	1.9932291	34205.99
18.87	1522.69	3332.5	2.3142361	34206.31
18.79	1522.77	4362.75	3.0296875	34207.02
18.76	1522.8	4761.25	3.3064236	34207.30
18.54	1523.02	7345.25	5.1008680	34209.10
18.29	1523.27	10283.75	7.1414930	34211.14
17.82	1523.74	16233.75	11.273437	34215.27
17.09	1524.47	26410.5	18.340625	34222.34
16.39	1525.17	37519	26.054861	34230.05
15.37	1526.19	56626	39.323611	34243.32
14.83	1526.73	68064.5	47.267013	34251.26
14.45	1527.11	76739	53.290972	34257.29
13.8	1527.76	96860	67.263888	34271.26
13.26	1528.3	116635.5	80.996875	34284.99
12.78	1528.78	136908.5	95.075347	34299.07
12.35	1529.21	157400	109.30555	34313.30
12.01	1529.55	174697	121.31736	34325.31
11.23	1530.33	197320	137.02777	34341.02
11.01	1530.55	216182	150.12638	34354.12
10.83	1530.73	238034	165.30138	34369.30
10.89	1530.67	273924	190.225	34394.22
10.96	1530.6	298232	207.10555	34411.10
10.93	1530.63	318542	221.20972	34425.20
10.57	1530.99	350292	243.25833	34447.25
8.61	1532.95	384482	267.00138	34471.00
7.71	1533.85	406196	282.08055	34486.08
7.47	1534.09	426326	296.05972	34500.05
7.68	1533.88	440791	306.10486	34510.10
7.7	1533.86	449604	312.225	34516.22
8.18	1533.38	459724	319.25277	34523.25
8.61	1532.95	469751	326.21597	34530.21
9.39	1532.17	491109	341.04791	34545.04
9.73	1531.83	505848	351.28333	34555.28


RUNGE LANDFILL HYDROGRAPH R20—93—21
Depth—22.96ft. Screen—4.73ft. Dia—4"
Elevation Above Mean Sea—Level (ft.)
(Thousands)
1.519
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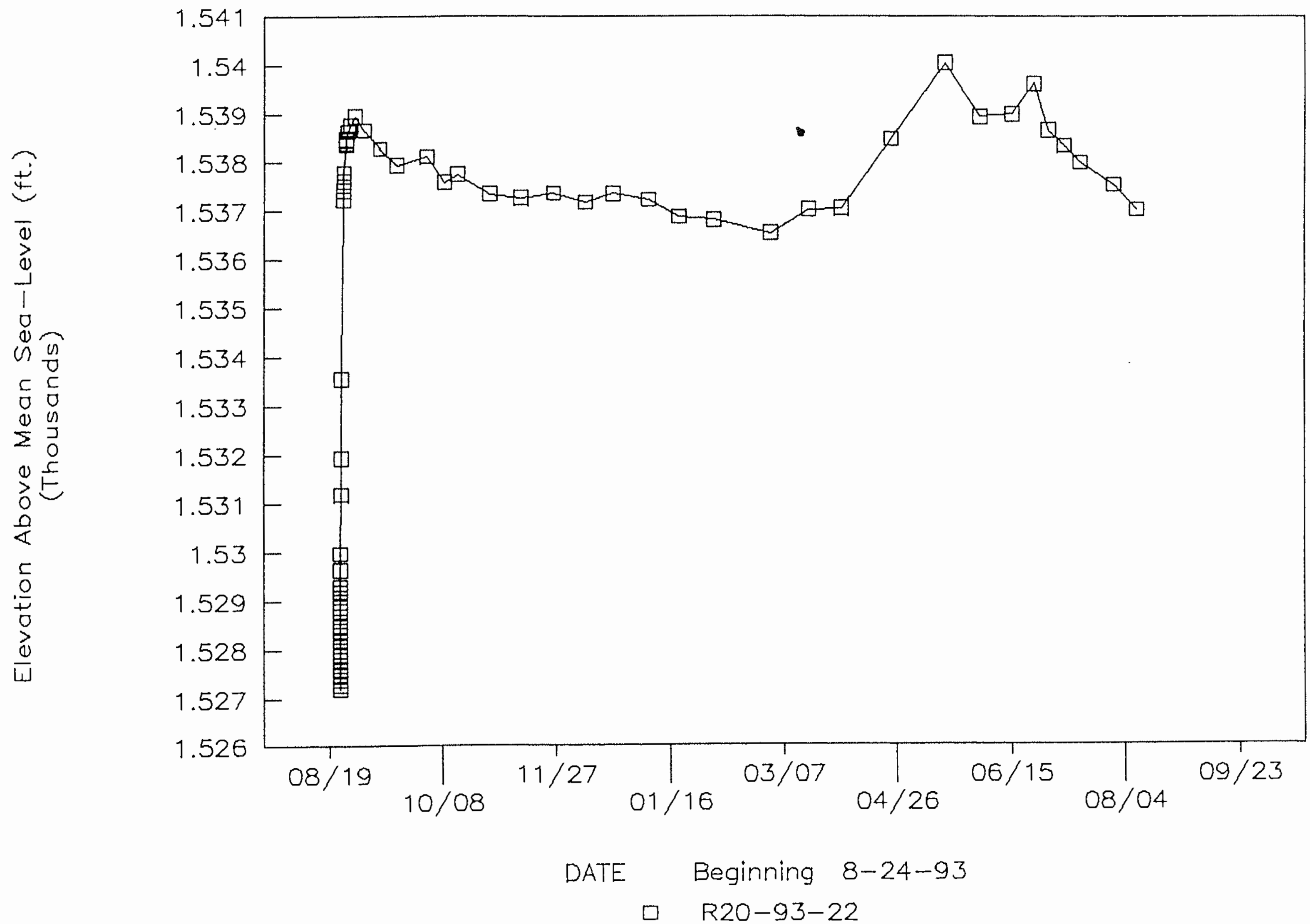
10/08
11/27
01/16
03/07
04/26
06/15
08/04
09/23
DATE
Beginning 8—23—93
R20—93—21

	ELEV.	HYDROGRAPHS		
R20-93-21	1542.36		1440	
WATER LEVEL	WATER LEVEL ELEVATION	TIME(min)	DAYS	DATE
				34204
22.45	1519.91	0	0	34204
22.44	1519.92	1.17	0.0008125	34204.00
22.43	1519.93	2	0.0013888	34204.00
22.4	1519.96	5.75	0.0039930	34204.00
22.38	1519.98	10.02	0.0069583	34204.00
22.36	1520	17.25	0.0119791	34204.01
22.34	1520.02	29.67	0.0206041	34204.02
22.32	1520.04	60.84	0.04225	34204.04
22.31	1520.05	92.51	0.0642430	34204.06
22.3	1520.06	175.63	0.1219652	34204.12
22.28	1520.08	323.43	0.2246041	34204.22
22.28	1520.08	387.43	0.2690486	34204.26
22.18	1520.18	1325.43	0.9204375	34204.92
22.15	1520.21	1830.26	1.2710138	34205.27
22.06	1520.3	2783.93	1.9332847	34205.93
22.03	1520.33	3245.68	2.2539444	34206.25
21.95	1520.41	4272.43	2.9669652	34206.96
21.91	1520.45	4674.43	3.2461319	34207.24
21.71	1520.65	7258.93	5.0409236	34209.04
21.45	1520.91	10197.43	7.0815486	34211.08
20.92	1521.44	16146.93	11.213145	34215.21
20.05	1522.31	26323.93	18.280506	34222.28
19.13	1523.23	38872.43	26.994743	34230.99
16.77	1525.59	57978.93	40.263145	34244.26
15.76	1526.6	69421.68	48.2095	34252.20
15.08	1527.28	78086.93	54.227034	34258.22
14.22	1528.14	98205.43	68.198215	34272.19
13.76	1528.6	117982.93	81.932590	34285.93
13.43	1528.93	138255.93	96.011062	34300.01
13.33	1529.03	158747.93	110.24161	34314.24
13.23	1529.13	176045.93	122.25411	34326.25
13.13	1529.23	198667.93	137.96384	34341.96
13.13	1529.23	217529.93	151.06245	34355.06
12.96	1529.4	239381.93	166.23745	34370.23
13.04	1529.32	274938.93	190.92981	34394.92
19.15 Tritium	1523.21	299577.93	208.04022	34412.04
17.28	1525.08	319893.93	222.14856	34426.14
13	1529.36	351643.93	244.19717	34448.19
6.87	1535.49	385833.93	267.94022	34471.94
7.64	1534.72	407547.93	283.01939	34487.01
7.89	1534.47	427677.93	296.99856	34500.99
8.35	1534.01	442138.93	307.04092	34511.04
8.44	1533.92	450955.93	313.16384	34517.16
8.64	1533.72	460983.93	320.12772	34524.12
21.99	1520.37	471208.93	327.22842	34531.22
17.87	1524.49	492460.93	341.98675	34545.98
14.69	1527.67	507199.93	352.22217	34556.22

RUNGE LANDFILL HYDROGRAPH R20−93−22

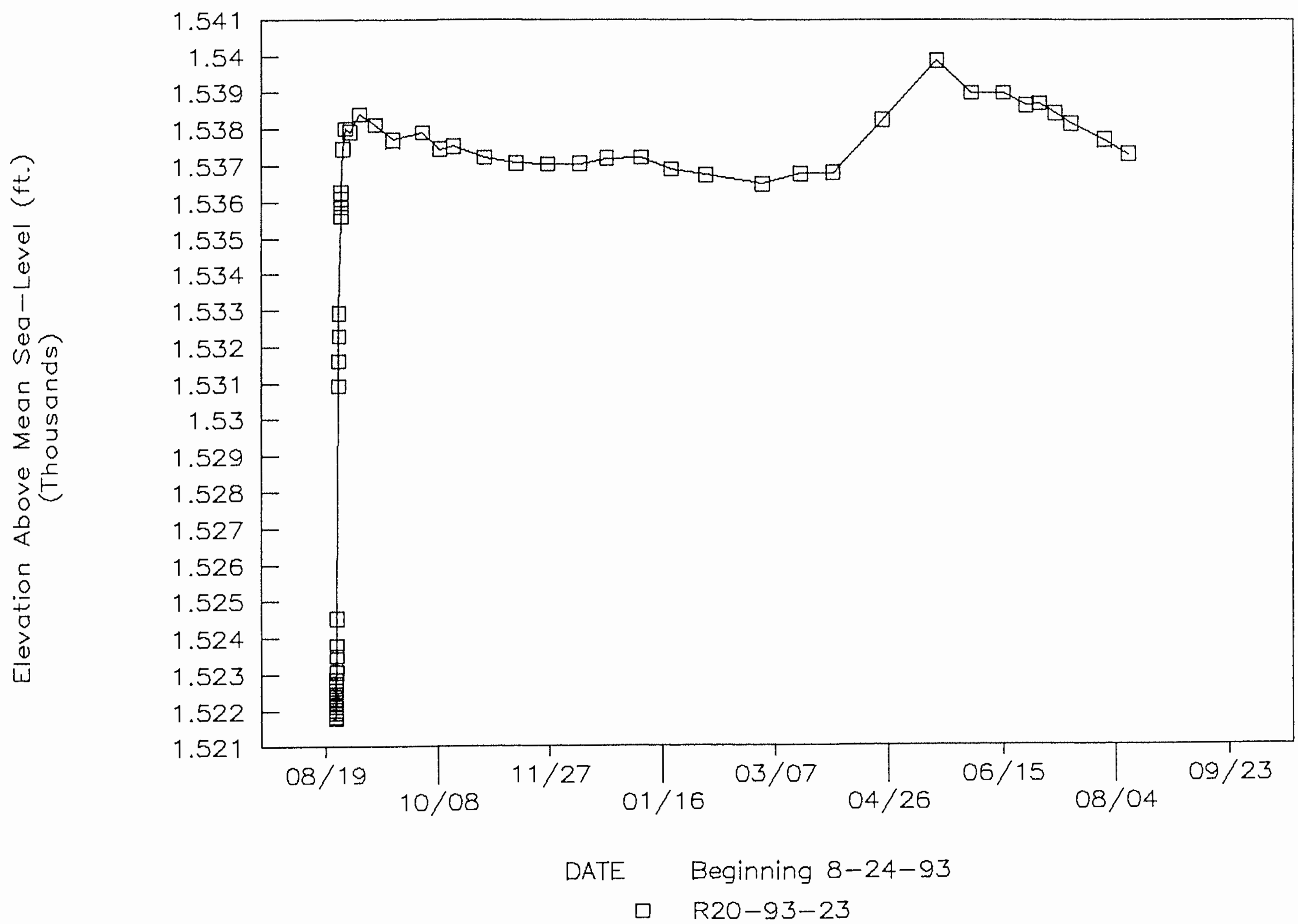
Depth−19.25ft. Core−1.58ft. Dia.−4″



R20−93−22	ELEV. 1545.18	HYDROGRAPHS	1440	
WATER LEVEL	WATER LEVEL ELEVATION	TIME(min)	DAYS	DATE
				34205
18	1527.18	0	0	34205
17.9	1527.28	1.92	0.0013333	34205.00
17.8	1527.38	4.33	0.0030069	34205.00
17.7	1527.48	6.98	0.0048472	34205.00
17.6	1527.58	9.7	0.0067361	34205.00
17.5	1527.68	12.53	0.0087013	34205.00
17.4	1527.78	15.33	0.0106458	34205.01
17.3	1527.88	18.38	0.0127638	34205.01
17.2	1527.98	21.3	0.0147916	34205.01
17.1	1528.08	24.3	0.016875	34205.01
17	1528.18	27.12	0.0188333	34205.01
16.8	1528.38	33.78	0.0234583	34205.02
16.7	1528.48	37.13	0.0257847	34205.02
16.6	1528.58	40.66	0.0282361	34205.02
16.5	1528.68	44.09	0.0306180	34205.03
16.4	1528.78	47.74	0.0331527	34205.03
16.3	1528.88	51.42	0.0357083	34205.03
16.1	1529.08	59	0.0409722	34205.04
16	1529.18	63.05	0.0437847	34205.04
15.9	1529.28	66.95	0.0464930	34205.04
15.55	1529.63	81.61	0.0566736	34205.05
15.21	1529.97	97.77	0.0678958	34205.06
14	1531.18	164.6	0.1143055	34205.11
13.25	1531.93	206.68	0.1435277	34205.14
11.63	1533.55	360.1	0.2500694	34205.25
7.94	1537.24	1311.43	0.9107152	34205.91
7.75	1537.43	1451.1	1.0077083	34206.00
7.56	1537.62	1609.85	1.1179513	34206.11
7.39	1537.79	1772.6	1.2309722	34206.23
6.81	1538.37	2801.6	1.9455555	34206.94
6.77	1538.41	2937.35	2.0398263	34207.03
6.72	1538.46	3074.1	2.1347916	34207.13
6.69	1538.49	3202.6	2.2240277	34207.22
6.54	1538.64	4516.1	3.1361805	34208.13
6.41	1538.77	5785.1	4.0174305	34209.01
6.24	1538.94	8725.35	6.0592708	34211.05
6.52	1538.66	14679.85	10.194340	34215.19
6.89	1538.29	24855.85	17.261006	34222.26
7.24	1537.94	35992.35	24.994687	34229.99
7.06	1538.12	55096.1	38.261180	34243.26
7.59	1537.59	66510.1	46.187569	34251.18
7.43	1537.75	75188.1	52.213958	34257.21
7.84	1537.34	95275.6	66.163611	34271.16
7.91	1537.27	115074.1	79.912569	34284.91
7.82	1537.36	135347.1	93.991041	34298.99
8.01	1537.17	155841.1	108.22298	34313.22
7.83	1537.35	173131.1	120.22993	34325.22
7.95	1537.23	195760.1	135.94451	34340.94
8.3	1536.88	214623.1	149.04381	34354.04
8.37	1536.81	236472.1	164.21673	34369.21
8.65	1536.53	272370.1	189.14590	34394.14
8.16	1537.02	296671.1	206.02159	34411.02
8.13	1537.05	316983.1	220.12715	34425.12
6.7	1538.48	348735.1	242.17715	34447.17
5.15	1540.03	382923.1	265.91881	34470.91
6.26	1538.92	404707.1	281.04659	34486.04
6.2	1538.98	424771.1	294.97993	34499.97
5.58	1539.6	439227.1	305.01881	34510.01
6.53	1538.65	448093.1	311.17576	34516.17
6.84	1538.34	457924.1	318.00284	34523.00
7.2	1537.98	468193.1	325.13409	34530.13
7.66	1537.52	489554.1	339.96812	34544.96
8.17	1537.01	504112.1	350.07784	34555.07

RUNGE LANDFILL HYDROGRAPH R20-93-23

Depth-24.49ft. Screen-4.73ft. Dia.-4"



	ELEV.	HYDROGRAPHS		
R20-93-23	1545.51		1440	
WATER LEVEL	WATER LEVEL ELEVATION	TIME(min)	DAYS	DATE
				34205
23.72	1521.79	0	0	34205
23.7	1521.81	0.33	0.0002291	34205.00
23.6	1521.91	3.46	0.0024027	34205.00
23.5	1522.01	8.53	0.0059236	34205.00
23.4	1522.11	13.8	0.0095833	34205.00
23.3	1522.21	21.5	0.0149305	34205.01
23.2	1522.31	31.03	0.0215486	34205.02
23.06	1522.45	45.75	0.0317708	34205.03
22.97	1522.54	57.95	0.0402430	34205.04
22.84	1522.67	74.37	0.0516458	34205.05
22.76	1522.75	84.8	0.0588888	34205.05
22.68	1522.83	96.33	0.0668958	34205.06
22.46	1523.05	131.11	0.0910486	34205.09
22.02	1523.49	198.58	0.1379027	34205.13
21.73	1523.78	250	0.1736111	34205.17
20.98	1524.53	401.03	0.2784930	34205.27
14.58	1530.93	1352.33	0.9391180	34205.93
13.91	1531.6	1491.33	1.0356458	34206.03
13.23	1532.28	1651.08	1.1465833	34206.14
12.58	1532.93	1813.33	1.2592569	34206.25
9.91	1535.6	2842.08	1.9736666	34206.97
9.66	1535.85	2978.33	2.0682847	34207.06
9.44	1536.07	3115.08	2.16325	34207.16
9.24	1536.27	3243.58	2.2524861	34207.25
8.05	1537.46	4557.08	3.1646388	34208.16
7.5	1538.01	5826.33	4.0460625	34209.04
7.6	1537.91	8766.33	6.0877291	34211.08
7.1	1538.41	14721.08	10.222972	34215.22
7.39	1538.12	24836.58	17.247625	34222.24
7.8	1537.71	36033.58	25.023319	34230.02
7.61	1537.9	55136.83	38.289465	34243.28
8.07	1537.44	66552.33	46.216895	34251.21
7.98	1537.53	75228.33	52.241895	34257.24
8.29	1537.22	95375.83	66.233215	34271.23
8.45	1537.06	115173.83	79.981826	34284.98
8.47	1537.04	135466.83	94.074187	34299.07
8.46	1537.05	155950.33	108.29884	34313.29
8.32	1537.19	173240.33	120.30578	34325.30
8.3	1537.21	195872.33	136.02245	34341.02
8.61	1536.9	214736.33	149.12245	34354.12
8.77	1536.74	236585.33	164.29536	34369.29
9.03	1536.48	272479.33	189.22175	34394.22
8.74	1536.77	296783.33	206.09953	34411.09
8.71	1536.8	317096.33	220.20578	34425.20
7.27	1538.24	348848.33	242.25578	34447.25
5.64	1539.87	383032.33	265.99467	34470.99
6.53	1538.98	404816.33	281.12245	34486.12
6.53	1538.98	424880.33	295.05578	34500.05
6.86	1538.65	439341.33	305.09814	34510.09
6.82	1538.69	448202.33	311.25161	34516.25
7.08	1538.43	458037.33	318.08147	34523.08
7.37	1538.14	468302.33	325.20995	34530.20
7.82	1537.69	489666.33	340.04606	34545.04
8.2	1537.31	504434.33	350.30161	34555.30

Appendix D

Inorganic Hydrochemistry

Appendix D. Inorganic Hydrochemistry

Well name	Date sampled	Well depth[2]	Depth to water[2]	Parameter[1] with concentration in milligrams per liter														Conductivity[3]	Field pH
				Ca	Mg	Na	K	Fe	Mn	HCO_3	SO_4	Cl	F	NO_3-N + NO_2-N	Hardness as $CaCO_3$	Alk T	TDS		
R20-93-02	08/03/93	73.24	55.90	484	141	420	27	<0.05	2.32	338	2320	23	0.38	0.49	1790	277	3910	4094	6.90
R20-93-03	08/17/93	53.64	49.32	562	192	279	32	0.21	2.21	399	2430	20	0.28	0.08	2190	327	3880	3990	6.79
R20-93-05	08/03/93	32.66	9.75	467	505	284	24	<0.05	4.26	421	3520	6.4	0.62	1.59	3250	345	5470	5120	7.11
R20-93-07	08/17/93	18.37	13.11	465	221	397	12	<0.05	<0.05	383	2550	6.8	1.08	3.09	2070	314	4090	4230	7.12
R20-93-08	08/17/93	22.99	17.92	496	265	228	20	<0.05	0.12	421	2430	5.3	0.61	2.31	2330	345	3920	3960	6.75
R20-93-09	08/03/93	18.62	12.65	514	322	62	19	<0.05	<0.05	434	2320	3.4	0.42	0.91	2610	356	3840	3579	6.84
R20-93-11	08/03/93	30.30	6.84	472	499	159	22	<0.05	3.96	396	3250	2.9	0.60	0.28	3230	325	5070	4628	6.89
R20-93-12	08/02/93	35.28	29.81	524	393	299	25	<0.05	5.36	335	3180	3.0	0.54	1.14	2930	275	4980	4741	7.01
R20-93-13	08/02/93	19.17	7.01	466	579	320	17	<0.05	0.08	467	3610	2.5	0.72	<0.04	3550	383	5750	5470	6.98
R20-93-14	08/02/93	75.33	58.28	427	266	564	21	<0.05	1.59	360	2960	18	0.82	1.13	2160	295	5000	4929	7.37
R20-93-16	08/02/93	30.27	20.58	484	291	592	22	<0.05	2.14	366	3220	12	0.60	1.69	2410	300	5280	5267	7.02
R20-93-17	08/02/93	29.71	23.10	550	242	202	23	0.22	5.30	386	2460	2.8	0.22	<0.04	2370	317	4010	3893	6.96
R20-93-18	08/17/93	23.69	4.95	445	645	351	18	<0.05	1.25	450	4020	2.5	0.88	0.45	3770	369	6350	5800	7.18
R20-93-19	08/02/93	18.92	7.23	438	947	472	17	0.05	<0.05	514	5450	3.9	0.74	0.42	4990	422	8450	7413	7.04
R20-93-20	08/17/93	20.06	17.71	412	997	796	26	0.06	<0.05	557	6360	7.3	0.90	2.68	5130	457	9700	8620	7.25
R20-93-21	08/17/93	22.96	21.24	429	996	596	37	0.05	0.05	510	5980	7.6	0.68	0.80	5170	418	8920	8020	7.16
R20-93-22	08/17/93	19.24	13.58	503	352	138	23	<0.05	0.05	489	2510	2.8	0.42	<0.04	2710	401	4060	3950	6.89
R20-93-23	08/17/93	24.49	20.93	510	327	110	22	<0.05	2.34	433	2420	2.6	0.41	0.34	2620	355	3860	3780	6.92

1 **Ca** - calcium; **Mg** - magnesium; **Na** - sodium; **K** - potassium; **Fe** - iron; **Mn** - manganese; **HCO_3** - bicarbonate; **SO_4** - sulfate; **Cl** - chloride; **F** - fluoride; **NO_3-N + NO_2-N** - nitrate-nitrogen plus nitrite-nitrogen; **Hardness as $CaCO_3$** - hardness as calcium carbonate; **Alk T** - total alkalinity; **TDS** - total dissolved solids.

2 Well depth and depth to water are presented in feet below top of well casing.

3 Conductivity is presented in micromhos per centimeter.

Appendix E

Tritium Analyses

Client: UNIVERSITY OF SOUTH DAKOTA Purchase Order: A-09575
Recvd : 94/03/22
Job# : 588
Final : 94/05/03

Contact: R. Davis 605/677-6403,-5895(f)
U.S.D., Earth Sciences/Physics
414 E. Clark St., Vermillion, SD 57069

Cust LABEL INFO	JOB.SX	REFDATE	QUANT	ELYS	TU		eTU
USD-WELL R20-93-14	588.01	940301	250	109	2.37	7	0.20
USD-WELL R20-93-21	588.02	940301	250	127	2.74	2	0.21
USD-WELL R20-93-16	588.03	940301	250	165 *	0.62	3	0.20
USD-WELL R20-93-02	588.04	940301	250	85	0.15	>	0.13
USD-WELL R20-93-07	588.05	940301	250	103	6.05	1	0.23
USD-WELL R20-93-11	588.06	940301	250	165 *	0.58	4	0.10
USD-WELL R20-93-15	588.07	940308	250	87	-0.03	5	0.18
USD-WELL R20-93-03	588.08	940301	250	111	1.31	6	0.14

* Average of duplicate runs

Client: UNIVERSITY OF SOUTH DAKOTA
Recvd : 94/07/15
Job# : 623
Final : 94/08/08

Purchase Order: A-09575
Contact: R. Davis 605/677-6403, -5895(f)
Dept. Earth Sciences & Physics
E. Clark St., Vermillion, SD 57069

Cust LABEL	INFO	JOB.SX	REFDATE	QUANT	ELYS	TU	eTU
UNIV.SD- 11	DIRECT	623.01	940606	60	DIR	-5	5
UNIV.SD- 12	DIRECT	623.02	940607	60	DIR	3	5
UNIV.SD- 13	DIRECT	623.03	940608	60	DIR	7	5
UNIV.SD- 14	DIRECT	623.04	940609	60	DIR	-3	5
UNIV.SD- 15	DIRECT	623.05	940613	60	DIR	4	5
UNIV.SD- 16	DIRECT	623.06	940614	60	DIR	-1	5
UNIV.SD- 17	DIRECT	623.07	940616	60	DIR	-2	5
UNIV.SD- 18	DIRECT	623.08	940617	60	DIR	0	5
UNIV.SD- 19	DIRECT	623.09	940621	60	DIR	1	5
UNIV.SD- 20	WELL R20-93-03	623.10	940630	250	118	0.75	0.13
UNIV.SD- 21	WELL R20-93-14	623.11	940630	250	109	1.10	0.20

Appendix F

Carbon-14 Analyses

GEOCHRON LABORATORIES a division of
KRUEGER ENTERPRISES, INC.

711 CONCORD AVENUE ✦ CAMBRIDGE, MASSACHUSETTS 02138 ✦ U.S.A
TELEPHONE: (617) 576-2591 TELEFAX: (617) 661-0148

RADIOCARBON AGE DETERMINATION | **REPORT OF ANALYTICAL WORK**

Our Sample No. GX-20115-AMS | Date Received: 07/21/94

Your Reference: letter of 07/15/94 | Date Reported: 09/29/94

Submitted by: Dr. Ralph K. Davis
Department of Earth Science
University of South Dakota
414 East Clark Street
Vermillion, South Dakota 57069

Sample Name: Sample #32 - Well R20-93-16 *Well depth = 30.27'*
groundwater

AGE = 9,299 +/- 120 C-14 years BP (C-13 corrected).
(31.90 +/- 0.48) % of the modern (1950) C-14 activity.

Description: Sample of groundwater.

Pretreatment: The sample was rapidly transferred, by aspiration, to an evacuated flask, and acidified to recover carbon dioxide from the dissolved carbonates for analysis. C-13 analysis was made on a small portion of the same evolved gas.

The sample was very small in size and analysis by accelerator mass spectrometry was required.

Comment:

$\delta^{13}C_{PDB}$ = -10.1 ‰

Notes: This date is based upon the Libby half life (5570 years) for ^{14}C. The error stated is $\pm 1\sigma$ as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid. The age is referenced to the year A.D. 1950.

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TELEPHONE: (617) 876-3691 TELEFAX: (617) 661-0148

RADIOCARBON AGE DETERMINATION REPORT OF ANALYTICAL WORK

Our Sample No. GX-20116-AMS Date Received: 07/21/94

Your Reference: letter of 07/15/94 Date Reported: 09/29/94

Submitted by: Dr. Ralph K. Davis
Department of Earth Science
University of South Dakota
414 East Clark Street
Vermillion, South Dakota 57069

Sample Name: Sample #33 - Well 320-93-11 *Well depth = 30.3'*
groundwater

AGE = 12,082 +/- 220 C-14 years BP (C-13 corrected).
(22.40 +/- 0.62) % of the modern (1950) C-14 activity.

Description: Sample of groundwater.

Pretreatment: The sample was rapidly transferred, by aspiration, to an evacuated flask, and acidified to recover carbon dioxide from the dissolved carbonates for analysis. C-13 analysis was made on a small portion of the same evolved gas.

The sample was very small in size and analysis by accelerator mass spectrometry was required.

Comment:

$\delta^{13}C_{PDB}$ = -12.3 ‰

Notes: This date is based upon the Libby half life (5570 years) for ^{14}C. The error stated is $\pm 1\sigma$ as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid. The age is referenced to the year A.D. 1950.

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RADIOCARBON AGE DETERMINATION — REPORT OF ANALYTICAL WORK

Our Sample No. GX-20113-AMS — Date Received: 07/21/94

Your Reference: letter of 07/15/94 — Date Reported: 09/29/94

Submitted by: Dr. Ralph K. Davis
Department of Earth Science
University of South Dakota
414 East Clark Street
Vermillion, South Dakota 57069

Sample Name: Sample 630 - Well R20-93-15 *well depth = 51.2'*
groundwater

AGE = 19,085 +/- 260 C-14 years BP (C-13 corrected).
(9.42 +/- 0.32) % of the modern (1950) C-14 activity.

Description: Sample of groundwater.

Pretreatment: The sample was rapidly transferred, by aspiration, to an evacuated flask, and acidified to recover carbon dioxide from the dissolved carbonates for analysis. C-13 analysis was made on a small portion of the same evolved gas.

The sample was very small in size and analysis by accelerator mass spectrometry was required.

Comment:

$\delta^{13}C_{PDB}$ = -11.9 ‰

Notes: This date is based upon the Libby half life (5570 years) for ^{14}C. The error stated is $\pm 1\sigma$ as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid. The age is referenced to the year A.D. 1950.

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RADIOCARBON AGE DETERMINATION — REPORT OF ANALYTICAL WORK

Our Sample No. GX-20114-AMS — Date Received: 07/21/94

Your Reference: letter of 07/15/94 — Date Reported: 09/29/94

Submitted by: Dr. Ralph K. Davis
Department of Earth Science
University of South Dakota
414 East Clark Street
Vermillion, South Dakota 57069

Sample Name: Sample #31 – Well R20-93-02 groundwater *Well depth = 73.24'*

AGE = 21,829 +/- 180 C-14 years BP (C-13 corrected).
(6.67 +/- 0.16) % of the modern (1950) C-14 activity.

Description: Sample of groundwater.

Pretreatment: The sample was rapidly transferred, by aspiration, to an evacuated flask, and acidified to recover carbon dioxide from the dissolved carbonates for analysis. C-13 analysis was made on a small portion of the same evolved gas.

The sample was very small in size and analysis by accelerator mass spectrometry was required.

Comment:

$\delta^{13}C_{PDB}$ = -16.4 ‰

Notes: This date is based upon the Libby half life (5570 years) for ^{14}C. The error stated is $\pm 1\sigma$ as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid. The age is referenced to the year A.D. 1950.

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TELEPHONE: (617) 876-3691 TELEFAX: (617) 661-0148

RADIOCARBON AGE DETERMINATION — REPORT OF ANALYTICAL WORK

Our Sample No. GX-20402-AMS

Date Received: 11/10/94

Your Reference: letter of 10/31/94

Date Reported: 12/14/94

Submitted by: Dr. Ralph K. Davis
Department of Earth Sciences
414 East Clark Street
University of South Dakota
Vermillion, South Dakota 57069

Sample Name: Sample # 40, Well # R20-93-14
groundwater

AGE = 10,933 +/- 200 C-14 years BP (C-13 corrected).
(25.96 +/- 0.64) % of the modern (1950) C-14 activity.

Description: Sample of groundwater.

Pretreatment: The sample was rapidly transferred, by aspiration, to an evacuated flask, and acidified to recover carbon dioxide from the dissolved carbonates for analysis. C-13 analysis was made on a small portion of the same evolved gas.

The sample was very small in size and analysis by accelerator mass spectrometry was required.

Comment:

$\delta^{13}C_{PDB} = -13.5$ ‰

Notes: This date is based upon the Libby half life (5570 years) for ^{14}C. The error stated is $\pm 1\sigma$ as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid. The age is referenced to the year A.D. 1950.

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TELEPHONE: (617) 876-3691 TELEFAX: (617) 661-0148

RADIOCARBON AGE DETERMINATION — REPORT OF ANALYTICAL WORK

Our Sample No. GX-20403-AMS

Date Received: 11/10/94

Your Reference: letter of 10/31/94

Date Reported: 12/14/94

Submitted by: Dr. Ralph K. Davis
Department of Earth Sciences
414 East Clark Street
University of South Dakota
Vermillion, South Dakota 57069

Sample Name: Sample # 42, Well # R20-93-03
groundwater

AGE = 17,880 +/- 110 C-14 years BP (C-13 corrected).
(10.93 +/- 0.15) % of the modern (1950) C-14 activity.

Description: Sample of groundwater.

Pretreatment: The sample was rapidly transferred, by aspiration, to an evacuated flask, and acidified to recover carbon dioxide from the dissolved carbonates for analysis. C-13 analysis was made on a small portion of the same evolved gas.

The sample was very small in size and analysis by accelerator mass spectrometry was required.

Comment

$\delta^{13}C_{PDB} = -12.7$ ‰

Notes: This date is based upon the Libby half life (5570 years) for ^{14}C. The error stated is $\pm 1\sigma$ as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.
The age is referenced to the year A.D. 1950.

Appendix G

$\delta\ ^{18}O$ and $\delta\ ^{2}H$ Analyses

New Addr
as of January 1
711 Concord A
Cambridge, MA
Telephone/Telefa
Numbers
remain the same

KRUEGER ENTERPRISES, INC.
GEOCHRON LABORATORIES DIVISION

[redacted] CAMBRIDGE, MASSACHUSETTS [redacted] (617) 876-3691

STABLE ISOTOPE RATIO ANALYSES — REPORT OF ANALYTICAL WORK

Submitted by: Dr. Ralph K. Davis
University of South Dakota
Earth Sciences and Physics Dept.
Akeley Sciences Center
414 E. Clark Street
Vermillion, SD 57069-2390

Date Received: 07/21/94
Date Reported: 08/08/94
Your Reference: A 51870

Our Lab. Number	Your Sample Number	Description	δD*	$\delta^{18}O$*
HOR-81072	#22 Well R20-93-15	Water	-67	- 9.5
HOR-81073	#23 Well R20-93-02	Water	-69	-10.7
HOR-81074	#24 Well R20-93-03	Water	-61	-10.1
HOR-81075	#25 Well R20-93-07	Water	-71	- 9.8
HOR-81076	#26 Well R20-93-14	Water	-63	-10.5
HOR-81077	#27 Well R20-93-21	Water	-62	-8.5 -8.4 **
HOR-81078	#28 Well R20-93-16	Water	-60 -58 **	- 9.6
HOR-81079	#29 Well R20-93-11	Water	-60	- 9.2

** Duplicate preparations and analyses.

*Unless otherwise noted, analyses are reported in ‰ notation and are computed as follows:

$$\delta R_{sample} ‰ = \left[\frac{R_{sample}}{R_{standard}} - 1 \right] \times 1000$$

Where:

D/H standard is SMOW
$^{18}O/^{16}O$ standard is SMOW

And:

$D/H_{standard}$ = 0.000316**
$^{18}O/^{16}O_{standard}$ = 0.0039948**

**Double atom ratio

Appendix H

Soil Moisture Content and Soil Classification

MOISTURE CONTENT DATA

TEST HOLE #	1	RUNGE LANDFILL		6/7/93			
Boring			wet soil +	dry soil +			water
depth (ft)	tin #	tin wt. (g)	tin	tin	dry soil	water	content
0.90-1.20	27	21.72	64.06	56.68	34.96	7.38	21.11
1.70-2.00	36	21.34	56.96	49.93	28.59	7.03	24.59
2.60-3.20	85	24.81	59.41	53.51	28.70	5.90	20.56
3.30-3.50	45-5	*					12.92
4.90-5.20	25	*					19.43
5.70-6.00	52	*					20.16
6.60-7.10	38	21.8	65.18	57.96	36.16	7.22	19.97
7.40-7.70	3	*					20.42
8.70-8.90	41	21.73	50.77	45.85	24.12	4.92	20.40
8.90-9.10	26	25.48	57.46	51.97	26.49	5.49	20.72
10.90-11.10	34	25.56	94.99	83.48	57.92	11.51	19.87
11.70-12.00	52	21.59	86.48	76	54.41	10.48	19.26
12.90-13.10	71	24.94	56.14	50.9	25.96	5.24	20.18
13.70-14.00	19	24.85	81.95	72.45	47.60	9.50	19.96
16.00 (shoe)	74	25.22	53.61	49.01	23.79	4.60	19.34
16.90-17.10	62	21.3	68.77	61.17	39.87	7.60	19.06
17.80-18.00	28	21.43	73.06	64.56	43.13	8.50	19.71
18.90-19.20	50	21.57	79.76	70.33	48.76	9.43	19.34
19.80-20.00	77	21.71	64.03	57.04	35.33	6.99	19.78
21.10-21.30	55	21.64	59.1	53.08	31.44	6.02	19.15
21.70-22.00	17	25.01	75.31	66.78	41.77	8.53	20.42
22.60-22.90	65	24.85	68.96	61.51	36.66	7.45	20.32
23.80-24.00	44	21.45	74.84	65.99	44.54	8.85	19.87
25.00-25.35	80	21.92	69.23	61.61	39.69	7.62	19.20
25.60-25.80	33	21.57	74.38	66.76	45.19	7.62	16.86
26.70-27.00	44 small	14.49	64.15	56.47	41.98	7.68	18.29
28.00 (shoe)	5	14.55	81.9	71.51	56.96	10.39	18.24
28.90-29.10	39	24.96	79.33	70.69	45.73	8.64	18.89
29.80-30.00	16	25.79	86.01	76.48	50.69	9.53	18.80
30.50-31.00	96	21.89	68.45	61.29	39.40	7.16	18.17
31.80-32.00	78	21.43	67.26	60.22	38.79	7.04	18.15
32.90-33.20	76	25.07	73.06	65.80	40.73	7.26	17.82
33.40-34.00	57	21.92	67.50	60.73	38.81	6.77	17.44
34.60-35.00	74	21.35	69.21	61.79	40.44	7.42	18.35
35.70-36.00	93	21.18	77.52	69.46	48.28	8.06	16.69
36.80-37.20	3-57	15.46	76.53	66.37	50.91	10.16	19.96
37.50-37.90	3-53	15.30	76.86	67.44	52.14	9.42	18.07
38.80-39.30	88	21.17	92.88	82.42	61.25	10.46	17.08
39.60-40.00	3-55	15.44	82.49	72.45	57.01	10.04	17.61
40.80-41.30	4-4	11.58	58.22	51.70	40.12	6.52	16.25
41.30-41.70	90	21.08	80.52	72.10	51.02	8.42	16.50
42.70-43.10	4-41	15.44	78.34	69.48	54.04	8.86	16.40

43.70-43.90	92	21.12	73.98	66.60	45.48	7.38	16.23
44.80-45.20	71	21.39	96.02	85.09	63.70	10.93	17.16
45.70-46.00	85	21.51	90.68	80.78	59.27	9.9	16.70
46.80-47.10	53	21.41	85.13	76.35	54.94	8.78	15.98
47.70-48.00	1	25.53	76.35	69.31	43.78	7.04	16.08
48.80-49.30	76	21.47	71.80	64.59	43.12	7.21	16.72
49.80-50.00	AR4	15.93	91.34	80.64	64.71	10.7	16.54
* ENTIRE CONTENTS OF THE BAG WERE WEIGHED (SANDY MAT'L)							

MOISTURE CONTENT DATA

TEST HOLE # 2		RUNGE LANDFILL		6/15/93			
Boring depth (ft)	tin #	tin wt. (g)	wet soil + tin	dry soil + tin	dry soil	water	water content
2.40-2.60	50	21.50	56.25	49.55	28.05	6.70	23.89
3.20-3.40	*						18.58
5.50-5.80	94	21.97	60.26	53.37	31.40	6.89	21.94
7.00-7.30	61	21.53	55.35	49.50	27.97	5.85	20.92
10.80-11.10	32	21.76	77.88	68.25	46.49	9.63	20.71
15.10-15.30	13	25.40	69.73	62.19	36.79	7.54	20.49
16.60-16.80	68	21.21	64.44	57.09	35.88	7.35	20.48
18.70-18.90	49	21.64	68.12	59.39	37.75	8.73	23.13
23.00-23.10	84	25.04	73.84	65.48	40.44	8.36	20.67
24.75-24.95	56	21.43	81.99	70.95	49.52	11.04	22.29
26.55-26.75	73	21.41	75.41	66.16	44.75	9.25	20.67
28.90-29.10	59	21.30	79.58	69.18	47.88	10.40	21.72
33.20-33.45	5	25.30	74.32	66.33	41.03	7.99	19.47
34.80-35.00	30	21.25	83.18	73.04	51.79	10.14	19.58
37.10-37.25	69	21.49	76.02	66.98	45.49	9.04	19.87
41.00-41.20	83	21.32	94.52	81.81	60.49	12.71	21.01
44.90-45.05	58	21.73	71.35	62.64	40.91	8.71	21.29
46.65-46.80	82	24.92	81.81	72.11	47.19	9.70	20.56
50.55-50.75	42	21.74	82.10	72.70	50.96	9.40	18.45
54.65-54.85	E-48	21.42	83.76	73.13	51.71	10.63	20.56
58.80-58.95	12	25.41	84.74	74.73	49.32	10.01	20.30
62.95-63.15	82	21.21	73.08	64.32	43.11	8.76	20.32
66.60-66.80	28	25.58	84.29	74.70	49.12	9.59	19.52

* ENTIRE CONTENTS OF BAG WERE WEIGHED (SANDY MAT'L)

MOISTURE CONTENT DATA

TEST HOLE #	14	RUNGE LANDFILL			6/15/93		
Boring			wet soil +	dry soil +			water
depth (ft)	tin #	tin wt. (g)	tin	tin	dry soil	water	content
2.60-2.85	19	24.86	70.02	61.79	36.93	8.23	22.29
4.70-5.00	27	21.74	70.93	60.26	38.52	10.67	27.70
6.70-7.05	38	21.75	80.70	70.79	49.04	9.91	20.21
8.55-8.80	16	25.76	70.60	62.76	37.00	7.84	21.19
13.00-13.20	85	24.70	85.11	76.07	51.37	9.04	17.60
16.85-17.20	41	21.72	90.57	78.87	57.15	11.70	20.47
20.90-21.05	36	21.33	73.40	64.90	43.57	8.50	19.51
22.80-23.00	26	25.44	74.24	66.37	40.93	7.87	19.23
26.90-27.20	74	25.17	103.62	90.81	65.64	12.81	19.52
29.50-29.70	55	21.58	74.31	65.25	43.67	9.06	20.75
32.50-32.70	74*	21.32	70.82	63.01	41.69	7.81	18.73
34.85-35.05	33	21.60	62.76	53.73	32.13	9.03	28.10
39.30-39.60	57	21.94	98.25	85.33	63.39	12.92	20.38
42.75-43.05	71	24.92	77.72	68.98	44.06	8.74	19.84
45.00-45.20	39	24.94	107.57	94.15	69.21	13.42	19.39
51.20-51.40	17	24.99	93.95	82.58	57.59	11.37	19.74
55.20-55.50	1	25.64	87.04	76.91	51.27	10.13	19.76
59.00-59.20	65	24.82	91.21	80.23	55.41	10.98	19.82
62.80-63.00	52	21.49	93.28	81.49	60.00	11.79	19.65

Glacial till soil properties with depth.

Sample/ Elevation	% gravel	% sand	% silt	% clay	LL	PI	A
1534.5	0	31	41	28	38.0	18.6	0.66
1533.0	8	28	39	25	43.6	26.6	1.06
1527.0	1	32	40	27	36.2	18.0	0.67
1525.0							
1523.3	3	35	41	21	41.7	21.9	1.04
1519.2	3	33	41	23	31.9	14.0	0.61
1517.0							
1514.8	6	35	37	22	35.4	14.9	0.68
1512.7	2	39	36	23	37.2	19.5	0.85
1510.6	2	39	39	20	39.9	20.2	1.01
1508.7							
1505.5	2	39	39	20	40.0	19.7	0.99
Average	3	35	39	23	38.2	19.3	0.84