

ABSTRACT

K. Chad Leinbach. HYDROGEOLOGY AND ENVIRONMENTAL QUALITY OF THE WATER TABLE AQUIFER IN THE VICINITY OF KENNEDY CREEK, BEAUFORT COUNTY, NORTH CAROLINA. (Under the direction of Richard K. Spruill, Department of Geology, December 1990)

The water table aquifer in the vicinity of Kennedy Creek, Beaufort County, North Carolina is dominated by Quaternary deposits of sand, clay, and peat. Hydraulic conductivities for peats and sands range from 4 to 5 and 15 to 25 ft/day and seepage velocities are approximately 11 and 70 ft/year. Groundwater flow is generally southward from uplands along the Tar River. The water table aquifer is probably in hydraulic connection with deeper aquifers in the area between the Tar River floodplain and the uplands. Diurnal variations in wind direction create creek level fluctuations, up to 3 feet, that do not affect the aquifer beyond 150 feet from the creek. Sustained southeastern winds cause infrequent flooding in the area. As these floods recede, higher discharges occur because hydraulic gradients are temporarily steepened.

Six point sources of possible contamination were identified in the vicinity of Kennedy Creek. Thirty monitoring wells were installed and ten wells already existed. Seventy-four groundwater and two surface water samples were analyzed for major and trace elements. Analytical results indicate that Fe and Mn are the most common elements with concentrations above North Carolina groundwater quality standards and that Fe levels in groundwater declined rapidly away from known point sources. Forty-nine soil samples were analyzed for major and trace elements. Analyses reveal that several elements exhibit a decrease in concentration downward from the land surface. Groundwater, bottom sediment from Kennedy Creek, sludges from the City of Washington's wastewater treatment plant and the local textile dying plant, and effluent samples from the WWTP (19) were analyzed for several EPA priority organic pollutants. Only one contaminant, Bis(2-ethylhexyl) phthalate (a plasticizer), was present above detection limits in 2 of 7 monitoring wells sampled. This contaminant is believed to have been introduced through plastic materials used in sample collection and analysis and is probably not present in groundwater. The six possible point sources in the area are not now introducing contaminants to the aquifer in amounts above analytical detection limits.

HYDROGEOLOGY AND ENVIRONMENTAL QUALITY
OF THE WATER TABLE AQUIFER IN THE VICINITY OF
KENNEDY CREEK, BEAUFORT COUNTY, NORTH CAROLINA

A Thesis
Presented to
the Faculty of the Department of Geology
East Carolina University

In Partial Fulfillment
of the Requirements for the Degree
Master of Science in Geology

by
Kenneth Chad Leinbach

December 1990

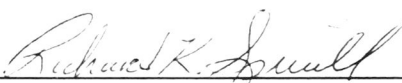
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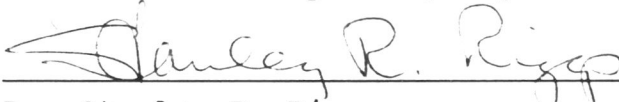
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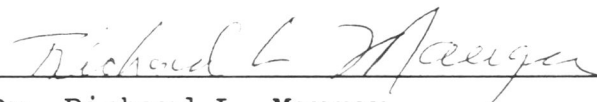
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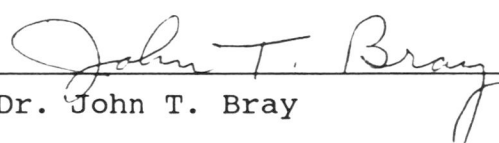
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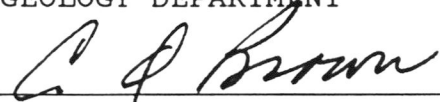

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ACKNOWLEDGEMENTS

First and foremost, I would like to thank National Spinning, Inc., William Reynolds, Bob Bennett, and Keith Norwood for financial support and a dedicated commitment to making this project possible. Second, to the City of Washington, Jerry Cuttler, and Russell Waters, I want to express my appreciation for financial support and unlimited cooperation throughout this project. To Dan Rhem, Jr. and Lee Knott, Jr., thank you for allowing access to your properties.

I would especially like to thank Dr. Richard Spruill for his comments, criticism, and persistence in keeping me on track throughout this study. To my committee, your support through comments, questions, and patience was greatly appreciated.

To the Department of Construction Management, thank you for allowing me the use of your surveying equipment. To the Chemistry Department at ECU, thank you for the exploratory gas chromatography analyses. To Charles Gabriel and Dr. Pietrafesa at the NCSU Geology Department, thank you for the FFT (Fast Fourier Transform) analysis and interpretation of water level data. I would also like to thank Drs. Skaggs and Evans at the NCSU Biological and Agricultural

Engineering Department for allowing use of their evaporation pan. To Tex Gilmore at Texas Gulf Phosphate, Inc., thank you for donating the Stevens recorders which yielded very interesting data.

Finally, I would like to thank several people for their comments, support, suggestions, and most of all their comic relief throughout my stay at ECU; they are as follows: Joe Allen, John Hyder, Rick Tarravechia, Buddy Hill, Eric Powers, Doug Yeates, Adrianne Amos, Ross Klingman and Jim Watson, thank you for many hours of fieldwork, assistance in final preparations, and of most importance your hilarious antics while at ECU; the "Brody Gang" Craig Hamilton, Sybil Lucas, Roy Flanagan, and Mitchell Williamson for assisting Dr. Bray in shaping my analytical background; and to the rest of the cast of characters in the "BullPen" who have made graduate school experience both exciting and unforgettable. Finally, my parents, family, and relatives who have supported me while in graduate school deserve the last and most important "Thank You".

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INTRODUCTION

Groundwater is considered by many to be the nation's most widespread and important natural resource (U.S. Water Resources Council, 1980). Unfortunately, human activities have resulted in contamination of this valuable resource (0.5 to 2.0 percent of the total), mainly where people depend on it for their existence (Pye and Kelley, 1984). A major potential long-term source of pollution is landfilling of solid and liquid waste. According to the United States Environmental Protection Agency (EPA) (1980), the estimated 200,000 U.S. landfills in operation receive more than 390 million tons of refuse annually (Pye and Kelley, 1984). As water reacts with landfill wastes, an effluent known commonly as leachate is generated. Leachate contains a variety of inorganic and organic pollutants whose concentrations vary with the annual precipitation, pH, conditions of oxidation, composition of the refuse, and time.

North Carolina currently operates approximately 160 sanitary landfills. Groundwater quality standards for organic and inorganic contaminants have been exceeded at 36 of the 71 North Carolina sanitary landfills surveyed by Borden and Yanoschak (1989). Increased public concerns for environmental protection, clean water supplies, and better

human health have resulted in more stringent design and monitoring standards for operating and planned landfills.

Prior to the mid 70's, many communities and towns across the nation operated open and unlined "dumps" in areas where land was generally not suited for such use. The City of Washington in Beaufort County, NC (Fig. 1) operated two small (less than 50 acres) landfills adjacent to Kennedy Creek from the mid 1960's until 1977.

The City of Washington operates a wastewater treatment plant (WWTP) adjacent to Kennedy Creek. The WWTP is permitted for a National Pollution Discharge Elimination System (NPDES), # NC0020648 with a design flow of 2.12 million gallons per day, which discharges into Kennedy Creek (NC EDF/PTRF, 1989). According to the NC EDF/PTRF (1989), Washington's WWTP is currently in compliance with all required monitoring parameters.

The hydrogeology of the water table aquifer will determine how and when the contamination from potential point sources will move. In the vicinity of Kennedy Creek, water table lithologies are dominated by Quaternary sands, gravels, and clays in upland areas and by peat deposits near the Pamlico-Tar River system. In this region, the water table aquifers recharge the underlying aquifers (Heath, 1980). Deeper aquifers supply the majority of groundwater

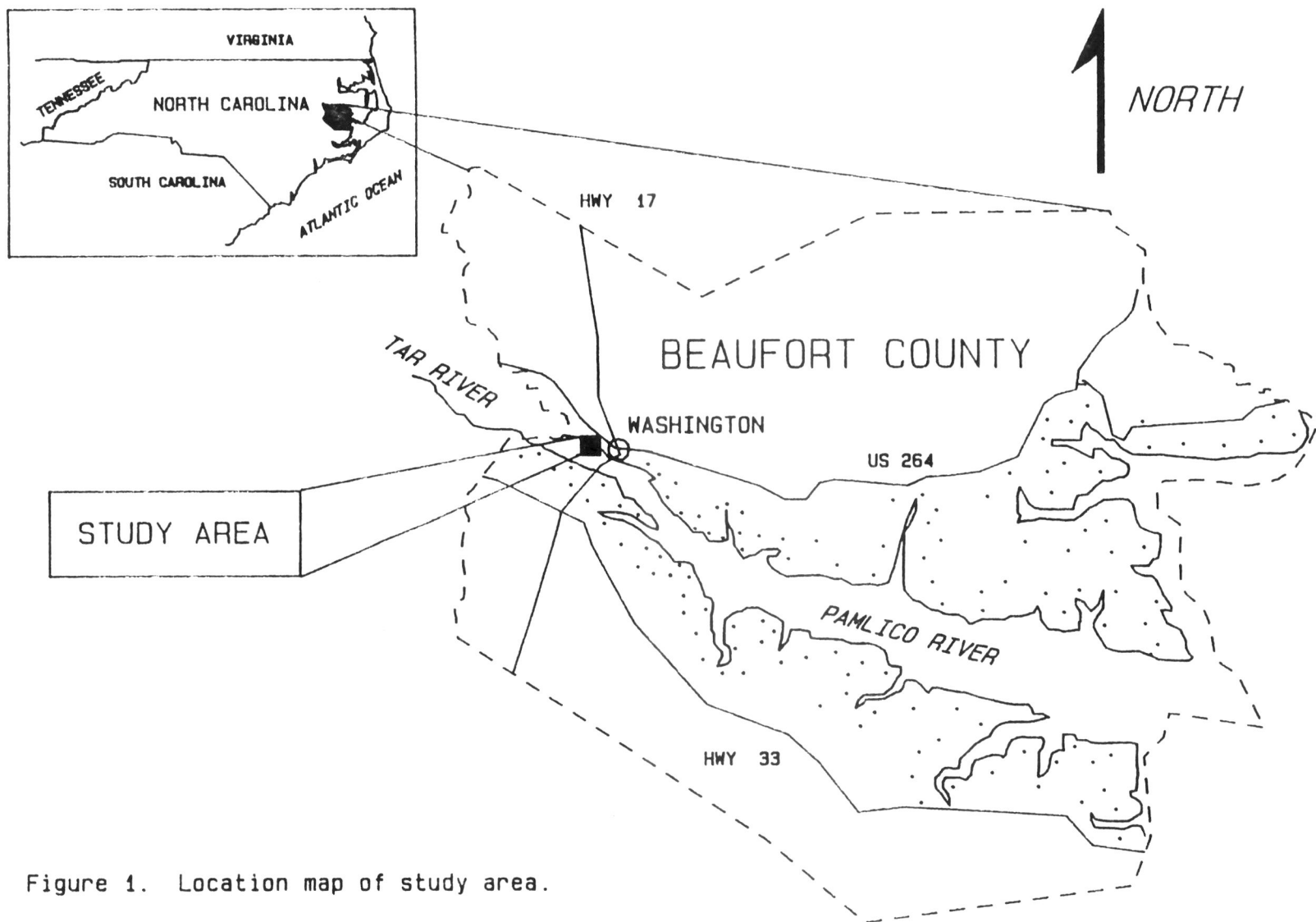


Figure 1. Location map of study area.

used in Beaufort County. The water table aquifer provides a limited local supply of water for agricultural and domestic uses.

The purpose of this study is to understand the hydrogeology and environmental status of the water table aquifer in the Kennedy Creek area. The specific objectives are as follows:

1. determine the hydrogeologic parameters such as hydraulic conductivity, gradient, direction of flow, and seepage velocity; construct a geologic cross-section illustrating the water table lithologies
2. construct water table contour maps from static water level data
3. determine groundwater recharge/discharge relationships in the vicinity of Kennedy Creek
4. analyze groundwater samples for major and trace elements and specific EPA priority organic compounds
5. analyze soil and bottom sediment samples for major and trace elements and selected EPA priority organic compounds
6. construct concentration isopleth maps from analytical data
7. identify point sources of contamination (if they exist) and suggest possible remediation strategies.

SITE HISTORY

Six possible point sources were identified in the Kennedy Creek area (Fig. 2). Historically, landfills were sited in low inaccessible areas with minimal development potential. Two such landfills were sited on the north shore of Kennedy Creek (Fig. 2). These contain an assortment of unclassified domestic and industrial materials.

Potential industrial point sources include a textile dying plant, waste water treatment plant (WWTP), a defunct coal-burning power plant, and an agricultural chemical distribution warehouse (Fig. 2). The agrochemical distribution warehouse is referred to hereafter as the "Superfund Site".

Brief summaries of the potential industrial point sources are as follows:

The textile plant produces sludge (from its dye process) that contains elevated levels of Cd, Cr, Cu, Pb, and Zn (Table 1). Sludge is removed from the waste treatment basins and land-applied elsewhere. In the fall of 1989, a small fire occurred in the plant. Run-off from this fire resulted in a reported fish kill (approximately 50) in Kennedy Creek (J. Camp, NC DEM, pers.comm. 1990).

From 1978-1983, the WWTP operated four holding ponds adjacent to Kennedy Creek as part of the waste treatment process. These ponds were abandoned, drained, and backfilled with assorted debris when the new plant went into operation in 1983.

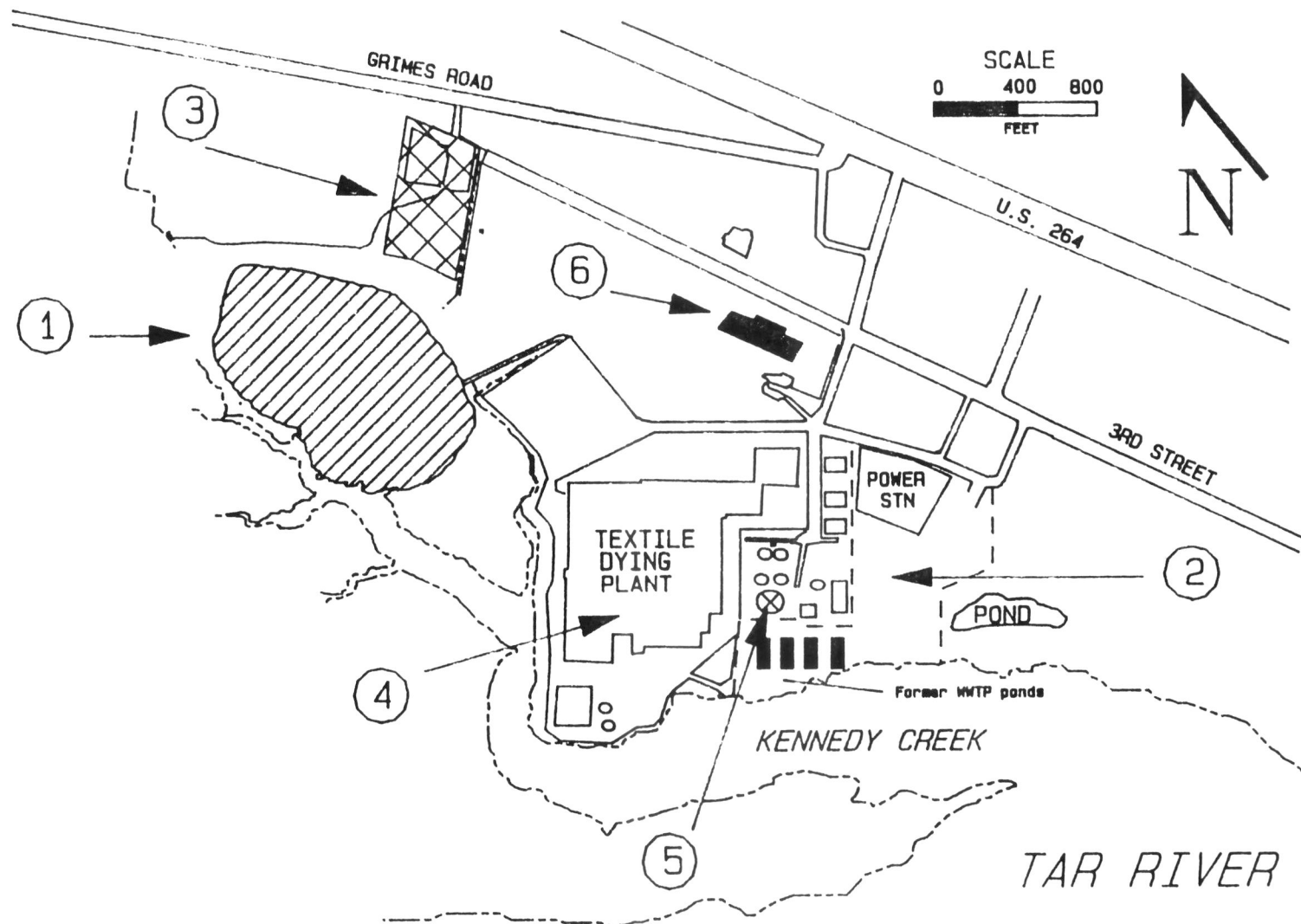


Figure 2. Potential point sources within the Kennedy Creek area. 1. City Dump 2. Landfill 3. Superfund site 4. Textile dying plant 5. Wastewater Treatment Plant 6. Now-defunct coal-burning power plant. Former settling ponds at Washington's WWTP were located in the Landfill.

Ash and slag were produced by the now-defunct coal-burning power plant from the early 1900's until the late 1950's. Ash and slag was used by the City of Washington Public Works Department as road fill, etc. (R. Waters, Public Works Dept., pers. comm., 1990).

The Superfund site is under active remediation by the NC State Superfund Branch. This site contained several pesticides and fumigates such as DDT, DDE, Aldrin, Eldrin, and Chlordane buried above the water table in an unlined trench (Nicholson, 1987) from the early 1970's until 1986. The trench was excavated and backfilled with sand in 1987 by the US EPA; the wastes were stockpiled for on-site incineration in 1987.

Table 1. Analysis of mixed liquor and sludge (in $\mu\text{g/L}$) generated at the textile plant. Analyses for total major and trace elements were performed by Environment I, Inc., October 23, 1984 (William Reynolds, Engineer, National Spinning Inc., pers. comm., 1989).

Element	Mixed Liquor	Sludge Samples		
		#1	#2	#3
Cd	15	45	175	93
Cr	970	1760	2770	1580
Cu	2760	16400	30700	23400
Ni	160	1080	1620	1740
Zn	12300	26700	89000	46500
P **	4600	14100	23000	23000

** P present as Phosphate

FIELD METHODS

Well Construction

Permits were obtained from the Division of Environmental Management (DEM) for construction of thirty monitoring wells. Well locations (Fig. 3) were based on a grid system that allowed adequate coverage of all expected potential point sources. Monitoring wells are denoted by a two letter code indicating a general location and a number. Wells beginning with CD, LF, and MW represent wells located in and around the City Dump, Landfill, and the Monitoring Wells owned by the textile plant and by the City of Washington.

Wells were constructed with 4" and 7" bucket augers decontaminated according to procedures outlined by the NC Division of Environmental Management (M. Purser, DEM, pers. comm.). The 7" auger was advanced to the water table to provide room for adequate grouting and the 4" auger was utilized below the water table to minimize caving problems. Wells constructed in the landfills required that a backhoe remove refuse before completing the wellbore. All wells were constructed of 2", schedule-40 PVC casing and screen (0.010 in. slot size) and packed with clean coarse sand. The length of the sand pack varied from a minimum of one

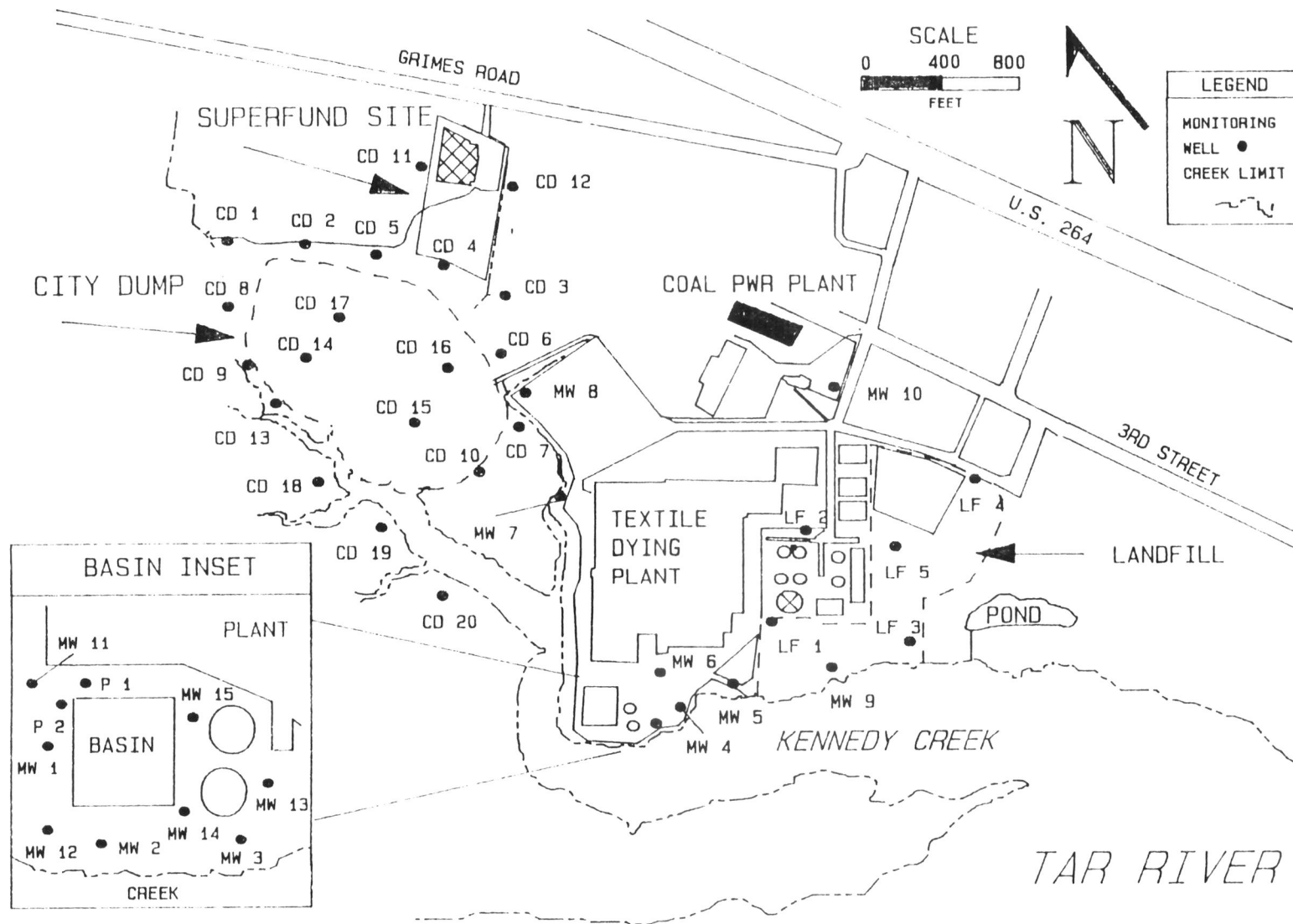


Figure 3. Monitoring well locations in the study area with a basin inset showing the location of monitoring wells around the wastewater treatment plant. P1 and P2 in the basin inset are piezometers.

foot above the top of the screen. A bentonite seal (one foot) was placed directly above the sand pack followed by a portland cement grout to land surface. Locking aluminum caps were placed at the top of the casing for protection. Wellhead elevations were surveyed with a Leitz Model 115 transit from benchmarks established by the US EPA and the textile plant.

Screened intervals vary in depth, but mainly span the upper aquifer in the vicinity of Kennedy Creek. Wells were developed by bailing approximately 15 well volumes of water from high-yielding wells while low-yielding wells were bailed for a period of 30 minutes. Bailing removes silt and clay from the sand pack and screen, resulting in increased yields and rapid collection of samples.

Determination of Hydraulic Conductivity

Hydraulic conductivity was determined by instantaneous withdrawal (slug) and constant drawdown tests on several wells screened in peat and sand. Solid 1.5" PVC cylinders were introduced into each well. The PVC cylinder was withdrawn from the well after static water level was re-established; water levels and times were recorded and analyzed by the Hvorslev method (Freeze and Cherry, 1979).

The WaTerra method (WaTerra Pumps Ltd.) for determining hydraulic conductivity was utilized on wells with high recovery rates. This method involves establishing a constant pumping rate with the WaTerra pump, verifying a constant head value with an electric water level meter, and measuring discharge with a graduated cylinder. The WaTerra method is often preferred over slug testing methods in sand-packed wells where hydraulic conductivity may be influenced by the sand pack.

Water Level Data and Piezometers

Static water level data were collected at two-week intervals with an electric water level meter from December 1989 to August 1990. Three sets of nested piezometers (Fig. 4) were constructed with 2" PVC casing (6" screened interval) and positioned at depths of approximately 5, 10, and 15 feet in order to assess recharge/discharge conditions via detection of variations in hydrostatic pressure gradients.

Continuous water levels were recorded during April 22 to May 23, 1990 with Stevens Type A-35 recorders. Recording stations (Fig. 4) were established directly on Kennedy Creek (SR#1), 25 feet away from the creek (SR#2), and 150 feet away from the creek (SR#3). These stations served to:

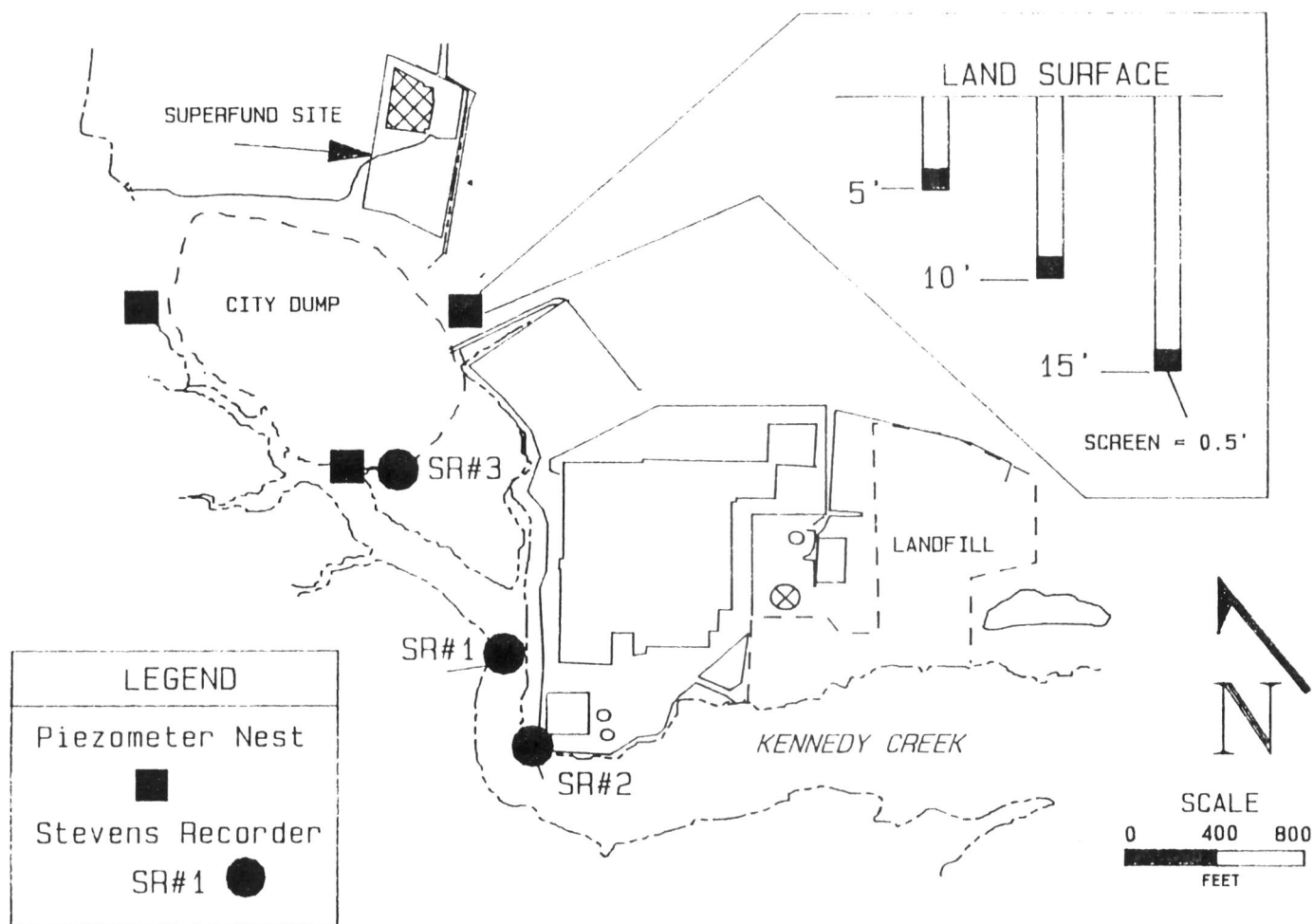


Figure 4. Piezometer nests and Stevens water level recorder stations. SR#1, SR#2, and SR#3 were located directly on, 25 feet, and 150 feet from Kennedy Creek, respectively.

1) monitor the surface/groundwater interconnection; 2) evaluate the effects of individual storm events on both the surface and groundwater systems; and 3) to gain an understanding of daily water level fluctuations.

Climatological records were supplied by personnel at the City of Washington's water treatment plant.

REGIONAL AND LOCAL GEOLOGY

The geology is characterized by eastward, shallow-dipping sedimentary units typical of the Atlantic Coastal Plain. Cretaceous to Recent formations (Winner and Coble, 1989) rest unconformably on a pre-Cretaceous igneous and metamorphic basement (Brown, 1959). Geologic logs of wells suggest that the Yorktown Formation (Pliocene) and the Castle Hayne Limestone (Eocene) underlie Quaternary surface deposits in the study area (Brown, 1959; and Nicholson, 1987).

Lithologies were determined from well logs and test boreholes in the study area (Appendix 1). Peat and unconsolidated sands are the dominate near-surface lithologies. Peats dominate near Kennedy Creek and sands are common farther from the creek (Figs 5 and 6). This peat/sand contact

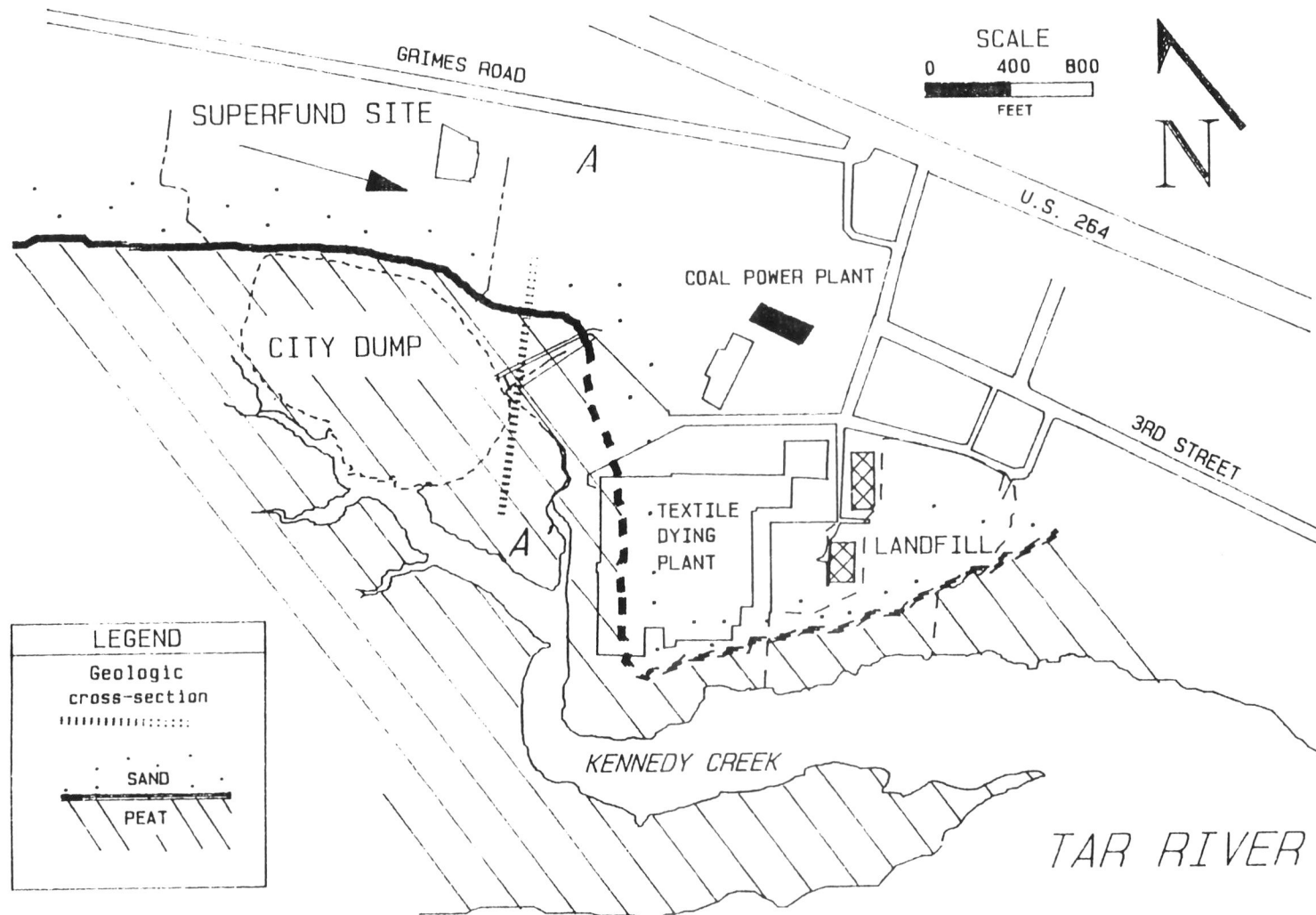


Figure 5. Map contact for sand/peat. Contact is dashed where covered by buildings and pavement. A geologic line of cross-section A-A' is Figure 6. Peat was removed to construct the textile waste treatment facility and former ponds (now backfilled) at the Washington WWTP (See Figure 2).

GEOLOGIC CROSS-SECTION OF THE WATER TABLE AQUIFER IN THE KENNEDY CREEK AREA

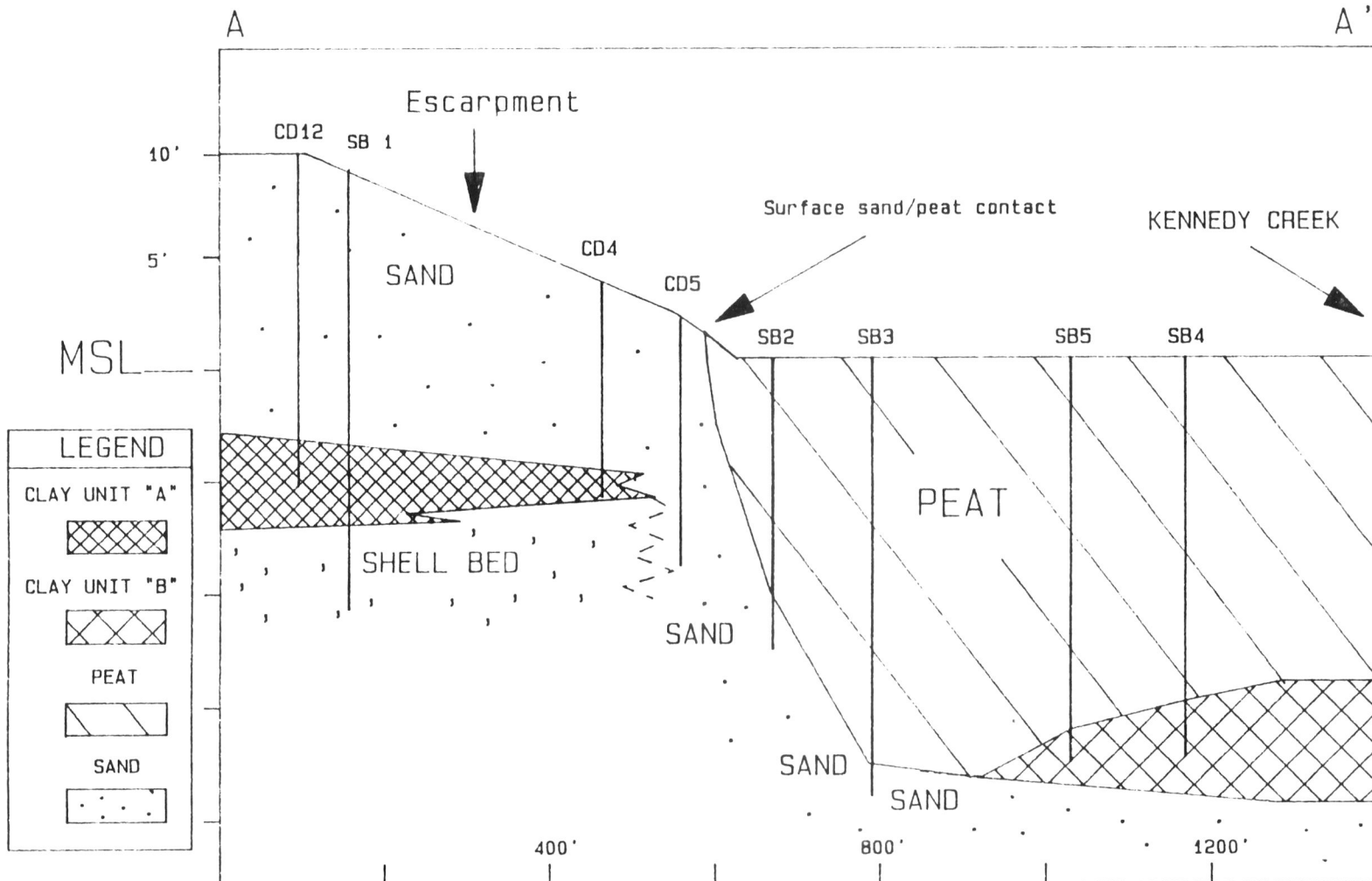


Figure 6. Water table aquifer lithologies encountered in the study area. Note that clay units A and B are not laterally continuous from the escarpment to the floodplain. See figure 5 for location of this section.

is often delineated by an escarpment (4 to 8 feet of local relief) that parallels the Tar-Pamlico river (see Fig. 6).

Sands northeast of Kennedy Creek and above clay unit "A" (Fig. 6) are medium-fine to medium-coarse, well-sorted, rounded to subrounded quartz sands containing minor fractions of heavy minerals and mica. A thin, orange-rust to black, oxidized zone (less than 0.5 feet) denotes the seasonal high water table. These sands are believed to correlate with units mapped by Maddry (1977) in Pitt County along the northern Tar River Valley.

The present day floodplain of the Tar river occupies a topographic low cut into the Yorktown Formation called the "Yorktown Unconformity" (Maddry, 1977). Holocene rise in sea level has resulted in Recent peat deposition in the Tar River Valley. Peats are black to brown and thicken from zero in the north to more than 16 feet to the south of the study area. Fournet (1990) reported carbon-14 dates (within the study area and on the south side of the Tar River) of approximately 3500 and 10,000 ybp for peat samples at 10.5 and 24 feet below MSL, respectively.

Confining layers below the aquifer are stratigraphically discontinuous. Clay unit "A" (Fig. 6) is 2 to 3 feet thick and varies laterally from an orange-brown clay with

shell fragments to a blue-green sandy clay. Clay unit "B" is gray and very compact; it may correlate with a unit in the Tar River Valley (Maddry, 1977).

An unnamed shell bed with minor amounts of clay and sand lies directly beneath clay unit "A". The shell bed and clay unit "A" are truncated by the peat/sand contact (Fig. 6) and are not part of the aquifer in the Kennedy Creek floodplain.

HYDROGEOLOGY

Regional Hydrogeology

The North Carolina Coastal Plain hydrogeologic system is composed of ten aquifers and nine confining units (Winner and Coble, 1989). The aquifers are composed primarily of unconsolidated sand and gravel, or moldic limestone. The water table aquifer is composed mainly of Quaternary sand and gravel with interbedded clay. The water table aquifer is the primary source of groundwater for domestic use on the barrier islands and in the Sandhills region of North Carolina.

The water table aquifer varies from approximately 3 to greater than 180 feet in thickness. Thicknesses are influenced by topography and maximum thicknesses occur in the recharge areas. Average estimated hydraulic conductivity is reported as 29 ft/day (Winner and Coble, 1989). The average storativity of the water table aquifer is estimated as 0.2 (Heath, 1987).

The water table aquifer serves as a reservoir for recharge to deeper aquifers. Sherwani (1973), Heath (1980), and Winner and Coble (1989) note that recharge to deeper aquifers in the Coastal Plain occurs by downward flow across semiconfined or leaky confining units.

Infiltration from rain is the main source of recharge to the water table aquifer. The region receives about 50 inches of precipitation annually. Heath (1980) suggests that the water table aquifer receives about 20 inches/year of recharge from precipitation. Recharge capacity is controlled in part by the lithology of the aquifer. Aquifers with moderate to high clay contents may receive 75% less recharge per year than a sand or gravel aquifer (Heath, 1980).

Head values in the water table aquifer fluctuate on an annual cycle in response to the following factors: 1) precipitation (recharge); 2) evapotranspiration; 3) air entrapment during recharge events; 4) bank storage near streams; 5) water levels in the estuaries (astronomical tides and wind phenomenon); 6) atmospheric pressure effects; 7) groundwater pumpage; 8) artificial recharge (leakage from catchment basins, etc.); and 9) irrigation and drainage (Freeze and Cherry, 1979). The water table declines from spring through summer when precipitation is moderate and transpiration is high. Most recharge occurs during the fall and winter months when evapotranspiration rates are low and rainfall is high.

Site Specific Hydrogeology

In the low-lying areas near Kennedy Creek, Holocene swamp forest peat deposits comprise the majority of the water table aquifer. Quaternary sands, gravels, and clays are common above the five-foot contour (peat/sand contact in Fig. 5) surrounding the Tar River and its tributaries. The water table aquifer is underlain by generally impermeable units of the Yorktown Formation. However, sands in the Yorktown Formation may locally comprise the lower parts of the water table aquifer (NC DNRCD, 1987).

Aquifer Geometry

A hydraulic connection between the water table aquifer and the Yorktown aquifer probably exists in the transition zone between clay units "A" and "B" (Fig. 7). Aquifer thickness exceeds 16 feet in the immediate vicinity of Kennedy Creek where clay unit "A" is truncated. The water table aquifer thins to 3 to 4 feet in the northern section of the study area and thickens gradually to approximately 20 feet in the uplands directly north of the study area.

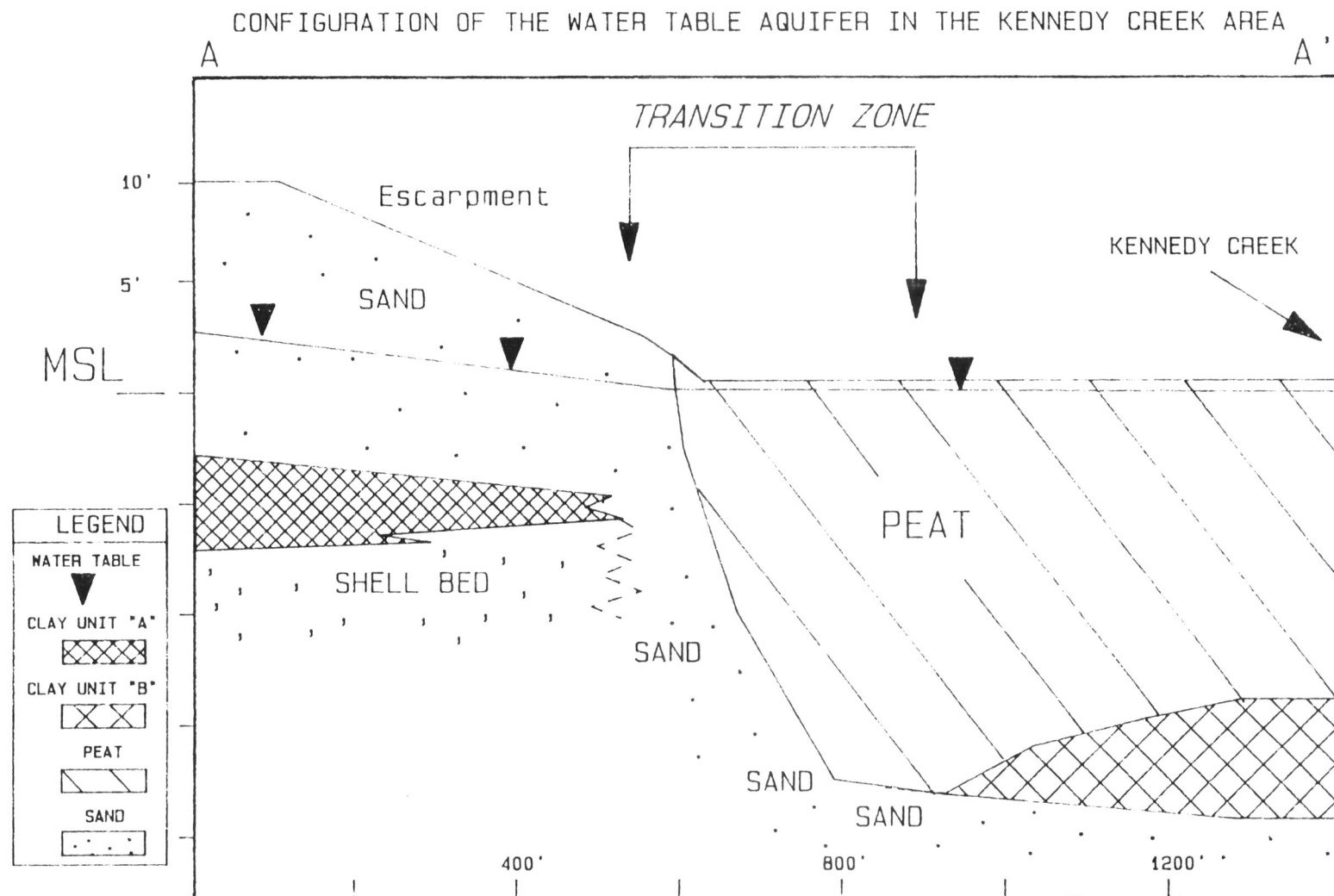


Figure 7. Configuration of the water table aquifer. The transition zone between clay units A and B and the escarpment is interpreted to be a connection between the underlying aquifer and the water table aquifer. See figure 5 for location of this section.

Description of the Potentiometric Surface

Head values (Appendix 2) for monitoring wells were used to construct equipotential maps. Figures 8a and 8b illustrate the maximum and minimum observed equipotential surfaces for the water table aquifer on January 15 and July 24, 1990, respectively. In the immediate vicinity of the textile wastewater treatment basin (Area "A" in Fig. 8b), a "mound" in the water table (Fig. 9) was present throughout the study. This "mound", nearly 3 feet high, is reflected by the difference in heads between MW 1 and MW 2 (Fig. 10a). Additional wells, MW 11-15 (Fig. 3), installed around the basin indicate that heads increase toward the basin. These data suggest that the water table receives recharge from the wastewater basin.

An evaporation experiment was conducted at the basin to assess the "leaky" basin problem. Water levels and time were recorded in the basin and in an evaporation pan (land pan) over a one day period. The decline in the basin level was attributed to evaporation. Leakage, if any, is too small to be detected as a net loss "exclusive" of that expected from evaporation. Major and trace elements, pH, and specific conductivity data from monitoring wells in the

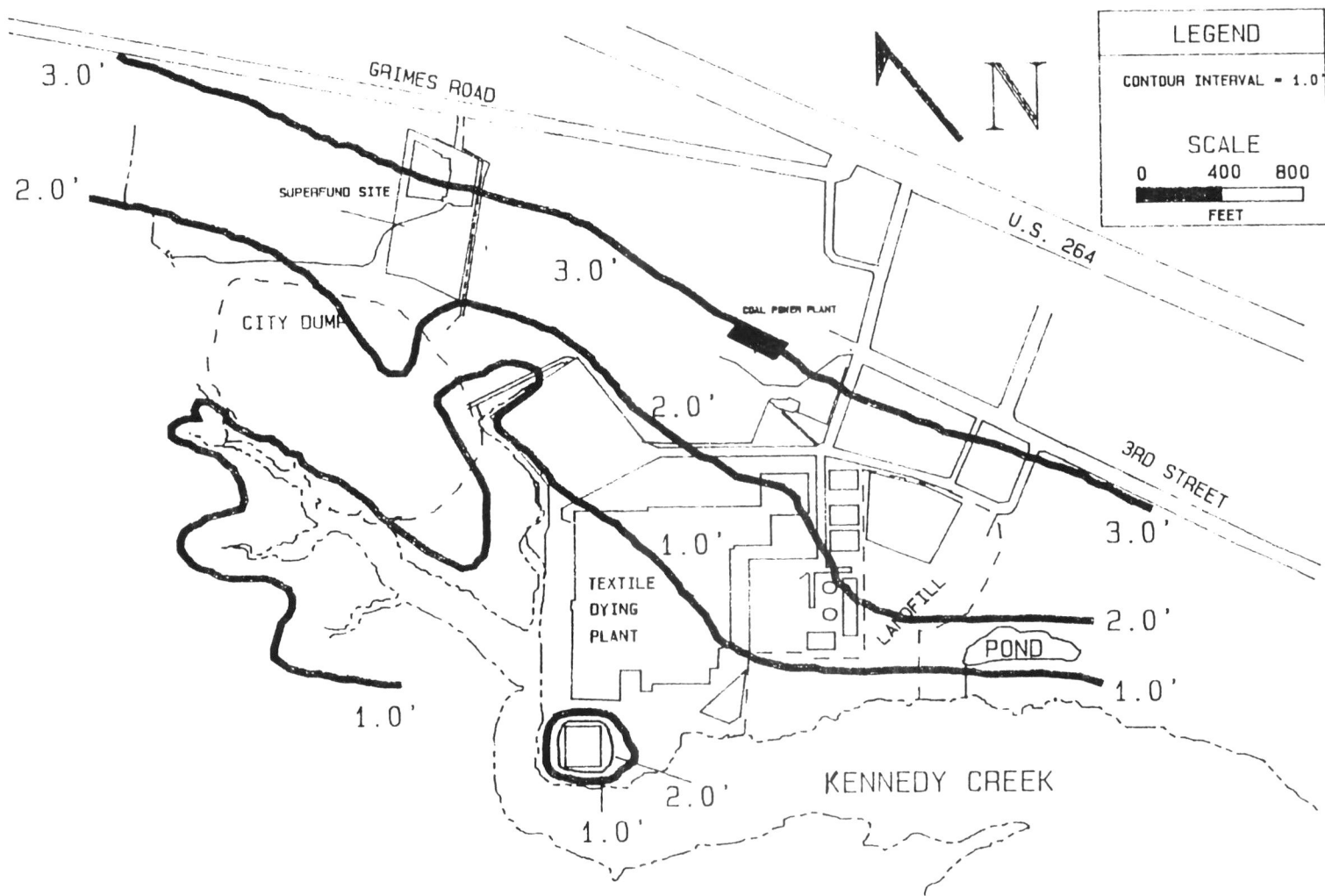


Figure 8a. Equipotential surface map for the water table at minimum observed head values on 1/15/90. Kennedy Creek is considered to be at MSL.

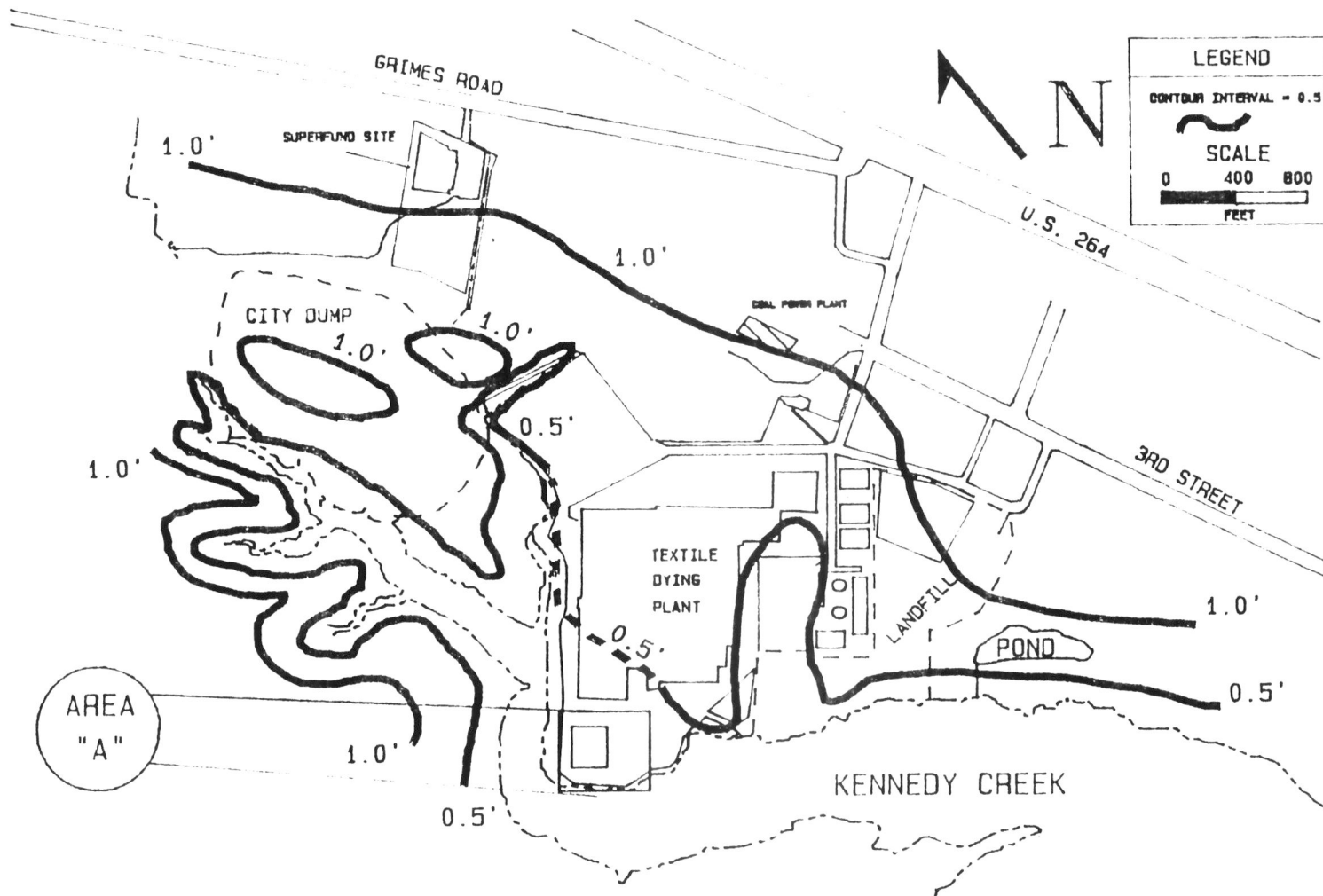


Figure 8b. Equipotential surface map for the water table aquifer at minimum observed head values on 7/24/90. Perturbations on the water table are the result of emplacement of landfills. Area "A" is the location of a mound in the aquifer that is enlarged in Figure 9. Contour lines are dashed where approximated and Kennedy Creek is considered to be at MSL.

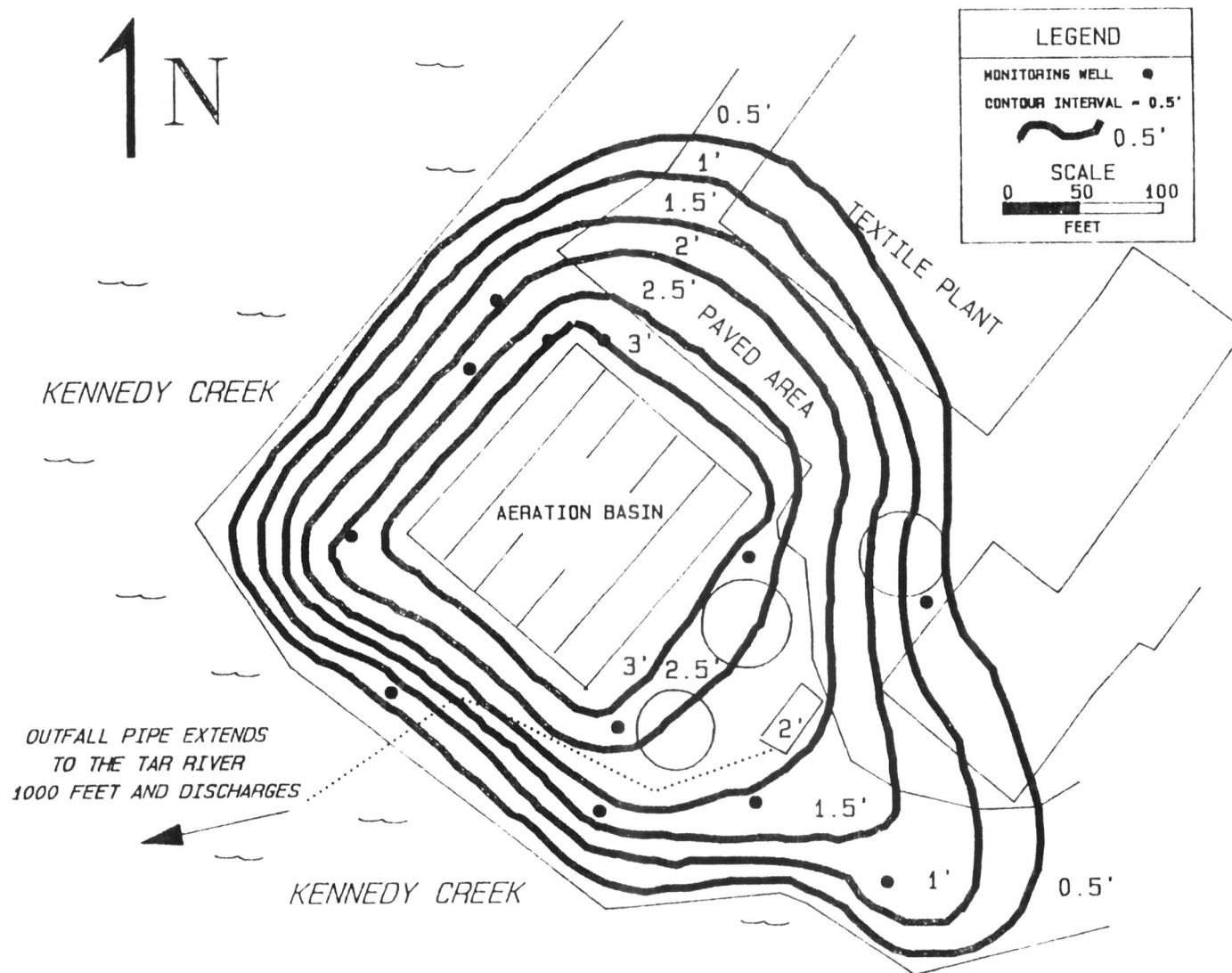


Figure 9. Groundwater mound on 7/24/90 around aeration basin (Area A). Location of area A is indicated in Figure 8b.

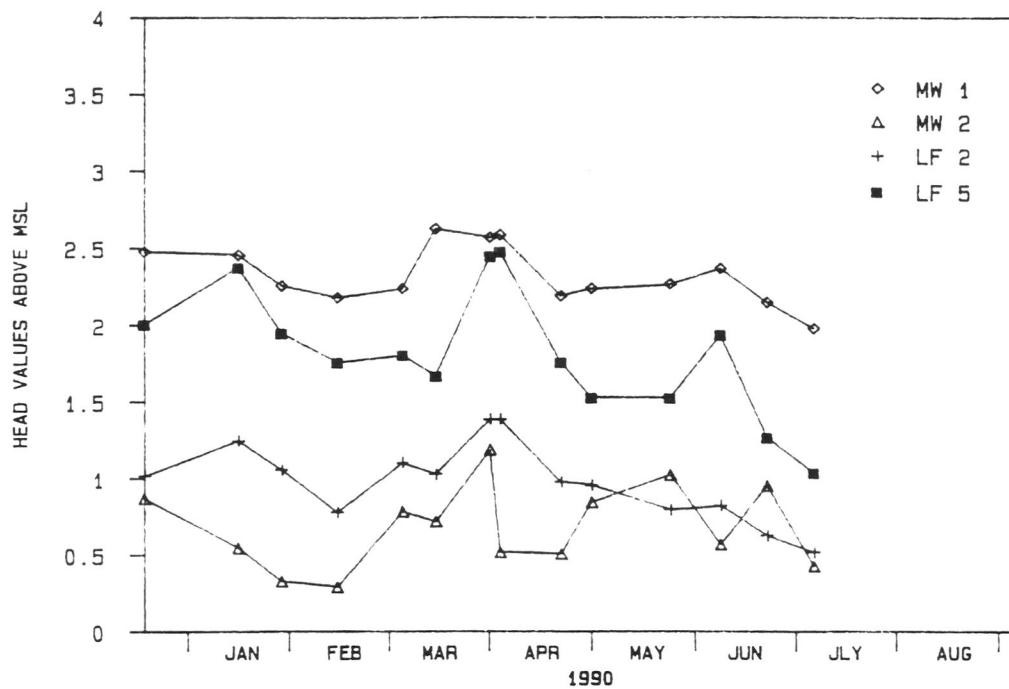


Figure 10a. Well hydrographs for selected wells near the textile waste treatment basin and landfill. See Figure 3 for well locations.

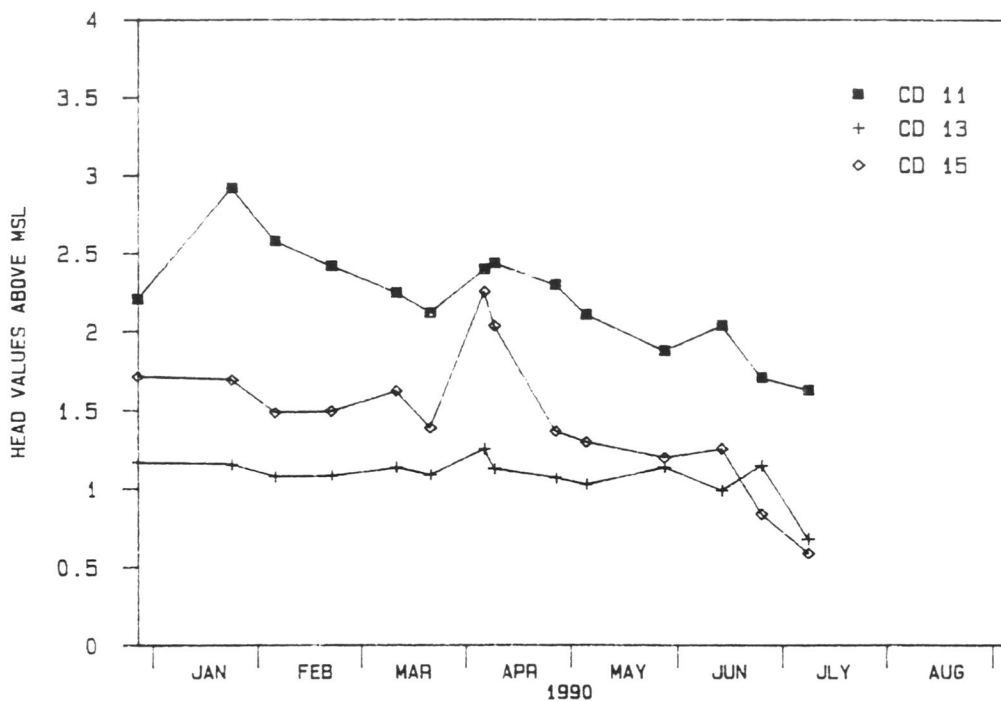


Figure 10b. Well hydrographs for selected wells surrounding the City Dump. See Figure 3 for well locations.

immediate vicinity of the aeration basin did not identify any significant levels of contaminants.

Local flow patterns are disrupted by the City Dump and Landfill (Fig. 8a and 8b). Surface elevations were raised by 2 to 4 feet, resulting in an increase in well head values from 0.2 to 0.4 feet. These increased heads are evident in wells screened in the Landfill and City Dump, LF 5 (Fig. 10a) and CD 15 (Fig. 10b), respectively.

The seasonal high water table appears to occur during the month of January, although my data do not represent a complete annual cycle. The typical seasonal trend of the water table aquifer is best depicted by the hydrograph from CD 11, located north of the escarpment along the Tar River (Fig. 10b).

The shallow water table responds rapidly to recharge events. A rainfall of 0.84 inches (0.07 ft) resulted in a 2.4 inch (0.2 ft) rise in the water table within thirty minutes. Continuous water levels recorded at a station (SR#3) 150 feet from Kennedy creek (Fig. 11) illustrate the relationship between the water table and precipitation events. After removing these short-term precipitation events, an overall decline of 0.3 ft (3.6") in the water table was observed during the period from April 22 to May 23, 1990.

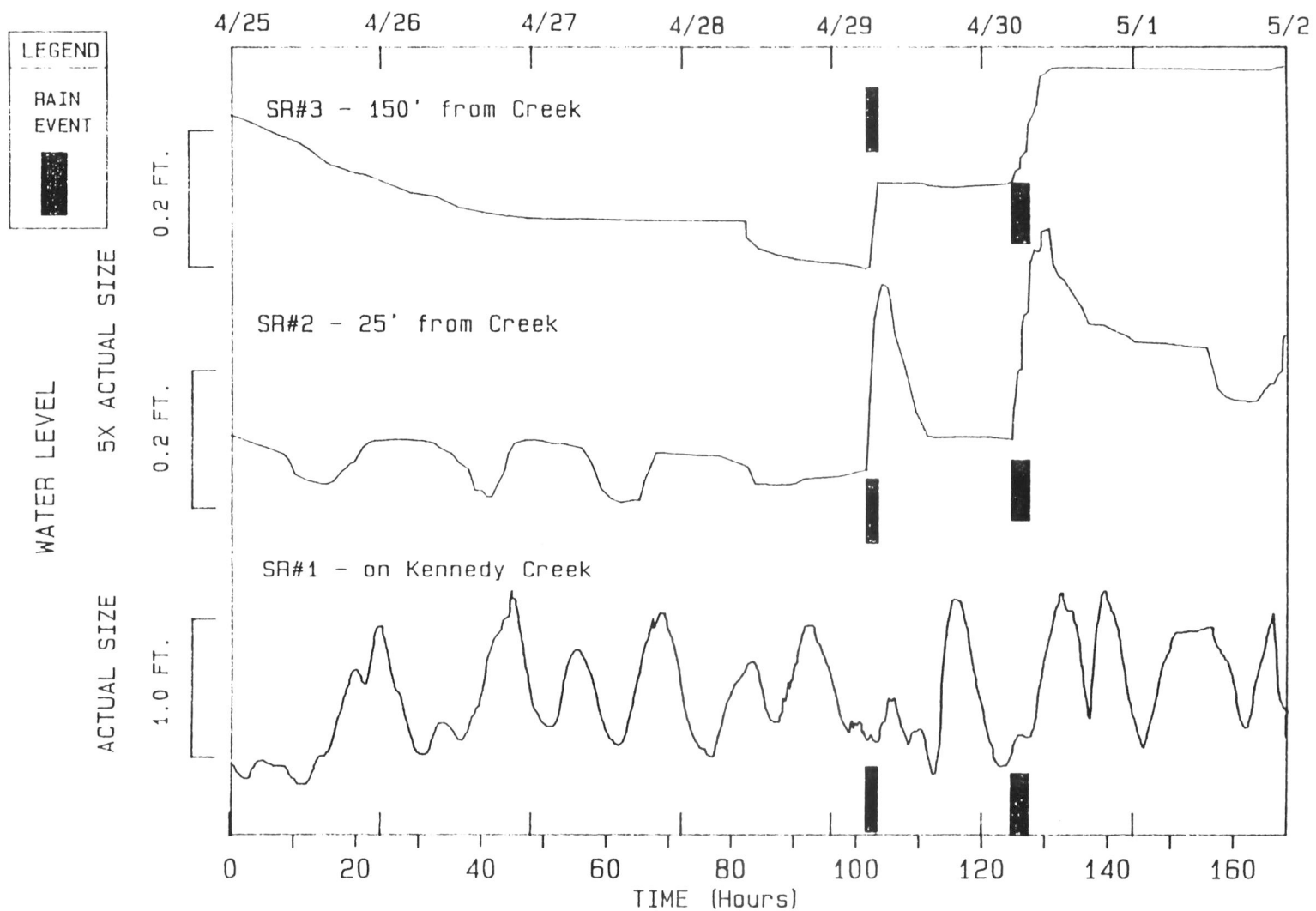


Figure 11. Continuous water level data showing effect of precipitation events on the creek and water table. A diurnal wind component affecting the creek (SR #1) is rapidly attenuated in the water table as shown by SR#2. See Figure 4 for locations of Stevens recorder stations.

A diurnal wind component, commonly known as the sea/land breeze (L. Pietrafesa, NC State University, pers. comm., 1990) affects creek levels in Kennedy Creek. Winds paralleling the creek from either the northwest or southeast have the most pronounced effect on creek levels. Astronomical tides account for less than 3% of water fluctuations in the upper Pamlico estuarine system (Jarrett, 1966). The nature of the hydraulic connection between the water table aquifer and Kennedy Creek can be evaluated by comparison of continuous water levels on the creek and in the aquifer (Fig. 11).

Creek level fluctuations (up to 3 feet) are attenuated to less than 0.2 feet over a distance of less than 25 feet from the creek. Water table fluctuations of up to 0.5 feet occurred in MW 2 only 15 feet from the creek (Fig. 10a). Data suggest that water level changes in Kennedy Creek from minor flood events affect water table elevations only within 150 feet of Kennedy Creek (Fig. 11).

Persistent southeastern winds result in the "stacking" of water in Kennedy Creek; northwest winds have the opposite effect. Minor flooding normally results from "stacking" events and is usually confined to the headwater region but major flood events (8 ft above MSL) in Kennedy Creek have been reported.

Wells located at the head of Kennedy creek are readily affected by wind-driven flood events. Three minor flood events are shown in Figure 12. Maximum groundwater and creek levels correspond to recorded peaks in wind velocity at the Washington WWTP. Water table fluctuations of up to 0.6 feet are not uncommon and normal water level is usually re-established in 30 to 48 hours. These floods result in lower hydraulic gradients on the water table aquifer and as floods recede, discharge rates increase due to higher hydraulic gradients.

Hydraulic Conductivity

Horizontal hydraulic conductivity varies over the study area according to lithology. Several wells, screened in peat and sand, were slug tested. Hydraulic conductivities for peat deposits average 4 to 5 ft/day. In the northern portion of the study area, medium-coarse sands have an average hydraulic conductivity of 15 to 25 ft/day.

Hydraulic Gradient

The hydraulic gradient on the water table averages 9.5×10^{-4} ft/ft and flow direction is southward towards Kennedy Creek. Steeper gradients occur during periods of recharge.

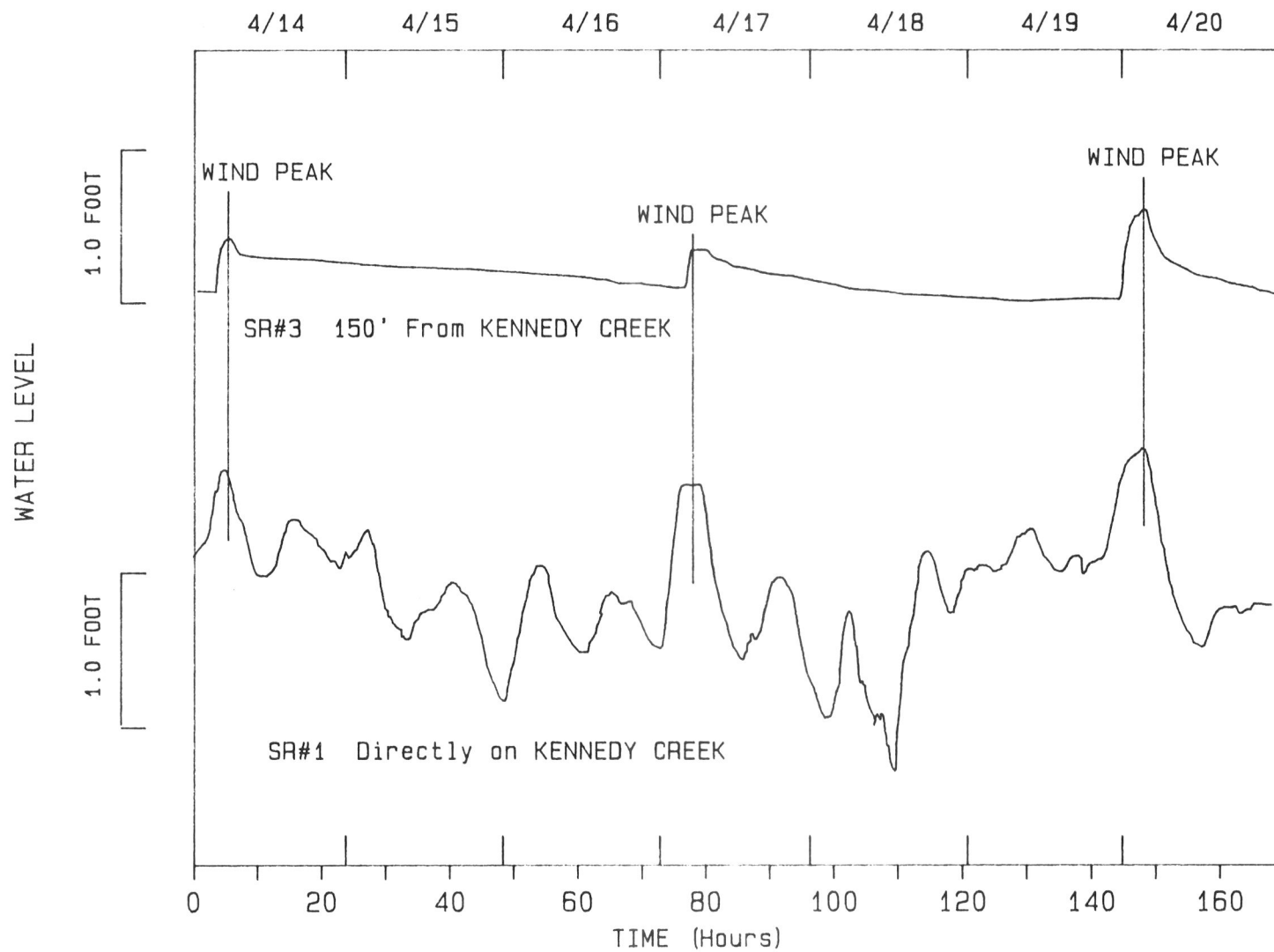


Figure 12. Groundwater levels in response to three minor wind-driven flood events with corresponding peaks in wind velocity. See Figure 4 for locations of Stevens recorder stations.

A seasonal decrease (1.4×10^{-3} to 5×10^{-4} ft/ft) in the slope of the water table occurred from January to June.

Groundwater Velocity

Darcian conditions of groundwater flow are assumed to be applicable to the water table aquifer. Groundwater seepage velocity was calculated assuming an effective porosity of 0.20 for the aquifer. Peats have an average seepage velocity of 0.031 ft/day or 11 ft/year. Sand units have a higher average seepage velocity of 0.19 ft/day or 68 ft/year due to their higher hydraulic conductivities. Seepage velocity decreases with the decrease in hydraulic gradient during the summer months.

Recharge/Discharge Conditions

Groundwater flow is assumed to be near horizontal from upland recharge areas to discharge areas along surface water bodies. Nested piezometers (Fig. 4) indicate a vertical upward decrease in head gradients of approximately 0.01 ft/ft based on stations located in the water table aquifer near Kennedy Creek. This upward vertical gradient indicates that the groundwater is rising toward a discharge area in the vicinity of Kennedy Creek.

CHEMISTRY

General

The fate of metallic ions in natural systems has been the focus of numerous studies. Major factors affecting metal behavior are changes in pH, Eh, temperature, and solubility. Transport of metals through natural systems depends on redox conditions, cation exchange capacity (CEC) of the ambient substrate, microbial activity, and sedimentation processes. Metals such as Cr, Pb, and Zn are known to have an affinity for material with a high CEC. Organic matter possesses the highest CEC by volume and is second only to expandable clays in CEC by weight (Brady, 1984). Jenne and Zachara (1987) noted that oxides of Fe and Mn and organic matter are the most important substrates for metal sorption and that complexing and competition among dissolved ligands affects the availability for uptake of heavy metals by organisms.

At pH levels of 6 to 7, oxidizing conditions immobilize the majority of metals and metalloids except anionic forms of Cr and Se (Cherry and others, 1984). Reducing conditions increase metal mobility by causing solution of Fe and Mn oxides and release of metals previously sequestered by these oxides (Suarez and Langmuir, 1976). Cherry and others

(1984) state that in the majority of groundwater systems, "toxic inorganic constituents generally do not occur in concentration levels above mandatory drinking water standards and despite the potential for mobilization of toxic inorganic compounds by complexing with organic compounds, immobility of the heavy metals is the rule rather than the exception".

Previous Works

Landfills across the nation are the ultimate resting place for many industrial and domestic wastes. These wastes create leachates that have contaminated groundwater supplies in the past and will continue to pose a threat to groundwater resources in the future. Infiltration from rain is the single most important factor governing the generation of leachate. Many workers (Borden and Yanoschak, 1989; Lu and others, 1985; Baedecker and Apgar, 1984; Harmsen, 1983; Kimmel and Braids, 1980) have found high levels of ammonia, bacteria, chlorides, heavy metals, nitrates, and viruses associated with landfill leachate.

Solid wastes undergo progressive stages of aerobic decay, acid fermentation, and methanogenesis during leachate production (Lu and others, 1985). Harmsen (1983) noted increases in heavy metal concentrations in leachate during

the acid fermentation stage due to low pH (< 5.5) and complexing with organic acids. As solid waste decomposition progresses to the methanogenesis stage, pH values increase to a narrow range (6.6 to 7.4) and heavy metal ions previously in solution tend to adsorb in CEC materials and become immobile (Lu and others, 1985).

Contamination of drinking water supplies from landfill leachate is a main concern in landfill design and placement. Leachate production from landfills in North Carolina has resulted in violations of North Carolina drinking water standards as outlined in Subchapter 2L of the North Carolina Administrative Code (NC DEM, 1985) at approximately 36 of the 71 landfills studied by Borden and Yanoschak (1989). Drinking water standards for North Carolina are referred to hereafter as NC-MCL's (Maximum Contaminant Levels).

Borden and Yanoschak (1989), Baedecker and Apgar (1984), and Kimmel and Braids (1980) noted high amounts of Fe and Mn associated with landfills and their respective leachate plumes. Iron and Mn are the most common ions present in monitoring wells associated with landfills in North Carolina. Arsenic, Cd, Cr, Pb, and Zn were found in concentrations above the NC-MCL in many wells. Chlorinated solvents, petroleum hydrocarbons, and pesticides were the most common organic groundwater contaminants detected in North Carolina landfills (Borden and Yanoschak, 1989).

Coal-burning power plants generate coal slag and fly ash. Groenewold and Manz (1982) assessed groundwater contamination from leachate produced by the disposal of fly ash in North Dakota. Leachate contained concentrations of As, Se and sulfate above EPA drinking water standards and high levels of Mo, Ca, Na, and Mg. High pH values (7 to 12) were correlated with high levels of As and Se. Groenewold and Manz (1982) suggested that burial of fly ash may introduce metallic ions to the groundwater system. Arsenic and Se concentrations decreased with time as pH levels declined from 11-12 down to 6-7. Dodd and others, (1981) observed high levels of sulfate, Ca, Cl, Mg, Na, K, and Mo in groundwater downgradient from a fly ash disposal site in Ontario, Canada.

Recent studies of the Pamlico River estuary (Harding and Brown, 1976; Riggs and others, 1989) suggest that the distribution of trace metals in bottom sediments is directly related to wastewater discharges from anthropogenic point sources. Significantly elevated levels of many trace elements occur in estuarine sediments in areas of human activity.

An assessment of the concentrations of heavy metals occurring in the benthic environment of the Pamlico estuarine system was conducted by Riggs and others (1989). The study delineated "areas of concern" (AOC's) that are

characterized by elevated concentrations of one or more elements (As, Cd, Cr, Cu, Hg, Ni, Pb, and Zn) that are moderately bound by organic-rich muds within the upper 5 cm of sediment.

Results of recent sampling and analysis of bottom sediments for metals (Riggs and others, 1989) are summarized in Table 2. These values represent concentrations in a leachable fraction resulting from a partial digestion procedure (Riggs and others, 1989). These concentrations may approximate the "potentially bioavailable" metals in the system. Trace element anomalies were calculated as "enrichment factors" by calculating the ratio of specific elemental concentrations to the "trimmed mean" of the Pamlico River system. The "trimmed mean" is calculated by taking all data that fall within two standard deviations of the mean of the original sample population and recalculating the mean for the new sample population. Kennedy Creek, a major AOC, shows increases in many elements including Ag, As, Cd, Co, Cr, Cu, Hg (highest in study), Ni, P, Pb, V, and Zn. Bottom sediments from Kennedy Creek contained the highest percentage of organic matter (25%) in the estuarine system.

Table 2. Summary of analytical results (in ppm) for selected trace elements from Kennedy Creek bottom sediments. Elemental concentrations are the result of a partial leach and enrichment factors were based on the trimmed mean for the Pamlico River estuarine system (from Riggs and others, 1989).

Element	Pamlico Estuary Average	Kennedy Creek Average	Kennedy Creek Range	Maximum Enrichment Factor
As	12.8	21.2	5.8 - 35.4	3 X
Cd	0.36	0.85	0.3 - 1.7	5 X
Cr	10.5	27.3	5.9 - 58.8	6 X
Cu	13.6	51.5	17.6 - 84.4	6 X
Hg	0.09	0.44	0.16 - 1.3	14 X
Pb	35.9	68.5	29.8 - 86.9	2 X
Ni	2.7	8.4	1.5 - 13.3	5 X
Zn	77.0	377.9	151.2 - 490.3	6 X

Surface water quality surveys of a wide range of parameters have been conducted in the Pamlico and Tar rivers during the past thirty years. Rader and others, (1987) conducted heavy metal analyses from 1979 to 1987 in the Tar-Pamlico rivers and reported that over 90% of their samples fell below analytical detection limits for Cr, Hg, Ni, and Pb. They noted that Cu and Zn were the elements most frequently detected and that Cu and Zn levels were below detection limits in 75% of the samples.

Simmons and Heath (1979) classified groundwater in the vicinity of Kennedy Creek as occurring in geochemical Zone 5. Zone 5 is characterized by a water chemistry typical of sands, limestones, shell beds, and clays of the Inner Coastal Plain.

To the north of Kennedy Creek, an abandoned agrochemical distribution center is under active remediation by the NC Superfund Branch (Fig. 2). Pesticides and fumigates formerly buried close to the water table were a potential source of contaminants. Groundwater sampling by the NC Superfund Branch indicated no contamination in local industrial supply and privately owned wells screened from 200 to 250 feet, but the water table aquifer was not sampled.

High concentrations of metals may accumulate in geologic materials characterized by a high CEC such as peat. Damman (1978) reported that high levels of Ca, Fe, Mn, P, Pb, and Zn occurred in the upper 2 feet of peat bogs in Denmark. The highest concentrations of Al, Fe, Pb, and Zn in these peats occurred in the zone of water table fluctuation. Redox conditions at the water table produce oxides of Fe and Mn which may provide a chemical "sink" for several metallic species due to their role as "geochemical scavengers" (Cherry and others, 1984). Daniel (1981) suggested that some surficial metal concentrations observed in peats from Dare County, North Carolina could be the result of element-lifting capabilities in living plants.

Mercury has been intensely studied because of its toxic effects in the environment. Evans and others, (1984) reported background mercury levels between 40 to 193 ng/g, (parts per billion; ppb) in peat deposits of the Western

Pamlico-Albemarle Peninsula. Daniel (1981) reported Hg values in peats ranging up to 400 ppb in the same area. Mercury in these peat-dominated environments was found to be tightly bound to organic chelates. Drainage waters from peat mining operations in the Pamlico-Albemarle Peninsula yielded Hg concentrations from 0 to 23 ppb (Evans and others, 1984).

Soils were analyzed for a variety of inorganic and organic parameters at the Superfund site by the NC State Superfund Branch in 1986. Contaminants identified include Aldrin, Chlordane, DDT, DDE, Dieldrin, carbon disulfide, hexachlorobenzene, naphthalene, phenanthrene, acenaphthylene, fluorene, dibenzofuran, and 2-methyl naphthalene (Nicholson, 1987).

SITE SPECIFIC CHEMISTRY

Kennedy Creek is classified (NC DEM, 1985) as Class C waters, best suited for "fish and wildlife propagation, secondary recreation, agriculture and other uses requiring waters of lower quality". Groundwater in the vicinity of Kennedy Creek is considered as Class GA; "an existing or potential source of drinking water supply for humans" (NC DEM, 1985).

Sample Descriptions And Locations

Samples of water and bottom sediments from Kennedy Creek, groundwater from monitoring wells adjacent to Kennedy Creek, and soils from the water table aquifer were analyzed for a wide variety of inorganic and organic constituents in order to evaluate contamination potential.

Groundwater

Major and Trace Elements

Water samples were collected from all monitoring wells and analyzed for soluble major and trace elements by inductively coupled argon plasma emission spectroscopy (ICAPES) and Hg was analyzed by cold vapor atomic absorption (CVAA) at the Laboratories of the Elemental Analytical Group at the ECU School of Medicine. A list of elements, methods, accuracy, precision, limits of detection, and analytical results for groundwater sample Sets #1 and #2 are listed in Appendix 3. Several well volumes were removed from each well one day prior to sampling in order to collect water representative of the aquifer. Samples were collected and stored according to EPA protocol (Scalf and others, 1981).

Thirty-five groundwater samples representing Set #1 were collected on December 22 and 23, 1989 and labeled according to well number (Fig. 13). Forty groundwater samples representing Set #2 were collected on May 26, 1990 and labeled according to well number (Fig. 14). Set #2 included five additional groundwater samples (MW 11-15) from wells located around the aeration basin at the textile plant (Fig. 14). Also, groundwater Set #2 included two Kennedy Creek water samples (KC-T and KC-B) collected at the top and bottom (2 feet) of the water column downstream from the City Dump (Fig. 14).

Organic Constituents

Various types of samples were collected for analysis of organic constituents according to EPA protocol (Scalf and others, 1981) and submitted to Chemical and Environmental Technology, Inc. (C&ET, Inc.) in Research Triangle Park, NC, accompanied by a chain-of-custody form. C&ET, Inc. analyzed samples for acid and base neutral extractables (EPA Methods 625 and 8270) and petroleum hydrocarbons (EPA Method 602, 8020, and 3540). A pesticide/PCB scan (EPA Method 608) was performed on one groundwater sample (CD 4-G) downgradient from the Superfund site (Fig. 15). Analytical detection limits, organic constituents for each method, and sample results are listed in Appendix 4.

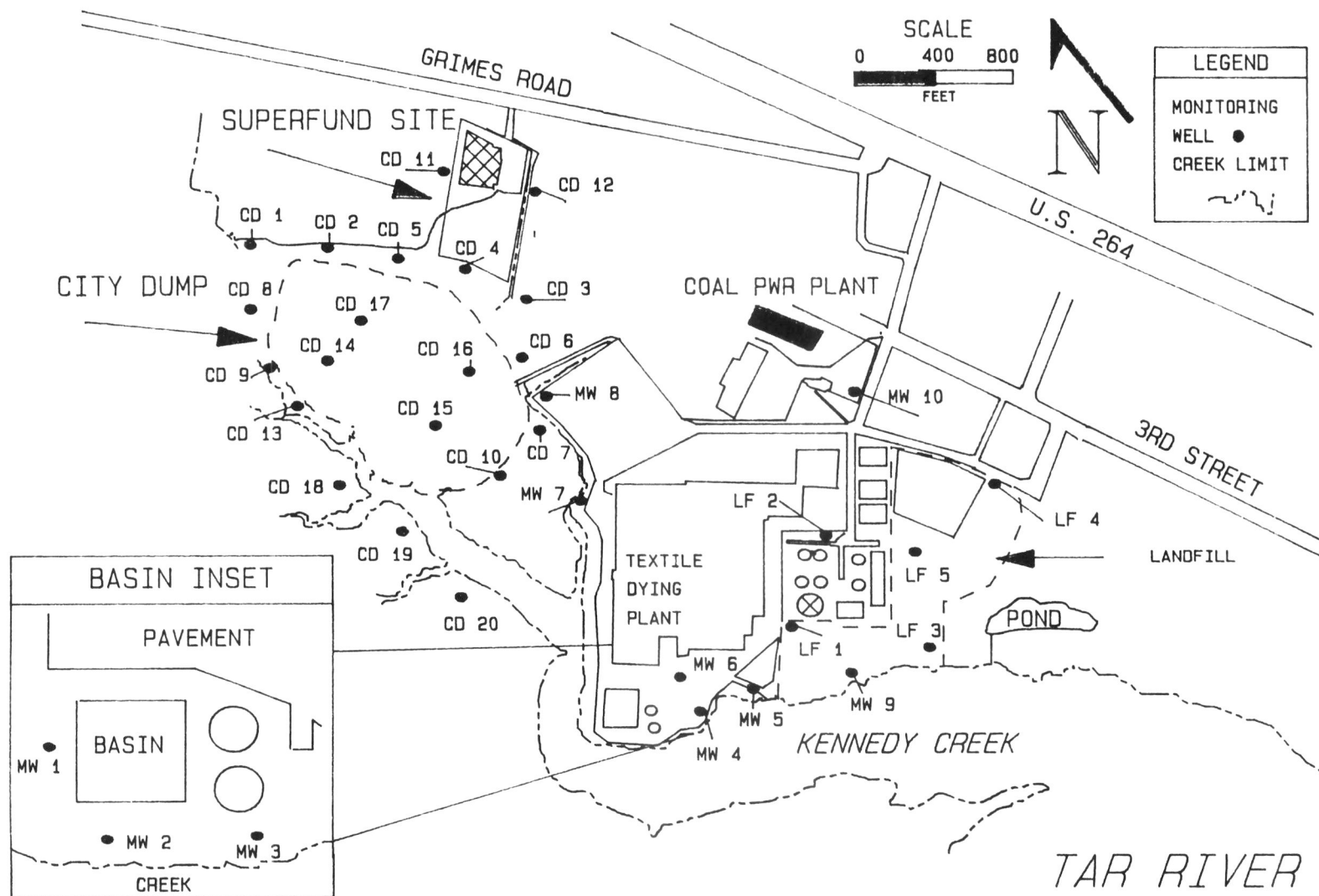


Figure 13. Groundwater sampling locations for Set #1 taken on 12/22-12/23/89.

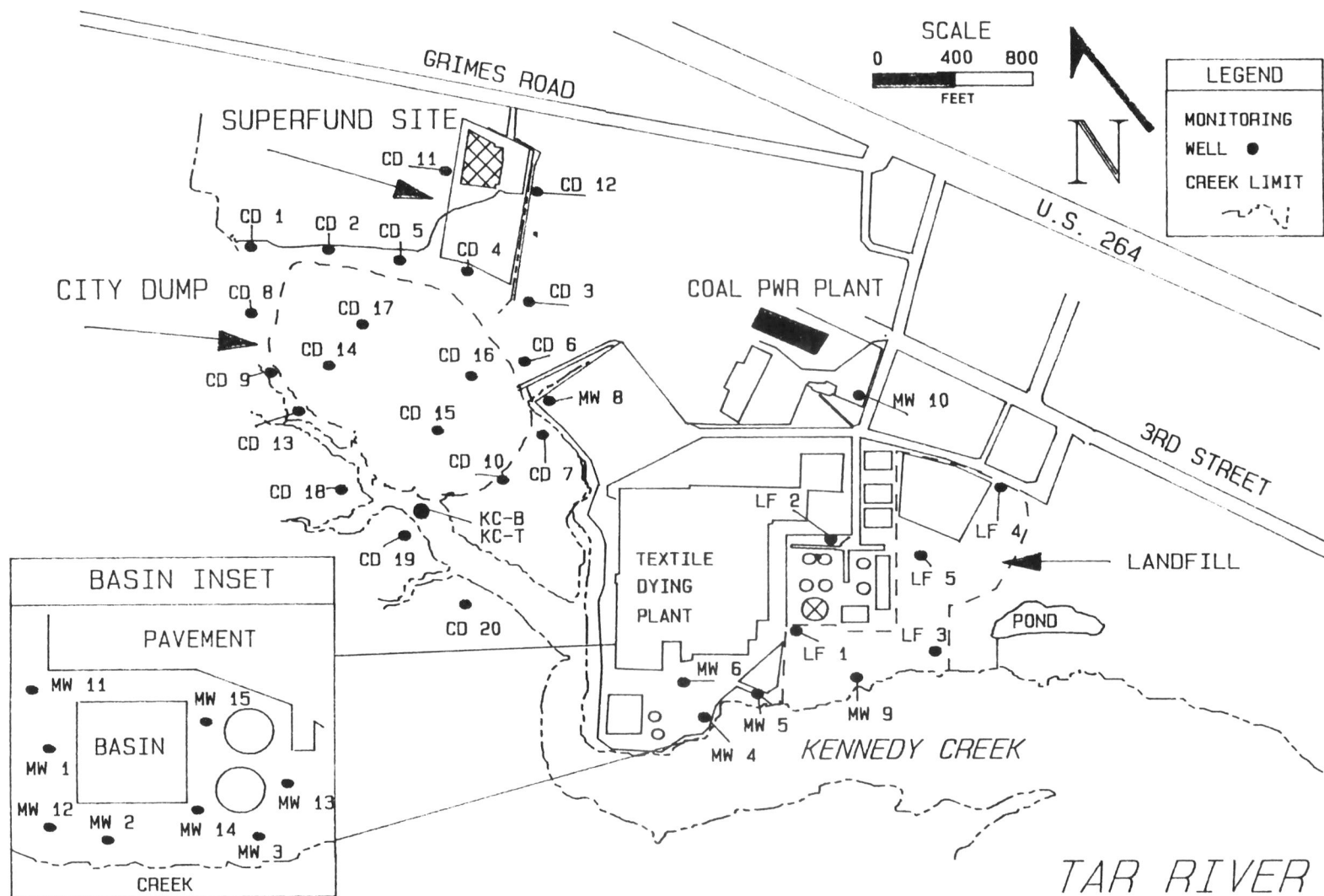


Figure 14. Groundwater sampling locations for Set #2 taken on 5/26/90. Kennedy creek samples KC-T and KC-B are located just downstream from the City Dump.

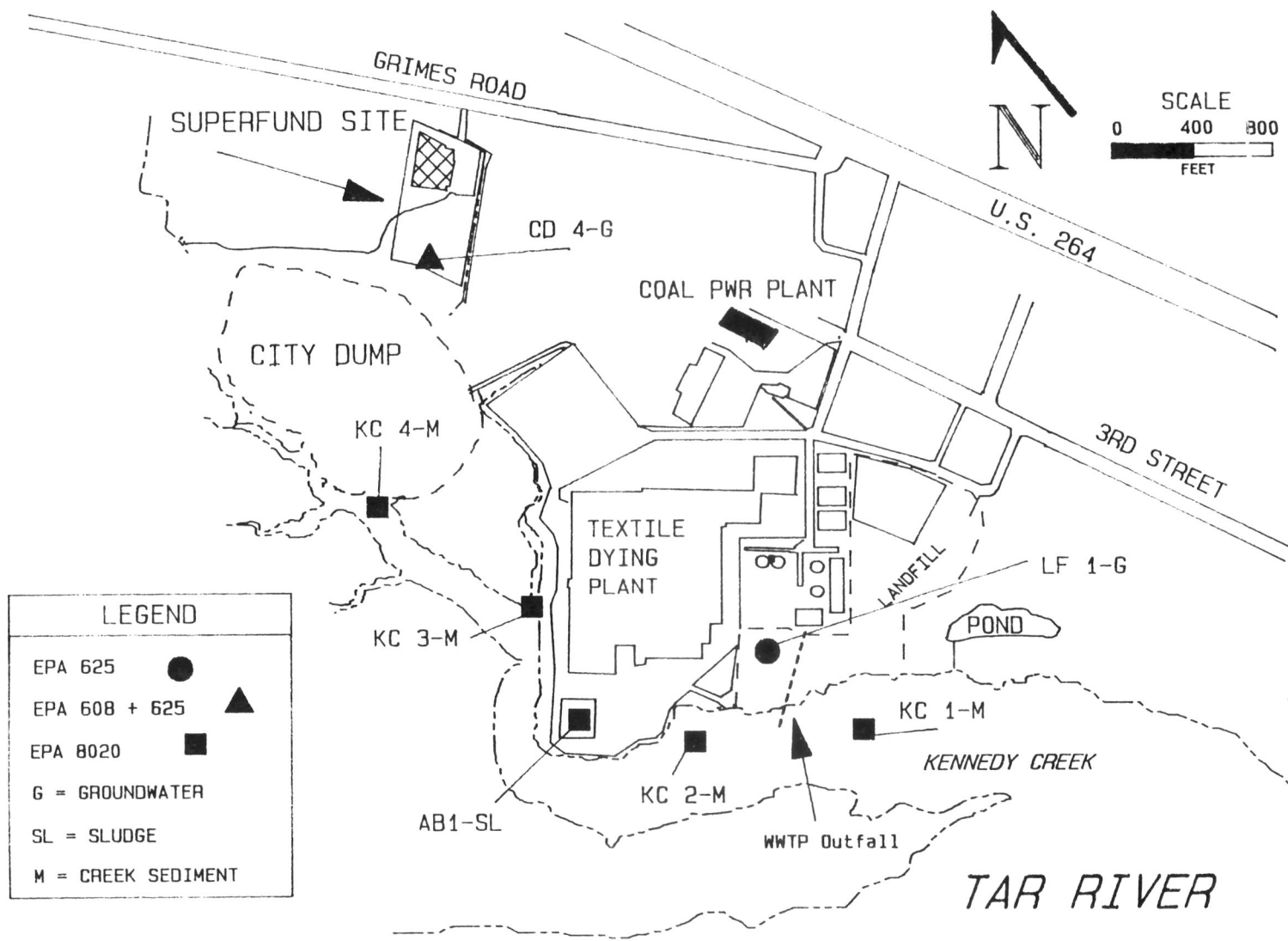


Figure 15. Locations and types of samples for organic Set #1 collected on 2/17/90 and sent to C&ET, Inc. for analyses. See Appendix 4 for an explanation of EPA Methods.

Organic samples were labeled as follows: G = ground-water, M = creek sediment, SL = sludge, and D = effluent (discharge). Organic sample Set #1 included the following types and number of samples analyzed: groundwater (2); bottom sediments (upper foot) from Kennedy Creek (4); and sludge/mixed liquor from the aeration basin at the textile dying facility (1). Organic sample Set #2 contained the following types and number of samples analyzed: groundwater (6); bottom sediments from Kennedy Creek (3); sludge/mixed liquor from the aeration basin at the textile dying facility (1); sludge from the Washington's WWTP (1); and discharge from the WWTP (1). Locations and sample types for organic Set #1 and #2 are shown in Figures 15 and 16.

Soils

Soil samples were collected and analyzed by an EPA approved leaching procedure followed by ICAPES and CVAA determinations for major and trace elements. Forty-nine samples were collected with a hand auger or Macauley Sampler in seventeen boreholes along four transects (Fig. 17). The four transects are positioned around the Superfund Site, through the City Dump and Landfill, and along the property of the textile plant. The sampling scheme was designed to:

- 1) obtain information on metal concentrations near various

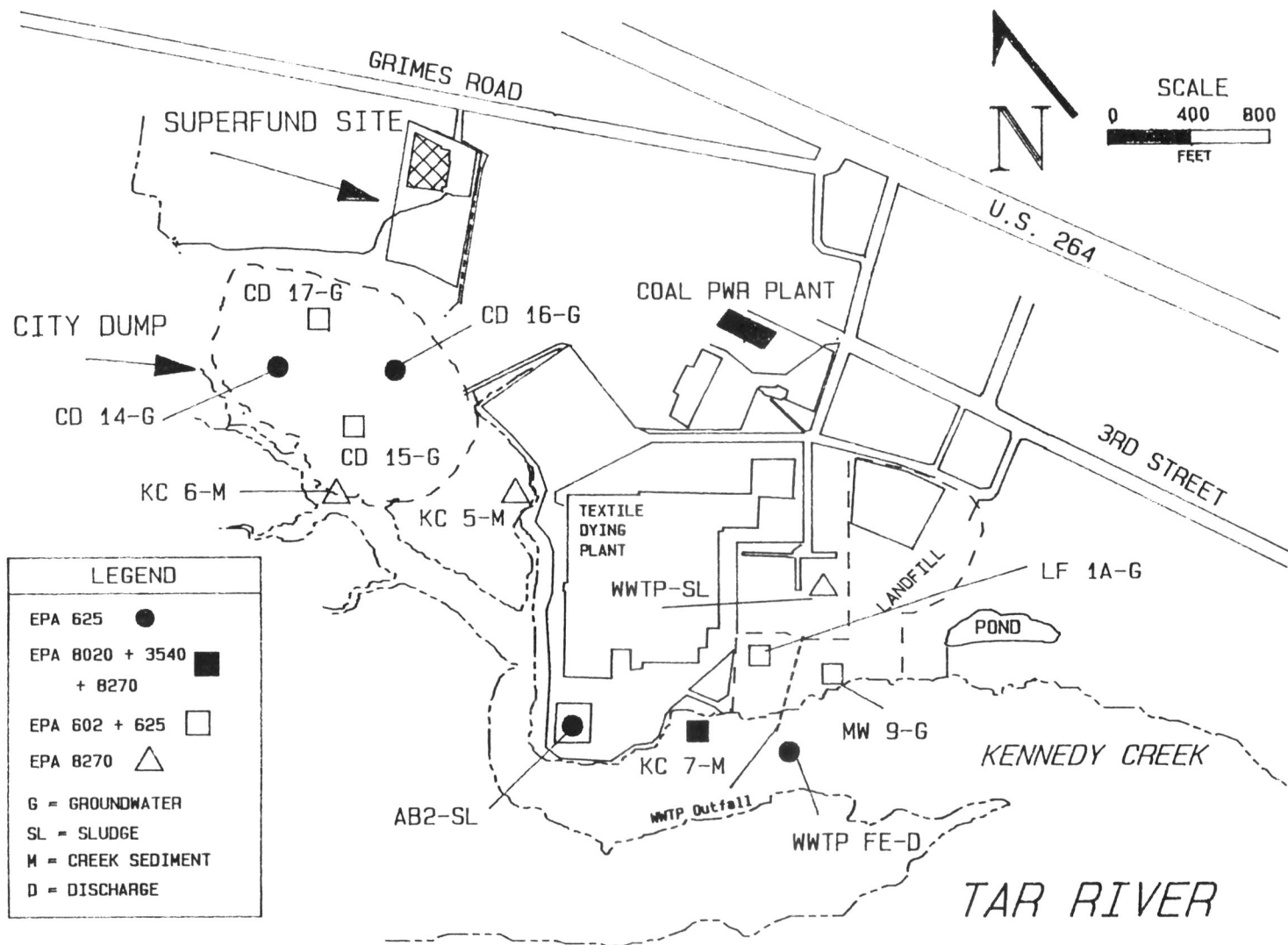


Figure 16. Locations and types of samples for organic Set #2 taken on 7/17/90 and sent to C&ET Inc. for analyses. See Appendix 4 for an explanation of EPA Methods.

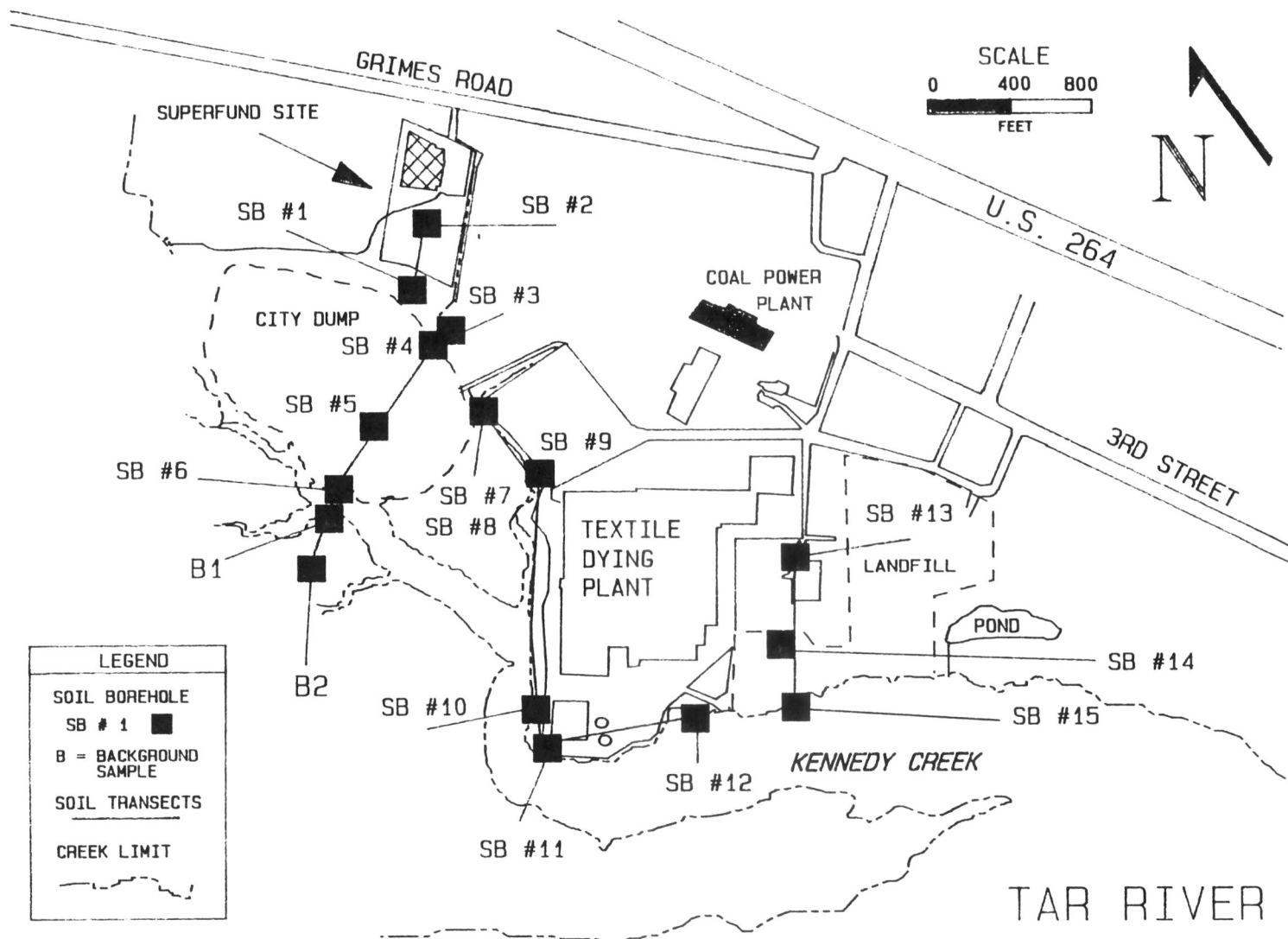


Figure 17. Soil sampling transects with borehole locations. Background soil boreholes, on the southside of Kennedy Creek, are labeled B1 and B2.

potential point sources; 2) delineate possible horizontal and vertical trends; and 3) illustrate possible variations in metal content in the vicinity of Kennedy Creek. Samples were collected in each boring at two foot intervals (where applicable). Each interval was homogenized, split, and refrigerated (4°C) after sampling. Soils were collected from borings B1 and B2, on the south side of Kennedy Creek (Fig. 17), in order to assess elemental "background" concentrations in an area presumed to be unaffected by anthropogenic point sources. Methods, accuracy, precision, limits of detection, and analytical results for each soil sample are listed in Appendix 5.

Results

Bottom Sediments

These are the first analyses for organic contaminants in Kennedy Creek bottom sediments. The analytical results indicate that organic contaminants are not present in amounts above detection limits (See Figs. 15 and 16 for sample locations and Appendix 4 for results).

Surface Water

Values for several metals in top and bottom surface water from Kennedy Creek are presented in Table 3. Arsenic, Cd, Cr, Cu, Ni, Pb, and Se concentrations are below detection limits in both samples. Sample KC-T contained Fe slightly above the NC-MCL (0.3 mg/L) and Mn close to the NC-MCL (0.05 mg/L).

Table 3. Heavy metal concentrations (total) in the top and bottom waters of Kennedy Creek (in ppm). Limits of detection (LOD) for all elements are listed in Appendix 3.

Element	KC-T	KC-B	LOD
As	BDL	BDL	0.066
Cd	BDL	BDL	0.003
Cr	BDL	BDL	0.003
Cu	BDL	BDL	0.007
Fe	* 0.522	BDL	0.423
Mn	0.042	0.036	0.007
Ni	BDL	BDL	0.008
Pb	BDL	BDL	0.026
Se	BDL	BDL	0.019
Zn	0.03	0.04	0.004

* Above NC-MCL

Groundwater

All groundwaters that are considered in excess of NC-MCL's are summarized in Table 4. Based on two sets of analyses and seventy-four samples, Fe and Mn concentrations account for 98% of the samples that exceed NC-MCL's.

Table 4. Summary of major and trace elements and organic constituents in excess of NC-MCL's for groundwater in ppm (mg/L). The values reported for Fe and Mn are averages (n=2) of groundwater Sets #1 and #2. All other values are actual, not averaged. Refer to Figs. 14, 15, 16, and 17 for sample locations.

Major and Trace Elements (ppm)			Organic Constituents (ppm)
Well #	Fe	Mn	
CD 7	0.5	0.06	NA
CD 8	1.6	0.09	NA
CD 9	5.2	0.27	NA
CD 10	0.34	0.23	NA
CD 13	1.6	0.56	NA
CD 14	94	0.89	BDL
CD 15	44	0.86	BDL
CD 16	37	0.29	PD ¹
CD 17	48	0.45	PD ²
LF 3	25	1.0	NA
LF 4	19	1.6	NA
LF 5	37	0.87	NA
*MW 9	28	1.2	BDL
MW 4	BDL	0.9	NA
Well #	Cd	Pb	
CD 2	0.015	0.360	NA

BDL = Below detection limit

NA = Not Analyzed

PD¹ = 0.028 ppm Bis(2-ethylhexyl) phthalate

PD² = 0.066 ppm Bis(2-ethylhexyl) phthalate

* Note - MW9 is not averaged (n=1) as a result of an error (groundwater Set#1) in the digestion procedure.

The highest Fe and Mn levels are in wells located in and around the City Dump and the Landfill. Averaged Fe concentrations in the City Dump site (Fig. 18) range from 30 to 100 ppm (100 to 300 times the NC-MCL); Mn values range from 0.4 to 1.0 ppm (9 to 20 times the NC-MCL). Groundwaters surrounding the City Dump and the Landfill contain Fe and Mn in the range of 0.5 to 8 ppm and 0.1 to 0.6 ppm, respectively. Away from the City Dump, Fe concentrations generally decline to less than 2 or 3 ppm and are lower in Fe than water pumped from the Castle Hayne aquifer at the Slatestone water facility operated by the City of Washington (J. Cuttler, Dir. Water Treatment Plant, pers. comm., 1990). Cadmium and Pb levels (0.015 ppm and 0.36 ppm, respectively) exceeded NC-MCL's (Cd, 0.004 ppm and Pb, 0.05 ppm) in well CD 2 (Fig. 17).

Analyses for organics in groundwater from the City Dump, Landfill, and Superfund sites revealed one compound above analytical detection limits (Table 4). This contaminant, Bis(2-ethylhexyl) phthalate, was found in wells CD 16 (28.1 ppb) and CD 17 (66.2 ppb) (Fig 17).

Bis(2-ethylhexyl) phthalate, a phthalate ester, is listed as #94 on the EPA's list of 129 priority pollutants. Phthalate esters may occur naturally (US EPA, 1977), but they are primarily synthesized for industrial use as

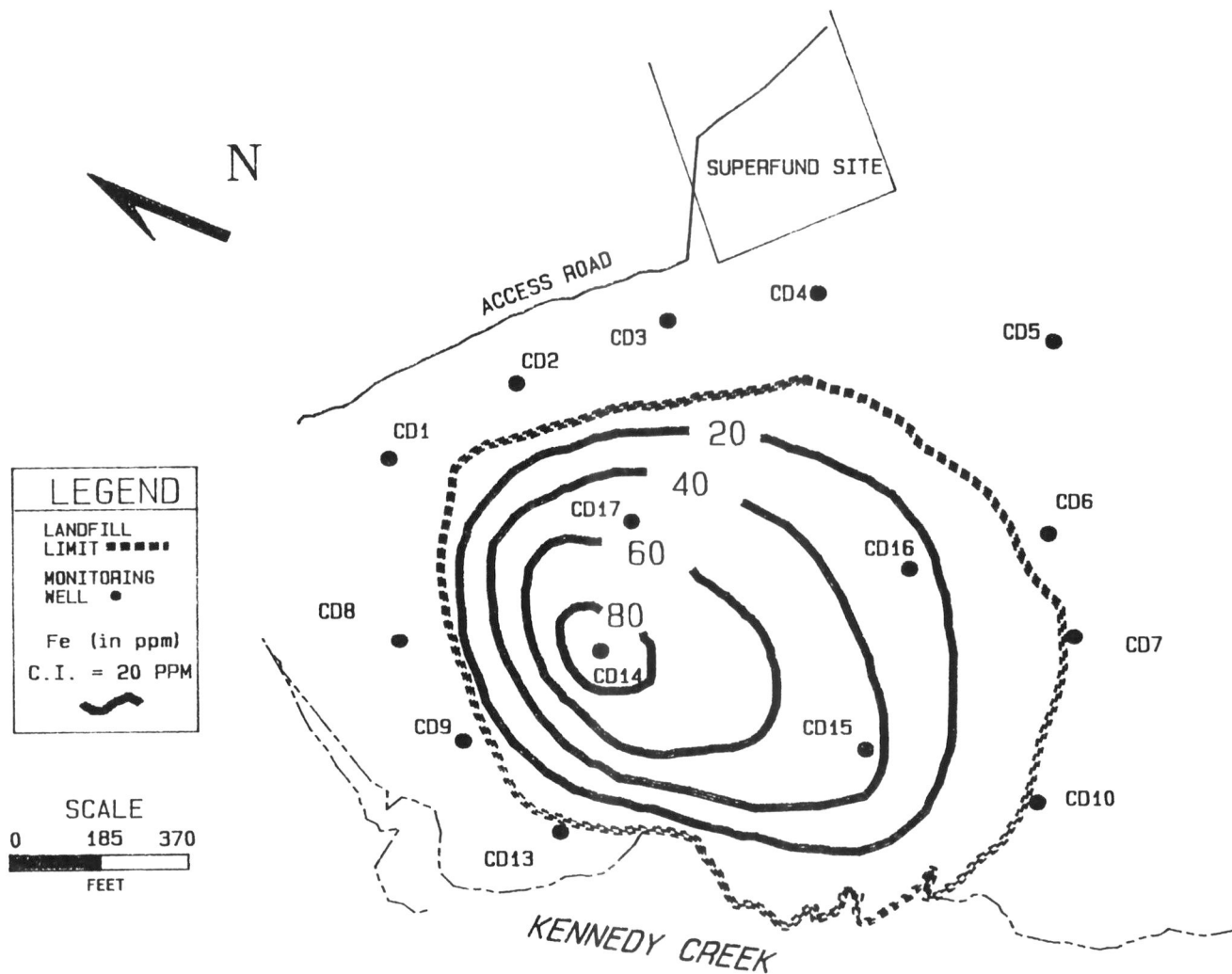


Figure 18. Isopleth map of averaged Fe values for groundwater in the City Dump. Contour interval is 20 ppm. Iron values were typically less than 2 to 3 ppm in groundwater away from the City Dump.

plasticizers or as an additive in vacuum pump oil. From discussions with private consultants, this contaminant is believed to be introduced into samples via plastic materials required as part of the sampling protocol (B. Nelson, Engineering Tectonics, P.A., pers. comm., 1990).

Soils

The peat cores showed a significant downward decrease in Cu, Fe, Mn, Pb, and Zn concentrations (Table 5) similar to results reported by Damman (1978). A semilog plot of elemental concentrations for borehole SB #4 (Table 5) versus depth is shown in Figure 19. In addition, Al, Cr, K, Mg, Ni, P, Ti, and V levels decreased with depth. Levels of Ca and Na increased with depth. Elevated levels of As, Hg, and Sn occurred in several upper sample intervals but no apparent downward trend was present. Mercury was detected in several peat samples in the range of 60 to 250 ppb. In SB #9 (Table 5), the peat also displays downward decreases in elemental concentrations; although now buried by three feet of sandy fill, this peat was once at the surface. Background samples (1B-4B) displayed similar trends in elemental distribution.

Elemental distributions for Cu, Fe, Mn, Pb, and Zn in selected boreholes. (in ppm)						
CORE DEPTH FROM LAND SURFACE (FEET)	0	SB # 3	SB # 4	SB # 6	0	SB #9
	2	Cu - 4.1 Fe - 2420 Mn - 26 Pb - 9 Zn - 17	Cu - 20 Fe - 6770 Mn - 43 Pb - 52 Zn - 180	Cu - 12.5 Fe - 8880 Mn - 85 Pb - 44 Zn - 190	1	Cu - 5.9 Fe - 4910 Mn - 44 Pb - 18 Zn - 34
	4	Cu - 1.5 Fe - 600 Mn - 9.7 Pb - 3 Zn - 5.9	Cu - 8 Fe - 3200 Mn - 35 Pb - 20 Zn - 76	Cu - 2.5 Fe - 4390 Mn - 48 Pb - 4 Zn - 13	3	Cu - 2.8 Fe - 3740 Mn - 16 Pb - 3 Zn - 16
	6	Cu - 1.8 Fe - 230 Mn - 5.5 Pb - 1 Zn - 2	Cu - 5.9 Fe - 3750 Mn - 16 Pb - 10 Zn - 44	Cu - 1.7 Fe - 2030 Mn - 47 Pb - 1 Zn - 5.1	FORMER EXPOSED PEAT	
	8		Cu - 1.4 Fe - 163 Mn - 5.7 Pb - 2 Zn - 7.1	Cu - 2.4 Fe - 2000 Mn - 35 Pb - 3 Zn - 15	5	Cu - 11 Fe - 10300 Mn - 100 Pb - 18 Zn - 45
	10		Cu - 1.8 Fe - 216 Mn - 13 Pb - 3 Zn - 7.6	Cu - 1.5 Fe - 1550 Mn - 16 Pb - 3 Zn - 6.1	7	Cu - 4.2 Fe - 7020 Mn - 60 Pb - 13 Zn - 11

Table 5. Soil borings SB # 3, 4, and 6 (See Fig. 18 for locations) show a vertical decrease in Cu, Fe, Mn, and Zn in peat. The seasonal water table fluctuates from 0 - 1 foot below land surface. SB #9 shows the same trend in peat formerly exposed at the surface. See Figure 19 for plot of SB #9.

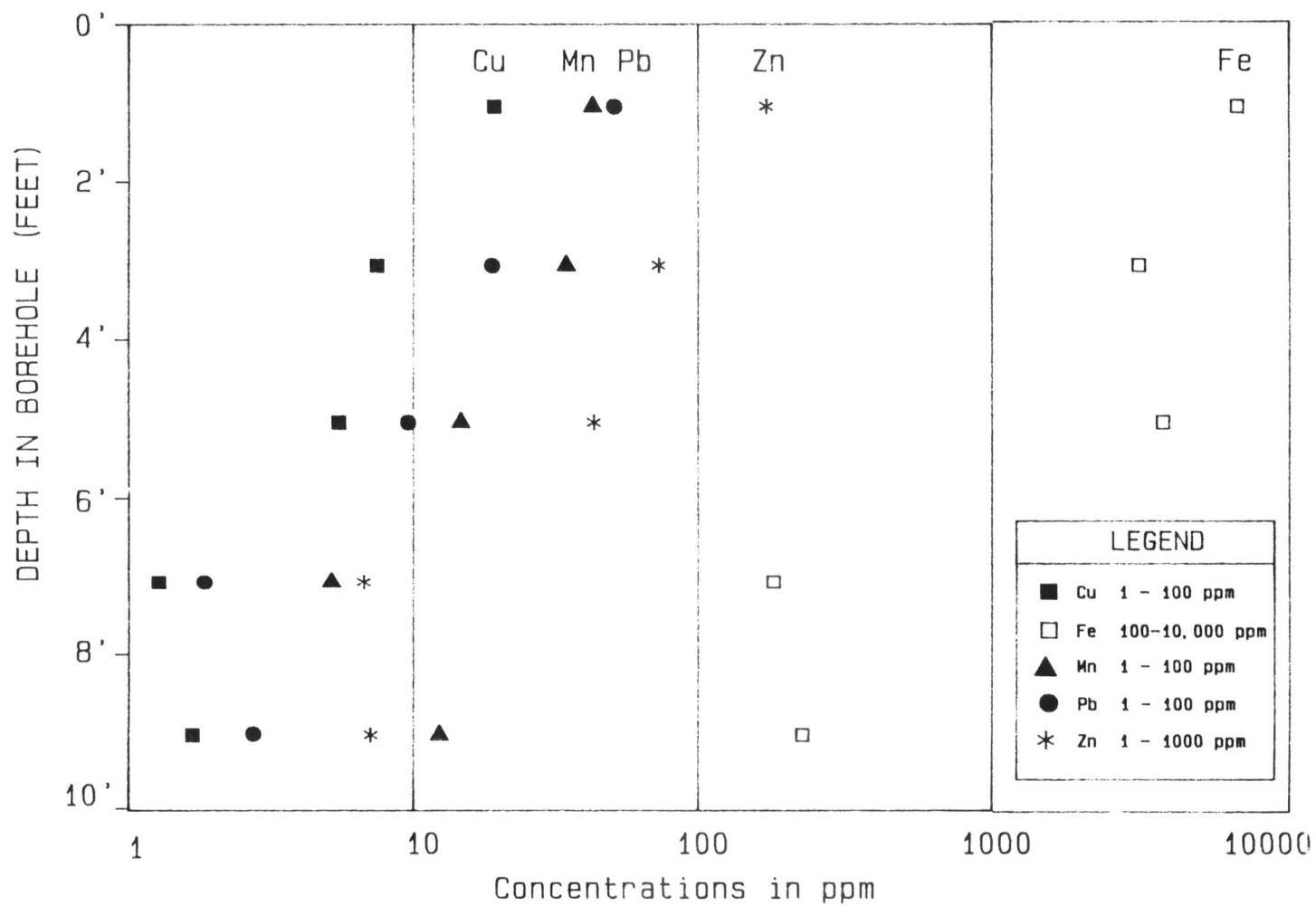


Figure 19. Vertical distribution of selected elements in peats from borehole SB #4. Values represent homogenized 2 foot intervals plotted at the midpoint of the sample interval. Location of SB #4 is shown in Figure 17.

Average and maximum elemental values for several trace elements in soils are presented in Table 6 with corresponding borehole, sample number, and soil type. Peat from beneath the City Dump, SPL 14, contained the highest levels of Cd, Ni, Sn, and Zn (Table 6). A sandy soil (fill), SPL 20, adjacent to the parking lot at the textile plant contained the highest Cu level (10 times the average) and elevated levels of Cr, Fe, Pb, V, and Zn. Background sample 4B, a peat collected across Kennedy Creek from the City Dump, contained the highest As level (Table 6).

Table 6. Average and maximum elemental values for trace elements in soil samples (in ppm). Soil borehole locations, sample number and type (Table 13) for maximum values are provided. A summary of average, maximum, and minimum major and trace elemental values for soils is presented in Table 15 (Appendix 5).

Element	Average (n=57)	Maximum Value	Soil Borehole	Sample #	Soil Type
As	3.4	38.5	SB #B2	SPL 4B	Peat
Cd	0.04	0.89	SB #5	SPL 14	Peat
Cr	6.5	33	SB #9	SPL 28	Peat
Cu	9.7	140	SB #7	SPL 20	Sand
* Hg	0.02	0.250	SB #6	SPL 15	Peat
Ni	1.8	5.5	SB #5	SPL 14	Peat
P	215	961	SB #7	SPL 20	Peat
Pb	7.7	52	SB #4	SPL 6	Peat
Sn	4.5	24	SB #5	SPL 14	Peat
Zn	26.7	200	SB #5	SPL 14	Peat

* Hg - (n=45)

SUMMARY AND CONCLUSIONS

The water table aquifer is characterized by Holocene swamp-forest peat deposits. Pleistocene to Recent sands and clays dominate the water table aquifer to the north. Hydraulic conductivities range from 4 to 5 ft/day for peats to 15 to 25 ft/day for sands. Average seepage velocities for peats are 0.031 ft/day and sands equal 0.19 ft/day. Groundwater flow patterns have been altered by the emplacement of two landfills and industrial plant expansion. A small, persistent "mound" in the water table is believed to be caused by a leaky wastewater treatment basin at the textile basin. Additional evaporation studies at the textile wastewater treatment basin are needed to assess whether or not the basin is leaking.

No geochemical evidence has been generated to suggest that contaminants from the wastewater treatment basin are entering the groundwater. However, mixing with ambient groundwater may be responsible for diluting any potential effluent to levels below analytical detection limits.

The water table aquifer and deeper aquifers may be connected in a transition zone between the uplands to the north and the wetlands adjacent to the creek. Lateral truncation of clays in the subsurface and upward decreasing head values in the water table aquifer suggest that Kennedy Creek receives discharge from the water table aquifer.

Persistent southeastern winds result in small scale flood events that create lower hydraulic gradients on the water table. As these wind-driven floods recede, hydraulic gradients steepen and discharge increases above the normal rate. The diurnal wind component on Kennedy Creek is attenuated by an order of magnitude in the water table aquifer within 25 feet from the creek.

EPA priority metals were not present in water from Kennedy Creek above analytical detection limits at the time of sample collection and analysis. The absence of Fe in the lower half of the water column may result from surface water oxidation and precipitation of Fe-Mn in oxides at the surface water/sediment interface (Lee and Jones, 1987).

Iron and Mn account for almost all cases in which metals in groundwater exceed NC-MCL's. Groundwater in wells located in and around the City Dump and Landfill contain the highest levels of Fe and Mn. The City Dump and Landfill may

have either progressed beyond acid fermentation stages or has not gotten there yet as evidenced by pH values from 6 to 7. Iron concentrations declined rapidly away from these sources. Less than 15 feet beyond the perimeter of the City Dump, concentrations of Fe decrease by one to two orders of magnitude. The rapid decline in Fe levels may result from one or more of the following: 1) the high CEC of the aquifer material (peat and clay); 2) dilution by ambient groundwater; 3) a decrease in the amount of complexing agents in the leachate by formation of precipitates; and 4) subtle changes in pH, dissolved oxygen, etc.

Organic analyses of leachate from two wells within the City Dump reveal that one EPA priority organic pollutant, Bis(2-ethylhexyl) phthalate (an ester), was present in the ppb range. This contaminant may be indicative of sampling and/or analytical materials used according to sampling protocol.

Peats are enriched in several elements in the uppermost sample interval. A sharp vertical geochemical gradient for the following elements Al, Cr, Cu, Fe, K, Mg, Mn, Ni, P, Pb, Ti, V, and Zn may be interpreted as a result of the presence of oxidizing conditions at the water table. Under these conditions, oxides of Fe and Mn readily form at the water table. This concentration of elements near the land surface

may be the result of the presence of a high water table, plant uptake ability, and/or the metal scavenging ability of Fe and Mn oxides. The result may be the accumulation and/or possible immobilization of several elements in peats adjacent to Kennedy Creek.

Data generated by this study suggests that presently no detectable amounts of contaminants are being introduced into Kennedy Creek from the groundwater system. However, this study did not adequately address the potential contribution of metals from coal fly ash and dust, urban run-off from parking lots, accidental or intentional chemical spills, long-term low-level input of metals below analytical detection limits, and abnormal conditions (large-scale storms, etc.).

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APPENDIX 1. Monitoring well logs.

Monitoring wells were constructed under guidelines of the NC Division of Environmental Management through permits 06-0214-WM-0173 and 06-0215-WM-0177.

Wells MW 1-8 were constructed under the auspices of the textile plant located within the study area. Wells MW 9 and 10 were constructed under the auspices of the City of Washington, North Carolina. Well locations are presented in Figure 3.

KEY -- CD = Wells located in and adjacent to the City Dump
 LF = Wells located in and adjacent to the Landfill
 MW = Wells located on textile plant property
 NOTE - All depths are feet.

<u>CD 1</u>		<u>CD 2</u>	
0-2	Brown clayey sand	0-5	Brown medium sand
2-4	Tan-orange to white-gray mottled sandy clay	5-5.9	Orange medium-fine sand
4-6	White-tan medium sand		
6-8.3	Orange medium-coarse sand		
<u>CD 3</u>		<u>CD 4</u>	
0-2	Brown-black medium sand	0-2	Brown-tan medium sand
2-4	Brown medium-fine sand	2-6	White medium-fine sand
4-5	Orange medium sand	6-7.5	Orange medium-coarse sand
5	Orange clay with shell fragments	7.5-8.2	Blue-green clay
<u>CD 5</u>		<u>CD 6</u>	
0-1	Brown medium sand	0-6.2	Peat
1-7	White-yellow medium-fine sand		

<u>CD 7</u>		<u>CD 8</u>	
0-8.2	Peat	0-8.9	Peat
<u>CD 9</u>		<u>CD 10</u>	
0-7.7	Peat	0-6.4	Peat
<u>CD 11</u>		<u>CD 12</u>	
0-0.5	Orange-brown clayey sand	0-1	Brown clayey sand
0.5-3	Orange-brown fine sand	1-2.5	Orange-brown sandy clay
3-5	Tan-yellow medium sand	2.5-4	Brown-yellow medium sand
5-6	Brown-orange medium sand	4-5.5	White-gray medium sand
6-8.5	White medium sand	5.5-8.5	Gray fine sand
8.5-9	Rusty orange medium sand	8.5-9.5	Rusty orange medium sand
9-11	Orange medium-coarse sand	9.5-11	Gray-fine sand
11-11.3	Orange clay with shell fragments	11-11.5	Orange-brown clay with shell fragments
<u>CD 13</u>		<u>CD 14</u>	
0-6.1	Peat	0-1.5	Sandy landfill cover
		1.5-9.3	Landfill debris
<u>CD 15</u>		<u>CD 16</u>	
0-1.5	Sandy landfill cover	0-1.5	Sandy landfill cover
1.5-5	Landfill debris	1.5-4.7	Landfill debris
5-8	Peat		
<u>CD 17</u>		<u>CD 18</u>	
0-1.5	Sandy landfill cover	0-6.7	Peat
1.5-8.4	Landfill debris		
<u>CD 19</u>		<u>CD 20</u>	
0-6.3	Peat	0-6.7	Peat

LF 1

0-2 Gray medium sand
with trash
2-4 Brown medium-fine
sand
4-6.5 White-yellow medium-
fine sand
6.5-7.5 White medium clayey
sand
7.5-8.6 Orange-brown clay

LF 2

0-3 Brown medium-fine
sand
3-4.5 Gray fine clayey
sand
4.5-7 White-gray fine
sand

LF 3

0-6 Landfill debris

LF 4

0-1 Sandy landfill
cover
1-6 Landfill debris
6-11 Yellow medium
sand

LF 5

0-1 Sandy landfill
cover
1-5 Landfill debris
5-11 Yellow medium
sand

MW 11

0-4 Fill sand with
trash
4-8 Peat

MW 12

0-6 * Yellow fine-
medium fill sand

MW 13

0-12 * Yellow fine-
medium fill sand

MW 14

0-6.5 * Yellow fine-
medium fill sand

MW 15

0-13 * Yellow fine-
medium fill sand

* Note - Fill sand refers to construction fill material
used to establish a suitable substrate for
building purposes.

Wells owned by textile plant - MW 1-8

MW 1

0-7 Light brown fine
to medium sand fill
7-15.5 Peat
15.5-17 Clay

MW 2

0-2 Light brown sand
fill with wood
fragments
2-17 Peat

MW 3

No records provided
but lithologies are
similar to MW 2
and MW 4

MW 4

0-2 Light grayish-brown
clayey fine sand fill
5-7 Lt. gray fine to
medium sand fill
10-17 Peat with thin
black medium sand
lens at 12.5

MW 5

0-2 Light grayish-brown
silty fine sand fill
5-7 Light gray medium
sand fill
10-12 Light gray fine to
medium sand
15-17 Gray silty fine
sand with shell
fragments

MW 6

0-7 Light brown to yellow
brown silty fine
sand fill with trash
10-12 Blue-gray and yellow-
brown sandy clay
with small shell
fragments
15-22 Light gray and yellow-
brown fine to med.
sand with shells
and thin clayey
lenses

MW 7

0-2 Gray-brown fine
sandy silt to coarse
sand fill
4-6 Lt. gray fine to
medium sand fill
6-16 Peat
18-21 Light-dark gray
fine to coarse sand
with shells

MW 8

0-2 Gray fine-medium
sand fill
5-16 Peat
16-17 Gray fine to medium
sand with shell
fragments

Wells owned by the City of Washington, NC

<u>MW 9 (Well B1)</u>		<u>MW 10 (Well B2)</u>	
0-0.5	Gray-brown fine to medium sand fill	0-2.5	Yellow-tan fine silty sand
0.5-3	Brown-gray fine to medium sand fill with debris	2.5-6	Tan, red, yellow fine silty sand
3-9	Gray-black fine to medium sand with silty clay and wood fill	6-8.5	Orange-red to tan fine to medium silty sand
9-14	Brown to gray black fine-medium sandy silt	8.5-14	Brown-tan fine to coarse sand with some small gravel
14-15	Gray brown fine-medium-coarse silty sand	14-15	Gray to tan-brown fine to medium sandy silty clay

APPENDIX 2. Head values in monitoring wells.

Head values are in feet above mean sea level.

Well #	Date of data collection					
	12/18/89	1/15/90	1/28/90	2/14/90	3/6/90	3/16/90
CD 1	1.37	1.74	1.47	1.3	1.16	1.02
CD 2	1.48	1.94	1.56	1.42	1.27	1.15
CD 3	1.73	2.2	1.88	1.74	1.58	1.5
CD 4	1.89	2.39	2.1	2.01	1.9	1.74
CD 5	1.89	1.81	2.17	2.12	2.01	1.84
CD 6	1.59	1.65	1.67	1.54	1.62	1.43
CD 7	1.34	1.29	1.2	1.18	1.32	1.21
CD 8	1.57	1.58	1.5	1.52	1.53	1.4
CD 9	1.46	1.46	1.33	1.33	1.36	1.27
CD 10	1.28	1.15	1.11	1.05	1.21	1.06
CD 11	2.21	2.92	2.58	2.42	2.25	2.12
CD 12	1.96	2.7	2.41	2.22	2.08	1.96
CD 13	1.17	1.16	1.08	1.09	1.14	1.09
CD 14	1.87	1.89	1.64	1.66	1.77	1.57
CD 15	1.72	1.7	1.49	1.5	1.63	1.39
CD 16	2	2.02	1.78	1.8	1.9	1.64
CD 17	1.78	1.78	1.58	1.59	1.69	1.49
CD 18	6.21	0	6.21	1.2	1.28	1.12
CD 19	6.15	0	6.15	0.92	1.07	0.94
CD 20	5.76	0	5.76	0.77	0.84	0.71
LF 1	0.87	0.99	0.63	0.52	0.82	0.73
LF 2	1.02	1.25	1.06	0.78	1.11	1.03
LF 3	1.44	1.44	1.11	1.1	1.35	1.14
LF 4	2.2	2.52	2.23	2.13	2.18	2.06
LF 5	2.01	2.38	1.95	1.76	1.81	1.67
MW 1	2.48	2.46	2.26	2.18	2.24	2.63
MW 2	0.87	0.55	0.33	0.29	0.79	0.72
MW 3	1.72	2.07	1.37	1.33	1.6	1.5
MW 4	1.13	0.87	0.51	0.48	1.04	0.89
MW 5	0.83	0.73	0.49	0.45	0.86	0.67
MW 6	0.61	0.6	0.33	0.42	0.7	0.55
MW 7	0.93	0.7	0.47	0.5	0.84	0.77
MW 8	1.22	1.19	1.19	0.9	1.01	0.83
MW 9	1.12	1.11	0.94	0.93	1.3	1
MW 10	2.1	2.65	2.45	2.22	2.17	2.13

Date of data collection						
Well #	4/1/90	4/4/90	4/22/90	5/1/90	5/24/90	6/8/90
CD 1	1.21	1.27	1.25	1.12	0.95	1.09
CD 2	1.54	1.58	1.4	1.26	1.09	1.19
CD 3	1.84	1.9	1.7	1.56	1.34	1.47
CD 4	2.09	2.08	1.82	1.75	1.56	1.47
CD 5	2.14	2.15	1.83	1.78	1.52	1.5
CD 6	1.84	1.71	1.4	1.68	1.68	1.11
CD 7	1.52	1.4	1.27	1.07	1.48	1.2
CD 8	1.55	1.57	1.48	1.38	1.5	1.26
CD 9	1.55	1.46	1.28	1.19	1.33	1.18
CD 10	1.41	1.31	1.15	1.11	1.33	1.05
CD 11	2.4	2.44	2.3	2.11	1.88	2.04
CD 12	2.27	2.27	2	1.85	1.52	1.61
CD 13	1.26	1.13	1.07	1.03	1.14	0.99
CD 14	2.16	2.08	1.63	1.49	1.48	1.63
CD 15	2.26	2.04	1.37	1.3	1.2	1.26
CD 16	2.5	2.3	1.61	1.44	1.34	1.5
CD 17	2.06	1.98	1.52	1.44	1.44	1.51
CD 18	1.46	1.32	1.26	1.29	1.39	1.11
CD 19	1.31	1.08	1.06	1.04	1.19	0.8
CD 20	1.12	0.89	0.82	0.84	1.04	0.44
LF 1	1.37	1.4	0.8	0.74	0.55	0.61
LF 2	1.39	1.39	0.98	0.96	0.8	0.83
LF 3	2.04	1.85	1.22	1.12	1.3	1.46
LF 4	2.53	2.48	2.01	1.99	1.95	2
LF 5	2.45	2.48	1.76	1.53	1.53	1.94
MW 1	2.57	2.59	2.19	2.24	2.27	2.37
MW 2	1.19	0.52	0.51	0.85	1.03	0.57
MW 3	1.94	1.54	1.28	1.62	1.72	1.55
MW 4	1.5	0.86	0.72	1.04	1.27	0.86
MW 5	1.14	0.89	0.63	0.84	0.88	0.54
MW 6	0.85	0.81	0.64	0.72	0.64	0.36
MW 7	1.14	0.56	0.63	0.8	0.96	0.52
MW 8	1.35	1.02	0.94	1.12	1.13	0.76
MW 9	2.01	1.65	0.87	1.00	1.4	0.83
MW 10	2.02	2.06	1.72	1.52	1.2	1.46
MW 11			1.66	2.11	2.2	1.82
MW 12				2.22	2.24	2.35
MW 13				2.31	2.34	2.46
MW 14				2.29	2.29	2.42
MW 15				2.39	2.4	2.54
P1				2.37	2.38	2.53
P2				2.38	2.39	2.52

Date of data collection			
Well #	6/22/90	7/6/90	7/24/90
CD 1	0.91	0.83	0.6
CD 2	0.97	1.78	0.62
CD 3	1.1	0.9	0.76
CD 4	1.01	0.79	0.92
CD 5	1.07	0.97	0.93
CD 6	1.09	0.66	1.31
CD 7	1.25	0.95	0.82
CD 8	1.24	0.68	0.82
CD 9	1.25	0.87	0.81
CD 10	1.25	0.92	0.84
CD 11	1.71	1.63	1.27
CD 12	1.27	1.1	0.96
CD 13	1.15	0.68	0.81
CD 14	1.24	1.04	1.02
CD 15	0.84	0.59	0.64
CD 16	0.96	0.73	0.87
CD 17	1.12	0.91	0.91
CD 18	1.41	1.19	1.01
CD 19	1.17	0.99	0.79
CD 20	1.05	0.68	0.58
LF 1	0.36	0.37	0.31
LF 2	0.63	0.52	0.39
LF 3	1.08	0.74	0.78
LF 4	1.59	1.4	1.28
LF 5	1.27	1.04	0.91
MW 1	2.15	1.98	2.69
MW 2	0.96	0.43	0.82
MW 3	1.57	1.16	1.76
MW 4	1.15	0.49	1.2
MW 5	0.64	0.41	0.65
MW 6	0.39	0.44	0.48
MW 7	0.95	0.34	0.92
MW 8	0.93	0.56	0.82
MW 9	0.69	0.45	0.5
MW 10	1.07	0.93	0.75
MW 11	1.51	1.3	1.89
MW 12	2.1	1.97	2.59
MW 13	2.22	2.1	1.9
MW 14	2.16	2.04	2.85
MW 15	2.28	1.82	2.37
P1	2.26	2.11	2.87
P2	2.27	2.11	2.85

APPENDIX 3. Analytical methods, accuracy, precision, detection limits, and raw data for ground-water Set #1 and #2 and surface water from Kennedy Creek.

Samples were analyzed in the Laboratories of Elemental Analytical Group at the ECU School of Medicine under the direction of Dr. John Bray. Inductively coupled argon plasma emission spectroscopy (ICAPES) and atomic absorption spectrometry (AAS) techniques were utilized in this study. Elements, analytical procedures, and instrumentation are summarized in the Table 7.

The ICAPES instrument was a Jarrell-Ash Plasma Atom-comp (Mark II System) modified with the Ward Scientific, Ltd., WICS and MDA (Multiple Data Acquisition) hardware and software upgrades. Analyses were made with a six point, simultaneous scan of all elemental profiles to provide on-peak and off-peak (baseline) readings for each element. The ICAPES instrument was calibrated with appropriate matrix matched multi-element standards in order to correct for inter-element interferences. Wavelengths for elemental analyses with ICAPES are listed in Table 8.

Samples were analyzed for Hg by AAS according to the manual cold vapor technique (US EPA, 1986) referred to hereafter as cold vapor atomic absorption (CVAA). The CVAA instrument used was a Instrumentation Laboratories Atomic

Absorption Spectrophotometer Model 951, modified with a commercially available cold vapor generator (IL model AVA 440).

Methods for the analyses of groundwater in this study are described in "Test Methods for Evaluating Solid Waste" (EPA, 1986). Slight modifications were made to Methods 3010 and 7470. These modifications include the following: 1) 100 mL tubes were used instead of Griffin beakers; 2) a heating block was used in place of a hot plate; and 3) the final dilution resulted in a five fold concentration of the digestate over that original sample concentration.

Table 7. Elements, analytical procedures, and instrumentation for groundwater samples.

ELEMENT(S)	ANALYTICAL PROCEDURE	INSTRUMENT
Hg	EPA Method 7470	CVAA
<u>Major</u> Al, Ca, Fe, K, Mg, Mn, Na, and Si	EPA Method 3010	ICAPES
<u>Trace</u> As, Be, Cd, Co, Cr, Cu Li, Mo, Ni, P, Pb, Se Sn, Ti, U, V, Y, and Zn	EPA Method 3010	ICAPES

Table 8. Wavelengths (in nm) used for elemental analyses with ICAPES.

Element	Wavelength	Element	Wavelength
Al	308.2	Na	588.9
As	193.6	Ni	231.6
Be	234.8	P	213.6
Ca	317.9	Pb	220.3
Cd	228.8	Se	196.0
Co	228.6	Si	288.1
Cr	267.7	Sn	283.9
Cu	324.7	Ti	334.9
Fe	259.9	U	385.9
K	766.5	V	292.4
Li	670.7	Y	371.0
Mg	279.5	Zn	213.8
Mn	257.6		

GROUNDWATER SET #1

Overall, accuracy for all elements was +/- 10%, based on percent recovery of known concentrations of standards, except for K, Mg, Se and Ni. Concentrations for K and Mg in both sets of samples were one-half the values provided with the NBS (National Bureau of Standards) Standard 1643b - Trace Elements in Water. Poor Se results are common and probably a function of volatility and/or spectral interferences. Values for Ni have been consistently low for this study.

Accuracy was calculated by subtracting blank corrected standard concentrations from NBS controls divided by the NBS controls. Accuracy's are expressed as percent recovered from the NBS control. Precision was expressed as two times the standard deviation about the mean concentrations for the NBS controls. Lower limit of detection is defined as two times the standard deviation about the mean of the blanks. Accuracy, precision, and limit of detection for groundwater Set #1 are listed in Table 9.

Groundwater Set #1 was analyzed for Hg and all samples were below detection. The lower limit of detection for Hg was 0.5 ppb. Groundwater Set #2 was not analyzed for Hg based on results obtained from Set #1.

Table 9. Accuracy, precision, and detection limits for Set #1.

	Accuracy	Precision		Lower Limit of Detection
ELEMENT	% RECOVERED FROM NBS CONTROLS	NBS STANDARD 1643 MEAN	(n=3) (2 X SD)	Blanks (n=9) (2 X SD)
Al	NA	NA	NA	0.05
As	106	0.052	0.004	0.098
Be	95	0.018	0.003	0.001
Ca	94	32.914	6.438	0.218
Cd	70	0.014	0.004	0.007
Co	96	0.025	0.005	0.003
Cr	NA	NA	NA	0.002
Cu	96	0.021	0.003	0.012
Fe	99	0.098	0.014	0.064

Table 9. continued

K	51	1.53	0.496	1.878
Li	NA	NA	NA	0.015
Mg	53	7.896	1.478	0.83
Mn	79	0.022	0.006	0.007
Mo	92	0.078	0.023	0.004
Na	101	8.052	1.035	0.553
Ni	63	0.031	0.01	0.041
P	NA	NA	NA	0.3
Pb	97	0.023	0.009	0.019
Se	62	0.006	0.007	0.038
Si	NA	NA	NA	1.279
Sn	NA	NA	NA	0.051
Ti	NA	NA	NA	0.002
U	NA	NA	NA	0.076
V	93	0.042	0.007	0.001
Y	NA	NA	NA	0.001
Zn	91	0.06	0.013	0.024

NA = Not Analyzed

RAW DATA SET #1

Collected December 22-23, 1990 Analyzed February 15, 1990. Samples followed by an "A, B, or C" are lab controls. Sample LF 1U was not filtered.

BDL = Below Detection Limit

Elements reported as ppm.							
Well #	CD1	CD2	CD3	CD4	CD5	CD6	CD7
Element							
Al	BDL	0.061	0.838	BDL	BDL	BDL	BDL
As	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Be	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Ca	7.3	17.1	8.0	18.4	7.9	31.8	78.6
Cd	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Co	BDL	BDL	BDL	0.007	BDL	BDL	BDL
Cr	BDL	BDL	0.003	BDL	BDL	BDL	BDL
Cu	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Fe	BDL	BDL	0.6	BDL	BDL	0.4	0.5
K	2.9	6.3	10.4	7.1	4.5	4.3	8.9
Li	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Mg	1.0	2.7	1.4	1.7	1.2	6.0	9.6
Mn	0.011	BDL	0.018	0.032	BDL	0.031	0.040
Mo	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Na	2.2	34.4	116	3.0	2.2	112	115
Ni	BDL	BDL	BDL	BDL	BDL	BDL	BDL
P	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Pb	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Se	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Si	BDL	2.2	2.0	2.1	1.1	1.1	2.0
Sn	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Ti	BDL	BDL	0.017	BDL	BDL	BDL	BDL
U	BDL	BDL	BDL	BDL	BDL	BDL	BDL
V	BDL	BDL	0.003	BDL	BDL	BDL	BDL
Y	BDL	0.002	0.003	BDL	0.002	BDL	BDL
Zn	0.046	BDL	0.037	BDL	0.114	BDL	BDL

Elements reported as ppm.

Well #	CD8	CD9	CD10	CD11	CD12	CD13	CD14	CD15
Element								
Al	BDL	BDL	BDL	BDL	BDL	BDL	0.136	BDL
As	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Be	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Ca	70.4	82.3	19.5	15.7	19.7	126	176	85.0
Cd	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Co	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Cr	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Cu	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Fe	0.9	2.3	0.2	BDL	BDL	1.4	88.9	31.2
K	5.7	8.9	5.5	4.3	3.0	21.0	9.5	5.0
Li	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Mg	5.6	11.5	14.5	1.2	1.0	23.4	14.7	7.6
Mn	0.043	0.2	0.13	BDL	BDL	0.53	1.08	0.81
Mo	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Na	112	117	117	1.1	1.9	190	29.2	22.7
Ni	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
P	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Pb	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Se	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Si	2.1	2.5	2.1	BDL	BDL	3.0	BDL	2.8
Sn	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Ti	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
U	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
V	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Y	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Zn	BDL	BDL	BDL	BDL	BDL	0.022	0.053	BDL

Elements reported as ppm.

Well #	CD16	CD17	CD18	CD19	CD20	CD1R	CD6R	MW1
Element								
Al	BDL	BDL	BDL	0.078	0.059	BDL	BDL	BDL
As	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Be	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Ca	38.6	208	65.5	34.7	30.5	13.6	53.3	21.3
Cd	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Co	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Cr	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Cu	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Fe	0.2	53.1	BDL	0.4	0.1	BDL	0.8	2.0
K	BDL	18.7	15.5	14.9	13.0	5.7	9.1	BDL
Li	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Mg	1.9	19.8	20.3	28.1	27.0	1.8	10.3	1.6
Mn	0.07	0.55	0.04	0.13	0.09	0.02	0.06	0.04

Elements reported as ppm.

Well #	CD16	CD17	CD18	CD19	CD20	CD1R	CD6R	MW1
Element								
Mo	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Na	7.1	47.7	398	398	364	4.1	222	24
Ni	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
P	BDL	BDL	0.374	BDL	BDL	BDL	0.332	BDL
Pb	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Se	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Si	BDL	BDL	2.0	1.8	BDL	2.0	2.6	3.1
Sn	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Ti	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
U	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
V	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.002
Y	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Zn	0.029	0.026	BDL	BDL	BDL	0.024	BDL	BDL

Elements reported as ppm.

Well #	MW2	MW3	MW4	MW5	MW6	MW7	MW8
Element							
Al	BDL	BDL	0.083	BDL	BDL	BDL	0.106
As	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Be	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Ca	197	71.9	112	87.1	107	33.4	79.5
Cd	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Co	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Cr	0.004	BDL	BDL	BDL	BDL	BDL	BDL
Cu	BDL	BDL	0.013	BDL	BDL	BDL	BDL
Fe	3.5	12.5	0.1	22.5	0.7	0.8	5.8
K	38.1	3.9	5.4	11.3	7.1	4.0	4.0
Li	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Mg	181.6	6.2	5.1	7.7	5.8	10.7	8.5
Mn	0.703	0.456	0.155	0.118	0.619	0.097	0.210
Mo	BDL	BDL	BDL	BDL	BDL	0.009	BDL
Na	3240	47.6	4.3	82.9	42.2	65.4	34.4
Ni	BDL	BDL	BDL	BDL	BDL	BDL	BDL
P	BDL	0.873	BDL	BDL	BDL	BDL	BDL
Pb	BDL	BDL	BDL	BDL	BDL	BDL	0.021
Se	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Si	BDL	1.6	2.6	2.2	3.0	2.7	2.2
Sn	0.247	BDL	BDL	BDL	BDL	BDL	BDL
Ti	BDL	BDL	BDL	BDL	BDL	BDL	0.003
U	BDL	BDL	BDL	BDL	BDL	BDL	BDL
V	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Y	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Zn	BDL	BDL	BDL	BDL	BDL	0.065	BDL

Elements reported as ppm.

Well #	MW10	LF1A	LF1B	LF1C	LF1U	LF2	LF3
Element							
Al	BDL	0.073	0.099	0.087	44.22	BDL	BDL
As	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Be	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Ca	61.4	166	170	167	170	36.7	135
Cd	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Co	BDL	BDL	BDL	BDL	0.008	BDL	BDL
Cr	BDL	BDL	BDL	BDL	0.037	BDL	BDL
Cu	BDL	BDL	BDL	BDL	0.059	BDL	BDL
Fe	BDL	0.1	0.1	BDL	22.7	BDL	18.3
K	2.3	3.6	4.0	4.2	4.0	2.8	14.1
Li	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Mg	8.2	7.0	7.3	7.0	7.5	1.9	14.9
Mn	0.003	BDL	BDL	BDL	0.108	BDL	1.09
Mo	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Na	9.5	80	88.6	88.7	78.8	10.6	38.6
Ni	BDL	BDL	BDL	BDL	BDL	BDL	BDL
P	BDL	BDL	BDL	BDL	0.996	BDL	BDL
Pb	BDL	BDL	BDL	BDL	0.036	BDL	BDL
Se	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Si	BDL	BDL	BDL	BDL	1.7	BDL	1.4
Sn	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Ti	BDL	BDL	BDL	BDL	0.424	BDL	BDL
U	BDL	BDL	BDL	BDL	BDL	BDL	BDL
V	BDL	BDL	BDL	BDL	0.056	BDL	BDL
Y	BDL	BDL	BDL	BDL	0.025	0.001	BDL
Zn	0.033	0.052	0.072	BDL	0.062	BDL	BDL

Elements reported as ppm.

Well #	LF4	LF5	Well #	LF4	LF5
Element			Element		
Al	BDL	BDL	Mo	0.007	BDL
As	BDL	BDL	Na	6.6	51.9
Be	BDL	BDL	Ni	BDL	BDL
Ca	344	158	P	BDL	BDL
Cd	BDL	BDL	Pb	BDL	BDL
Co	BDL	BDL	Se	BDL	BDL
Cr	BDL	BDL	Si	BDL	BDL
Cu	BDL	BDL	Sn	BDL	BDL
Fe	6.6	41.2	Ti	BDL	BDL
K	9.9	6.2	U	BDL	BDL
Li	BDL	BDL	V	BDL	BDL
Mg	17.6	10.0	Y	BDL	BDL
Mn	1.84	1.2	Zn	0.293	0.137

GROUNDWATER SET #2

Accuracy, precision, and limit of detection are listed for groundwater Set #2 in Table 10 followed by raw data for each sample. All methods and modifications stated above for Set #1 are applied to Set #2. Set #2 contains surface water samples KC-T and KC-B.

Table 10. Accuracy, precision and limits of detection for groundwater Set #2.

ELEMENT	Accuracy	Precision		LOD
	% RECOVERED FROM NBS CONTROLS	NBS STANDARD 1643 MEAN	(n=3) (2 X SD)	Blanks (n=9) (2 X SD)
Al	NA	NA	NA	0.066
As	111	0.0542	0.015	0.075
Be	95	0.0181	0.001	0.0
Ca	100	35.1207	2.69	0.069
Cd	78	0.0155	0.002	0.003
Co	96	0.025	0.002	0.005
Cr	NA	NA	NA	0.003
Cu	95	0.0207	0.002	0.007
Fe	57	0.0564	0.029	0.423
K	55	1.6521	0.374	0.58
Li	NA	NA	NA	0.002
Mg	54	8.0691	0.553	0.008
Mn	76	0.0214	0.002	0.007
Mo	100	0.0848	0.007	0.001
Na	104	8.3054	0.401	0.799
Ni	69	0.0337	0.003	0.008
P	NA	NA	NA	0.031
Pb	82	0.0195	0.009	0.026
Se	67	0.0065	0.002	0.019
Si	NA	NA	NA	1.704
Ti	NA	NA	NA	0.001
U	NA	NA	NA	0.012
V	92	0.0417	0.002	0.001
Y	NA	NA	NA	0.001
Zn	93	0.0614	0.006	0.004

NA = not analyzed

RAW DATA SET #2

Collected: May 26, 1990 Analyzed: June 5-6, 1990

Elements reported as ppm.							
Well #	CD1	CD2	CD3	CD4	CD4A	CD4B	CD5
Element							
Al	BDL	0.127	0.117	BDL	BDL	BDL	BDL
As	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Be	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Ca	15.8	23.5	4.7	21.2	20.7	21.7	9.6
Cd	BDL	0.015	BDL	BDL	BDL	BDL	BDL
Co	BDL	BDL	BDL	0.011	0.010	0.011	BDL
Cr	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Cu	0.011	BDL	BDL	BDL	BDL	BDL	BDL
Fe	BDL	BDL	BDL	BDL	BDL	BDL	BDL
K	4.8	9.1	7.4	7.0	6.7	7.1	4.7
Li	BDL	0.002	BDL	0.002	BDL	BDL	BDL
Mg	2.0	4.3	1.3	2.0	2.0	2.1	1.3
Mn	0.008	0.026	BDL	0.033	0.032	0.033	BDL
Mo	BDL	BDL	0.002	BDL	BDL	BDL	BDL
Na	4.8	5.0	73.7	2.9	2.9	3.0	3.0
Ni	BDL	BDL	BDL	BDL	BDL	BDL	BDL
P	0.03	0.05	0.23	0.04	0.03	BDL	0.03
Pb	BDL	0.365	BDL	BDL	BDL	BDL	BDL
Se	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Si	3.25	2.65	2.28	2.87	2.91	2.07	BDL
Ti	BDL	0.009	0.003	BDL	BDL	BDL	BDL
U	BDL	BDL	BDL	BDL	BDL	BDL	BDL
V	BDL	BDL	0.002	BDL	BDL	BDL	BDL
Y	BDL	0.001	BDL	BDL	BDL	BDL	0.002
Zn	0.019	0.064	0.023	0.018	0.031	0.032	0.072

Elements reported as ppm.							
Well #	CD6	CD7	CD8	CD9	CD10	CD11	CD12
Element							
Al	BDL	BDL	BDL	BDL	BDL	BDL	BDL
As	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Be	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Ca	21.9	133	172	152	52.1	25.3	18.7
Cd	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Co	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Cr	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Cu	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Fe	BDL	0.6	2.3	8.1	0.5	BDL	BDL
K	6.4	15.4	13.5	12.6	15.3	6.0	3.1
Li	BDL	BDL	BDL	0.006	BDL	0.002	BDL
Mg	3.6	15.3	12.1	22.6	37.7	1.7	0.9

Elements reported as ppm.

Well #	CD6	CD7	CD8	CD9	CD10	CD11	CD12
Element							
Mn	0.019	0.094	0.134	0.335	0.319	BDL	BDL
Mo	BDL	BDL	BDL	BDL	BDL	0.002	BDL
Na	133	335	275	142	345	1.4	4.8
Ni	BDL	BDL	BDL	BDL	BDL	BDL	BDL
P	0.42	0.10	0.11	0.08	0.31	0.90	0.04
Pb	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Se	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Si	2.87	4.37	2.43	2.26	BDL	BDL	BDL
Ti	BDL	BDL	BDL	BDL	BDL	BDL	BDL
U	BDL	BDL	BDL	BDL	BDL	BDL	BDL
V	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Y	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Zn	0.015	0.002	0.027	0.036	BDL	0.018	0.016

Elements reported as ppm.

Well #	CD13	CD14	CD15	CD16	CD16A	CD16B	CD17
Element							
Al	BDL	BDL	BDL	BDL	BDL	BDL	BDL
As	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Be	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Ca	151	166	136	193	197	187	179
Cd	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Co	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Cr	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Cu	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Fe	1.8	100.0	57.4	49.9	50.4	48.3	44.1
K	19.3	10.1	9.5	6.5	6.7	6.5	13.0
Li	0.004	0.002	0.004	0.002	BDL	BDL	0.004
Mg	27.2	14.2	12.2	11.5	11.6	11.2	17.0
Mn	0.605	0.702	0.919	0.513	0.521	0.499	0.358
Mo	BDL	0.001	BDL	BDL	BDL	BDL	BDL
Na	136	33.6	20.7	21.2	21.2	20.7	39.1
Ni	BDL	BDL	BDL	BDL	BDL	BDL	BDL
P	0.04	BDL	BDL	0.03	0.04	0.04	0.09
Pb	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Se	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Si	2.60	2.30	3.21	1.87	BDL	2.13	1.80
Ti	BDL	BDL	BDL	BDL	BDL	BDL	BDL
U	BDL	BDL	BDL	BDL	BDL	0.015	BDL
V	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Y	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Zn	0.015	0.014	0.015	0.023	0.010	0.016	0.042

Elements reported as ppm.

Well #	CD18	CD19	CD20	MW1	MW1B	MW2	MW3
Element							
Al	0.063	0.187	0.175	BDL	BDL	BDL	BDL
As	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Be	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Ca	45.1	17.7	11.5	13.7	13.6	134	61.6
Cd	BDL	BDL	BDL	BDL	BDL	0.003	BDL
Co	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Cr	BDL	BDL	BDL	BDL	BDL	0.003	BDL
Cu	BDL	BDL	BDL	0.007	BDL	BDL	0.009
Fe	BDL	BDL	BDL	0.8	1.0	1.6	10.4
K	11.4	10.1	8.0	0.9	0.8	31.2	4.4
Li	0.002	BDL	BDL	0.002	BDL	0.004	0.003
Mg	14.1	13.2	10.4	0.5	0.5	161.1	4.9
Mn	0.029	0.049	0.037	0.007	0.007	0.487	0.329
Mo	BDL	BDL	BDL	0.002	0.002	BDL	BDL
Na	322	292	214	5.6	5.6	2910	96.2
Ni	BDL	BDL	BDL	BDL	BDL	BDL	BDL
P	0.62	0.36	0.47	1.91	1.86	0.20	1.38
Pb	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Se	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Si	2.17	2.86	3.55	2.26	1.71	5.38	4.96
Ti	BDL	0.003	0.002	BDL	BDL	BDL	BDL
U	BDL	BDL	BDL	BDL	BDL	BDL	BDL
V	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Y	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Zn	0.008	0.019	0.011	0.025	0.045	0.037	0.010

Elements reported as ppm.

Well #	MW4	MW5	MW6	MW8	MW9	MW10	MW11
Element							
Al	BDL	BDL	BDL	BDL	BDL	BDL	0.115
As	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Be	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Ca	103	72.7	215	64.4	168	33.3	93.7
Cd	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Co	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Cr	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Cu	BDL	BDL	BDL	0.007	BDL	BDL	BDL
Fe	BDL	2.7	BDL	3.4	28.2	BDL	2.9
K	5.0	9.3	9.3	5.3	12.7	1.3	2.5
Li	BDL	BDL	BDL	BDL	0.003	BDL	BDL
Mg	4.9	4.4	3.9	6.9	10.7	2.1	8.3
Mn	0.026	0.038	0.008	0.196	1.235	BDL	0.060
Mo	BDL	BDL	BDL	BDL	0.003	BDL	0.001
Na	7.3	64	56.4	50.2	95.8	3.9	34.2

Elements reported as ppm.

Well #	MW4	MW5	MW6	MW8	MW9	MW10	MW11
Element							
Ni	BDL	BDL	BDL	BDL	BDL	BDL	BDL
P	BDL	0.04	BDL	0.07	BDL	BDL	BDL
Pb	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Se	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Si	2.28	3.34	2.33	4.16	1.91	2.54	4.32
Ti	BDL	BDL	BDL	BDL	BDL	BDL	BDL
U	BDL	BDL	BDL	BDL	0.023	BDL	BDL
V	BDL	BDL	BDL	BDL	BDL	BDL	0.003
Y	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Zn	0.024	0.027	0.026	0.029	0.011	0.020	0.015

Elements reported as ppm.

Well#	MW12	MW12A	MW12B	MW13	MW14	MW15	LF1	LF2
Element								
Al	BDL	BDL	BDL	BDL	0.109	0.366	BDL	BDL
As	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Be	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Ca	27.6	27.4	32.5	103	29.9	15.2	166	11.9
Cd	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Co	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Cr	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Cu	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Fe	1.3	1.3	1.6	BDL	0.9	BDL	BDL	BDL
K	14.7	14.7	17.8	13.1	1.6	1.6	7.6	1.2
Li	0.018	0.018	0.021	BDL	0.002	0.007	BDL	BDL
Mg	8.6	8.3	10.6	3.4	1.8	1.0	3.7	0.7
Mn	0.159	0.144	0.172	0.055	0.109	0.008	BDL	BDL
Mo	0.001	0.002	0.002	0.001	0.003	BDL	0.002	BDL
Na	396	407	362	28.5	6.6	12.1	44.8	3.3
Ni	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
P	10.56	10.55	12.51	0.57	0.20	0.41	0.03	BDL
Pb	0.236	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Se	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Si	1.92	BDL	2.10	3.54	3.86	4.25	BDL	BDL
Ti	0.006	BDL	BDL	BDL	BDL	BDL	BDL	BDL
U	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
V	0.002	BDL	0.002	BDL	BDL	0.003	0.002	BDL
Y	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Zn	0.021	BDL	0.011	0.040	0.077	0.100	0.016	0.04

Elements reported as ppm.

Well #	LF3	LF4	LF5	KC-B	KC-T
Element					
Al	BDL	BDL	BDL	0.067	0.076
As	BDL	BDL	BDL	BDL	BDL
Be	BDL	BDL	BDL	BDL	BDL
Ca	185	248	134	15.6	16.2
Cd	BDL	BDL	BDL	BDL	BDL
Co	BDL	BDL	BDL	BDL	BDL
Cr	BDL	BDL	BDL	BDL	BDL
Cu	BDL	BDL	BDL	BDL	BDL
Fe	33.3	31.3	34.5	BDL	0.5
K	14.9	8.9	6.3	4.6	4.4
Li	BDL	BDL	BDL	BDL	0.002
Mg	14.1	11.6	5.0	6.3	6.8
Mn	0.909	1.341	0.546	0.037	0.042
Mo	BDL	0.002	0.002	0.014	0.013
Na	29.0	6.2	82.5	93.6	94.3
Ni	BDL	BDL	BDL	BDL	BDL
P	0.03	BDL	BDL	0.04	0.06
Pb	BDL	BDL	BDL	BDL	BDL
Se	BDL	BDL	BDL	BDL	BDL
Si	BDL	BDL	2.44	BDL	BDL
Ti	BDL	BDL	BDL	BDL	BDL
U	0.019	0.033	0.022	BDL	BDL
V	BDL	BDL	BDL	0.004	0.004
Y	BDL	BDL	BDL	BDL	BDL
Zn	0.023	0.177	0.017	0.046	0.030

APPENDIX 4. Organic parameters, detection limits, and results for Set #1 and Set #2.

Samples were submitted to Chemical & Environmental Technology, Inc., Research Triangle Park, North Carolina. Procedures for analytical methods for EPA 602, 608, 625, and 8270 are outlined in the Federal Register, Vol. 49, No. 209, October 26, 1986. EPA Method 8020 is outlined in "Test methods for evaluating solid wastes", SW-846, Vol. 3, September, 1986. EPA Method 3540 is described in "Guidelines for addressing fuel leaks", California Water Quality Control Board, September, 1985. Organic constituents and detection limits are listed in Table 11. Sample results are listed after Table 11.

Table 11. Constituents and detection limits for organic analyses.

METHOD 602 Petroleum Hydrocarbons (BTEX)

<u>Parameter</u>	<u>Detection Limit</u>
Benzene, $\mu\text{g/kg}$	NP
Toluene, $\mu\text{g/kg}$	NP
Ethylbenzene, $\mu\text{g/kg}$	NP
Xylenes, $\mu\text{g/kg}$	NP

METHOD 3540 Total High Density Petroleum Hydrocarbons

Hydrocarbons, High, mg/kg	NP
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NP = Not Provided

METHOD 608 Pesticides / PCB's

<u>Parameter</u>	<u>Detection Limit (μg/L)</u>
Aldrin	0.004
BHC - alpha	0.003
BHC - beta	0.006
BHC - delta	0.009
BHC - gamma	0.004
Chlordane	0.004
4,4'- DDD	0.011
4,4'- DDE	0.004
4,4'- DDT	0.012
Dieldrin	0.002
Endosulfan I	0.014
Endosulfan II	0.004
Endosulfan sulfate	0.066
Endrin	0.006
Endrin aldehyde	0.023
Heptachlor	0.003
Heptachlor epoxide	0.083
Toxaphene	0.24
PCB - 1016	nd
PCB - 1221	nd
PCB - 1232	nd
PCB - 1242	nd
PCB - 1248	0.065
PCB - 1254	nd
PCB - 1260	nd

nd = not determined

Method 625/8270 Acid/Base Neutral Extractables**ACIDS**

<u>Parameter</u>	<u>Detection Limit (μg/L)</u>
4-Chloro-3-methylphenol	10.0
2-Chlorophenol	10.0
2,4-Dichlorophenol	10.0
2,4-Dimethylphenol	10.0
2,4-Dinitrophenol	50.0
2-Methyl-4,6-dinitrophenol	50.0
2-Nitrophenol	10.0
4-Nitrophenol	50.0
Pentachlorophenol	50.0
Phenol	10.0
2,4,6-Trichlorophenol	10.0

BASE NEUTRALS

<u>Parameter</u>	<u>Detection Limit (µg/L)</u>
Acenaphthene	10.0
Acenaphthylene	10.0
Anthracene	10.0
Benzo(a)anthracene	10.0
Benzo(b)fluoranthene	10.0
Benzo(k)fluoranthene	10.0
Benzo(ghi)perylene	10.0
Bis(2-chloroethyl)ether	10.0
Bis(2-chloroethoxy)methane	10.0
Bis(2-ethylhexyl)phthalate	10.0
Bis(2-chloroisopropyl)ether	10.0
4-Bromophenyl phenyl ether	10.0
Butyl benzyl phthalate	10.0
2-Chloronaphthalene	10.0
4-Chlorophenyl phenyl ether	10.0
Chrysene	10.0
Dibenzo(a,h)anthracene	10.0
Di-n-butylphthalate	10.0
1,2-Dichlorobenzene	10.0
1,3-Dichlorobenzene	10.0
1,4-Dichlorobenzene	10.0
3,3'-Dichlorobenzidine	10.0
Diethyl phthalate	10.0
Dimethyl phthalate	10.0
2,4-Dinitrotoluene	10.0
2,6-Dinitrotoluene	10.0
Di-n-octylphthalate	10.0
Fluoranthene	10.0
Fluorene	10.0
Hexachlorobenzene	10.0
Hexachlorobutadiene	10.0
Hexachloroethane	10.0
Ideno(1,2,3-cd)pyrene	10.0
Isophorone	10.0
2-Methylnaphthalene	10.0
Naphthalene	10.0
Nitrobenzene	10.0
n-Nitrosodi-n-propylamine	10.0
Phenanthrene	10.0
Pyrene	10.0
1,2,4-Trichlorobenzene	10.0

RESULTS - ORGANIC SET #1

Refer to Figure 15 for locations and sample descriptions.

BDL = Below Detection Limit for ALL parameters listed above.

NA = Not Analyzed

PD = Parameter(s) Detected

Sample #	METHOD		
	EPA 608	EPA 625	EPA 8270
AB1-SL	NA	NA	BDL
CD 4-G	BDL	BDL	NA
KC 1-M	NA	NA	BDL
KC 2-M	NA	NA	BDL
KC 3-M	NA	NA	BDL
KC 4-M	NA	NA	BDL
LF 1-G	NA	BDL	NA

RESULTS - ORGANIC SET #2

Refer to Figure 16 for sample locations and descriptions.

BDL = Below Detection Limit for **ALL** parameters listed above.

NA = Not Analyzed

PD = Parameter(s) Detected

Sample #	METHOD		
	EPA 602	EPA 625/8270	EPA 3540+8020
AB2-SL	NA	BDL	NA
CD 14-G	NA	BDL	NA
CD 15-G	BDL	BDL	NA
CD 16-G	BDL	PD ¹	NA
CD 17-G	BDL	PD ²	NA
KC 5-M	NA	BDL	NA
KC 6-M	NA	BDL	NA
KC 7-M	NA	BDL	BDL
LF 1A-G	BDL	BDL	NA
MW 9-G	BDL	BDL	NA
WWTP FE-D	NA	BDL	NA
WWTP-SL	NA	BDL	NA

PD¹ = CD 16-G had a reported level of 28.1 µg/L of Bis(2-ethylhexyl) phthalate.

PD² = CD 17-G had a reported level of 66.2 µg/L of Bis(2-ethylhexyl) phthalate.

**APPENDIX 5. Analytical methods, accuracy, precision,
sample descriptions, detection limits,
and raw data for inorganic analyses of soils.**

Collected: April 7-11, 1990 Analyzed: May 17, 1990

Soil samples were analyzed at the Laboratories of the Elemental Analytical Group at the ECU School of Medicine. Elements, analytical methods, and instrumentation used for soil analyses are listed in Table 12. Soils were analyzed by Methods 3050 and 7471 in "Test methods for evaluating solid wastes" (EPA, 1986). Modifications of Method 3050 were made during this study and they included the following: 1) 100 mL tubes were used instead of conical beakers; 2) a heating block was used in place of a hot plate; and 3) the digestate was concentrated by a factor of two. The alternative autoclave digestion procedure for determining Hg in soils by CVAA was employed. Sample descriptions, depth, and numbers according to borehole are listed in Table 13.

Table 12. Elements, analytical procedures, and instrumentation for soil samples.

ELEMENT(S)	ANALYTICAL PROCEDURE	INSTRUMENT
Hg	EPA Method 7471	CVAA
<u>Major</u> Al, Ca, Fe, K, Mg, Mn, Na, and Si	EPA Method 3050	ICAPES
<u>Trace</u> As, Be, Cd, Co, Cr Cu, Li, Mo, Ni, P, Pb, Se, Sn, Ti, U, V, and Zn	EPA Method 3050	ICAPES

Table 13. Soil sample descriptions, depth, and locations according to borehole (See Fig. 18 for borehole locations).

Sample #	Description and Depth	Borehole # and Location
SPL1	PEAT, 0-1'	SB #1
SPL2	SAND, 1-3'	Downgradient from
SPL3	SANDY CLAY, 3-5'	Superfund Site
SPL4	SAND, 7-9'	SB #2
SPL5	SAND, 9-11'	North of SB # 1
SPL11	PEAT, 0-2'	SB #3
SPL12	PEAT, 2-4'	50' NE of City Dump
SPL13	PEAT, 4-6'	
SPL6	PEAT, 0-2'	
SPL7	PEAT, 2-4'	SB #4
SPL8	PEAT, 4-6'	NE edge of City Dump
SPL9	PEAT, 6-8'	
SPL10	PEAT, 8-10	
SPL14	PEAT, 5-7'	SB #5
		Under City Dump beside CD 15
SPL15	PEAT, 0-2'	
SPL16	PEAT, 2-4'	SB #6
SPL17	PEAT, 4-6'	Adjacent to Dump and
SPL18	PEAT, 6-8'	50' NE of City Dump
SPL19	PEAT, 8-10	

Table 13. cont.

SPL20	SAND, 0-2'	SB #7 and 8
SPL21	PEAT, 2-4'	Next to MW 8
SPL22	PEAT, 4-6'	
SPL26	MUDDY PEAT, 0-1'	
SPL27	FILL SAND, 1-3'	SB #9
SPL28	PEAT, 3-5'	Beside SW Corner of
SPL29	PEAT, 5-7'	Parking Lot
SPL42	PEAT, 0-2'	
SPL43	PEAT W/CLAY	SB #10
	LENSES, 2-4'	Along shoreline near
SPL44	PEAT W/CLAY	Aeration basin
	LENSES, 4-6'	
SPL45	PEAT, 6-8'	
SPL23	PEAT, 0-2'	
SPL24	PEAT, 2-4'	SB #11
SPL25	PEAT, 4-6'	Next to Aeration basin
SPL38	SAND, 0-2'	
SPL39	SAND, 2-3.5	SB #12
SPL40	PEAT, 3.5-5.5'	Along shoreline near
SPL41	PEAT, 5.5-7.5	MW 5
SPL35	SAND, 6-8'	SB # 13,
SPL36	SAND, 8-10'	Beside LF 2,
SPL37	SAND, 4-6'	SB #14
		Beside LF 1
SPL30	PEAT, 4-6'	
SPL31	PEAT, 6-8'	SB # 15
SPL32	PEAT, 8-10'	Beside WWTP Outfall
SPL33	PEAT, 10-12'	
SPL34	PEAT, 12-14'	
SPL 1B	PEAT, 0-2'	SB B1, <u>Background</u>
SPL 2B	PEAT, 2-4'	Across Kennedy Creek
		from City Dump
SPL 3B	PEAT, 0-2'	SB B2, <u>Background</u>
SPL 4B	PEAT, 2-4'	150' from the shoreline
		across Kennedy Creek

Accuracy was calculated by averaging the elemental percent recovered from three "spiked" soil sets (n=4). Precision (reproducibility) was expressed as two times the standard deviation about "spiked" sets. The limit of detection was defined as two times the standard deviation about laboratory blanks.

CVAA analyses for Hg yielded the following: 1) a limit of detection of 0.06 ppm; and 2) a standard estimate of error of +/- 0.007 ppm.

Accuracy, precision, and detection limits are listed in Table 14. Average, maximum, and minimum values for major and trace elements in soils are listed in Table 15.

Table 14. Accuracy, precision, and detection limits (in ppm) for soil samples.

Element	Accuracy (% Recovery)	Reproducibility (n=4)		Detection Limit (n=6)
	Avg. %	MEAN	(2X S.D.)	(2X S.D.)
Al	99	2152	477	0.423
As	82	BDL	4.25	0.072
Be	99	0.64	0.02	0.003
Ca	100	1782	79.6	0.299
Cd	89	NA	NA	0.014
Co	95	0.39	0.23	0.006
Cr	95	1.59	0.33	0.007
Cu	97	3.58	0.23	0.006
Fe	106	676	140	1.77
K	101	100	11.2	1.90
Li	91	10.8	0.06	0.02

Table 14. continued.

Element	Accuracy (% Recovery)	Reproducibility (n=4)		Detection Limit (n=6)
	Avg. %	MEAN	(2X S.D.)	(2X S.D.)
Mg	92	339	55.1	0.082
Mn	97	10.7	1.51	0.033
Mo	79	0.63	0.31	0.008
Na	100	284	24.8	0.128
Ni	68	0.65	0.35	0.017
P	92	64.4	10.3	0.435
Pb	78	2.51	0.91	0.027
Se	79	NA	NA	0.054
Si	100	656	127	1.44
Sn	99	9.4	1.26	0.074
Ti	98	102	3.49	0.046
Tl	105	NA	NA	0.161
U	103	NA	NA	0.054
V	96	14.5	0.63	0.010
Y	99	0.68	0.11	0.008
Zn	96	9.7	0.5	0.015

Table 15. Average, maximum, and minimum elemental values for soil samples (in ppm).

Element	Average (n=57)	Maximum Value	Minimum Value
Al	6400	21200	432
As	3.4	38.5	0.0
Be	0.3	0.7	0.0
Ca	3760	9500	0.0
Cd	0.04	0.89	0.00
Co	1.8	4.8	0.0
Cr	6.5	33	0.4
Cu	9.7	140	0.4
Fe	4360	10800	163
* Hg	0.02	0.250	0.0
K	184	470	0.0
Li	3.6	13.3	0.0
Mg	706	1380	25.4
Mn	29.8	156	0.5
Mo	3.5	46.3	0.0
Na	705	1700	0.0
Ni	1.8	5.5	0.0
P	215	961	0.0
Pb	7.7	52	0.0
Si	659	1230	170
Sn	4.5	24	0.0
Ti	68.7	182	5.1
U	0.9	16.5	0.0
V	9.5	26.4	0.8
Y	3.5	8.7	0.0
Zn	26.7	200	1.4

* Hg - (n=45)

RAW DATA FOR SOILS

BDL == Below Detection Limit

* == Mercury analyses were performed by CVAA.

Elements reported as ppm extractable from dried sediment.

	SPL1	SPL2	SPL3	SPL4	SPL5	SPL6
Element						
Al	3990	3970	2160	1080	1370	13300
As	6.4	BDL	BDL	BDL	2.6	BDL
Be	0.21	0.28	0.26	0.22	0.18	0.28
Ca	1400	240	170	BDL	57	4500
Cd	BDL	BDL	BDL	BDL	BDL	BDL
Co	0.9	0.9	1.6	0.6	2.0	2.0
Cr	4.0	4.1	4.5	1.7	2.1	10
Cu	4.6	0.8	0.4	0.4	0.7	20
Fe	4500	1070	2000	818	4720	6770
*Hg	BDL	BDL	BDL	BDL	BDL	0.194
K	170	160	140	BDL	BDL	300
Li	1.8	1.2	1.3	BDL	BDL	5.7
Mg	208	189	165	25.4	36.4	604
Mn	160	24	15	4.1	38	43
Mo	BDL	BDL	BDL	BDL	BDL	0.5
Na	44	13	BDL	BDL	BDL	72
Ni	1.1	0.9	BDL	BDL	BDL	3.5
P	160	35	47	65	270	320
Pb	31	2.4	BDL	BDL	BDL	52
Si	910	1230	820	500	410	950
Sn	8.2	BDL	BDL	BDL	BDL	7.8
Ti	87	160	85	64	24	130
U	BDL	BDL	BDL	BDL	BDL	BDL
V	9.2	4.4	4.4	4.9	6.3	17
Y	1.8	2.4	2.6	1.4	1.2	3.2
Zn	99	4.7	3.1	1.4	1.9	180

Elements reported as ppm extractable from dried sediment.

	SPL7	SPL8	SPL9	SPL10	SPL11	SPL12
Element						
Al	3060	1800	600	980	7010	1980
As	BDL	BDL	BDL	BDL	2.9	BDL
Be	0.15	BDL	BDL	0.14	0.27	0.15
Ca	5700	5100	6700	9500	4600	5000
Cd	BDL	BDL	BDL	BDL	BDL	BDL
Co	0.8	0.7	BDL	BDL	1.0	0.5
Cr	3.0	2.6	0.5	0.7	4.7	1.5
Cu	8	5.9	1.4	1.8	4.1	1.5
Fe	3200	3750	163	216	2420	600
*Hg	BDL	BDL	BDL	BDL	BDL	BDL
K	120	110	BDL	BDL	230	110
Li	BDL	1.15	BDL	BDL	2.06	BDL
Mg	350	240	290	250	480	300
Mn	35	16	5.7	13	27	9.7
Mo	BDL	BDL	0.5	0.7	BDL	BDL
Na	71	110	180	340	160	270
Ni	0.8	BDL	BDL	BDL	1.6	BDL
P	110	70	40	60	150	58
Pb	20	11	2.0	2.8	9.2	3.1
Si	700	630	220	280	760	630
Sn	5.3	BDL	BDL	3.7	BDL	BDL
Ti	44	24	6.0	10	89	32
U	BDL	BDL	BDL	BDL	BDL	BDL
V	5.7	3.0	1.1	1.7	9.8	3.0
Y	0.8	0.5	0.5	1.1	2.0	0.6
Zn	76	44	7.1	7.6	17	5.9

	SPL12A	SPL12B	SPL12-1	SPL13	SPL14	SPL15
Element						
Al	2040	2090	2500	730	2760	15600
As	BDL	BDL	BDL	BDL	BDL	BDL
Be	0.17	0.17	0.18	BDL	BDL	0.51
Ca	5570	5770	5750	4900	6200	3000
Cd	BDL	BDL	BDL	BDL	0.89	BDL
Co	0.5	BDL	0.4	BDL	1.6	3.8
Cr	1.6	1.5	1.8	0.6	5.2	17
Cu	1.8	1.7	2	0.7	26.5	12.5
Fe	640	720	750	230	10800	8900
*Hg	BDL	BDL	BDL	BDL	0.12	0.25
K	100	94	100	BDL	190	410
Li	BDL	BDL	BDL	BDL	1.5	13
Mg	330	350	370	270	780	1270

Elements reported as ppm extractable from dried sediment.

	SPL12A	SPL12B	SPL12-1	SPL13	SPL14	SPL15
Element						
Mn	11	11	12	5.5	90	85
Mo	BDL	BDL	BDL	BDL	0.7	0.7
Na	280	290	300	360	260	420
Ni	BDL	BDL	0.8	BDL	5.5	4.6
P	66	64	70	39	200	550
Pb	3.2	3.8	4.3	1.4	41.6	43.8
Si	640	750	610	320	620	890
Sn	BDL	BDL	BDL	BDL	24	12
Ti	31	32	38	12	34	120
U	BDL	BDL	BDL	BDL	BDL	BDL
V	3.4	3.4	3.9	1.4	4.8	21
Y	0.7	0.7	0.7	BDL	1.9	6.3
Zn	6.3	6.6	7.3	2.0	200	190

	SPL16	SPL17	SPL18	SPL19	SPL20	SPL21
Element						
Al	4080	1800	2440	4170	21200	11600
As	BDL	BDL	BDL	BDL	12.7	4.1
Be	0.27	0.22	0.27	0.36	0.43	0.34
Ca	2900	3400	3100	3500	5200	6300
Cd	BDL	BDL	BDL	BDL	BDL	BDL
Co	1.8	0.5	0.8	0.7	2.4	1.6
Cr	3.5	1.2	2.2	3.5	15	8.3
Cu	2.5	1.7	2.4	1.5	140	46
Fe	4390	2040	2000	1550	7870	5130
*Hg	BDL	BDL	BDL	BDL	BDL	BDL
K	170	73	110	190	360	210
Li	3.1	1.0	1.6	2.2	6.4	4.7
Mg	720	650	640	540	630	640
Mn	48	47	35	16	41	38
Mo	0.4	BDL	BDL	BDL	0.5	0.4
Na	890	1100	1100	870	230	550
Ni	1.5	BDL	BDL	BDL	3.5	2.3
P	130	85	89	91	960	440
Pb	4.3	BDL	2.8	1.5	25	15
Si	700	450	650	890	870	790
Sn	BDL	3.7	BDL	BDL	9.9	6.0
Ti	41	11	20	32	120	92
U	BDL	BDL	BDL	BDL	BDL	BDL
V	6.2	2.9	4.0	7.0	25	16
Y	3.0	2.1	2.2	4.1	4.0	3.1
Zn	13	5.1	15	6.0	160	68

Elements reported as ppm extractable from dried sediment.

	SPL22	SPL23	SPL24	SPL25	SPL25A	SPL25B
Element						
Al	430	5280	9700	10600	10700	10200
As	BDL	BDL	BDL	8.2	6.7	BDL
Be	BDL	0.37	0.50	0.65	0.65	0.63
Ca	6900	2400	2500	1800	1800	1700
Cd	BDL	BDL	BDL	BDL	BDL	BDL
Co	BDL	1.8	3.4	4.5	4.7	4.6
Cr	0.4	4.9	9.5	9.8	9.9	9.2
Cu	0.8	2.9	4.4	3.7	3.5	3.4
Fe	200	4570	5500	8790	9770	9380
*Hg	BDL	BDL	0.10	BDL	BDL	BDL
K	BDL	240	370	360	470	420
Li	BDL	4.4	8.7	11	11	11
Mg	460	860	1050	1360	1380	1320
Mn	6.9	19	40	32	32	30
Mo	BDL	0.4	BDL	0.6	0.5	0.9
Na	700	1410	1460	1700	1690	1650
Ni	BDL	1.5	2	3.3	2.9	3.1
P	26	250	400	280	280	260
Pb	BDL	5.3	7.3	3.2	2.3	2.3
Si	170	780	920	930	1000	800
Sn	BDL	3.6	4.2	9.1	10	8.9
Ti	5.1	47	93	100	110	100
U	BDL	BDL	BDL	BDL	BDL	BDL
V	0.8	9.3	14	15	15	14
Y	BDL	3.9	5.0	8.1	8.0	7.8
Zn	1.4	13	14	9.8	9.8	9.3

	SPL25-1	SPL26	SPL27	SPL28	SPL29	SPL30
Element						
Al	10600	7130	4040	20000	8370	1580
As	6.6	7.4	2.6	7.3	8.1	BDL
Be	0.64	0.27	0.30	0.63	0.52	0.31
Ca	1770	2230	1330	2390	3780	2560
Cd	BDL	BDL	BDL	BDL	BDL	BDL
Co	4.8	1.5	1.8	4.6	3.3	0.8
Cr	9.5	7.7	5.4	33	8.0	1.4
Cu	3.7	5.9	2.8	11	4.2	1.9
Fe	9750	4910	3750	10400	7020	2290
*Hg	BDL	BDL	BDL	0.10	BDL	BDL
K	430	210	350	470	220	BDL
Li	11	3.1	1.7	8	6.1	BDL
Mg	1300	470	290	910	980	1100

Elements reported as ppm extractable from dried sediment.

	SPL25-1	SPL26	SPL27	SPL28	SPL29	SPL30
Element						
Mn	31	44	16	100	60	34
Mo	0.6	BDL	BDL	0.7	0.5	BDL
Na	1650	110	64	600	650	1400
Ni	2.9	2.2	1.1	3.5	2.3	BDL
P	260	190	250	870	260	66
Pb	2.3	18	2.8	18	13	BDL
Si	530	730	490	970	950	520
Sn	9.2	BDL	BDL	10	4.8	4.3
Ti	100	130	49	130	80	12
U	BDL	BDL	BDL	BDL	BDL	BDL
V	15	14	6.4	26	13	3.5
Y	7.8	2.5	2.3	6.6	5.1	1.9
Zn	9.6	34	16	45	11	4.4

	SPL31	SPL32	SPL33	SPL34	SPL35	SPL36
Element						
Al	2120	1900	3800	4870	5070	1350
As	BDL	BDL	BDL	BDL	BDL	BDL
Be	0.31	0.25	0.33	0.42	0.14	0.11
Ca	3050	3450	4350	4680	167	50
Cd	BDL	BDL	BDL	BDL	BDL	BDL
Co	1.2	1.2	1.6	2	0.7	0.4
Cr	1.7	1.8	3.2	3.7	3.6	1.1
Cu	2.4	2.3	3.5	2.7	1.4	0.5
Fe	2200	1880	3110	1240	800	940
*Hg	BDL	BDL	0.087	BDL	BDL	BDL
K	120	BDL	BDL	BDL	101	BDL
Li	BDL	BDL	1.5	2.1	1.2	BDL
Mg	1190	1190	1100	780	160	42
Mn	25	17	14	5	12	6.8
Mo	BDL	0.6	1.3	1.3	BDL	BDL
Na	1640	1550	1480	1300	9	BDL
Ni	1.3	1.2	1.9	1.8	1.5	0.6
P	69	57	83	76	BDL	BDL
Pb	2.4	2.5	6.2	2.6	1.5	BDL
Si	590	480	770	970	560	350
Sn	4.6	5.7	5.2	BDL	BDL	BDL
Ti	17	12	25	37	140	45
U	BDL	3.3	BDL	BDL	BDL	BDL
V	4.8	4.0	6.8	7.4	5.2	4.3
Y	2.6	2.3	3.7	4.0	1.3	0.7
Zn	3.8	4.1	14	7.1	5.1	2.1

Elements reported as ppm extractable from dried sediment.

Element	SPL37	SPL38	SPL39	SPL40	SPL41	SPL42
Al	2690	1870	3300	3390	3690	7770
As	BDL	BDL	3.5	BDL	BDL	7.4
Be	0.13	0.16	0.17	0.31	0.40	0.33
Ca	230	2830	4030	6860	7760	3340
Cd	BDL	BDL	BDL	BDL	BDL	BDL
Co	0.9	0.9	1	1	0.8	2.2
Cr	3.2	6.9	6.9	3.3	4.9	8.6
Cu	0.8	2.6	2.4	8.8	2.9	4.4
Fe	1960	1640	2030	3050	930	5650
*Hg	BDL	BDL	BDL	BDL	BDL	BDL
K	120	120	140	BDL	BDL	160
Li	0.7	0.7	1.1	1.1	BDL	3.8
Mg	170	160	240	920	770	550
Mn	21	11	13	56	43	30
Mo	BDL	BDL	BDL	0.8	0.6	0.4
Na	13	36	78	720	680	170
Ni	0.9	1.4	1.4	1.5	1.5	2.7
P	33	200	360	140	180	290
Pb	1.8	3.8	4.9	1.5	2.8	12
Si	400	360	540	640	690	780
Sn	BDL	BDL	BDL	5.5	BDL	5.7
Ti	89	58	84	45	34	99
U	BDL	1.4	BDL	11	17	BDL
V	5.2	5.8	5.6	16	8.0	12
Y	2.6	1.4	1.8	2.5	3.4	5.5
Zn	3.8	27	17	8.7	4.7	31

Element	SPL43	SPL44	SPL44A	SPL44B	SPL44-1	SPL45
Al	12800	16100	15400	15300	10800	9510
As	BDL	5.0	4.7	5.4	8.5	BDL
Be	0.48	0.47	0.44	0.47	0.33	0.36
Ca	3600	3800	3700	3730	2650	3700
Cd	BDL	BDL	BDL	BDL	BDL	BDL
Co	2.7	4.8	4.5	4.6	3.2	3.4
Cr	11	14	13	14	9.7	7.9
Cu	4.3	8	7.6	7.6	5.4	5.6
Fe	5760	9450	9200	9140	6360	7360
*Hg	BDL	0.082	BDL	BDL	BDL	BDL
K	334	379	365	410	247	218
Li	5.52	8.74	8.78	8.23	6.22	5.90
Mg	745	981	951	949	654	949
Mn	27	44	42	43	30	43

Elements reported as ppm extractable from dried sediment.

Element	SPL43	SPL44	SPL44A	SPL44B	SPL44-1	SPL45
Mo	0.3	0.5	0.7	0.7	BDL	0.8
Na	310	590	580	560	400	810
Ni	3.5	4.7	4.5	4.4	3.1	3
P	360	350	410	390	250	14
Pb	9.8	13	13	14	8.3	4.4
Si	620	1020	600	900	620	880
Sn	4.6	8.9	10	7.4	6.4	5.4
Ti	140	180	150	170	130	120
U	BDL	BDL	BDL	BDL	BDL	BDL
V	15	23	20	20	15	14
Y	8.7	7.7	7.7	7.6	5.2	5.9
Zn	30	38	38	37	26	17

Element	SPL 1B	SPL 2B	SPL 3B	SPL 4B
Al	5580	2010	2880	5760
As	1.6	0.4	1.3	38.5
Be	0.20	BDL	0.17	0.17
Ca	2400	5000	2200	5900
Cd	BDL	BDL	BDL	BDL
Co	1.7	0.8	0.9	1.7
Cr	5.1	1.7	2.7	5.0
Cu	3.2	1.5	1.8	2.6
Fe	3720	7110	2270	9660
K	210	120	96	260
Li	4.1	1.4	2.2	5.2
Mg	740	810	770	1270
Mo	0.5	0.6	0.5	1.1
Mn	32	26	18	46
Na	700	1400	550	1500
Ni	1.6	0.8	1.0	1.6
P	210	80	120	180
Pb	4.7	0.2	2.1	6.1
Se	0.36	BDL	BDL	BDL
Si	870	480	560	1000
Sn	8.3	4.5	0.9	7.0
Ti	65.1	24.5	36.1	84.5
Tl	4.6	5.7	BDL	0.5
U	0.7	BDL	BDL	0.6
V	9.9	3.7	5.3	7.6
Y	2.7	1.9	1.9	4.6
Zn	9.1	2.4	5.5	6.0