2.0 HYDROGEOLOGY AND HYDROLOGY

2.1 REGIONAL HYDROGEOLOGY

2.1.1 HYDROGEOLOGY

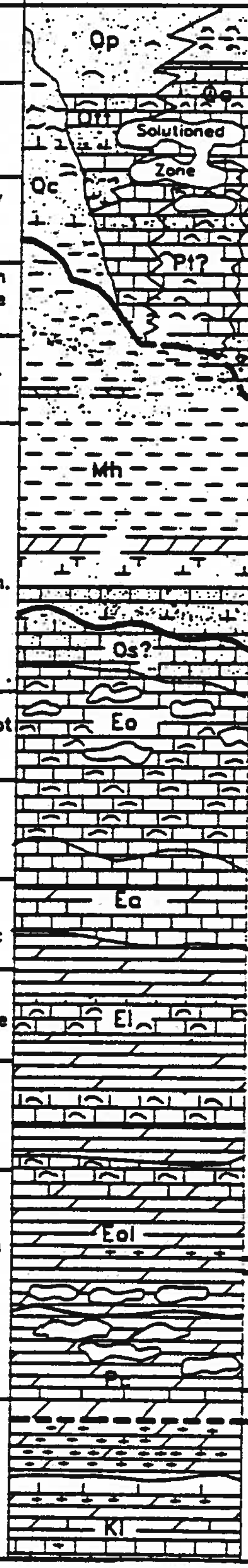
There are three physiographic regions in Palm Beach County: the coastal ridge, the sandy flatlands, and the everglades. There is a direct relationship between these physiographic regions and the hydrogeology/geology of the area. The coastal ridge is characterized by more topographic relief and a thicker and more transmissive surficial aquifer than the other two physiographic regions. The sandy flatlands are characterized by very low topographic relief and a moderately transmissive surficial aquifer. The everglades are topographically flat and have a thin, highly mineralized surficial aquifer. Thick organic sediments in the everglades prevent recharge from entering the surficial aquifer and diluting/flushing the relict seawater.

The geology and hydrogeology of Palm Beach County, which includes the project area, has been described by Schroeder, Milliken and Love (1954), Fischer (1980), and Miller (1988). A typical hydrogeological section for eastern Palm Beach County is presented on **Figure 2-1**. In general, the major hydrogeologic units pertinent to this study in descending order are:

1. A moderate to highly transmissive surficial aquifer;
2. A thick regional aquitard; and
3. The Floridan aquifer system.

The surficial aquifer consists primarily of sand, shell, sandstone, and limestone in distinctive geologic layers. Three geologic units, the Pamlico Formation, the Anastasia Formation, and the Fort Thompson Formation make up the surficial aquifer. According to Shine, Padgett and Barfknecht (1989), the surficial aquifer in eastern Palm Beach County ranges in thickness between 420 feet in the Atlantic coastal ridge to 120 feet in the sandy flatlands. The overall trend is that the surficial aquifer thickens from west to east.

GEOLOGIC UNIT	AGE OR PERIOD	APPROXIMATE THICKNESS (FT)	GENERAL LITHOLOGY		HYDRAULIC CHARACTERISTICS
PAMLICO FM. (Qp)	Late Pleistocene	0 – 50	Quartz sand with shelly or silty intervals.		SURFICIAL AQUIFER SYSTEM
ANASTASIA FM. (Qa)	Pleistocene	0 – 200+	Ranges from sand and shell to well-cemented biogenic limestone.		BISCAYNE AQUIFER Extremely Permeable Solutioned Limestone
FORT THOMPSON FM. (Qa)		0 – 40+	Ranges from shelly marl to biogenic limestone.		
CALOOSAHATCHEE FM. (Qc)	Plio-Pleistocene	0 – 50?	Shell and marl with sand and limestone intervals.		Unconfined aquifer Permeability ranges over 3 orders of magnitude. May be semiconfined locally.
TAMIAMI FM. (Pt)	Pliocene	0 – 100+	Reefal limestone and talus deposits. Some sandy limestone.		
HAWTHORN GROUP (Mh)	Miocene	500 – 700	Sandy silt grading into dense, green clay with beds of limestone, sandy shell or dolomite. phosphate common. Limestone and marl common in basal unit.		INTERMEDIATE CONFINING UNIT Extremely low permeability sediments
SUWANNEE FM. (Os)	Oligocene	0 – 100?	Silty to clean, pale orange limestone. Not reliably described in study area.		Main Producing Interval in Study Area
OCALA GROUP (Eo)	Eocene	0 – 500	Highly fossiliferous pale orange limestone. Commonly fractured and solutioned.		FLORIDAN AQUIFER SYSTEM
AVON PARK FM. (Ea)		500 – 700	Fossiliferous, chalky to granular limestone with dolomitic beds.		
LAKE CITY FM. (El)		> 1500 ?	Chalky, fossiliferous limestone and dense brown dolmite.		Major Intra-Aquifer Confining Unit
OLDSMAR FM. (Eol)		700 – 900	Biogenic, limestone grading downward into solutioned, crystalline dolomite.		
CEDAR KEYS FM. (Pc)	Paleocene	> 500	Cavernous grey to brown dolomite with intervals of creamy white limestone. Anhydrite common in lower section.		Disposal Zone ("Boulder Zone")
LAWSON FM. (Kl)	Late Cretaceous	?	Interbedded dolomite anhydrite and limestone.		SUBFLORIDAN CONFINING UNIT



SOURCE: SHINE, PADGETT AND BARFKNECHT, 1989

SOLID WASTE AUTHORITY OF PALM BEACH COUNTY

GENERALIZED HYDROGEOLOGICAL COLUMN EASTERN PALM BEACH COUNTY, FLORIDA

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Figure No. 2-1

The surface deposits consist of the Pamlico Formation (Pleistocene) and occur from the land surface to an average depth of approximately 25 feet. The Pamlico Formation mainly consists of sand and shell with occasional seams of organic deposits and silt. The Anastasia Formation (Pleistocene) underlies the Pamlico sand and consists of sand, shell, and extremely permeable solutioned limestone. The highly permeable solutioned limestone, or cavity-riddled zone, is really composed of sand and shells which are generally cemented to form coquina or sandstone; it is referred to as the Turnpike aquifer. This zone tends to underlie the area in the vicinity of Florida's Turnpike (several miles wide in east to west direction), and typically occurs between 50 and 125 feet below ground surface. Although the Anastasia Formation continues below this depth, the fines and clay content increases with depth, thus gradually reducing the permeability of the aquifer. Underlying the Anastasia Formation are the lower permeability sediments of the Fort Thompson Formation (Pleistocene). The Fort Thompson Formation consists of shelly marl with seams of sand and limestone and ranges in thickness from 0 to 40 feet. The contact of the Fort Thompson Formation with the lower permeability sediments of the Caloosahatchee (Plio-Pleistocene) and Tamiami Formations (Pliocene) form the base of the surficial aquifer.

The Tamiami Formation, the Caloosahatchee Formation, and Hawthorn Group sediments separate the surficial aquifer from the regional Floridan aquifer system. The Caloosahatchee and Tamiami Formations consist primarily of marl with seams of shell, sand, and limestone, and range in thickness from 0 to 150 feet. Based on published information (Scott and Lloyd, 1991), the Hawthorn Group (Miocene) sediments range in thickness from 600 feet near Lake Okeechobee to 750 feet in eastern Palm Beach County. The Hawthorn Group sediments are underlain by a thick sequence of permeable limestone and dolomite which comprise the Floridan aquifer system.

The Floridan aquifer is greater than 3,000 feet thick in this area. The upper zone is dominated by the Suwannee (Oligocene) and Ocala Group (Eocene) limestones. The upper zone ranges between 400 and 500 feet in thickness. Based on published data (Scott and Lloyd, 1991), the top of the Floridan aquifer slopes downward from -800 feet National Geodetic Vertical Datum (NGVD) in the northeastern part of Palm Beach County to -950 feet

NGVD in the southwestern part. The Floridan aquifer in Palm Beach County contains brackish water and is used primarily for irrigation purposes.

2.1.2 GROUNDWATER FLOW PATTERNS IN THE SURFICIAL AQUIFER

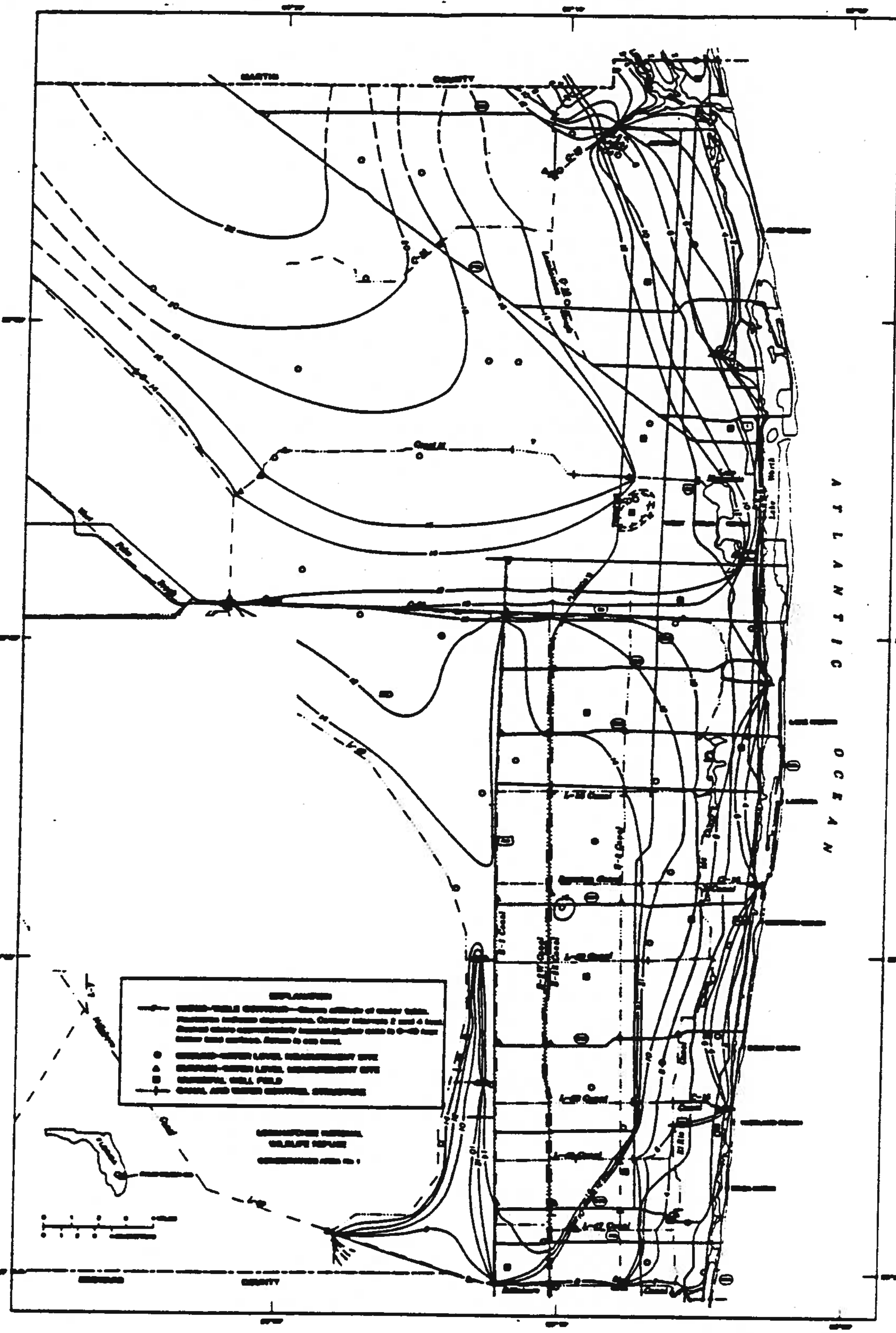
A groundwater elevation contour map for eastern Palm Beach County is presented on **Figure 2-2.** This map was developed for the period of October 24 through 26, 1988. As indicated on Figure 2-2, the highest groundwater elevations (greater than +22.0 feet NGVD) occur in the northern part of the county in the vicinity of the junction of State Road 710 and State Road 706 (west of the town of Jupiter). Groundwater elevations decline in all directions away from this groundwater mound. Southeast of the mound there is a water level plateau above +14.0 feet NGVD resulting from the influence of the M Canal and the West Palm Beach Water Catchment Area (WPBWCA). Water levels to the east of both the mound and the plateau decline gradually, reaching sea level at the coast. Water levels to the south of the plateau decline gradually toward the West Palm Beach Canal (C-51 Canal) and form a north-south groundwater divide in Palm Beach County.

2.2 SITE-SPECIFIC HYDROGEOLOGY OF THE SURFICIAL AQUIFER

2.2.1 GEOLOGY

The geology of the site has been the subject of several investigations by consultants and public agencies. Collectively, the results of the soil borings, well cuttings, and published data reveal three distinct hydrogeologic units in the surficial aquifer, each having different lithologic and hydraulic properties. The shallowest unit consists of the sand and shell of the Pamlico Formation. The intermediate depth unit is composed of the sand, shell, and limestone of the Turnpike aquifer. The deepest hydrogeologic unit consists of shell, sand, limestone, and marl of the Ft. Thompson and Caloosahatchee Formations, underlying the Turnpike aquifer.

The Hawthorn Group underlies the surficial aquifer deposits at the site at a depth of about 330 feet below ground surface (Fischer, 1980). The Hawthorn Group is a regional confining



SOURCE: KANE, 1992c

DATE OF MEASUREMENTS
OCTOBER 24-26, 1988

SOLID WASTE AUTHORITY OF PALM BEACH COUNTY

GROUNDWATER TABLE CONTOUR MAP OF THE SURFICIAL AQUIFER FOR EASTERN PALM BEACH COUNTY

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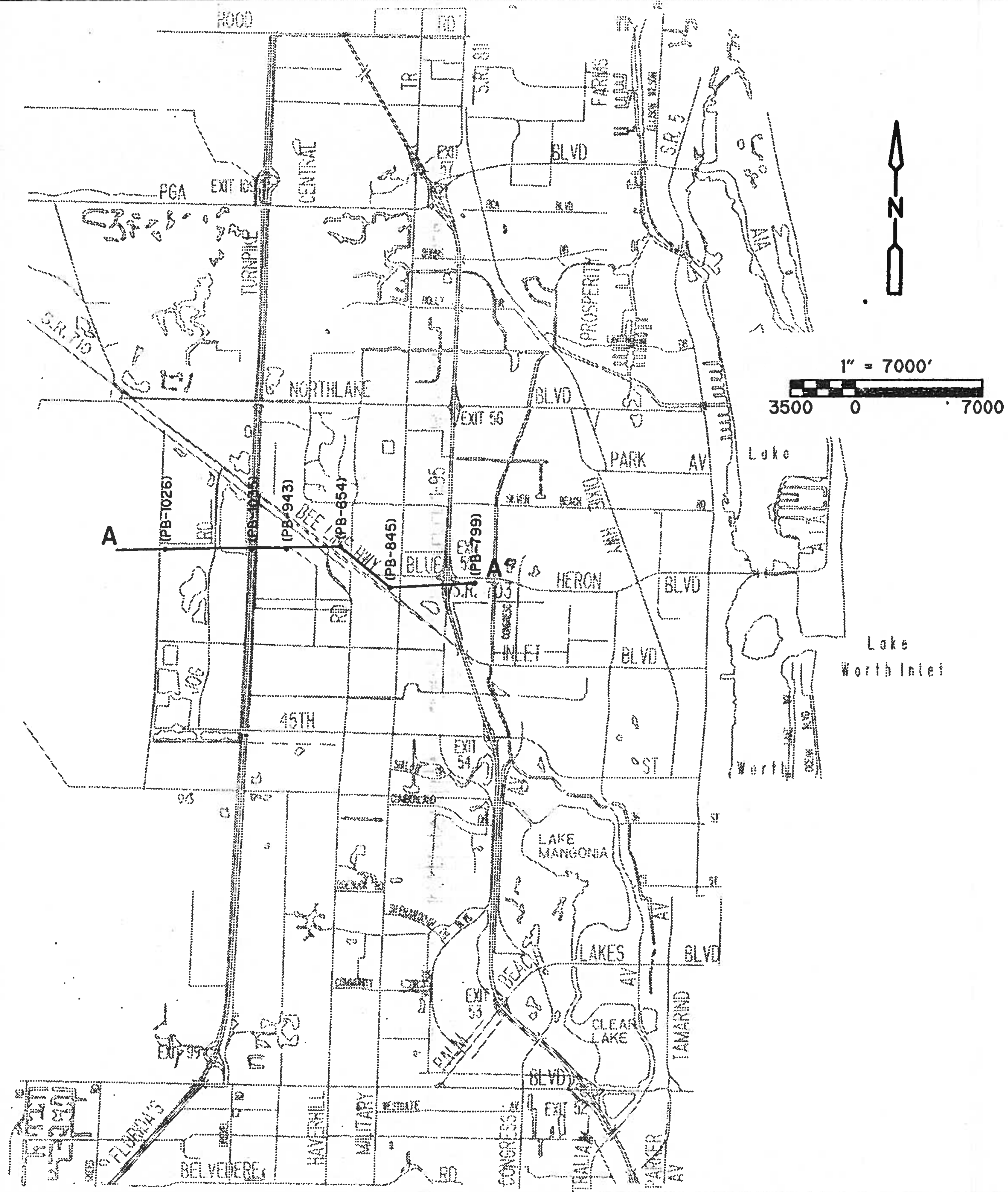
Figure No. 2-2

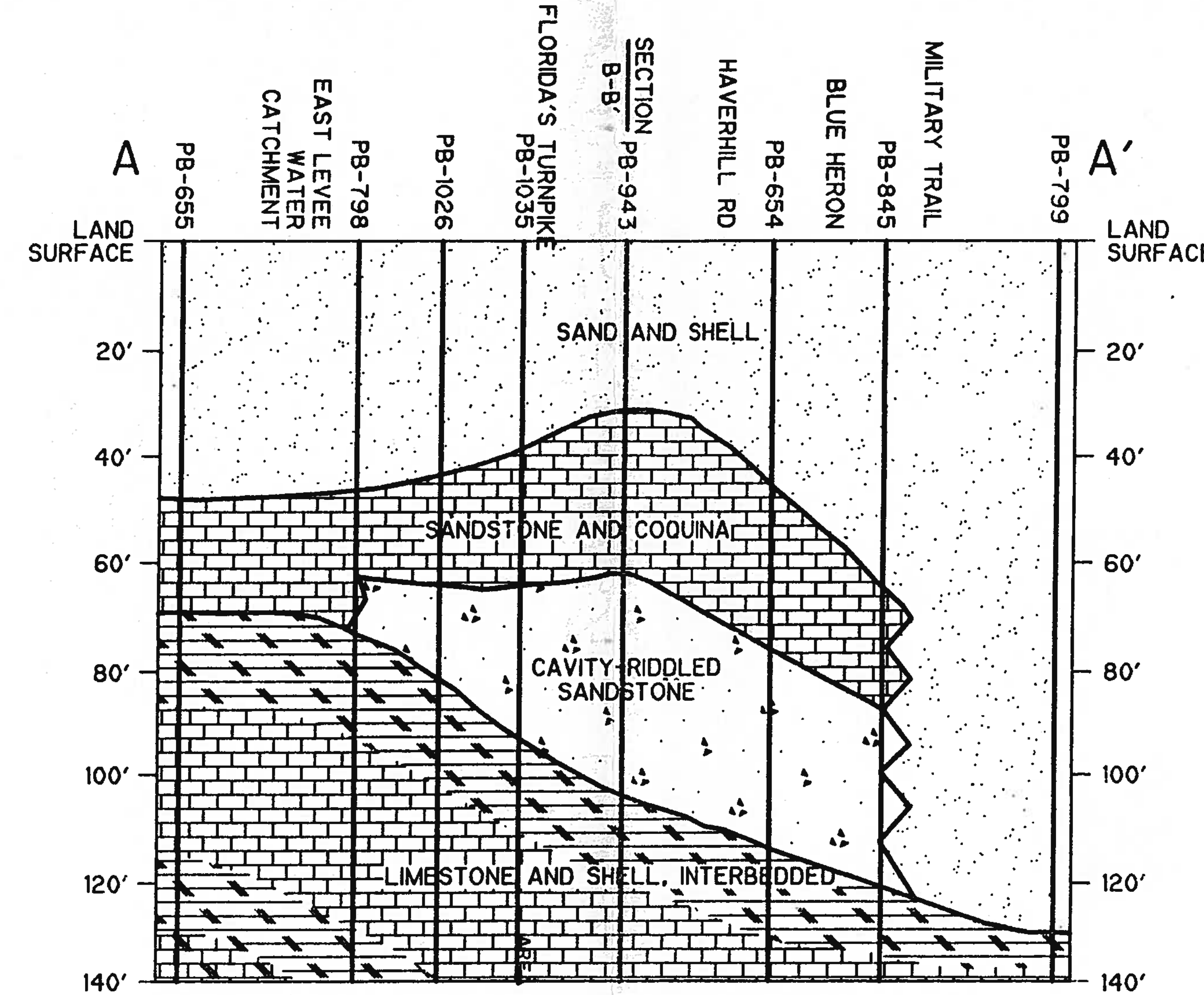
unit for the Floridan aquifer system. This unit is reported to be approximately 500 feet thick beneath the North County Regional Resource Recovery Facility (NCRRRF) and is considered to be relatively impermeable. The hydraulic conductivity of the Hawthorn Group is on the order of 10^{-4} feet per day.

A typical geologic cross section through the NCRRRF and Dyer Boulevard Landfill site are presented on **Figure 2-3**. A typical geologic cross section through the Dyer Boulevard Landfill is presented on **Figure 2-4**. The locations of the cross sections are presented on the attached base map. As indicated on both cross sections, the surficial aquifer system is composed of two distinctive hydraulic zones: the thinner, more transmissive Turnpike aquifer, and the remaining carbonate-dominated deposits that are located above and below the Turnpike aquifer.

2.2.2 AQUIFER HYDRAULICS

The project site is located in the sandy flatlands physiographic region (Shine, Padgett and Barfknecht, 1989). Based on published information, the surficial aquifer ranges in thickness between 230 and 270 feet at the NCRRRF. Additionally, the cavity-riddled zone (Turnpike aquifer) is 20 to 30 feet thick. The cavity-riddled zone extends to the west (WPBWCA) where it pinches out along the western border. Additionally, the cavity-riddled zone pinches out just north of the NCRRRF. The cavity-riddled zone is also referred to as the Turnpike aquifer. Numerous aquifer performance tests (APTs) have been performed in the vicinity of the NCRRRF and the Dyer Boulevard Landfill. One APT performed about 3,000 feet south of the Dyer Boulevard Landfill yielded a transmissivity of 82,000 gallons per day per foot (gpd/ft) (11,000 ft^2/day) for the cavity-riddled zone (Fischer, 1980). The screen interval of the pumping and observation wells ranged from 55 to 95 feet below ground surface. Geraghty & Miller (1982) performed four APTs west of the turnpike and estimated the average transmissivity to be approximately 120,000 gpd/ft (16,000 ft^2/day). An APT was also conducted at the Hood Road well field (Geraghty & Miller, 1979) approximately three miles north of the site, and yielded a transmissivity of 400,000 gpd/ft (53,500 ft^2/day). The biggest limitation in using APT data is that the pumping well and the observation wells





LEGEND:

PB-943 USGS MONITORING WELL ID NO.

SOURCE: FISCHER, 1980

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GEOLOGICAL SECTION A-A' OF THE SURFICIAL AQUIFER

Figure No. 2-3

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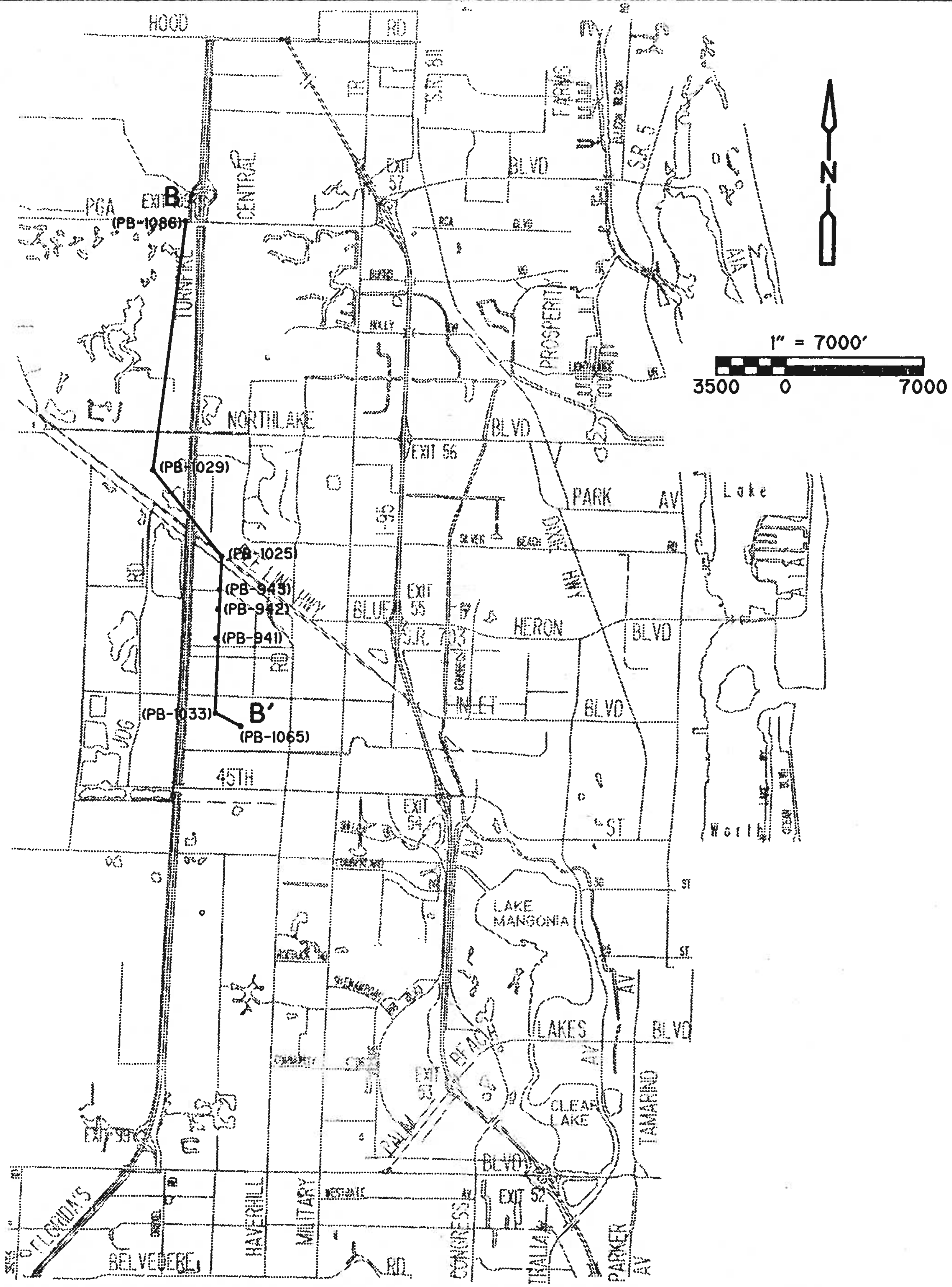
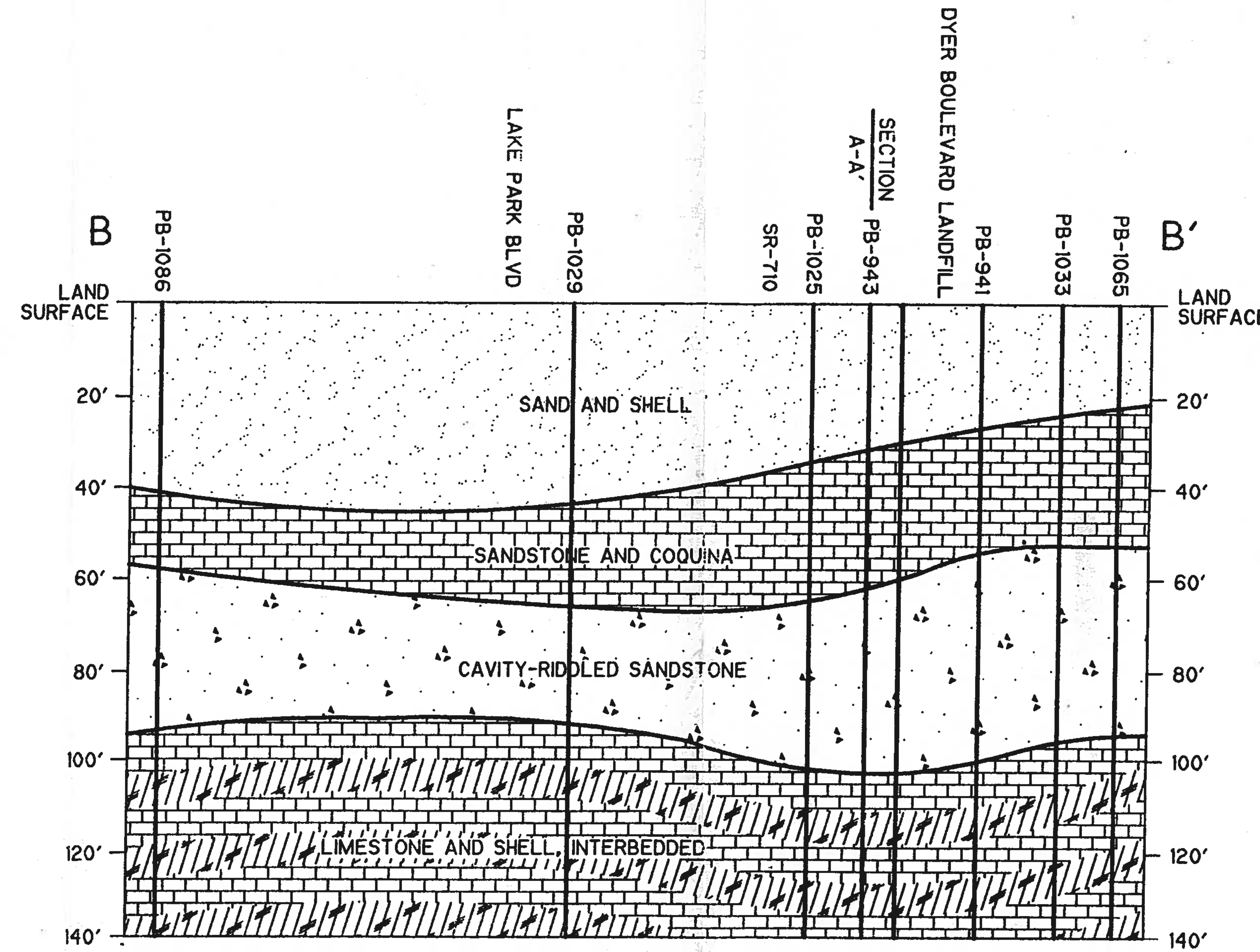
I:\BLROY\SWA-PBC\ACAD\ SWA0007 08/09/94 14:43:21 0:34:15 Brian L. Roy

I:\BLROY\SWA-PBC\ACAD\ SWA0008 08/09/94 14:49:38 1:19:13 Brian L. Roy





LEGEND:

PB-943 USGS MONITORING WELL ID NO.

SOURCE: FISCHER, 1980

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GEOLOGICAL SECTION B-B' OF THE SURFICIAL AQUIFER

Figure No. 2-4

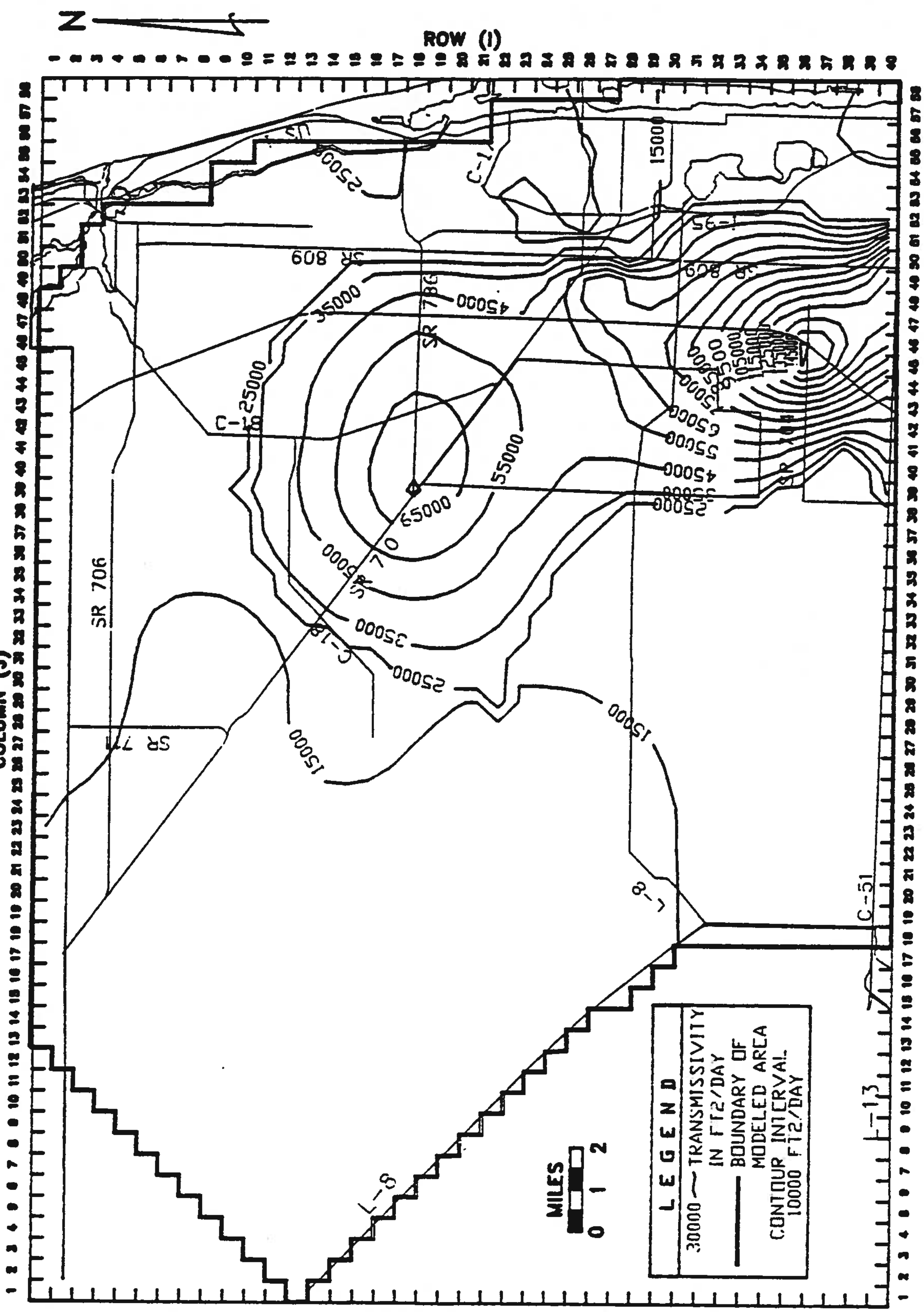
usually do not penetrate the entire thickness of the surficial aquifer. This was the case for the first two sets of APTs discussed above.

Another indirect method of estimating the transmissivity of the entire thickness of the surficial aquifer is to systematically adjust transmissivity in a numerical groundwater flow model to match the aquifer heads and flows for one or more time periods where the aquifer heads have been mapped. This process is referred to as model calibration and can yield relatively accurate results. In 1989, the South Florida Water Management District (SFWMD) completed a three-dimensional groundwater flow model for eastern Palm Beach County using the United States Geological Survey MODFLOW model (Shine, Padgett and Barfknecht, 1989). A map of the distribution of calibrated transmissivity values for the entire thickness of the surficial aquifer is presented on **Figure 2-5**. As indicated on this map, the composite transmissivity of the surficial aquifer ranges from 374,000 gpd/ft (50,000 ft^2/day) to 449,000 gpd/ft (60,000 ft^2/day). This estimate of transmissivity is consistent with the results of the Hood Road APT. The transmissivity values presented on Figure 2-5 provide reasonable initial estimates for groundwater modeling of the NCRRRF and Dyer Boulevard Landfill, and vicinity.

In addition to the APTs described above, a total of 14 short-term pumping tests were performed in the monitoring wells installed at the site prior to development. The results of the APTs indicated that the transmissivity of the screened zone of the aquifer ranged from 12,000 to 70,000 gpd/ft. Since the pumping and observation wells did not fully penetrate the entire thickness of the surficial aquifer, the results of the APTs were adjusted. The resulting transmissivities were used to develop a contour map as presented on Figure 2.3-7 in **Appendix A**. The average transmissivity of the total thickness of the surficial aquifer at the site was estimated to be approximately 101,000 gpd/ft.

2.2.3 HISTORICAL GROUNDWATER ELEVATIONS

In April and May 1984, several background monitor wells and soil borings were drilled at the NCRRRF. Based on data collected on May 23, 1984, the water table elevation ranged between +16.0 feet NGVD in the western portion of the site to +13.0 feet NGVD in the



SOURCE: SHINE, PADGETT AND BARFKNECHT, 1989

SOLID WASTE AUTHORITY OF PALM BEACH COUNTY

COMPOSITE TRANSMISSIVITY OF THE SURFICIAL AQUIFER IN NORTH PALM BEACH COUNTY

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Figure No. 2-5

eastern portion. Water levels were generally about 2 to 5 feet below land surface in 1984. Groundwater table depths were collected again on July 19, 1984 following a period of heavy rainfall. The water table elevations ranged between +17.0 feet NGVD in the western portion of the site to +14.0 feet NGVD in the eastern portion.

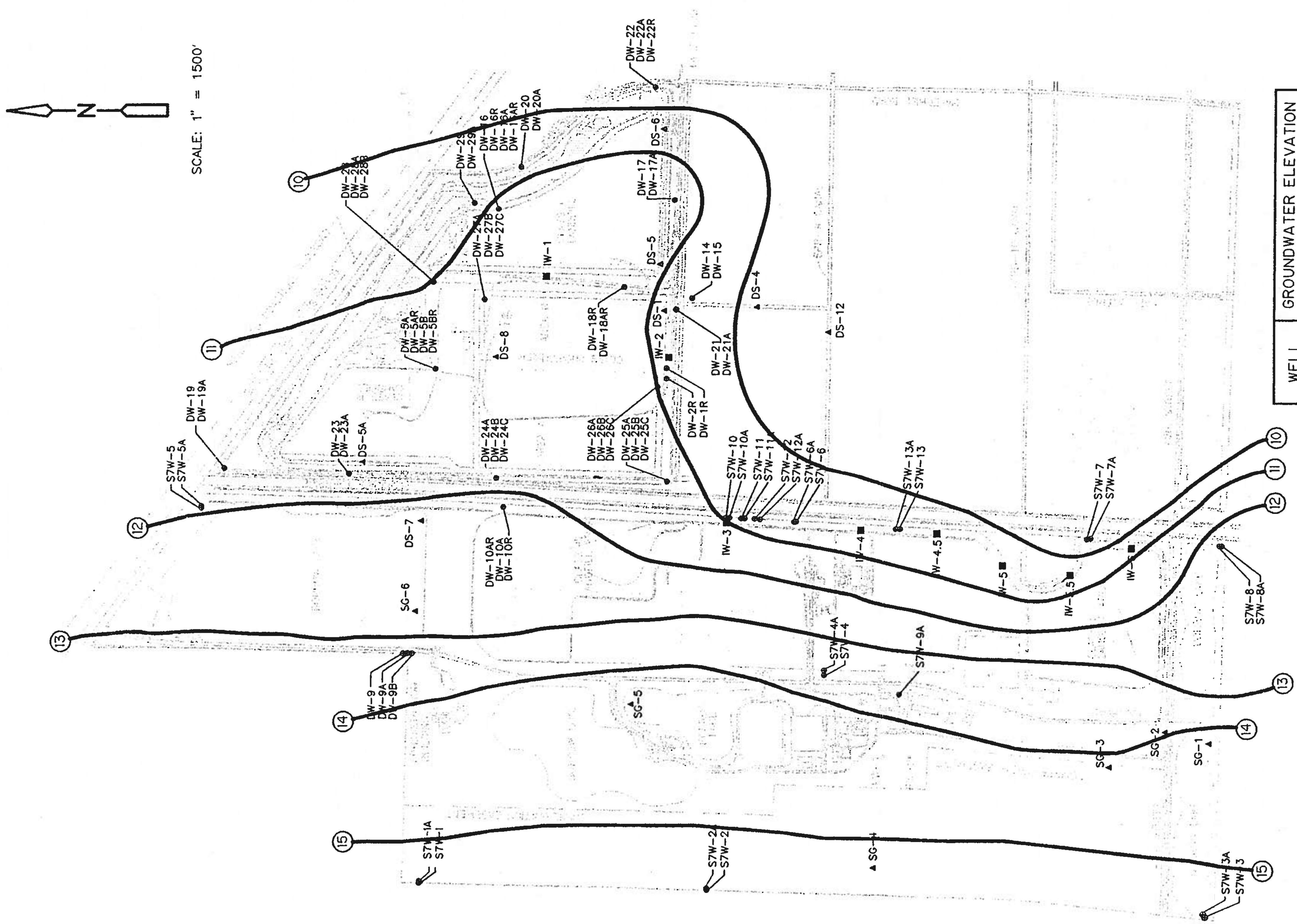
Camp Dresser & McKee Inc. has developed two sets of groundwater elevation contour maps, one set for March 1990 and another for April 1991. The contour maps for the shallow surficial and deep surficial aquifers for March 1990 are presented on **Figure 2-6** and **Figure 2-7**, respectively. The contour maps for the shallow surficial and deep surficial aquifers for April 1991 are presented on **Figure 2-8** and **Figure 2-9**, respectively.

A complete listing of all of the monitoring well water elevations is presented in **Table B-1B** through **Table B-3B** in **Appendix B**.

2.2.4 SHALLOW GROUNDWATER FLOW PATTERNS

As shown on Figure 2-6 and Figure 2-8, the hydraulic gradient in the upper portion of the surficial aquifer (water table) at the site is relatively flat. Based on measurements in the onsite monitoring wells, the average hydraulic gradient of the water table ranges from 0.00073 feet per foot in March 1990 to 0.0013 feet per foot in April 1991. The surface water features in and around the site (canals, ditches, interceptor wells, and borrow pits) influence the water table elevations at the site. Stormwater runoff is directed to onsite wet detention/ retention areas that provide storage and treatment of the stormwater before it discharges to the EPB-10 Canal. Additionally, a portion of the stormwater that recharges the water table (such as in the stormwater detention areas) seeps into the ditches and canals, since they are typically controlled at a lower level.

Based on the groundwater table contour map developed for March 1990, groundwater elevations ranged from +15.9 feet NGVD in the northwest (S7W-1) to +9.9 feet NGVD in the south-southeast portion of the site (S7W-7). This was a dry period and shallow groundwater elevations were relatively low. In April 1991, the shallow groundwater elevations ranged from +18.2 feet NGVD in the northwest portion of the site (S7W-1), to +14.5 feet NGVD in



WELL ID.	GROUNDWATER ELEVATION IN MARCH 1990 (feet NGVD)
DYER BOULEVARD LANDFILL	
DW-1R	10.98
DW-5AR	11.60
DW-15	10.77
DW-16R	11.16
DW-17	11.34
DW-18R	11.32
DW-19	11.45
DW-20	10.71
DW-21	10.85
DW-22R	9.93
DW-23	11.88
DW-24A	N/A
DW-25A	N/A
DW-26A	N/A
DW-28	11.00
DW-28B	N/A
DW-29	10.37
NCRRRF SITE	
S7W-1	15.88
S7W-2	15.79
S7W-3	15.74
S7W-4	13.06
S7W-5	11.90
S7W-6	10.59
S7W-7	9.94
S7W-8	12.31

LEGEND:

- MONITORING WELLS
- LANDFILL CELL AREAS
- STAFF GAUGES
- INTERCEPTOR WELLS
- LIMITS OF STORMWATER DETENTION SYSTEM
- 14 GROUNDWATER ELEVATION CONTOUR (feet NGVD) DASHED WHERE INFERRED BEYOND MEASURED DATA

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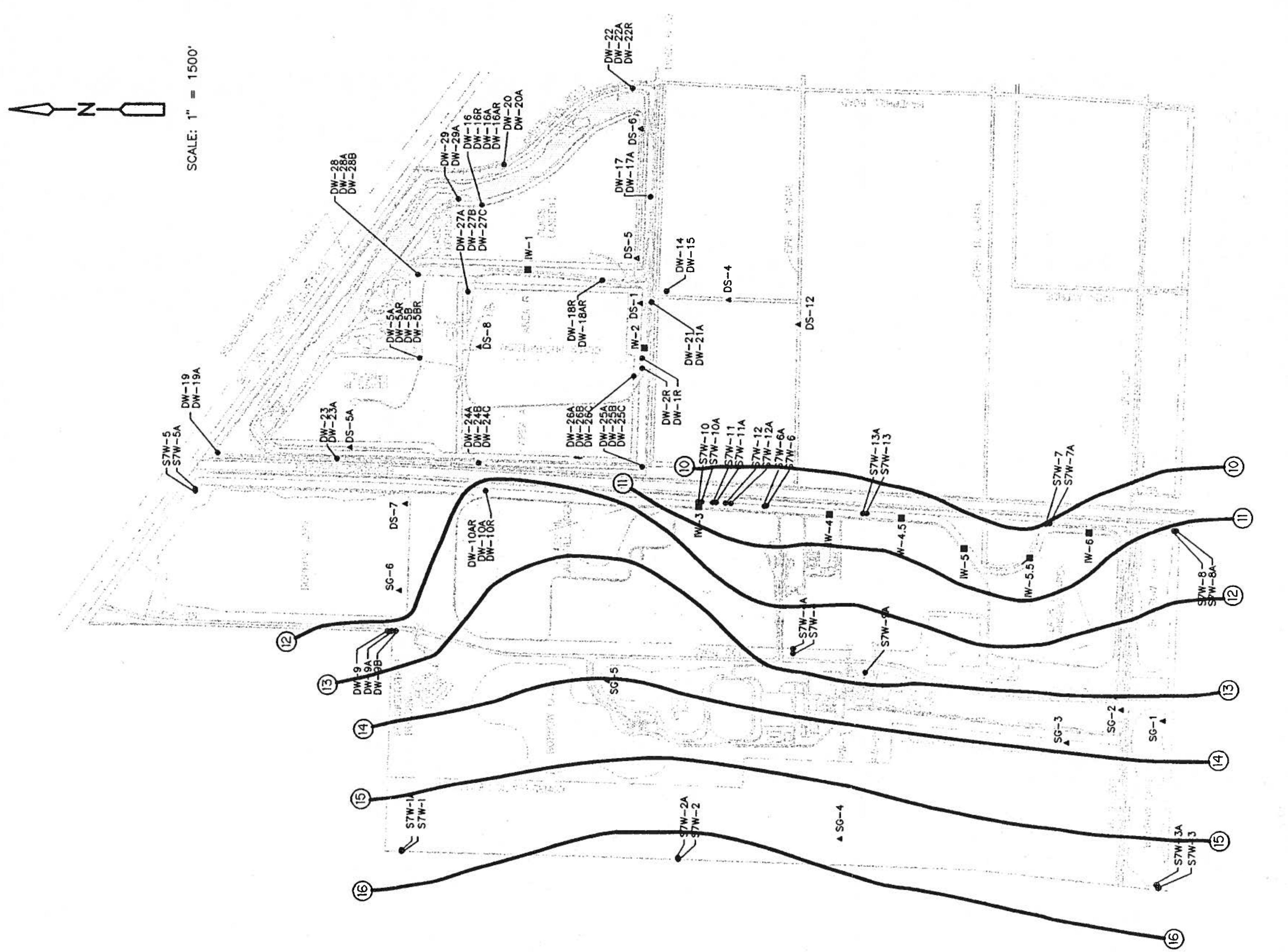
GROUNDWATER ELEVATION CONTOURS FOR THE UPPER (SHALLOW) SURFICIAL AQUIFER IN MARCH 1990

Figure No. 2-6



WELL ID.	GROUNDWATER ELEVATION IN MARCH 1990 (feet NGVD)
DYER BOULEVARD LANDFILL	
DW-10AR	12.12
DW-24C	N/A
DW-25C	N/A
DW-26C	N/A
DW-27C	N/A
NCRRRF SITE	
S7W-1A	15.87
S7W-2A	16.34
S7W-3A	15.53
S7W-4A	12.79
S7W-5A	11.80
S7W-6A	10.66
S7W-7A	10.00
S7W-8A	11.11
S7W-9A	12.96

LEGEND:

- MONITORING WELLS
- LANDFILL CELL AREAS
- STAFF GAUGES
- INTERCEPTOR WELLS
- LIMITS OF STORMWATER DETENTION SYSTEM
- 14 GROUNDWATER ELEVATION CONTOUR (feet NGVD) DASHED WHERE INFERRED BEYOND MEASURED DATA

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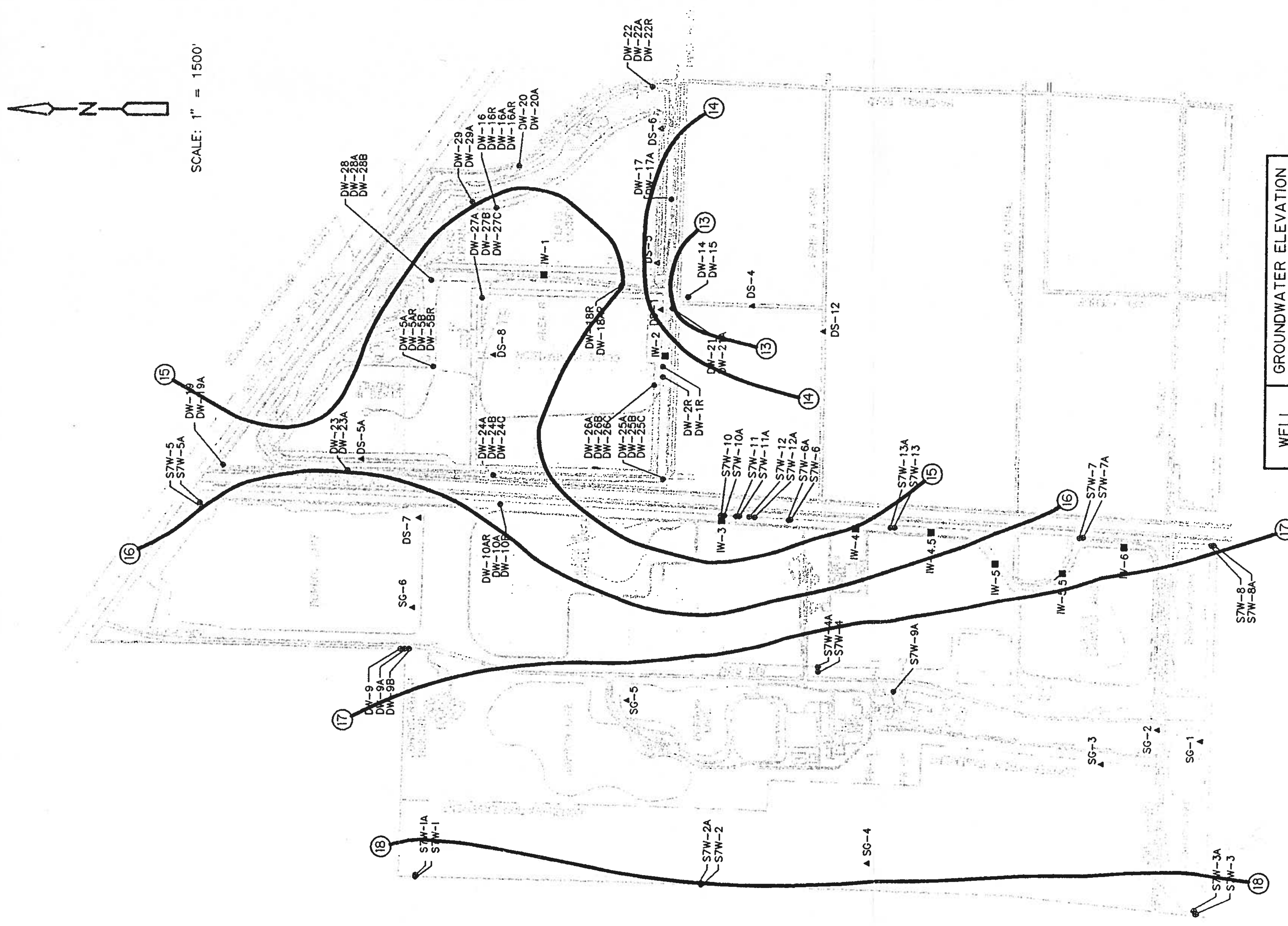
GROUNDWATER ELEVATION CONTOURS FOR THE LOWER (DEEP) SURFICIAL AQUIFER IN MARCH 1990

Figure No. 2-7



WELL ID.	GROUNDWATER ELEVATION IN APRIL 1991 (feet NGVD)
DYER BOULEVARD LANDFILL	
DW-1R	14.23
DW-5AR	15.69
DW-15	12.64
DW-16R	15.47
DW-17	13.46
DW-18R	15.02
DW-19	15.31
DW-20	15.21
DW-21	13.97
DW-22R	14.50
DW-23	15.01
DW-24A	15.42
DW-25A	14.23
DW-26A	14.10
DW-28	15.26
DW-28B	15.27
DW-29	14.65
NCRRRF SITE	
S7W-1	18.23
S7W-2	18.00
S7W-3	18.20
S7W-4	17.40
S7W-5	15.88
S7W-6	14.52
S7W-7	N/A
S7W-8	16.98

LEGEND:

- MONITORING WELLS
- LANDFILL CELL AREAS
- STAFF GAUGES
- INTERCEPTOR WELLS
- LIMITS OF STORMWATER DETENTION SYSTEM
- 14 GROUNDWATER ELEVATION CONTOUR (feet NGVD) DASHED WHERE INFERRED BEYOND MEASURED DATA

SOLID WASTE AUTHORITY OF PALM BEACH COUNTY

GROUNDWATER ELEVATION CONTOURS FOR THE UPPER (SHALLOW) SURFICIAL AQUIFER IN APRIL 1991

Figure No. 2-8

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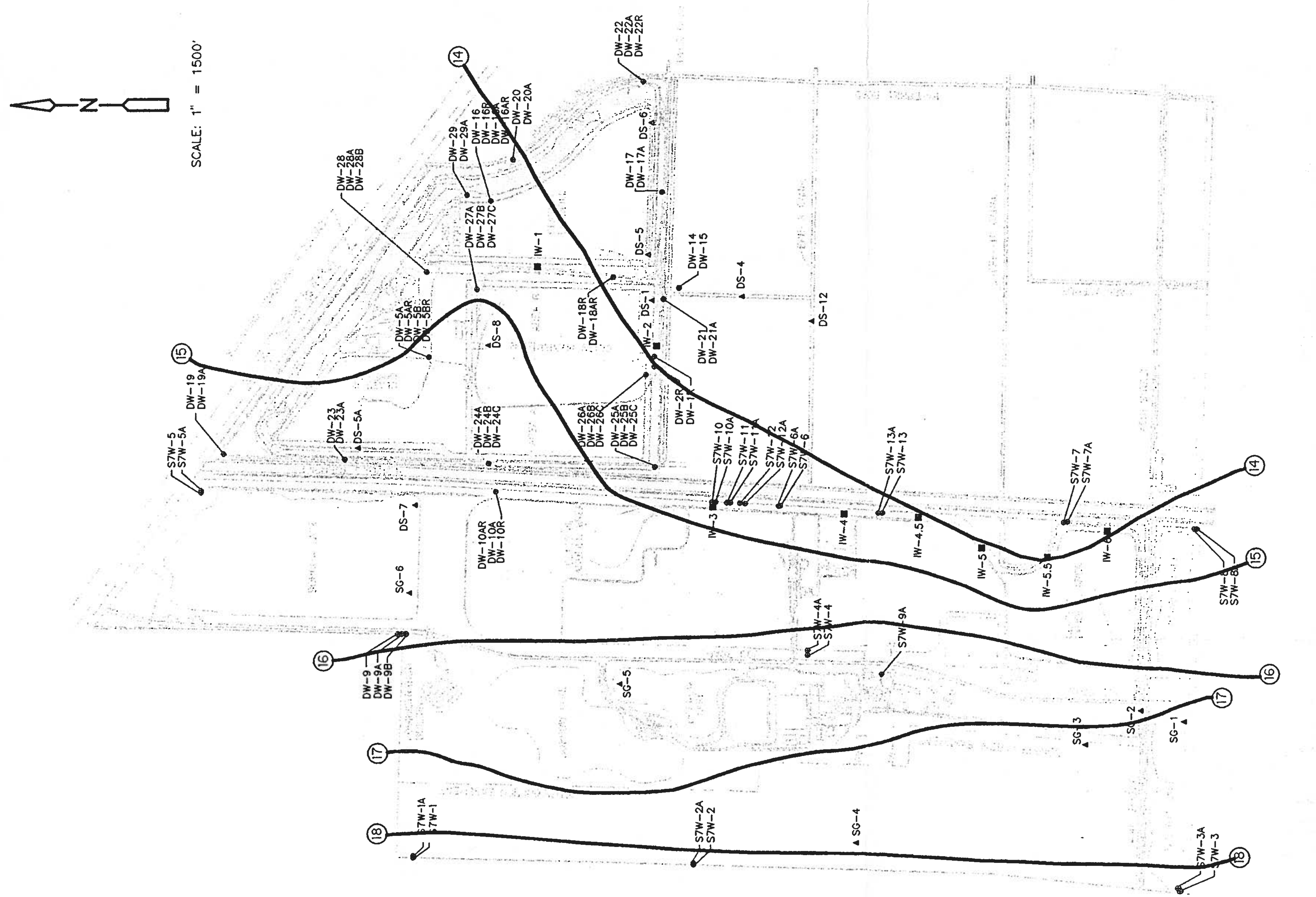

WELL ID.	GROUNDWATER ELEVATION IN APRIL 1991 (feet NGVD)
DYER BOULEVARD LANDFILL	
DW-10AR	15.63
DW-24C	15.69
DW-25C	14.29
DW-26C	14.06
DW-27C	14.96
NCRRRF SITE	
S7W-1A	18.30
S7W-2A	18.13
S7W-3A	18.22
S7W-4A	16.42
S7W-5A	15.65
S7W-6A	14.39
S7W-7A	13.11
S7W-8A	14.84
S7W-9A	16.47

LEGEND:

- MONITORING WELLS
- LANDFILL CELL AREAS
- STAFF GAUGES
- INTERCEPTOR WELLS
- LIMITS OF STORMWATER DETENTION SYSTEM
- GROUNDWATER ELEVATION CONTOUR (feet NGVD) DASHED WHERE INFERRED BEYOND MEASURED DATA

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GROUNDWATER ELEVATION CONTOURS FOR THE LOWER (DEEP) SURFICIAL AQUIFER IN APRIL 1991

Figure No. 2-9

the east-central portion (S7W-6). The EPB-9 Canal, which is located south of the Dyer Boulevard Landfill and east of the NCRRRF, appears to act as a sink for shallow groundwater in the area.

The seepage velocity for the upper surficial aquifer at this site can be estimated using Darcy's equation:

$$V_s = K_h i / n_e \qquad \text{Equation (1)}$$

where V_s = Seepage velocity (feet/day)

K_h = Horizontal hydraulic conductivity (feet/day)

i = Hydraulic gradient (feet/feet)

n_e = Effective porosity (unitless decimal)

From the groundwater table contour maps on Figures 2-6 and 2-8, the average hydraulic gradient is estimated to be approximately 0.00087. From the regional groundwater model constructed by the SFWMD (Technical Publication (TP) 89-4) the hydraulic conductivity and effective storage of the upper surficial aquifer in the vicinity of the site are approximately 50 feet/day and 0.25, respectively. The resulting seepage velocity in the upper surficial aquifer is approximately 0.17 feet/day (63 feet/year).

2.2.5 DEEPER GROUNDWATER FLOW PATTERNS

Based on the groundwater elevation contours developed for March 1990, groundwater elevations ranged from +16.3 feet NGVD in the northwest portion (S7W-1A) of the property to +10.0 feet NGVD in the southeast portion (S7W-7). In April 1991, the deeper surficial aquifer groundwater elevations ranged from +18.3 feet NGVD in the northwest portion of the site (S7W-1A) to +13.1 feet NGVD in the southeast portion (S7W-7A). Again, the groundwater elevations in the deeper portion of the surficial aquifer increased in response to the rainfall in April 1991. The upper portion of the aquifer is recharging the deep portion of the aquifer throughout the majority of the site. There is a small upward gradient along the boundary with the WPBWCA.

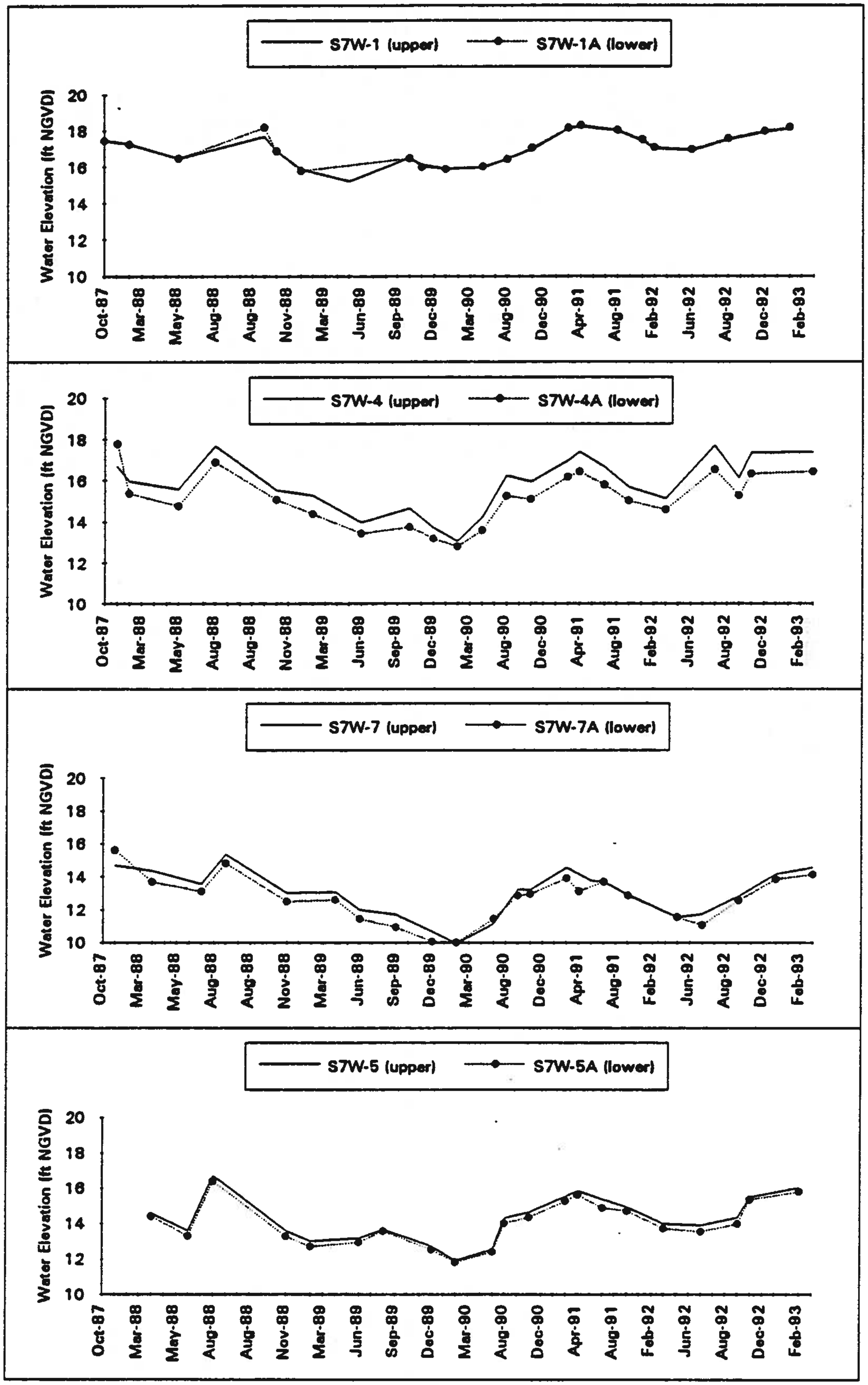
The average hydraulic gradient in the deeper portion of the surficial aquifer ranges from 0.0011 foot per foot in March 1990 to 0.00072 foot per foot in April 1991. It is believed that recharge in the WPBWCA recharges the surficial aquifer; however, the deeper portions of the aquifer are not as easily controlled as the water table by controlled surface water features. This phenomenon is also occurring on a much smaller scale in the south-central and southeast portions of the NCRRRF.

The vertical head difference between the upper and lower portions of the surficial aquifer is typically downward and ranges from 0.10 to 0.50 foot. However, in the vicinity of the borrow pits, the vertical hydraulic gradient is downward with a head difference of 1 to 3 feet.

The seepage velocity of the lower surficial aquifer at the site can also be estimated with equation (1). From the groundwater contour maps on Figures 2-7 and 2-9, the average hydraulic gradient is estimated to be approximately 0.00090. From the regional groundwater model constructed by the SFWMD (TP 89-4) the hydraulic conductivity and effective storage of the lower surficial aquifer in the vicinity of the site are approximately 150 feet/day and 0.25, respectively. The resulting seepage velocity in the lower surficial aquifer is approximately 0.54 feet/day (197 feet per year).

2.2.6 COMPARISON OF SHALLOW AND DEEP GROUNDWATER ELEVATIONS AT SELECTED WELL CLUSTERS

Groundwater levels for four monitoring well clusters, S7W-1, S7W-4, S7W-5, and S7W-7 are plotted with time on **Figure 2-10**. Monitoring wells S7W-1 and S7W-1A are located in the northwest corner of the site (adjacent to the WPBWCA) and are hydraulically upgradient of the NCRRRF. Monitoring wells S7W-4 and S7W-4A are located in the center of the site and are relatively uninfluenced by pumping or other hydraulic controls. Monitoring wells S7W-7 and S7W-7A are located in the southeast corner of the site and are influenced by pumping or other hydraulic controls. Monitoring wells S7W-5 and S7W-5A are located in the northern corner of the site (adjacent to State Road 710) and are influenced by the activities in the large borrow pit.



SOLID WASTE AUTHORITY OF PALM BEACH COUNTY

COMPARISON OF GROUNDWATER ELEVATIONS IN THE UPPER AND LOWER SURFICIAL AQUIFER AT SELECT WELL CLUSTERS

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Figure No. 2-10

From the measured groundwater elevations in these well clusters, it is evident that the vertical hydraulic gradient in the surficial aquifer is downward throughout the year. This indicates that the upper portion of the surficial aquifer is recharging the lower portion of the aquifer. Additionally, the upper and lower portions of the surficial aquifer appear to be hydraulically connected quite well. Water elevations at companion wells respond to recharge and discharge similarly with time.

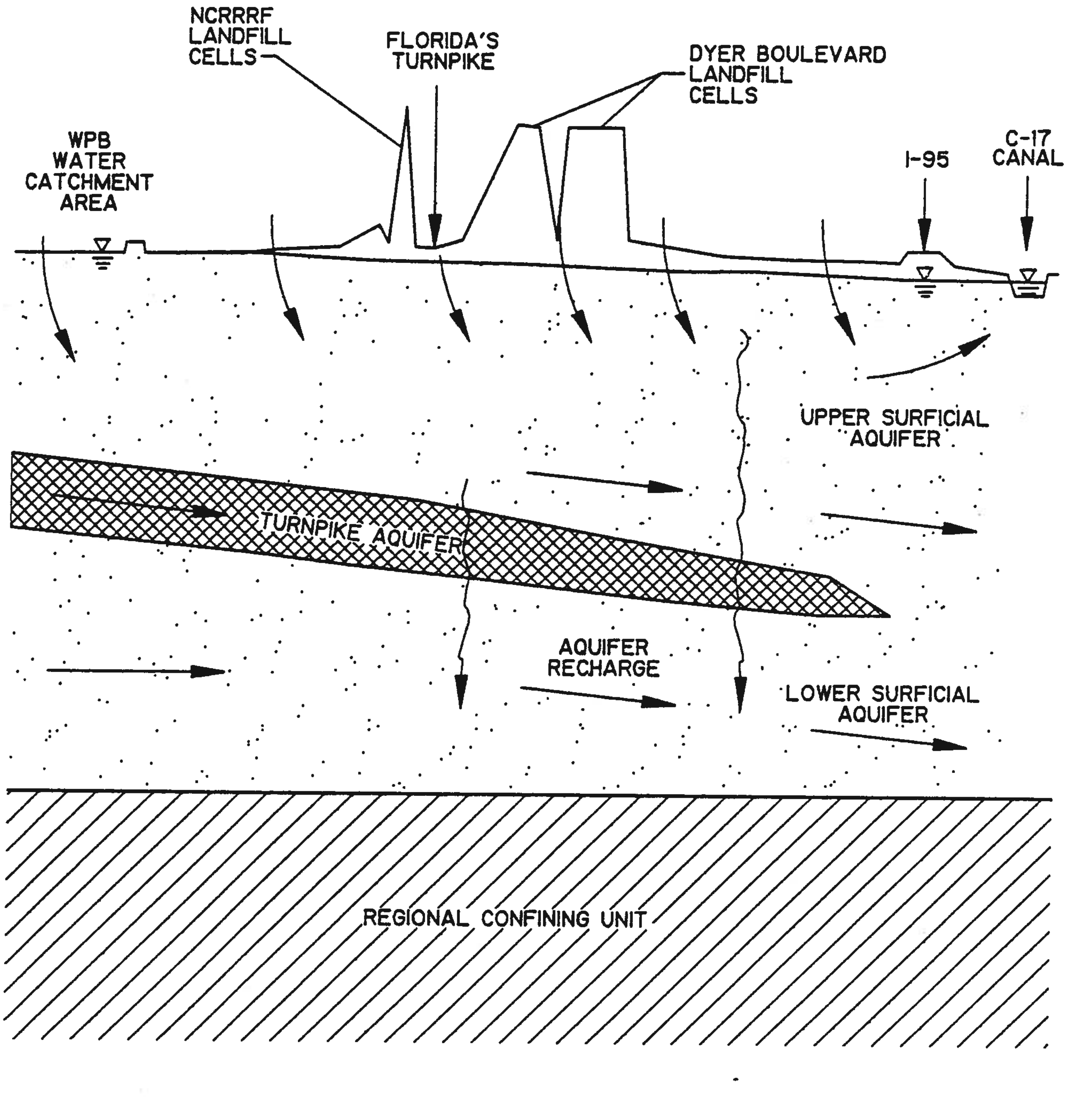
2.3 CONCEPTUAL GROUNDWATER FLOW MODEL

Based on water table contour maps of the surficial aquifer in Palm Beach County (Kane, 1992), the direction of groundwater flow is generally from Loxahatchee Slough in the west, toward the Atlantic Ocean in the east. On a local scale, however, groundwater movement is controlled by extensive ditch and canal systems that were constructed primarily for flood control purposes. These ditches/canals are also used to divert fresh water from the regional canals (M Canal, Palm Beach Canal, etc.) for groundwater recharge. The canals and ditches in Palm Beach County extend into the upper sands and do not penetrate the higher transmissive shell and limestone layers (production zone). Most of the groundwater recharge that occurs in Palm Beach County flows through the production zone. The conceptual model of groundwater flow for the project study area is presented on **Figure 2-11**.

2.4 RAINFALL AND EVAPOTRANSPIRATION

Rainfall and subsequent infiltration is the primary source of fresh water that replenishes the surficial aquifer system in south Florida. Due to a relatively high water table, a moderate percentage of rainfall "runs off" to surface waters such as ditches, lakes, creeks, rivers, and wetlands. In addition to runoff losses, water is also lost to evaporation and evapotranspiration (ET).

ET is the process by which water is transferred to the atmosphere from vegetative surfaces. The amount of water transferred by ET is governed by a number of environmental factors. Minimal ET rates occur during dark, cloudy days with high relative humidity, low temperatures, and no wind. ET rates are maximized on bright, sunny days with low relative



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SOLID WASTE AUTHORITY OF PALM BEACH COUNTY

CONCEPTUAL GROUNDWATER FLOW MODEL
FOR THE PROJECT STUDY AREA

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Figure No. 2-11

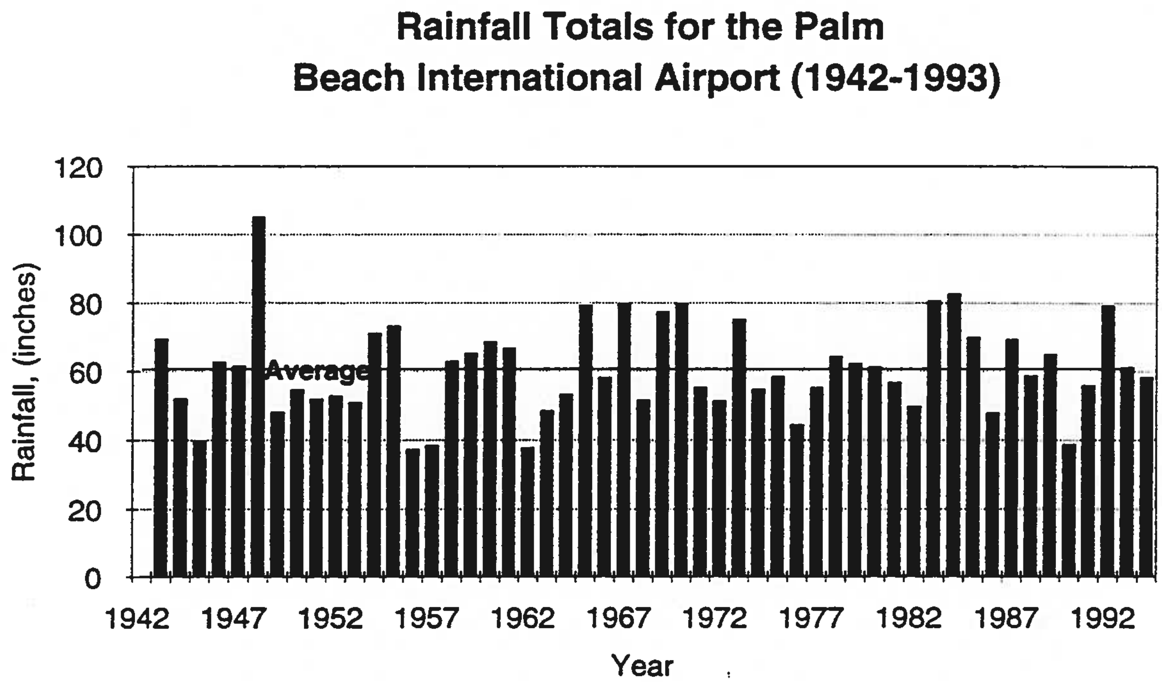
humidity, high temperatures, and moderate to high winds. Normally in central and south Florida, the month of May has the highest ET rates because of these factors (Augustin, 1984).

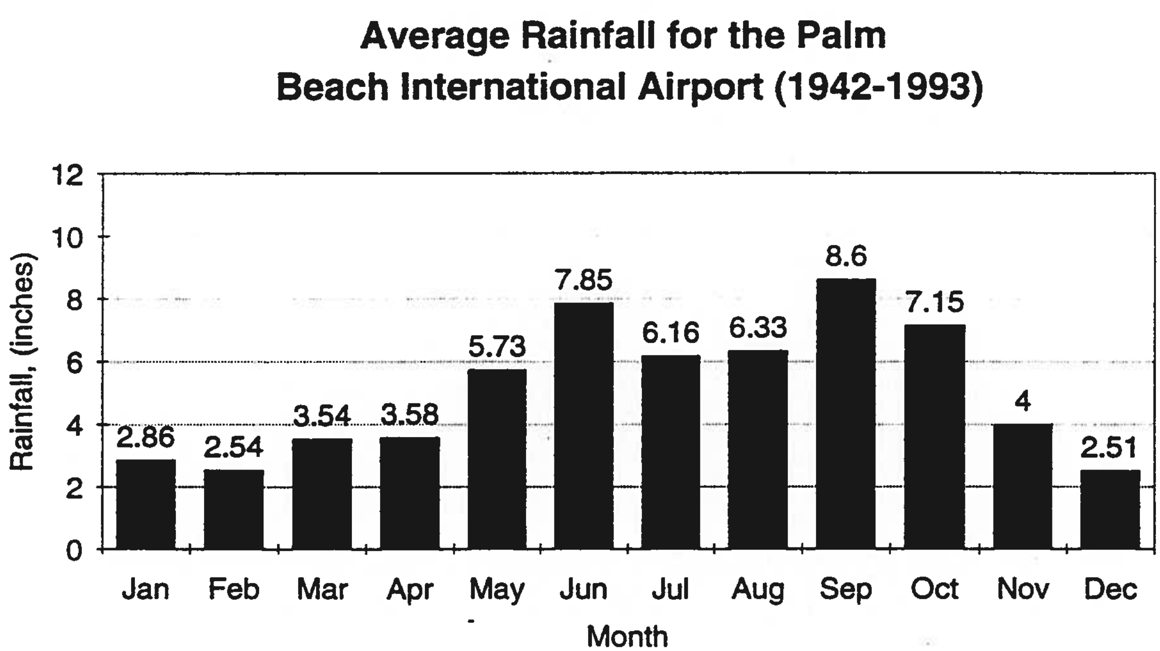
In general, the majority of rainfall returns to the atmosphere through evaporation and transpiration. Evaporation typically occurs from open bodies of water such as lakes, streams, and rivers. However, open water bodies cover only a small percentage of the landscape within the project area. ET, which is a combined process of direct evaporation and transpiration, occurs from all vegetation and is the predominant mechanism for returning rainfall to the atmosphere. ET values for cultivated crops throughout the United States are published throughout research literature. In contrast, ET rates for undeveloped forested areas such as wetlands and upland forests are not well known.

During full-scale experimental studies conducted over a 5-year period on St. Augustine and Bermuda grass in Ft. Lauderdale, Florida (Augustin, 1984), ET was observed to be 42.84 inches per year. Bush and Johnston (1988) have estimated, from regional groundwater flow studies, a composite ET of 43 inches per year.

The National Oceanic and Atmospheric Administration (NOAA) maintains a dedicated weather station at the Loxahatchee National Wildlife Refuge (NWR) and the Palm Beach International Airport (PBIA). The normal annual rainfall for the Loxahatchee NWR for the period 1941 through 1993 was 62.74 inches. The normal annual rainfall for the PBIA for the period 1942 through 1993 was 60.66 inches.

The annual rainfall totals and average monthly rainfall for the period 1942 to 1993 for the PBIA are presented graphically on **Figure 2-12**. The annual rainfall totals and average monthly rainfall for the period 1941 to 1993 for the Loxahatchee NWR are presented graphically on **Figure 2-13**. A comparison between the rainfall totals measured at the two NOAA stations for the period 1980 through 1993 is presented in **Table 2-1**. Monthly rainfall data for these two NOAA stations for the period of record are presented in **Appendix C**.





SOLID WASTE AUTHORITY OF PALM BEACH COUNTY

RAINFALL DATA FOR THE PALM BEACH INTERNATIONAL AIRPORT

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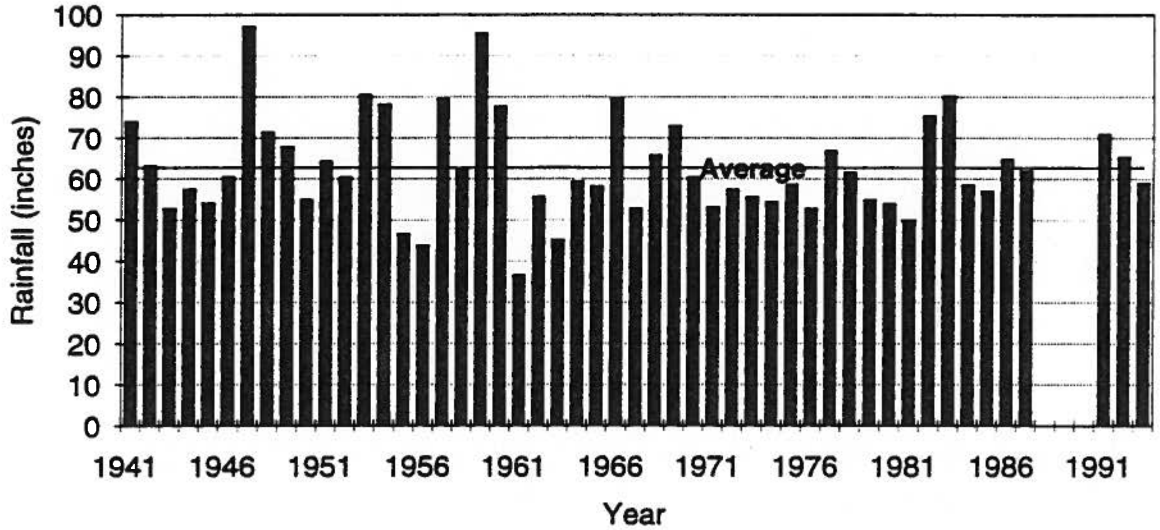
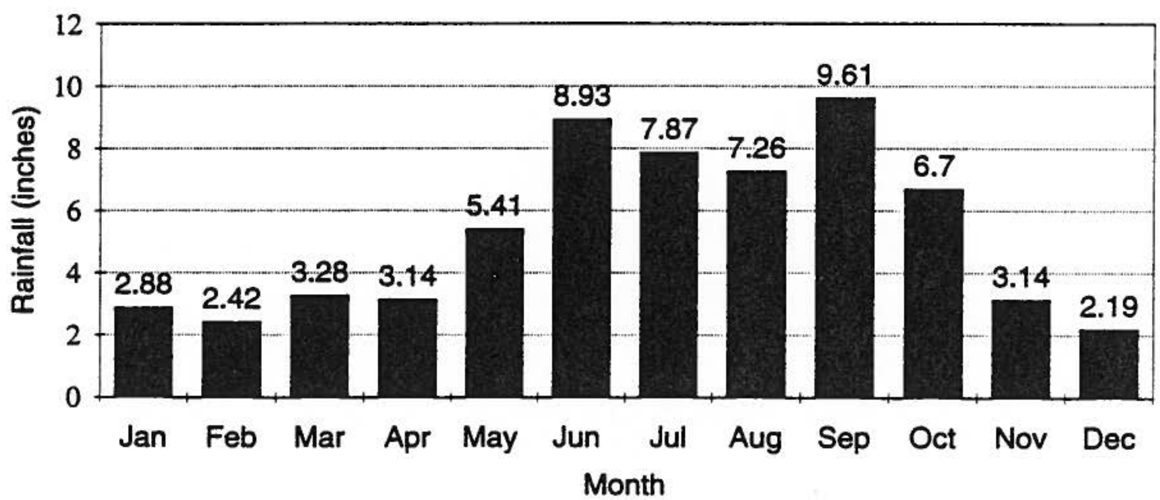
Figure No. 2-12

Rainfall Totals for the Loxahatchee NWR (1941-1993)



Average Rainfall for the Loxahatchee NWR (1941-1993)



SOLID WASTE AUTHORITY OF PALM BEACH COUNTY

RAINFALL DATA FOR THE LOXAHATCHEE NATIONAL WILDLIFE REFUGE

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Figure No. 2-13

TABLE 2-1

COMPARISON OF RECENT ANNUAL RAINFALL TOTALS MEASURED AT THE PALM BEACH INTERNATIONAL AIRPORT AND THE LOXAHATCHEE NATIONAL WILDLIFE REFUGE (NWR)

Year	Rainfall (inches)	
	Palm Beach International Airport	Loxahatchee NWR
1980	56.67	54.04
1981	49.74	50.10
1982	80.62	75.50
1983	82.71	80.29
1984	69.79	50.60
1985	47.99	57.08
1986	69.31	64.86
1987	58.69	62.15
1988	64.91	NR
1989	38.66	NR
1990	55.81	NR
1991	79.36	70.97
1992	61.11	65.07
1993	58.19	59.10
Average	66.45	67.62
Long-Term Average[1]	60.66	62.74

[1] Long-term average is the average annual rainfall for all of the years for the period of record.

NR = Not recorded.

2.5 OVERVIEW OF SURFACE WATER MANAGEMENT

There are several surface water features within a 2-mile radius of the NCRRRF Landfill: the C-17 (Earman River) Canal, the WPBWCA, the M Canal, the EPB-9 Canal, EPB-10 Canal, the Turnpike Canal, and the borrow pits at the NCRRRF. The locations of these surface water features are presented on Figure 1-1.

Surface water levels in the SFWMD C-17 Canal are controlled by a gated spillway known as Structure 44 (S-44). This structure is located just east of A1A, approximately 0.6 mile north of Northlake Boulevard. According to Cooper and Lane (1988), the structure is operated so that a headwater stage of +6.6 feet NGVD is maintained during the wet season and a headwater stage of +7.1 feet NGVD is maintained during the dry season to minimize seawater intrusion into the surficial aquifer.

Surface water levels in the WPBWCA are controlled at an elevation of +17.5 feet NGVD. However, the operating water elevations typically range between +16.0 and +17.5 feet NGVD. Discharge from the WPBWCA is via the M-1 Canal. The M Canal in turn discharges into Lake Mangonia. The M Canal is not part of the C-17 Canal surface water management basin and there is no exchange of water between the two systems. Lake Mangonia and Clear Lake are interconnected and surface water levels are equalized. When surface water levels in Lake Mangonia and Clear Lake exceed an elevation of +14.5 feet NGVD, such as during heavy rainfall events, water discharges from Clear Lake into the Stub Canal. The Stub Canal is connected to the C-51 Canal (the West Palm Beach Canal) which discharges into the Intracoastal Waterway north of Lake Worth. According to Cooper and Lane (1988), under operation as a water supply system, Lake Mangonia and Clear Lake are hydrologically independent of the C-17 and C-51 basins.

The surface water levels in the EPB-9, EPB-9A, and EPB-10 Canals are controlled between the elevations of +7.0 and +11.0 feet NGVD by a sharp-crested weir with adjustable flashboards located at the junction of C-17 near State Road 710. The EPB-9 Canal flows into the EPB-10 Canal west of I-95 and then the EPB-10 Canal discharges into the C-17 Canal east of I-95 and south of State Road 710. During dry periods, the weir boards are raised so that shallow groundwater levels do not drop and allow the seawater/freshwater interface to move further inland. During the wet season, the weir boards are lowered to prevent flooding in Northern Palm Beach County Water Control District (NPBCWCD) No. 7. The stormwater detention system for the NCRRRF discharges into the EPB-10 Canal during a 25-year, 3-day storm (14.27 inches) or greater event. The structure consists of a reinforced concrete box culvert with three rectangular weirs. The invert of the weirs are at an elevation of +18.64 feet NGVD. The normal pool elevation in the site's stormwater management system is controlled by three orifices. The invert elevation of the orifices is +16.67 feet NGVD.

The Turnpike Canal has a positive surface water outfall and discharges into the EPB-9 Canal at high water levels. The normal surface water levels are coincident with the surrounding groundwater table most of the time, but respond much quicker to rainfall. After a heavy rainfall, the Turnpike Canal acts as a recharge source for the surficial aquifer.

There are several borrow pits located at the NCRRRF. There are staff gauges installed in all of the borrow ponds and some of the stormwater detention facilities. There are a total of six staff gauges installed at the NCRRRF. The NCRRRF is located in NPBCWCD No. 7 and all of the surface water discharges from the site occur through the EPB-10 Canal. The water elevations at the NCRRRF range from approximately 17.0 feet NGVD in the western portion of the site (adjacent to the WPBWCA), to a low of approximately 13.0 to 14.0 feet NGVD in the eastern portion of the site (adjacent to the Turnpike).

2.6 CONCEPTUAL STEADY-STATE GROUNDWATER BUDGET

Based on data collected by the NOAA, the average annual rainfall is estimated to be approximately 62 inches per year. On an average annual basis, approximately 13 inches of the 62 inches of rainfall "runs off" to surface waters (Rumenik, 1988). Due to the highly permeable nature of the surface and near surface soils in the project area, the remaining 49 inches of rainfall recharges the surficial aquifer. The relationship between rainfall, stormwater runoff, and groundwater recharge is given below:

Rainfall = Stormwater Runoff + Aquifer Recharge

The volume of stormwater runoff is near average for south Florida; however, it is considered reasonable for this area due to high water tables and an extensive ditch canal network to collect the runoff. It must be noted that the actual amount of stormwater runoff that occurs at a particular site on an average annual basis is a function of the number and intensity of storm events and the imperviousness of the site. The estimate of 13 inches is a representative average for the land use in the area.

The average annual groundwater budget for the entire surficial aquifer within the site area (1,320 acres) is written as follows. All units are in inches per year over the site area.

$$Q_{re} + Q_i + Q_{cl} = Q_{et} + Q_o + Q_{cg} + Q_{sp} + \Delta S$$

Where inflows are:

Q_{re} = Aquifer Recharge = 49

Q_i = Groundwater Inflow = 13

Q_{cl} = Canal Loss = 6

and outflows are:

Q_{et} = Evapotranspiration From the Water Table = 43

Q_o = Groundwater Outflow = 6

Q_{cg} = Canal Gain = 8

Q_p = Aquifer Pumping = 11

ΔS = Change in aquifer storage = 0

and Total Inflow = Total Outflow = 68 inches per year.

The groundwater inflow and outflow terms as well as the canal gain and canal loss terms are taken from the recently developed groundwater flow model of the site. Groundwater inflow to the surficial aquifer from outside the watershed area is estimated to be approximately 13 inches per year. Since the WPBWCA on the western side of the project maintains water elevations above the water table, canal losses are estimated to be approximately six inches per year. Rainfall recharge increases the amount of groundwater flow in the surficial aquifer. Rainfall recharge is estimated to be approximately 49 inches per year. Of the 49 inches of rainfall recharge, approximately 43 inches per year is lost from the surficial aquifer as ET (Bush and Johnston, 1988). Groundwater outflow from the project area in the surficial aquifer is estimated to be approximately six inches per year. A substantial portion of groundwater recharge within the watershed area, approximately eight inches per year, becomes baseflow to the canals and ditches (EPB-9, EPB-10, and Turnpike Canals). Total pumping from the surficial aquifer was estimated from the SFWMD publication for Palm Beach County (Shine, Padgett and Barfknecht, 1989) and data provided by the Solid Waste Authority to be approximately 11 inches per year.

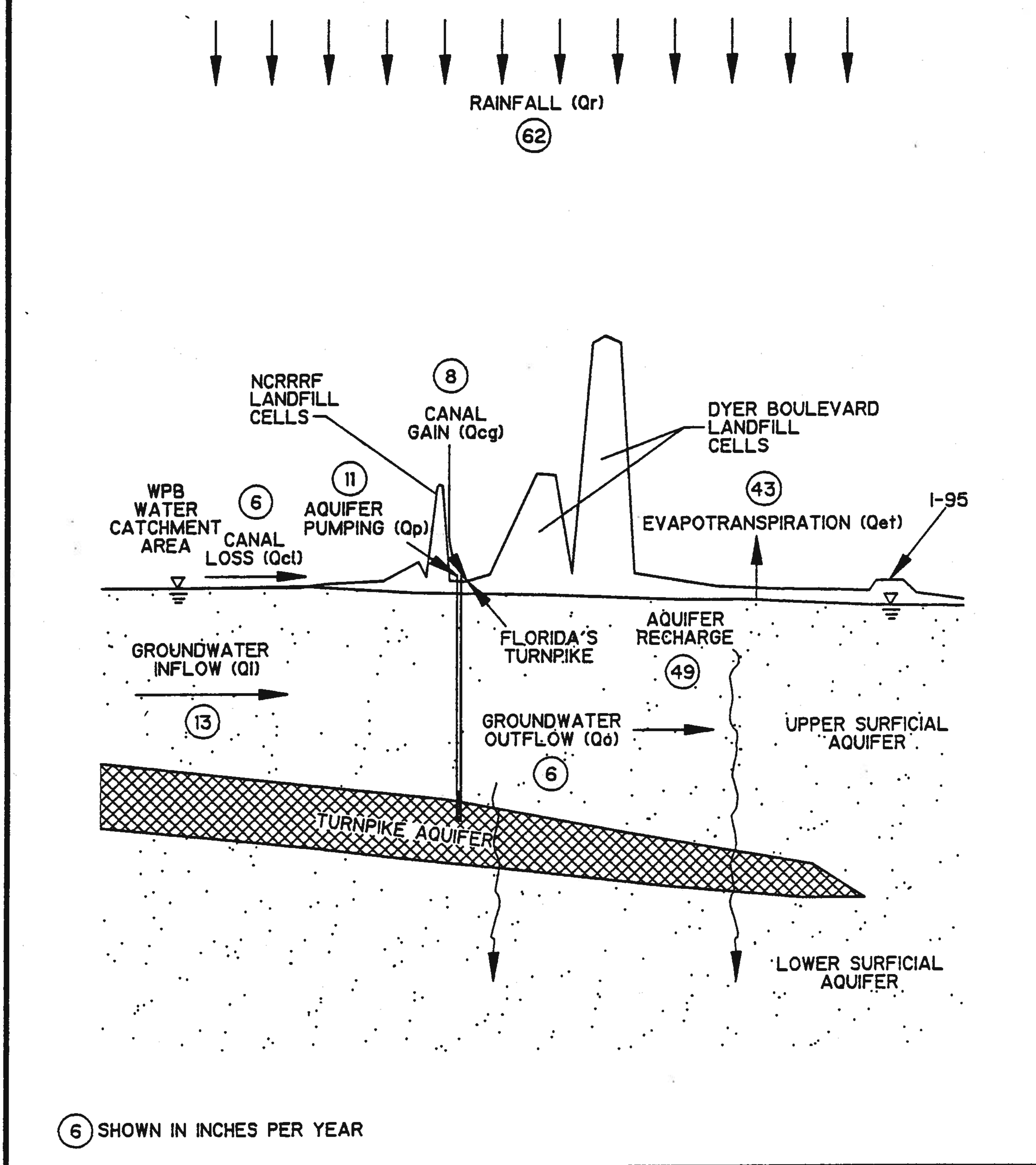
The average annual steady-state groundwater water budget for the watershed area is shown on **Figure 2-14**. One inch per year over the site area of 1,320 equals 0.098 million gallons per day.

2.7 SURFACE SOIL CHARACTERISTICS

The following soil characterizations are based on the Soil Conservation Service (SCS) soil survey of Palm Beach County (McCollum, *et al.*, 1978). These soil types are representative of conditions prior to development of the site as a solid waste resource recovery facility. The SCS soil data are presented for the purpose of describing the surface soils prior to development of the site as a solid waste resource recovery facility.

The 18 SCS soil units at the site are presented in **Table 2-2**. The distribution of SCS soil types in the vicinity of the site are shown on **Figure 2-15**. According to the SCS, the entire site is covered by poorly drained and very poorly drained soils.

All 18 soil units are listed as having severe limitations for use as sanitary landfills without modification, and are listed as poor for use as daily cover material. This is due in part by the high seasonal water table and the texture of the sands. The excessive wetness of the soil influences the design of the landfill in that the base of the landfill must be above the normal seasonal high water table to avoid flooding.



SOLID WASTE AUTHORITY OF PALM BEACH COUNTY

CONCEPTUAL ANNUAL GROUNDWATER BUDGET FOR THE NCRRRF

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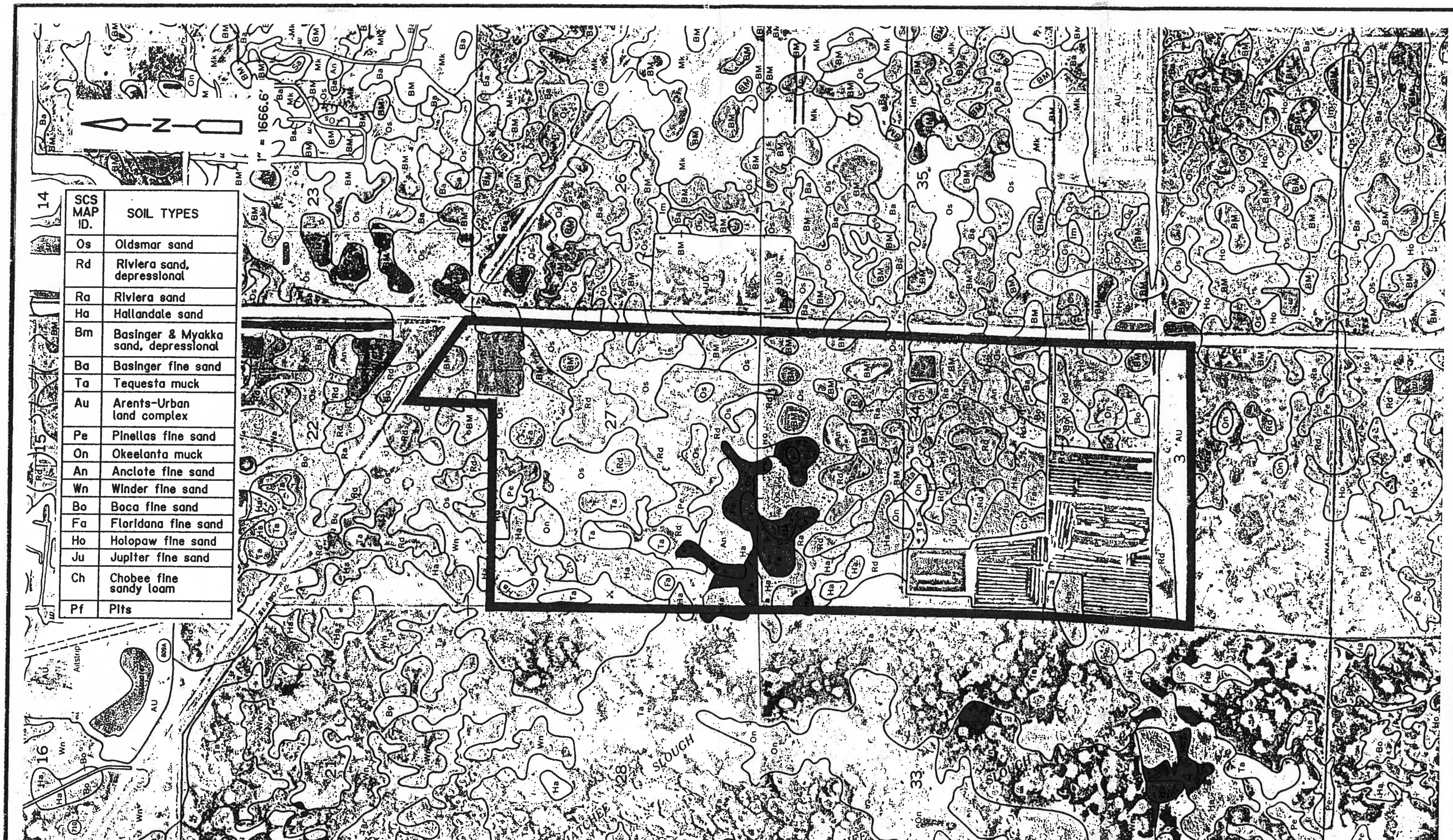
Figure No. 2-14

TABLE 2-2

ONSITE SCS SOIL TYPES

Series	SCS Map Unit	Drainage Characteristics
Oldsmar sand	Os	poorly drained
Riviera sand, depressional	Rd	poorly drained
Riviera sand	Ra	poorly drained
Hallandale sand	Ha	poorly drained
Basinger & Myakka sands, depressional	BM	very poorly drained
Basinger fine sand	Ba	poorly drained
Tequesta muck	Ta	very poorly drained
Arents-Urban land complex	Au	excessively drained
Pinellas fine sand	Pe	poorly drained
Okeelanta muck	On	very poorly drained
Anclote fine sand	An	very poorly drained
Winder fine sand	Wn	poorly drained
Boca fine sand	Bo	poorly drained
Floridana fine sand	Fa	very poorly drained
Holopaw fine sand	Ho	poorly drained
Jupiter fine sand	Ju	poorly drained
Chobee fine sandy loam	Ch	very poorly drained
Pits	Pf	not applicable



SOURCE: McCollum, et al, 1978

SOLID WASTE AUTHORITY OF PALM BEACH COUNTY

DISTRIBUTION OF SCS SOIL TYPES AT THE SITE

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Figure No. 2-15

2.8 WELL INVENTORY

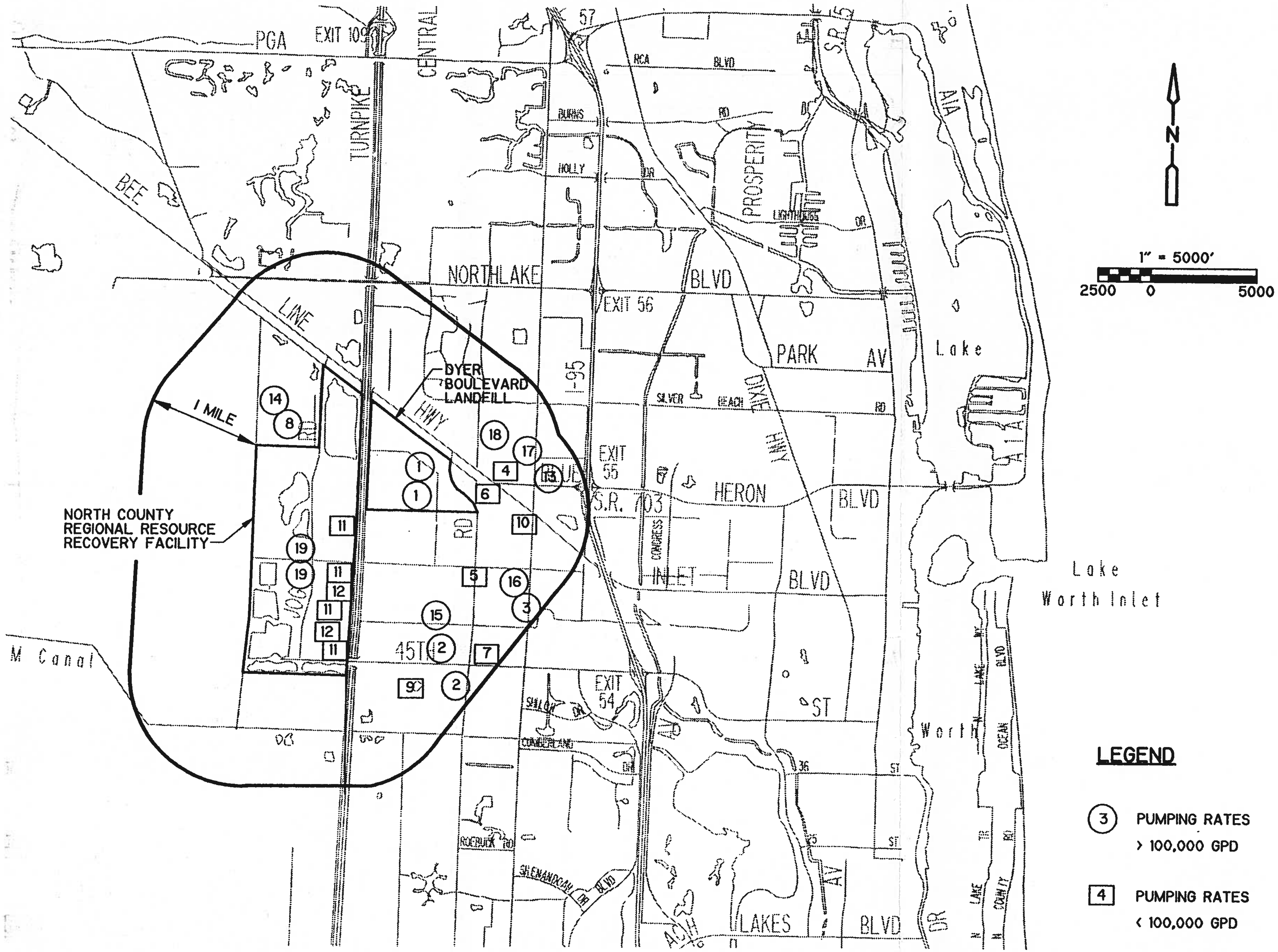
A well inventory was conducted within a 1-mile radius of the NCRRRF. This inventory was conducted by searching the files of the SFWMD followed by field reconnaissance and verification. Based on this inventory, a total of 28 wells owned by 15 different entities were identified within a 1-mile radius of the NCRRRF. The locations of all wells within one mile of the site are presented on **Figure 2-16**. The detail of the wells are summarized in **Table 2-3**.

As shown in Table 2-3, there are two public utilities; the City of West Palm Beach (three wells), and the City of Riviera Beach (seven wells), that own and operate well fields within one mile of the site. The majority of the entities (11) use their wells for irrigation purposes. The Solid Waste Authority of Palm Beach County owns 10 of the 28 wells; 2 wells are constructed for potable purposes that have not been used yet, and 8 of the wells are used for irrigation and to supply water for the waste to energy (WTE) plant on an as needed basis. The two wells installed at the Dyer Boulevard Landfill are the ones used for irrigation and groundwater control and the six wells located at the NCRRRF are currently being used to supply water to the WTE plant. Two of these six wells (Nos. 5 and 5.5) will be abandoned as part of the landfill's lateral expansion. The other four wells will continue to be used to supply water to the WTE plant on an as needed basis.

MAP ID

1. Solid Waste Authority of Palm Beach County
2. City of Riviera Beach
3. City of Riviera Beach
4. Holiday Country Club
5. Southern Building Products
6. Tropigas, Inc of Florida
7. C.A. Leslie & R.J. Katz
8. North Palm Beach Water Control District
9. Cypress Run Apartments
10. Standard Concrete Corp
11. Solid Waste Authority of Palm Beach County
12. Solid Waste Authority of Palm Beach County
13. Holigolf, Inc.
14. IronHorse Limited
15. Hood Road Corp
16. Lone Pine Golf Course
17. VA Medical Center
18. VA Medical Center
19. Solid Waste Authority of Palm Beach County

Note: See Table 2-3 for detailed data.



SOLID WASTE AUTHORITY OF PALM BEACH COUNTY

LOCATION OF WELLS WITHIN 1 MILE OF THE SITE

Figure No. 2-16

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TABLE 2-3

SOLID WASTE AUTHORITY OF PALM BEACH COUNTY
NCRRRF MONITORING PLANS

Well Inventory Near the NCRRRF and Dyer Boulevard Landfills

Map Index	Owner	Location Sec	Location Twp	Location Rg	Well No.	Install Date	Usage (1)	SFWMD Permit Number	Source	Pumping Rate Max	Pumping Rate Avg	Well Diameter (inches)	Well Depth (feet)	Cased Depth (feet)	Screened Interval (feet)	Permit Exp. Date
1	Solid Waste Authority of	6	42 S	42 E	IW-1	1986	Irrigation		Groundwater	0.864 MGD		6	128	55	55-125	
	Palm Beach County	35	42 S	42 E	IW-2	1986				0.864 MGD		6	128	55	55-125	
2	City of Riviera Beach	1,2	43 S	42 E	1	1962	PWS	50-00713-W	Groundwater	.575 MGD	.359 MGD	8	120	120	70-120	8/8/95
					2	1962						8	120	120	70-120	
					871	1988						14	130	70	70-130	
3	City of Riviera Beach	36	42 S	42 E	PW-9A	1978	PWS	50-00460-W	Groundwater			6				
					PW-10A	1978						6				
					PW-12A	1984						6				
					PW-21							6				
4	Holiday Country Club	25	42 S	42 E	1	1984	PWS	GP-84-031-W	Groundwater	3000 GPD	2250 GPD	2	100	92		
5	Southern Building Products	36	42 S	42 E	2	1990	PWS	50-02313-W	Groundwater	1150 GPD	1000 GPD	2	160	147	N/A	
6	Tropigas, Inc of Florida	25	42 S	42 E	1	1987	PWS	GP-86-0380-W	Groundwater	1550 GPD	620 GPD	2	70	60		20 yr rule
						1987	Irrigation					2	67	57	57-67	
7	C.A. Leslie & R.J. Katz	36	42 S	42 E	1	1987	PWS	GP-87-0320-W	Groundwater	600 GPD	600 GPD	3	156	140		20 yr rule
8	North Palm Beach County	22,27	42 S	42 E	P-2	1989	Irrigation	50-01906-W	Groundwater	.635 MGD		10	125	85	80-120	6/15/92
	Water Control District				P-1	1989						10	125	85	80-120	
9	Cypress Run Apartments	2	43 S	42 E	1	1990	Irrigation	50-02314-W	Groundwater	91600 GPD	80000 GPD	4	120	100	N/A (2)	5/10/2010
10	Standard Concrete Corp	25	42 S	42 E	A	1986	Industrial	GP-86-0229-W	Groundwater	50000 GPD	45000 GPD	6	100	80	80-100	20 yr rule
11	Solid Waste Authority of	34	42 S	42 E	IW-3	1987	Irrigation		Groundwater	0.864 MGD		6	128	55	55-125	
	Palm Beach County	34	42 S	42 E	IW-4	1988				0.864 MGD		12/6	114	62	22-42/62-112	
		34	42 S	42 E	IW-5	1988				0.864 MGD		12/6	114	62	22-42/62-112	
		3	42 S	42 E	IW-6	1988				0.864 MGD		12/6	114	62	22-42/62-112	
12	Solid Waste Authority of	34	43 S	42 E	IW-4.5	1988	Industrial	G-87-0416-W	Groundwater	0.864 MGD		12	55	55	15-45	
	Palm Beach County	3	42 S	42 E	IW-5.5	1988				0.864 MGD		12	55	55	15-45	
13	Holigolf, Inc.	25	42 S	42 E	1	1988	Irrigation	50-00255-W	Groundwater	.167 MGD		6	150			10/15/88
					2							6	150			

TABLE 2-3

SOLID WASTE AUTHORITY OF PALM BEACH COUNTY
NCRRRF MONITORING PLANS

Well Inventory Near the NCRRRF and Dyer Boulevard Landfills

Map Index	Owner	Location Sec	Location Twp	Location Rg	Well No.	Install Date	Usage (1)	SFWMD Permit Number	Source	Pumping Rate Max	Pumping Rate Avg	Well Diameter (inches)	Well Depth (feet)	Cased Depth (feet)	Screened Interval (feet)	Permit Exp. Date
14	IronHorse Limited	22,27	42 S	42 E			Irrigation	50-01905-W	Surface Water	34.25 MGM						6/15/92
15	Hood Road Corp	35	42 S	42 E		1984	Irrigation	50-01260-W	Surface Water	9.39 MGM						10/15/88
16	Lone Pine Golf Course	36	42 S	42 E		1989	Irrigation	50-00954-W	Surface Water	6.91 MGM						3/9/92
17	VA Medical Center	25	42 S	42 E		1993	Dewatering	50-02723-W	Surface Water	1.01 MGD						9/11/94
18	VA Medical Center	25	42 S	42 E		1991	Irrigation	50-02615-W	Surface Water	5.18 MGM						10/15/93
19	Solid Waste Authority of Palm Beach County	34	42 S	42 E	INJ-1 INJ-2	1986	Injection	N/A	Leachate	N/A		10	3500	3000	N/A	N/A

(1) PWS = Public Water Supply
(2) Not Applicable, open end

Note:
a) Top and bottom of well casing information was not available
b) Well construction technique information was not available
c) Static water elevation information was not available
d) All groundwater pumping from surficial aquifer