City of West Palm Beach
East Central Regional Wastewater Treatment Plant

Construction and Testing of Injection Well No. 7 and Dual Zone Monitoring Well No. 7

Volume 1 of 2

October 2004

Report

CDM

6365 N.W. 6th Way, Suite 320
Fort Lauderdale, Florida 33309
tel: 954 776-1731
fax: 954 928-1649

October 5, 2004

Mr. Joseph R. May, P.G.
UIC/TAC Chairman
Southeast District
Florida Department of Environmental Protection
400 North Congress Avenue, Suite 200
West Palm Beach, Florida 33401

Subject: City of West Palm Beach
East Central Regional Wastewater Treatment Plant
Construction and Testing of IW-7 and DZMW-7
FDEP Construction Permit 0048923-005-UC (IW-7, MW-7)

Dear Mr. May:

CDM is pleased to submit the subject document on the construction and testing of Injection Well No. 7 and associated Dual Zone Monitor Well No. 7 at the East Central Regional Wastewater Treatment Plant in Palm Beach County, Florida. The well was constructed and tested in accordance with the permit conditions and the construction specifications except for the various changes described in the report which were approved by the Department during construction and testing.

The enclosed report does not include signed and sealed record drawings (Appendix M) or the Operation and Maintenance Manual (Appendix Q). To date, the contractor has not installed the pad and various other items needed to complete the signed and sealed record drawings and the Operation and Maintenance Manual. Once the contractor has completed the work, they will be submitted under separate cover.

Based upon CDM's evaluation of the site-specific data, the following conclusions were reached:

- The base of the USDW was identified at a depth of approximately 2,000 feet below pad level (bpl).

- The top of the injection zone at the ECRWWTP site is located at least 645 feet below the base of the USDW after approximately 27 years of deep well injection at the site.

- The injection zone is between 2,675 and 3,650 feet bpl, and the bottom of the injection casing is at 2,962 feet bpl. It is anticipated that the primary interval for injection at IW-7 is a cavernous zone at a depth between 3,485 to 3,650 feet bpl. The water quality data and geophysical log responses for the IW-7 pilot hole indicate that secondarily treated domestic wastewater effluent from the existing onsite injection wells has migrated into the strata below 2,962 feet bpl. The native formation water was not evident from the injection zone background quality results.

- Effective vertical confinement is provided by dolomite and dolomitic limestone present below the base of the USDW. There appears to be three distinct confining layers overlying the injection zone: a good confining layer from 2,000 to 2,200 feet bpl, a very good confining layer from 2,250 to 2,450 feet bpl, and a good confining layer from 2,450 to 2,675 feet bpl. The lowest vertical permeability measured in the cores obtained in this interval during pilot hole construction was on the order of 10-7 cm/sec at depths of 1,880, 1,977.3, 2,302.7, 2,423.3, 2,426.3, 2,421.7, and 2,784.8 feet bpl. Other zones in the interval also showed very low vertical permeability. These low permeability zones, in combination with the more than 625 feet of homogeneous non-fractured limestone and dolomite, give extensive confinement to the waters below the USDW.

Based on the conclusions discussed in Section 8, which were drawn from the available data, IW-7 meets all of the regulatory requirements for a Class I injection well as defined by FDEP. Thus, it is recommended that the IW-7 Class I construction permit should be modified to allow operational testing once the signed and sealed drawings and the Operation and Maintenance Manual is submitted under separate cover.

The recommended maximum daily average injection rate for inclusion in the permit should be 22.03 MGD, which provides an injection velocity of 10 feet per second. The recommended maximum wellhead injection pressure over and above the static piezometric pressure for inclusion in a five-year operation permit should be 100 psi.

CDM

On behalf of the East Central Regional Wastewater Treatment Facilities Operations Board, we thank the Florida Department of Environmental Protection and the Underground Injection Control Technical Advisory Committee members who provided assistance with this project.

Should you have any questions about the report, please feel free to call.

Very truly yours,

Stewart J. Magenheimer, P.G.
Camp Dresser & McKee Inc.

SJM/DCF/ph
Enclosures

File: 10061-26918-015.GS [9]

c: Mark Silverman, FDEP WPB
Cathy McCarty, FDEP TAL
Ron Reese, USGS
Steve Anderson, SFWMD
Nancy Marsh, USEPA
Tom Lefevre, PBCHD
Ken Rearden, ECR
Mike Cravens, ECR
Dave Holtz, CDM WPB
Bob Maliva, CDM FTM

City of West Palm Beach East Central Regional Wastewater Treatment Plant

Construction and Testing of Injection Well No. 7 and Dual Zone Monitoring Well No. 7

October 2004

Stewart J. Magenheimer, P.G. #1168
Professional Geologist

Gregory A. Shaw, P.E. #59495
Professional Engineer

Report

10061-26918-015.GS

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Section 1
Introduction

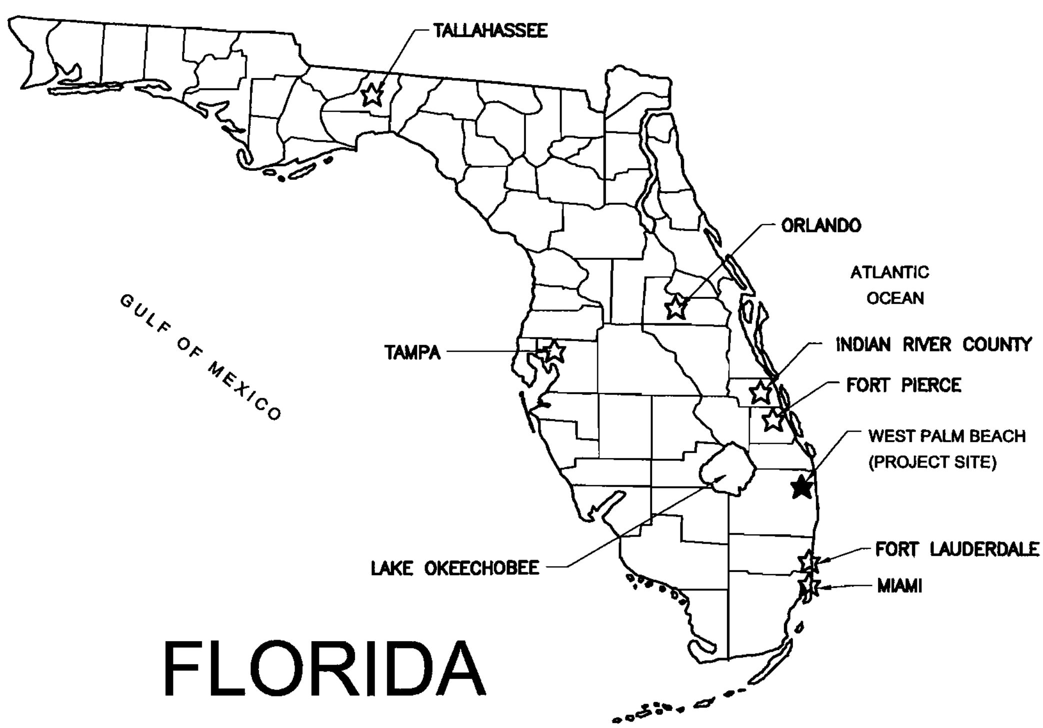
1.1 Background

The City of West Palm Beach East Central Regional Wastewater Treatment Plant (ECRWWTP) is located at 4325 North Haverhill Road, West Palm Beach, Palm Beach County, Florida, as shown on **Figures 1-1, 1-2,** and **1-3**. There are six existing Class I deep injection wells (IW) on site, Wells IW-1R, IW-2, IW-3, IW-4, IW-5, and IW-6, which are utilized for the disposal of treated effluent, as shown on **Figure 1-4**. Construction of wells IW-1R, IW-2, and IW-3 was completed in 1977, IW-4 was completed in 1979, IW-5 was completed in 1980, and IW-6 was completed in 1986. The six injection wells have been in operation since completion. The construction details for IW-1R, IW-2, IW-3, IW-4, and IW-5 are shown on **Figure 1-5** and IW-6, Dual Zone Monitor Well No. 2 (DZMW-2), and DZMW-6 are shown on **Figure 1-6.** Part of the effluent originates from two treatment plants at remote locations and pumped to this site. The remaining effluent is treated on site at the ECRWWTP.

In 2003, Camp Dresser & McKee Inc. (CDM) was retained to design, and monitor the construction and testing of one 26-inch diameter Class I Underground Injection Control Well (Injection Well No. 7 or IW-7), and an associated Dual Zone Monitor Well No. 7 (DZMW-7).

The construction of IW-7 began in September 2003, and was completed in April 2004. The construction for DZMW-7 began in December 2003, and was completed in April 2004. IW-7 has been constructed northwest of IW-6 as shown on **Figure 1-7**, with DZMW-7 located to the southwest of IW-7. On July 1, 2003, Youngquist Brothers, Inc., (YBI) based in Fort Myers, Florida, was contracted by the East Central Regional Wastewater Treatment Facilities Operations Board to construct IW-7 and DZMW-7. The Florida Department of Environmental Protection (FDEP) issued the construction permit for IW-7/DZMW-7 on March 11, 2003 (Permit No. 0048923-005-UC). The permit is included in Appendix A and contains general and specific conditions relating to the design parameters, specific construction criteria, testing and monitoring requirements. Specific Condition 5.b in the IW-7/DZMW-7 construction permit stated that specific data must be submitted, along with the request for operational testing approval, for the Underground Injection Control Technical Advisory Committee (UIC TAC) and USEPA review and FDEP approval prior to IW-7 operational testing approval. This report includes the specific data for IW-7 operational testing approval.

The results from the injection well and testing program are positive and reasonably assure the existence of good overlying confinement and of an injection zone which can accept the design injection rate of 15,300 gallons per minute (gpm), as demonstrated by the 24-hour injection test.



GENERAL LOCATION MAP

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Figure No. 1-1
City of WPB ECRWWTP, Florida
General Location Map

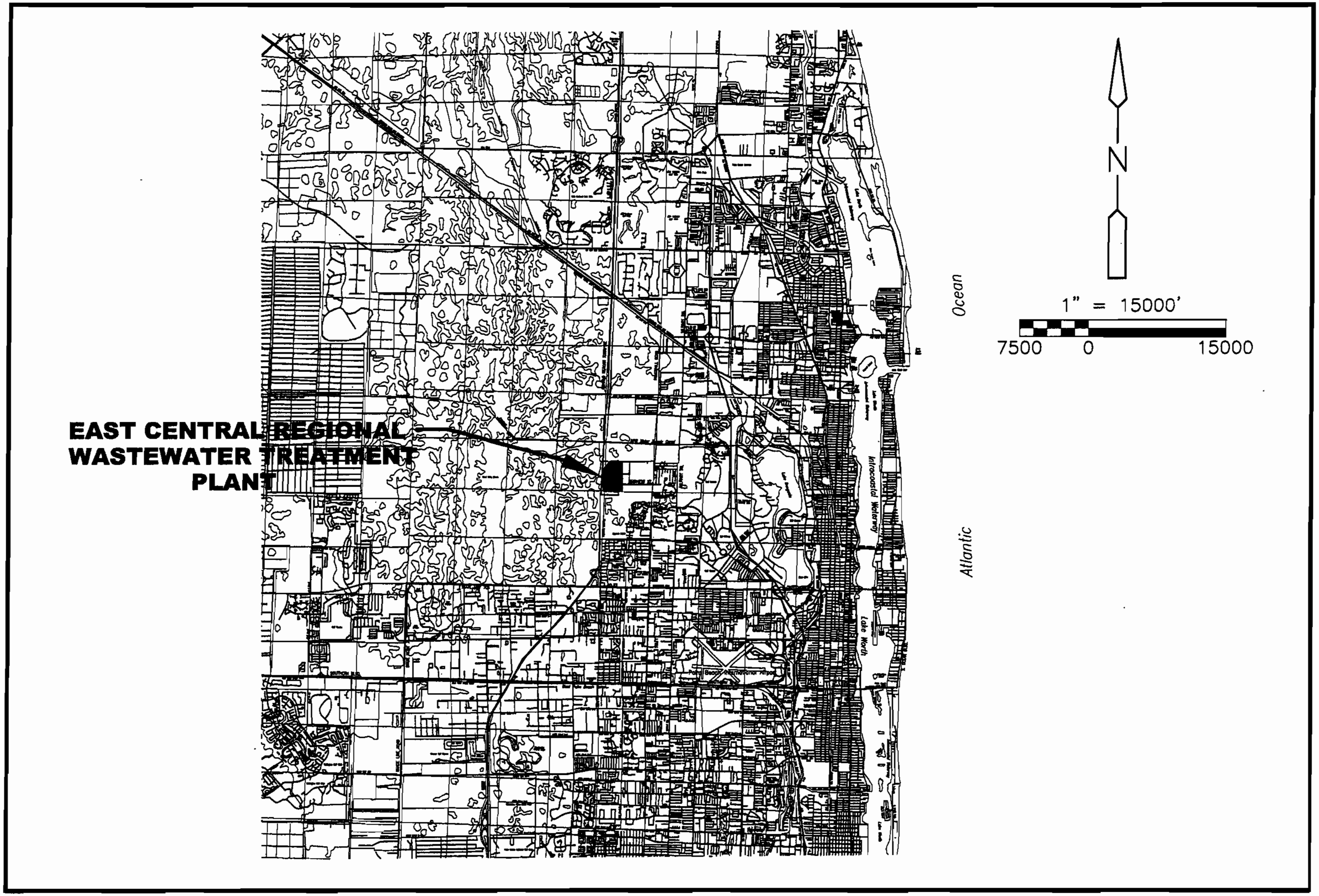

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Figure No. 1-2
City of WPB ECRWWTP, Florida
Location Map

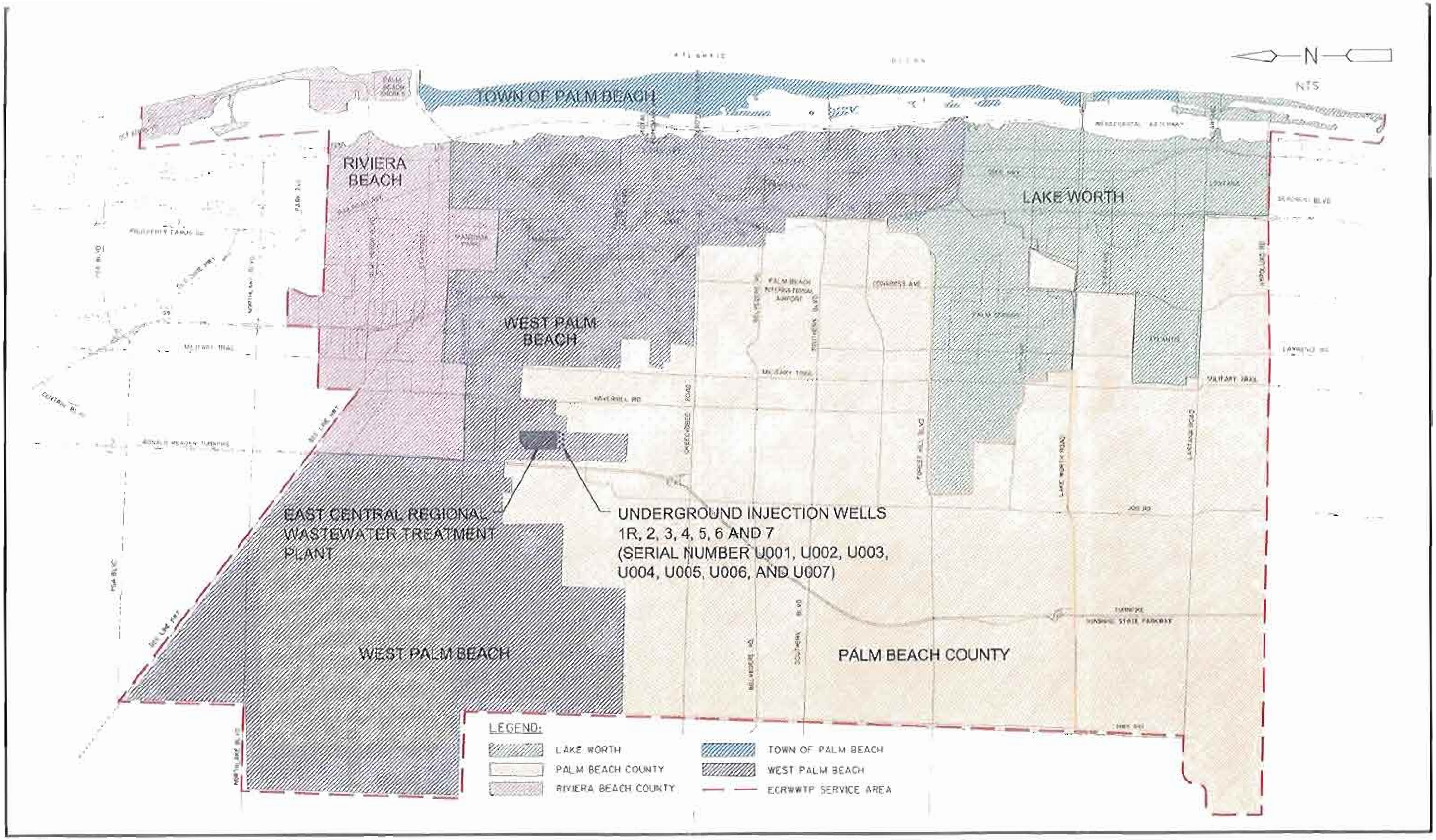

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Figure No. 1-3
City of WPB ECRWWTP, Florida
Area Map

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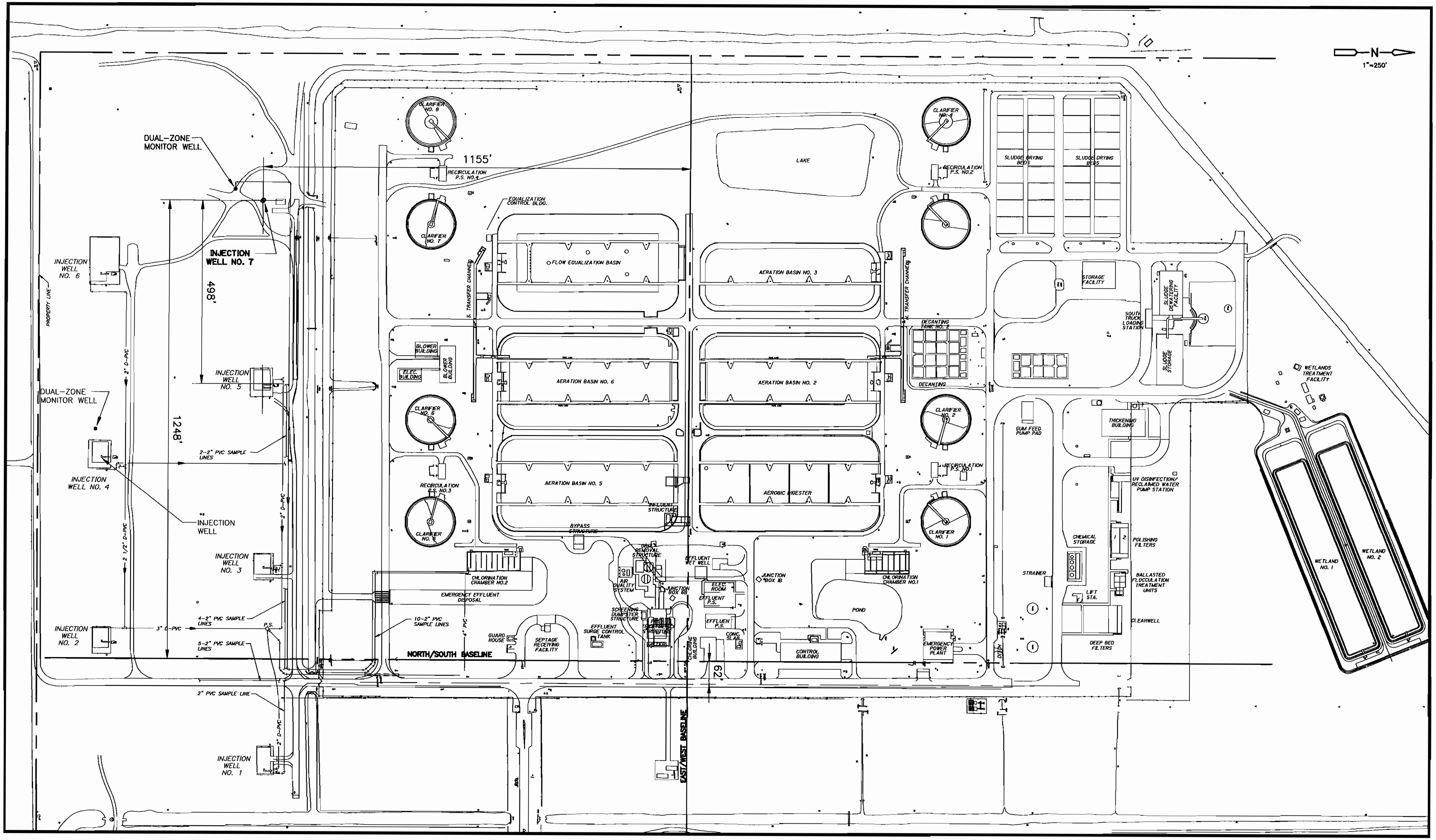

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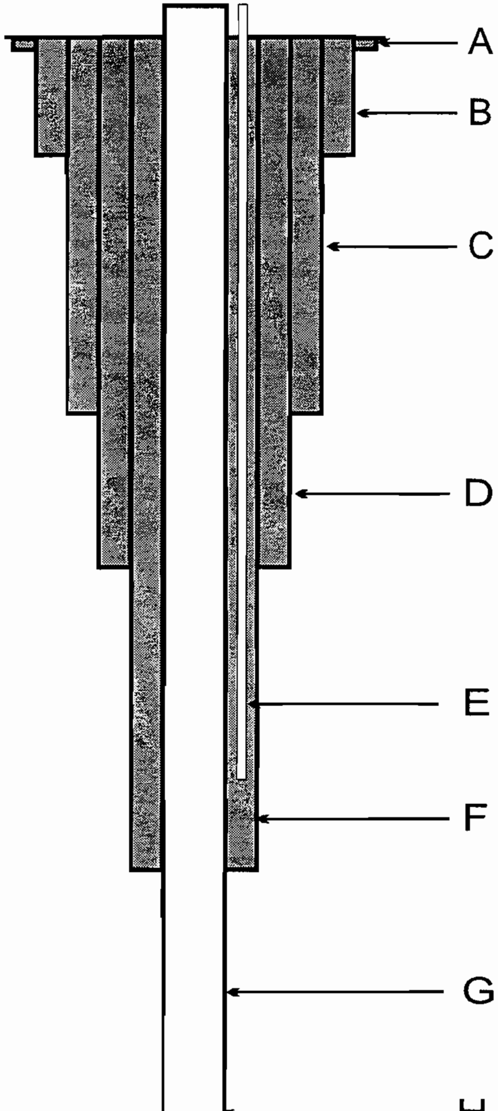
Figure No. 1-4
City of WPB ECRWWTP, Florida
Site Plan



EXPLANATION		WELL 1R	WELL 2	WELL 3	WELL 4	WELL 5
A	72-inch dia. casing	10	10	10	28	15
B	60-inch dia. casing 0.375-inch wall	114	115	114	117.6	123
C	48-inch dia. casing 0.375-inch wall	404	396	397	410	410
D	36-inch dia. casing 0.375-inch wall	1018	1030	1037	1042	1004
E	2-inch I.D. monitor tube Monitor zones	2258 2194-2208 2154-2168	Plugged	2321 2226-2238 2283-2293	Plugged	2399 2333-2343 2350-2380
F	24-inch dia. casing (26-inch dia. well 4) 0.375-inch wall	3026	3026	3034	2963	3282
G	Nominal 22-inch dia. open hole (24-inch dia. Well 4)	611	654	381	309	528
H	Total depth	3637	3680	3415	3272	3810

NOTES:

All depths are in feet below pad level.
All casing are steel.
All casing diameters are O.D.
Wall thickness of 2-inch monitor tubes is assumed to be 0.19 inches.

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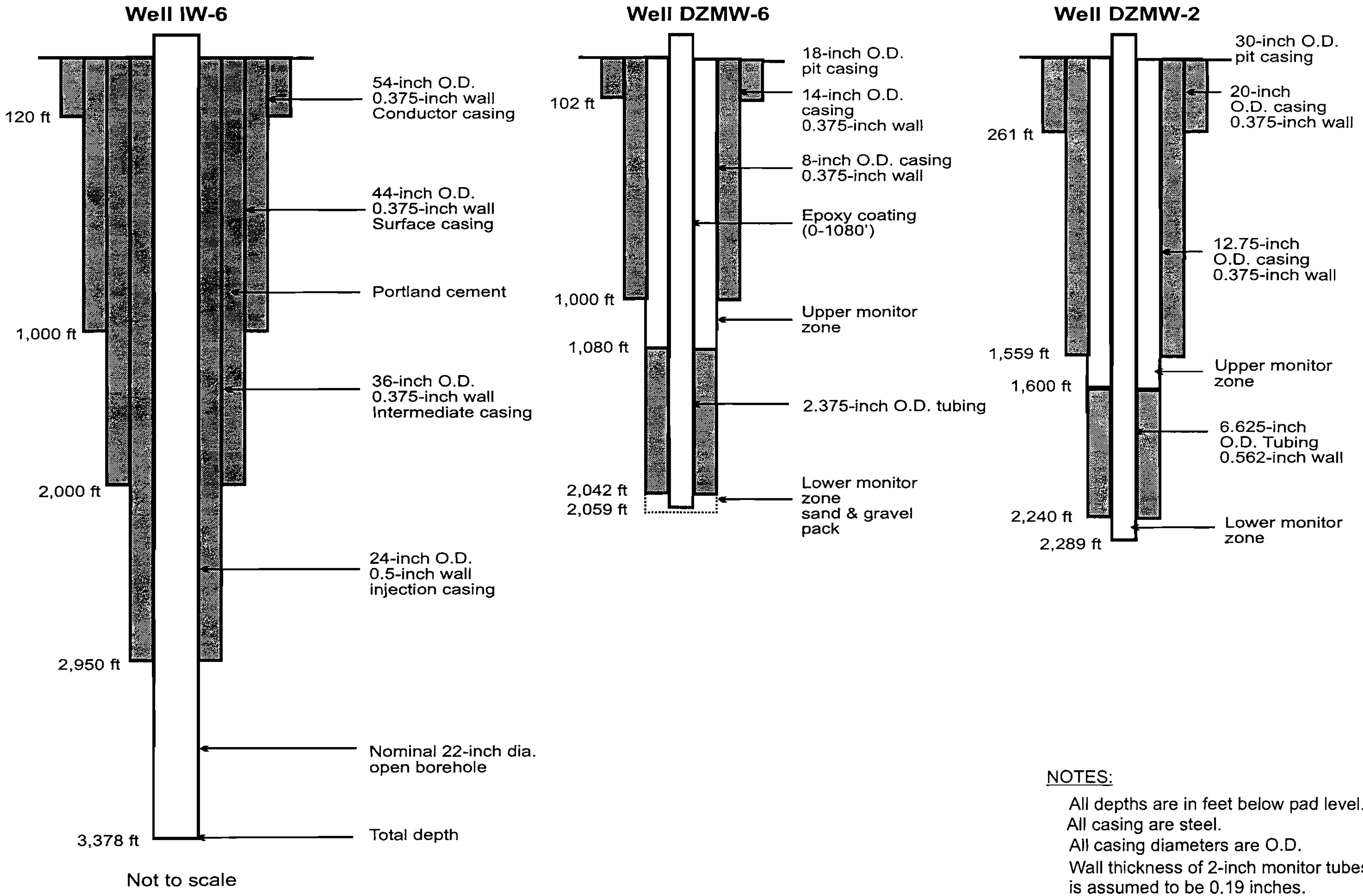
Figure No.1-5
City of WPB ECRWWTP, Florida
Injection Wells 1R, 2, 3, 4, and 5
Construction Details



NOTES:

All depths are in feet below pad level.
All casing are steel.
All casing diameters are O.D.
Wall thickness of 2-inch monitor tubes is assumed to be 0.19 inches.

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Figure No.1-6
City of WPB ECRWWTP, Florida
Injection Well 6 and Monitor Wells DZMW-2 and 6
Construction Details

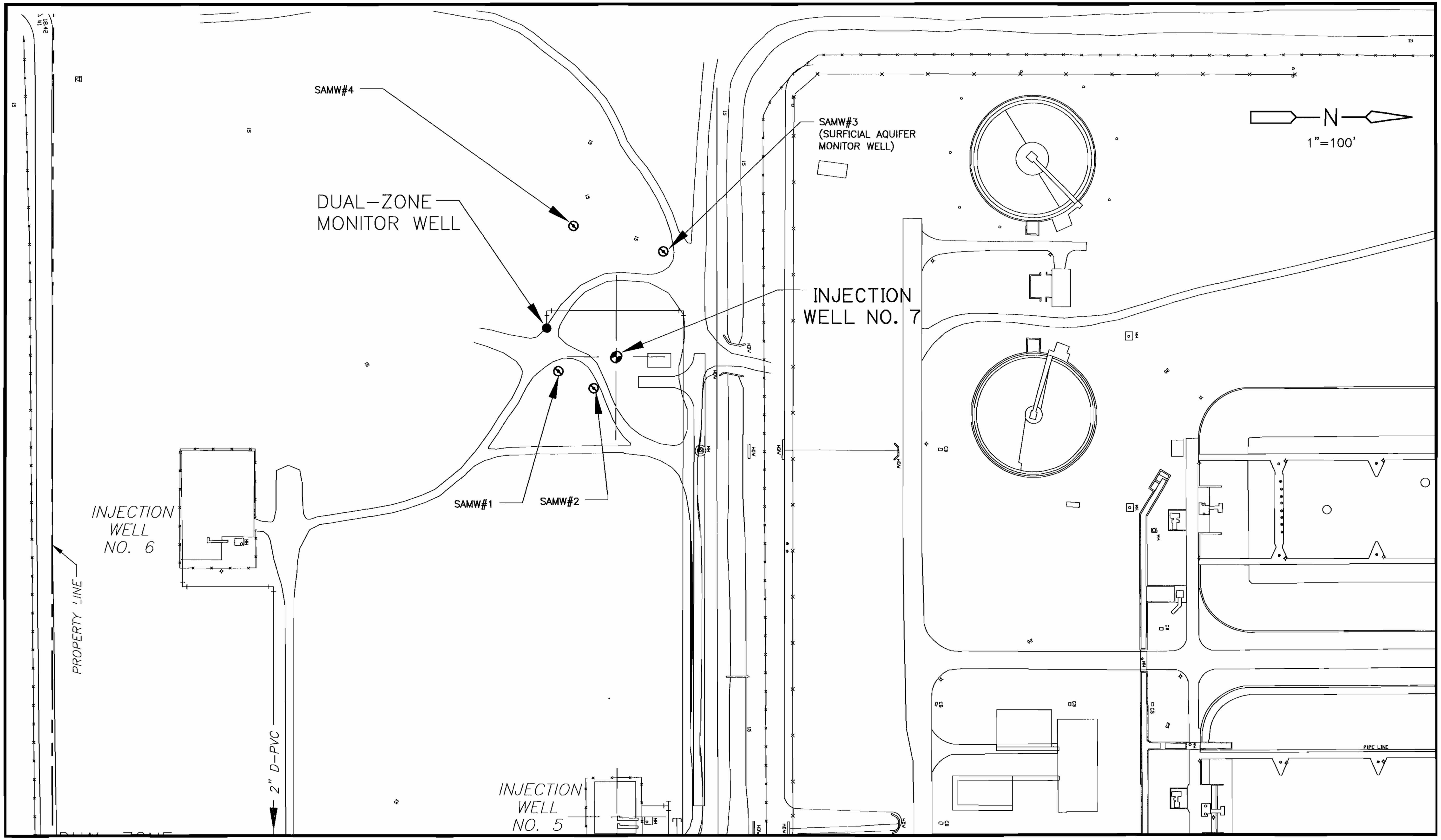

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Figure No. 1-7
City of WPB ECRWWTP, Florida
IW-7 Site Plan

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1.2 Permitting and Authorization

1.2.1 Permitting

Under the rules of the Florida Administrative Code (F.A.C.), FDEP is the permitting agency for both the construction and operation of deep injection wells in Florida. To evaluate complex deep injection projects, a Technical Advisory Committee (TAC) has been established whose TAC members assist and provide advice to the local FDEP on the technical aspects of underground injection for wastewater disposal. The local FDEP representative chairs the TAC and is ultimately responsible for coordinating the TAC recommendations.

Southeast Florida District FDEP-TAC representatives are as follows:

FDEP - West Palm Beach, Florida

Mr. Joseph May, P.G., TAC Chairman/U.I.C.

Mr. Mark A. Silverman, P.G., Project Manager/U.I.C.

FDEP - Tallahassee, Florida

Ms. Cathy McCarty, Project Manager/U.I.C.

Mr. Richard Deuerling, P.G., Program Manager/U.I.C.

SFWMD - West Palm Beach, Florida, Mr. Steve Anderson, P.G.

Palm Beach County Health Department - West Palm Beach, Florida, Mr. Tom Lefevre

USGS - Miami, Florida, Mr. Ronald Reese, P.G.

USEPA - Atlanta, Georgia, Ms. Nancy Marsh.

1.2.2 Authorization

CDM contracted with the East Central Regional Wastewater Treatment Facilities Operations Board to assist in presenting information to the permitting agencies and the TAC, to design the well system, to conduct the construction observation, to conduct the testing and sampling, and to prepare the reports on the results of the drilling and testing.

1.3 Purpose and Scope

This report presents the information required or requested by the FDEP permit on the description and testing of the strata penetrated during the construction of IW-7. It describes the characteristics of the injection zone, the characteristics of both the injection and the resident fluids, and the nature of the geologic formations that confine the injection zone from overlying zones of the Florida Aquifer System.

1.4 Site Description

The ECRWWTP is located immediately east of the Florida Turnpike approximately two miles north of Okeechobee Boulevard (State Road-704) in Palm Beach County. It is specifically located at 4325 North Haverhill Road, West Palm Beach, Florida 33409.

As shown on **Figure 1-8**, the existing site is located in the southwestern quarter of the southwestern quarter of Section 11, Township 43 South, Range 42 East. The wastewater treatment plant facilities occupy the central area of the site. The injection wells and the monitor wells are located in the southern portion of the site.

1.4.1 Topography

The natural land elevations throughout ECRWWTP vary from about 17 to 18 feet National Geodetic Vertical Datum (NGVD), and the natural land surface can be best described as fairly flat. Manmade alterations have created artificially higher and lower areas, most are associated with the filling prior to construction. Figure 1-8 shows the USGS map elevations to be approximately 17 feet throughout the area. However Figure 1-7 shows a detailed survey of the specific site to be between 13 feet and 19 feet.

The site is surrounded by a hydraulic barrier and the major drainage feature adjacent to the site is the M Canal (West Palm Beach Water Supply Canal) along the northern border as shown on **Figure 1-9**. The M Canal is connected to Lake Okeechobee and provides water to Lake Magnolia and Clear Lake. Clear Lake is the water source for the City of West Palm Beach drinking water supply. Within the ECRWWTP, there is no natural continuously flowing body of surface water.

1.4.2 Soils

The soils in the area were mapped by the United States Department of Agriculture, Soil Conservation Service (SCS) between 1968 and 1974, and a report was issued in 1978. The natural soils at the site varies from Basinger and Myakka sands (depressional), Holopaw fine sand, Immokalee fine sand, and Pinellas fine sand (see **Figure 1-10**), but construction on the site has greatly disturbed the soils. Only the subsurface materials below the top soils remain unchanged and then only when building foundations and road and canals have not replaced them.

Basinger and Myakka sands (depressional) are nearly level, very poorly drained, sandy soils that usually occurs in shallow depressions. The depressions are small to large isolated ponds or poorly defined narrow drainageways that have many branches. Both soils may occur separately or together. The water table is above the surface for 3 to 9 months or more in most years. Bedrock may be found below 60 inches. In its natural condition, it is flooded frequently for a very long duration each year (6 months or more after high rainfall).

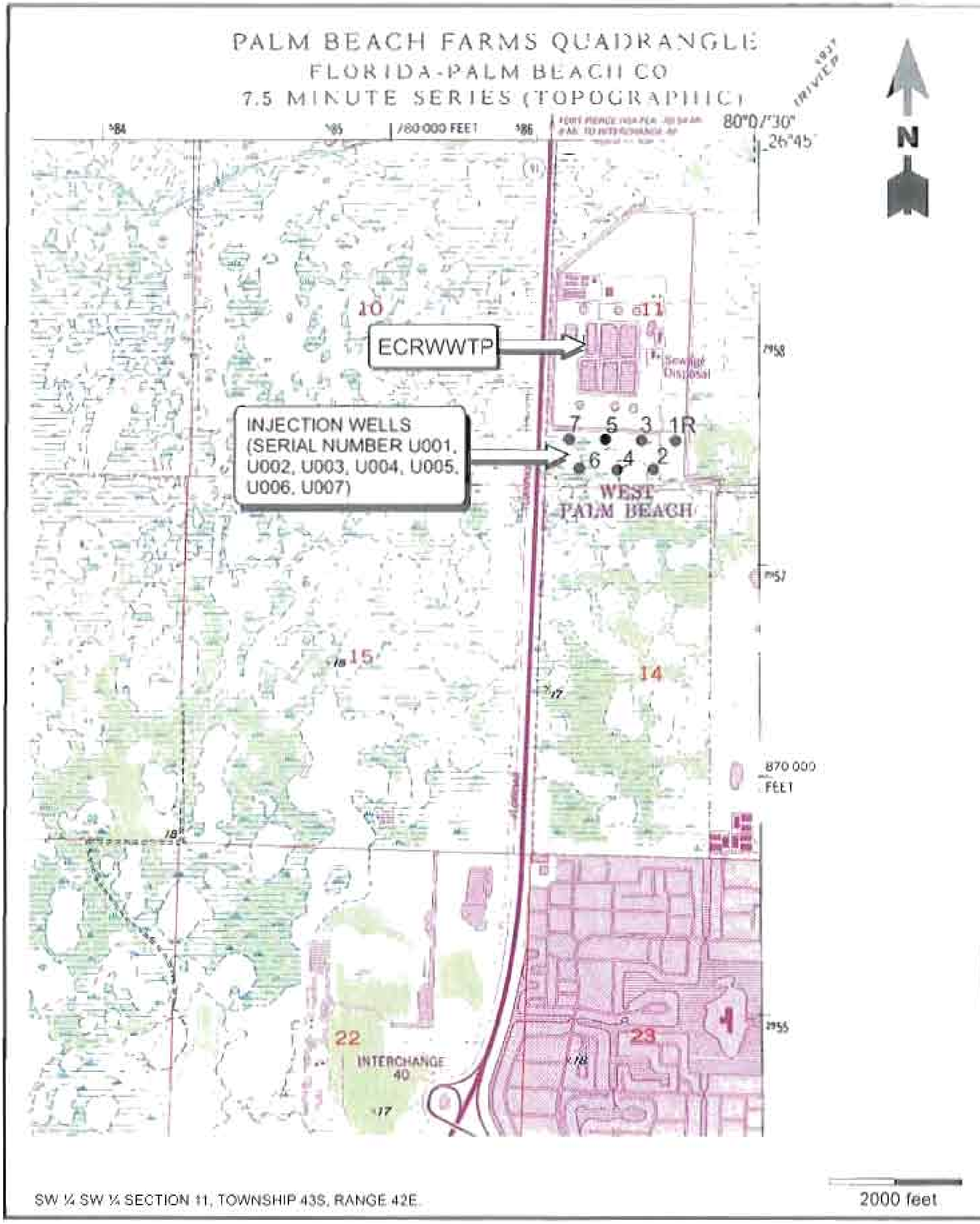

Figure No. 1-8
City of WPB ECRWWTP, Florida
Topographic Map

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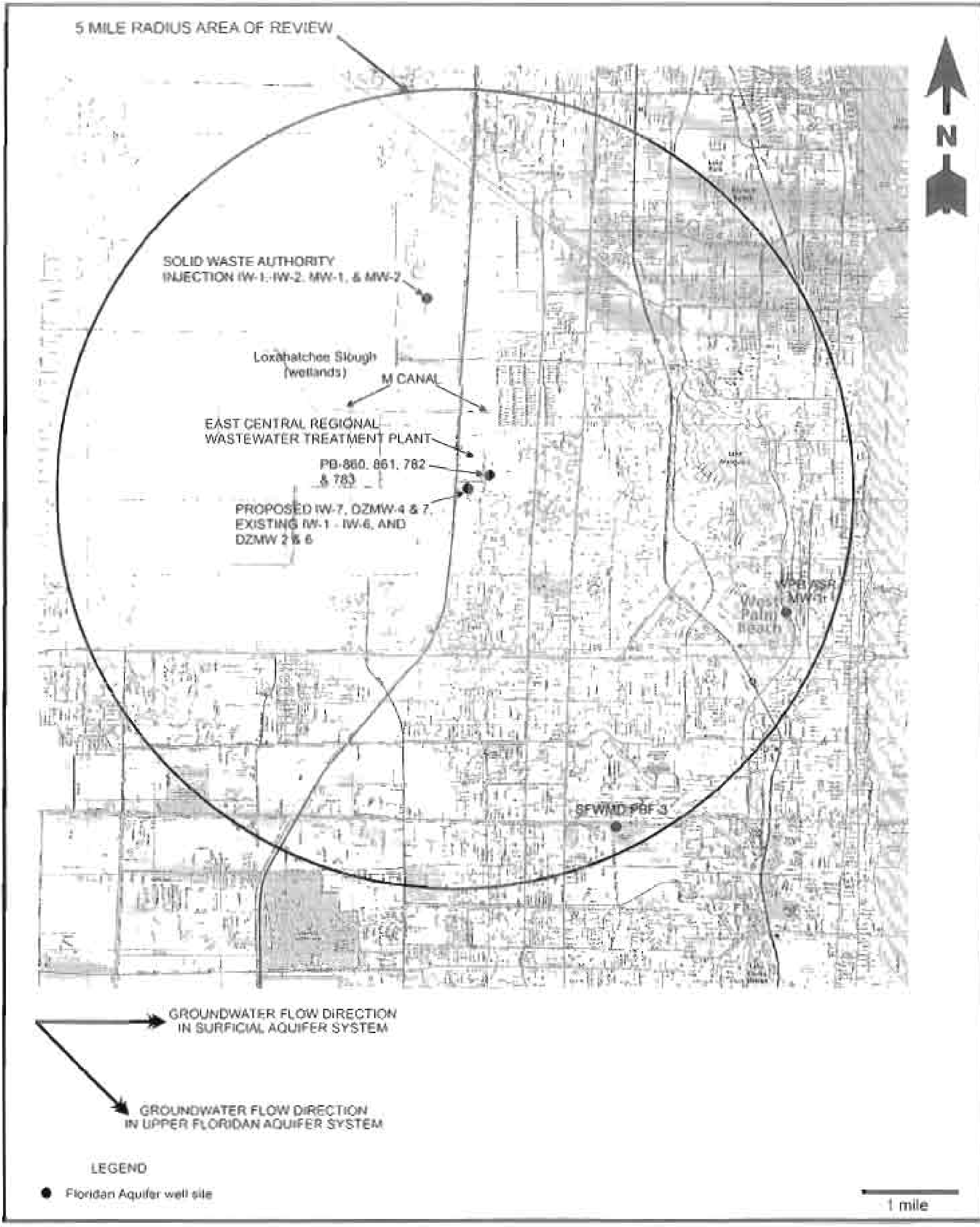

Figure No. 1-9
City of WPB ECRWWTP, Florida
Area of Review

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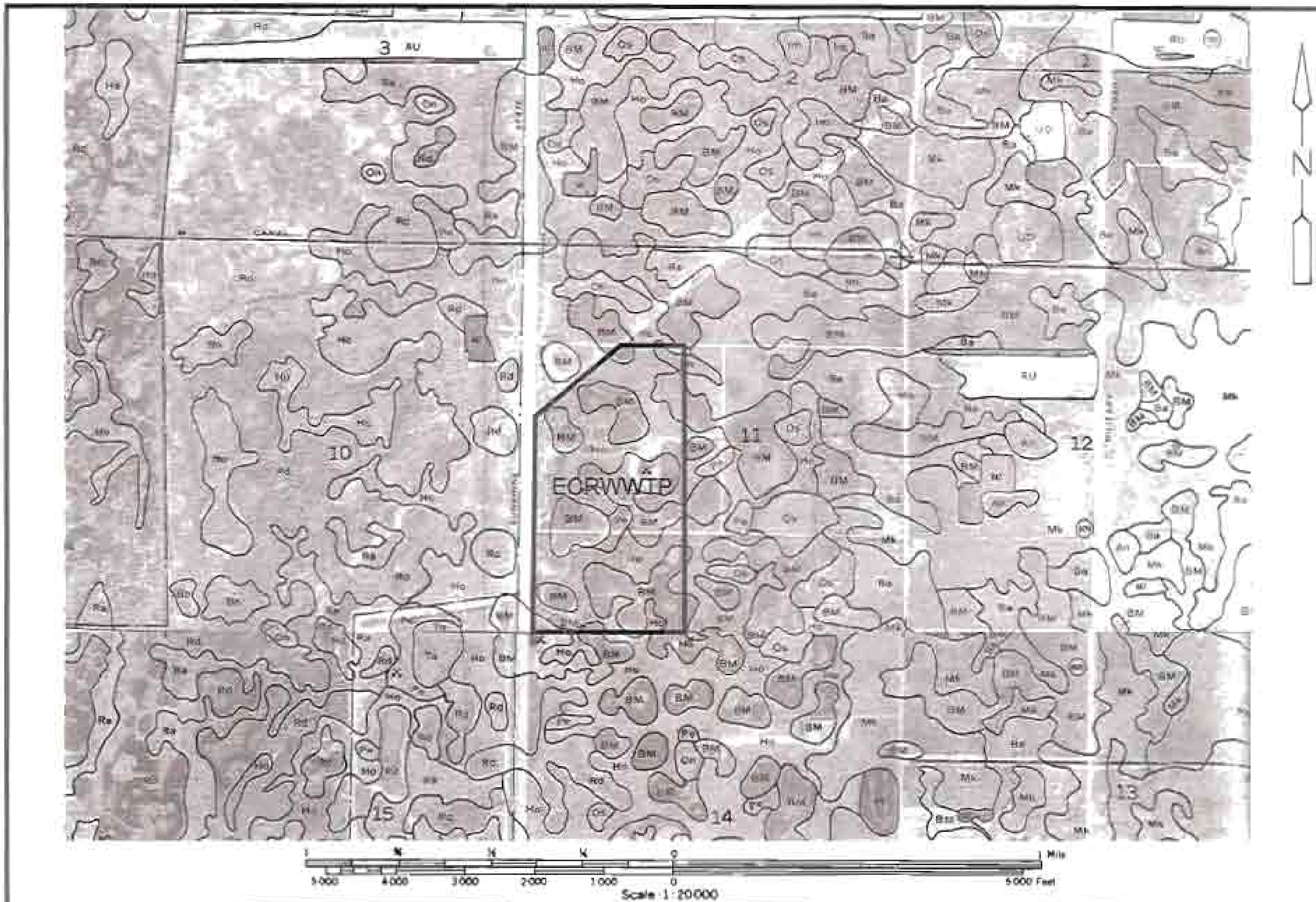

Source: USDA Soil Conservation Service, Soil Survey of Palm Beach County, 1978

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Figure No. 1-10
City of WPB ECRWWTP, Florida
Soil Map

Holopaw fine sand is a poorly drained soil that has a thick sandy surface layer and a loamy subsoil at a depth of 40 to 72 inches, and usually shows nearly level slopes. In its natural condition, the water table is within 10 inches of the surface for 2 to 6 months during most years. Depressions are covered by water for 6 months or more in most years. Bedrock may be found below 60 inches. Its drainage characteristics are poor because of its moderate permeability. The soil developed from a thin organic surface layer and contains a thin, brown-stained layer, which have a subsurface layer of brown and yellow soil.

Immokalee fine sand is a poorly drained, deep, sandy soil that has a dark-colored layer below a depth of 30 inches that is weakly cemented with organic matter, and usually shows nearly level slopes. In its natural condition, the water table is within 10 inches of the surface for 2 to 4 months during wet periods, within 10 to 40 inches for 8 months or more in most years, but is below 40 inches in dry periods. Bedrock may be found below 60 inches. Its drainage characteristics are poor because of its moderate permeability.

Pinellas fine sand is a poorly drained soil that has a sandy, calcareous subsurface layer and a loamy subsoil, and usually shows nearly level slopes that border sloughs and depressions. In its natural condition, the water table is within 10 inches of the surface for 1 to 3 months during wet periods, within 10 to 30 inches for 2 to 6 months in most years. Bedrock may be found below 60 inches. Its drainage characteristics are poor because of its moderate permeability.

Table 1-1 lists the soil types and groups them with their major hydrologic properties. The grouping follows the SCS classification of 1978.

1.5 Site Plan

East Central Regional Wastewater Treatment Plant Operations Board (Board) is comprised of representatives who are the largest users from five local governments. The Board provides direction and approval of budgets and contracts related to ECRWWTP. The five large users include the City of West Palm Beach, portions of Palm Beach County, the City of Lake Worth, the City of Riviera Beach, and the Town of Palm Beach. The ECRWWTP is located on 300 acres within the City of West Palm Beach. The ECRWWTP service area is roughly bounded by Hypoluxo Road to the south, Silver Beach Road and the Bee Line Highway to the north, State Road 441 to the west, and the Atlantic Ocean to the east as shown on Figure 1-3.

The plant was originally constructed as a 20 MGD, annual average daily flow (aadf), facility in 1975 to 1977. Expansion of the plant to 44 MGD was initiated prior to completion of the original facility. The plant was temporarily down rated to 40 MGD when one of the aeration basins was converted to an aerobic digester. In the late 1980's, the plant was expanded to 55 MGD, and converted from an extended aeration mode to a conventional activated sludge process with diffused aeration. Major facility upgrade projects were recently completed in 1996.

Table 1-1
Soil Types and Their Hydrologic Properties

Group Number (SCS, 1978)	Map Symbol	Soil Name	Drainage	Depth of Seasonal High Water Table (Inches)	Percolation Range (inches per hour)
9	BM	Basinger and Myakka sands, depressional	Very Poor	12	>20
9	Ho	Holopaw fine sand	Poor	0-12	6-20
9	Im	Immokalee fine sand	Poor	0-12	6-20
9	Pe	Pinellas fine sand	Poor	0-12	6-20

Source: Soil Conservation Service, 1978.

The existing facility capacity of 55 MGD (aadf) is expected to serve a population of approximately 500,000 in the projected 55 MGD design year for 2009, based on an average wastewater generation rate of 110 gallons per capita per day. In March 2004, construction began for the expansion of the plant to 70 MGD (aadf), which will provide adequate treatment, reuse, and disposal capacity for the service area.

Section 2
Hydrogeologic Data

The geophysical logs, the lithologic samples, the geologic cores, the formation water quality samples, and the single element packer test water quality samples collected during the drilling operation on IW-7 and DZMW-7 were used to develop the detailed descriptions of the geology and hydrogeology of the formations underlying the site. In this section these data are analyzed.

2.1 Lithologic Samples

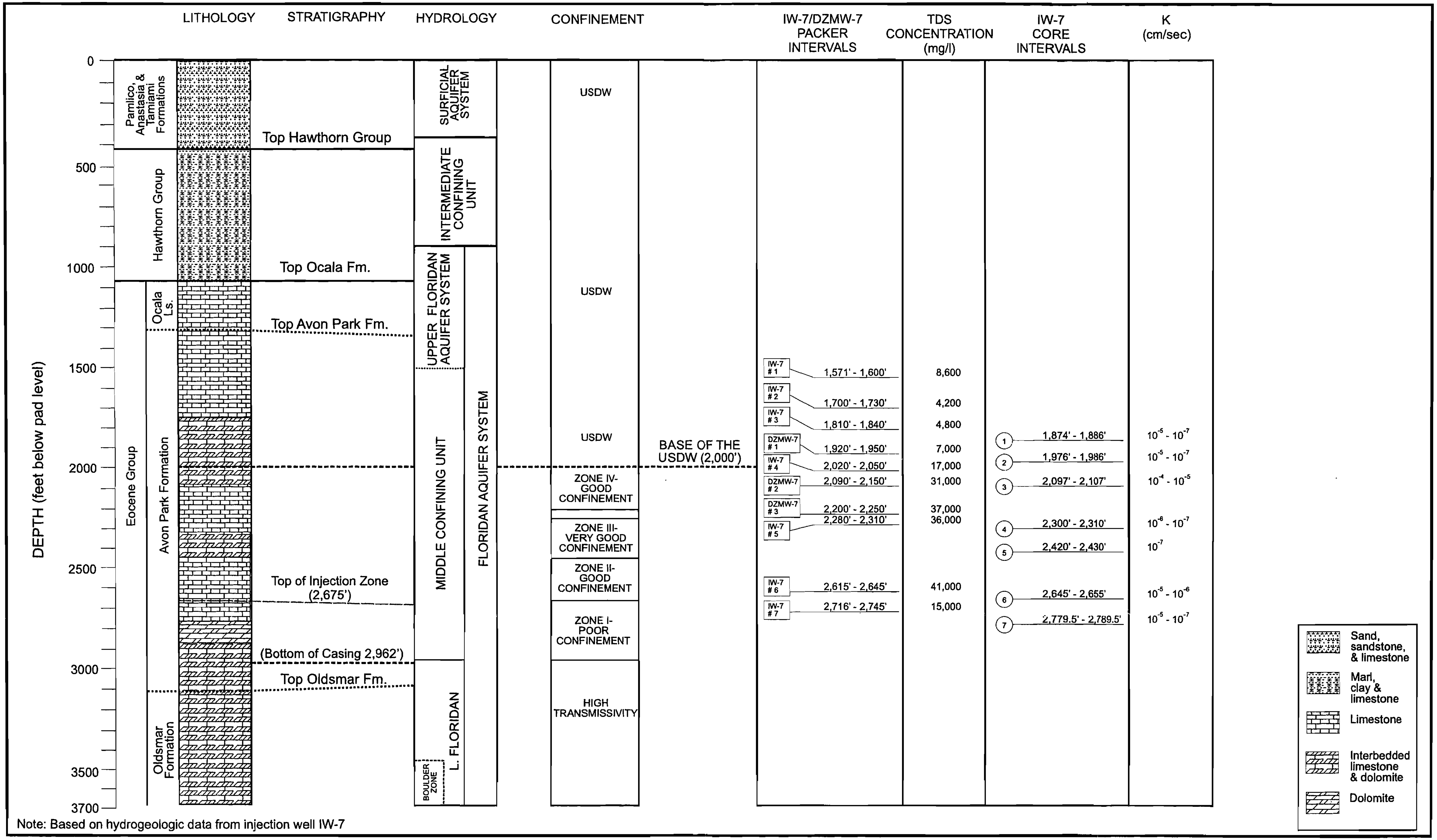
Representative formation samples were collected every ten feet during drilling of IW-7 and DZMW-7 pilot holes. Each sample was described by a geologist and recorded in the field in a Geologist Log (see Appendix B).

The depths of the various formations and hydrologic divisions were identified from the lithologic descriptions in the geologist log, core sample descriptions, and the geophysical logs. Data from IW-6 were also available for the lower geological units, but cuttings from the lower parts of IW-7 provided the principal source of data. Although data from IW-6 was also used, these data were restricted to a depth of 3,378 feet. Geologic and hydrologic identifications were primarily based on data from IW-7 for the upper geologic units.

Through examination of the lithologic samples (both formation samples and cores), and from previously existing data from IW-6, a column showing the geologic units penetrated at the site was developed. **Figure 2-1** shows the estimated depth ranges of the geologic units underlying the site.

2.2 Core Analyses

In compliance with the technical specifications and the permit conditions for construction of IW-7, a total of 8 attempts to collect cores were made during the drilling of the pilot hole. Of the 8 attempts, 7 cores were recovered. The cores were photographed and shown on **Figures 2-2A** through **2-2D**. The first three cores were collected above the intermediate casing seat depth and the other four cores were collected above the injection casing seat depth. The eight cores were collected from the Avon Park Formation, with insufficient recovery on one of the cores, which was not assigned a core number. No cores were collected from the Oldsmar Formation (see Figure 2-1). All 7 cores were four inches (10 cm) in diameter and up to ten to twelve feet in length. Three samples from each of the first five cores and 2 samples from each of the last two cores were selected by CDM for analysis by Ardaman & Associates, Inc. (AAI) laboratory. The core samples were photographed and shown on **Figures 2-3A** through **2-3J**. The cores are described in Section 2.2.1, followed by a discussion of the core sample analyses in Section 2.2.2.



P:\1006\126918\15B\CONSTRPT\FIG 2-1.CDR 8/6/04 NUNESAL

CDM

Figure No. 2-1
City of WPB ECRWWTP, Florida
Geologic Column for IW-7

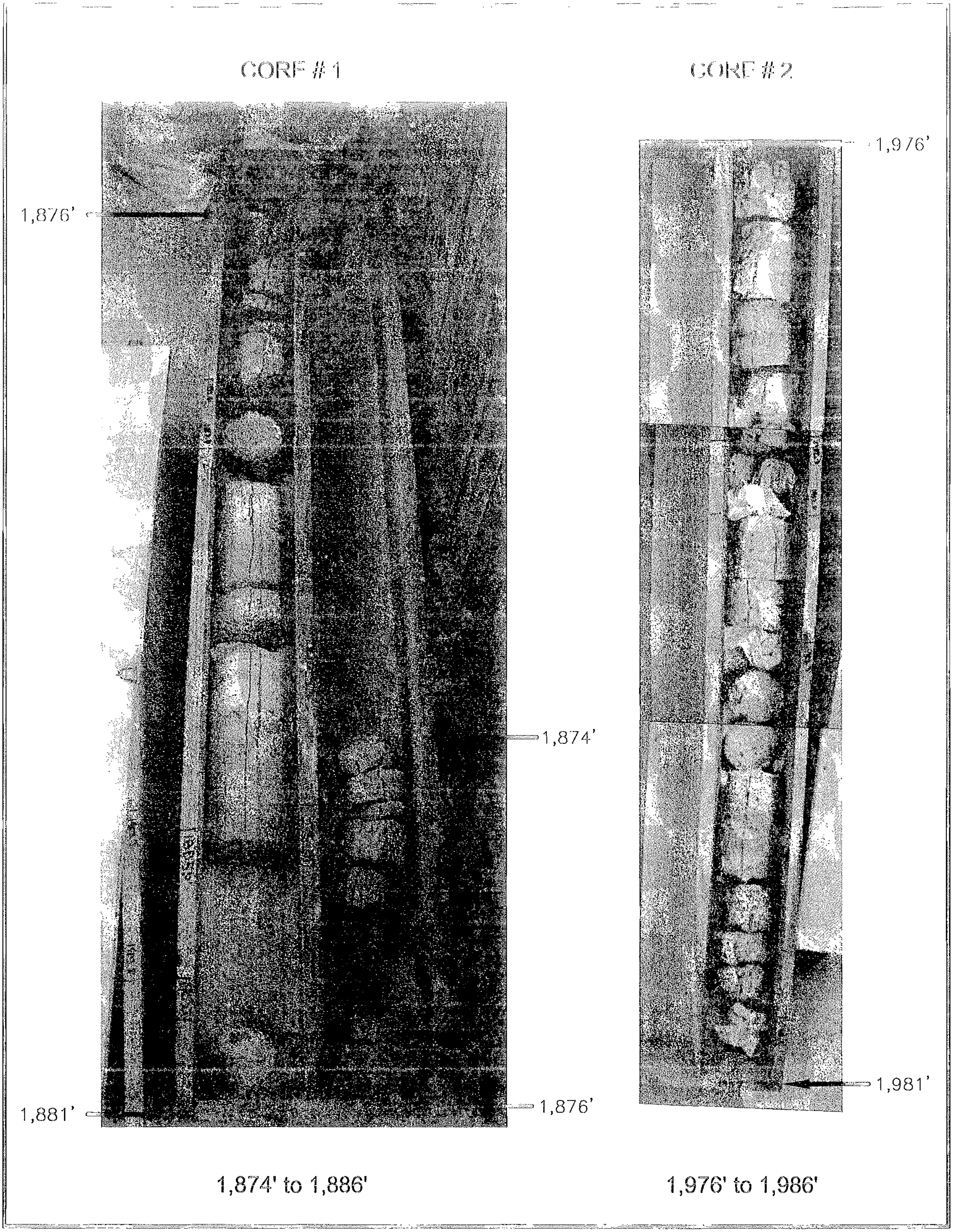


Figure No. 2-2A
City of WPB ECRWWTP, Florida
Geologic Cores # 1 and # 2

CDM

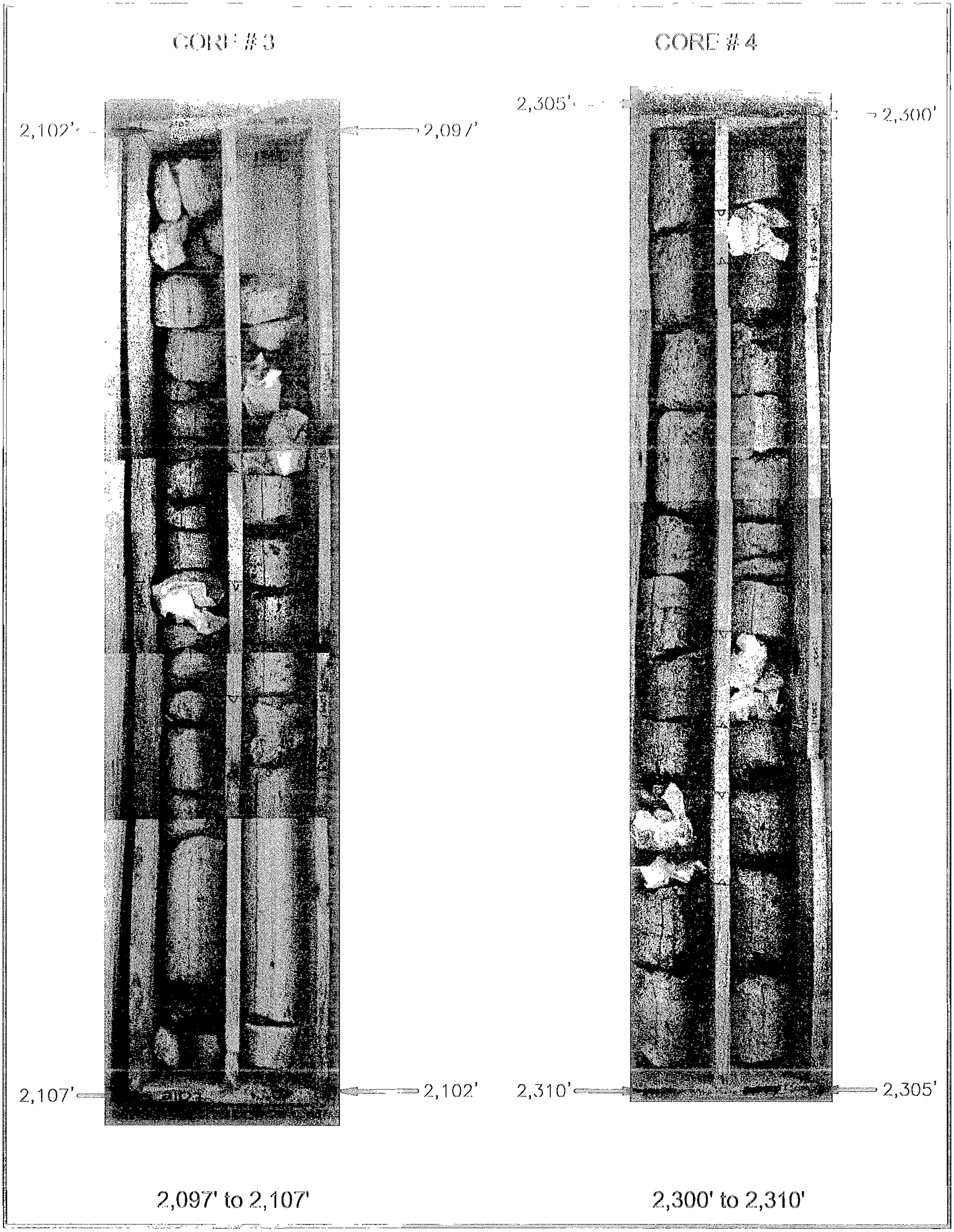


Figure No. 2-2B
City of WPB ECRWWTP, Florida
Geologic Cores # 3 and # 4

CDM

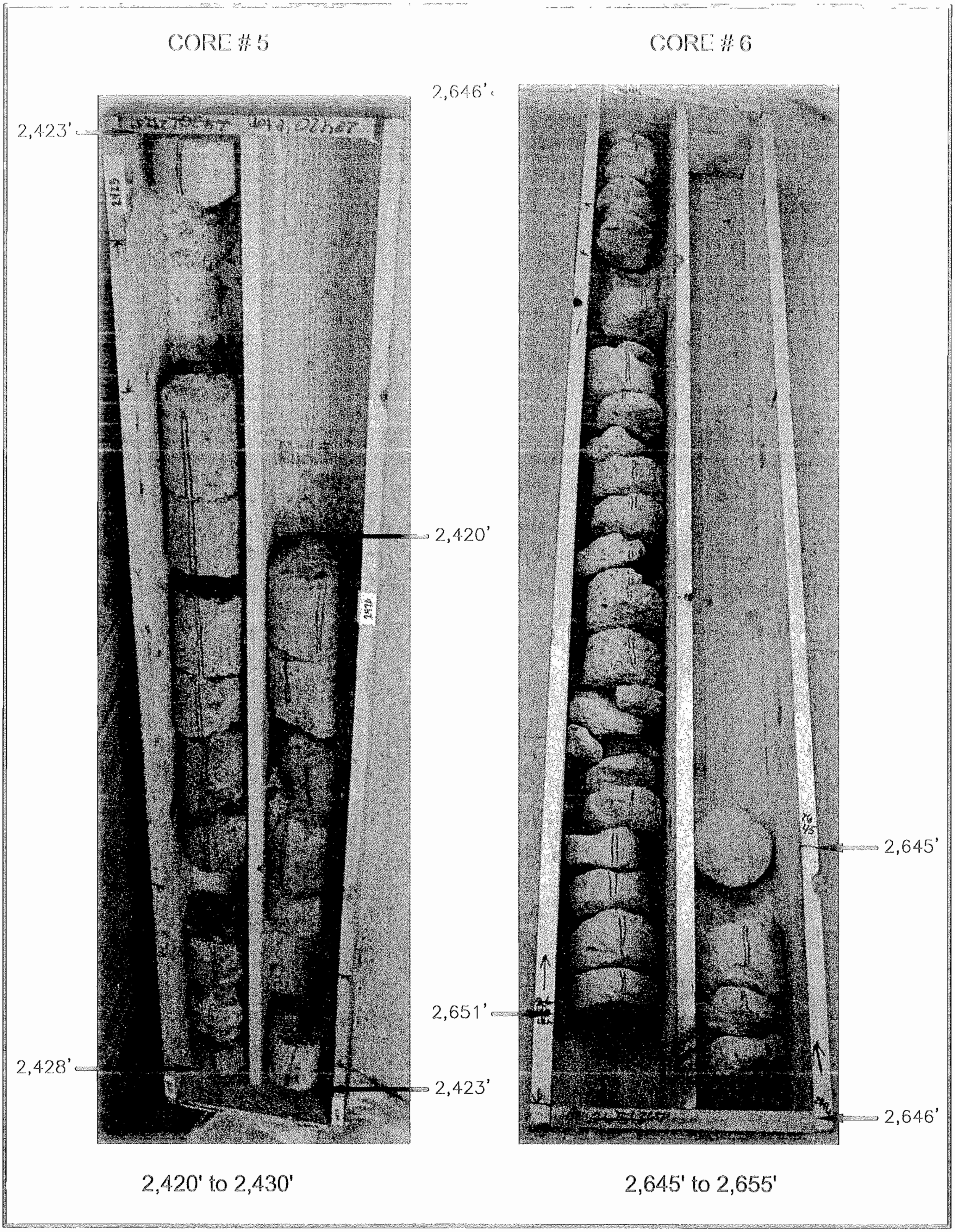
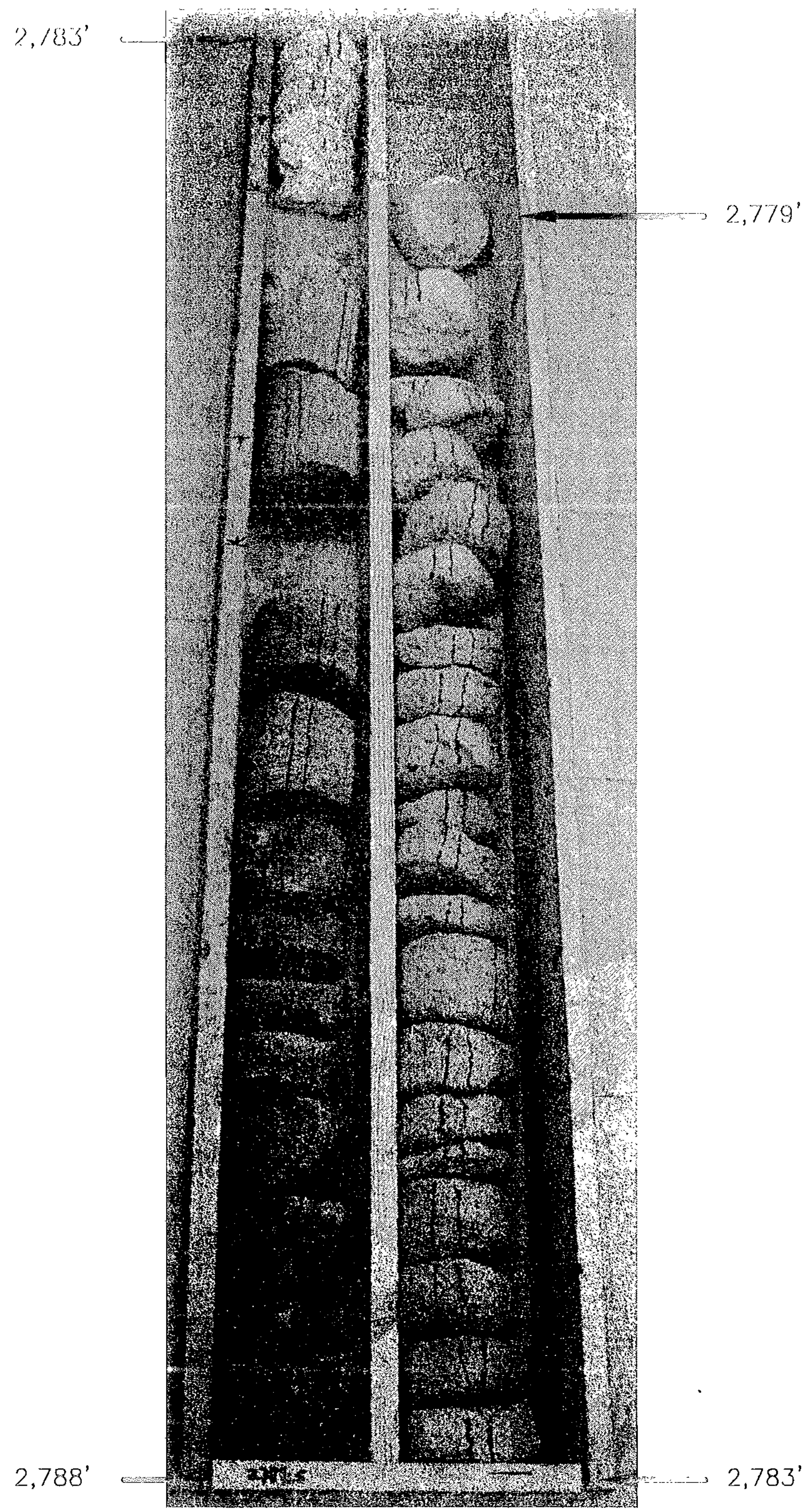


Figure No. 2-2C
City of WPB ECRWWTP, Florida
Geologic Cores # 5 and # 6

CDM

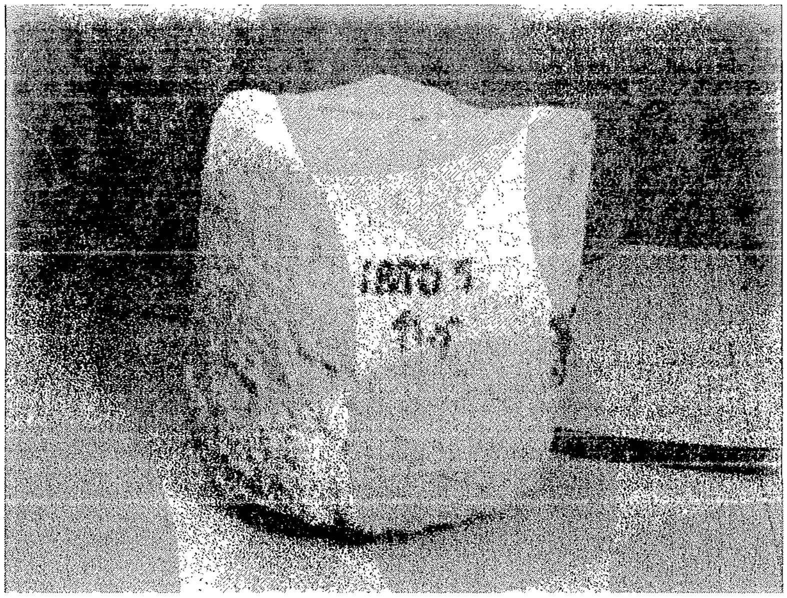
CORE # 7



2,779' to 2,789'

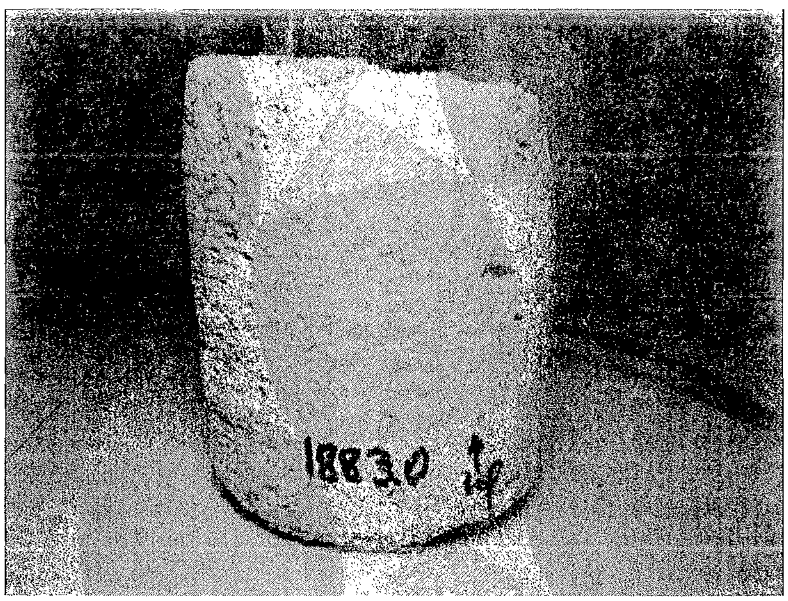
Figure No. 2-2D
City of WPB ECRWWTP, Florida
Geologic Core # 7

CDM



1875.5'

(The Core Sample was Mislabeled)

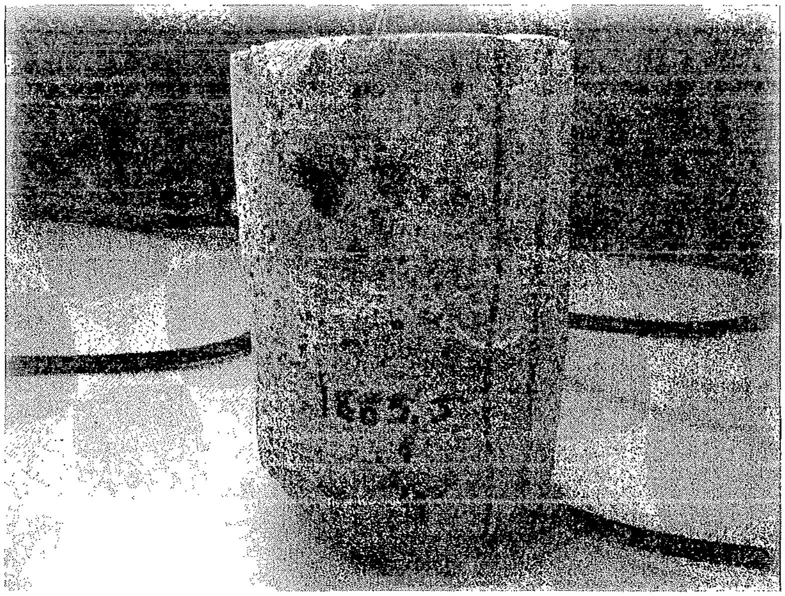


1878.0'

(The Core Sample was Mislabeled)

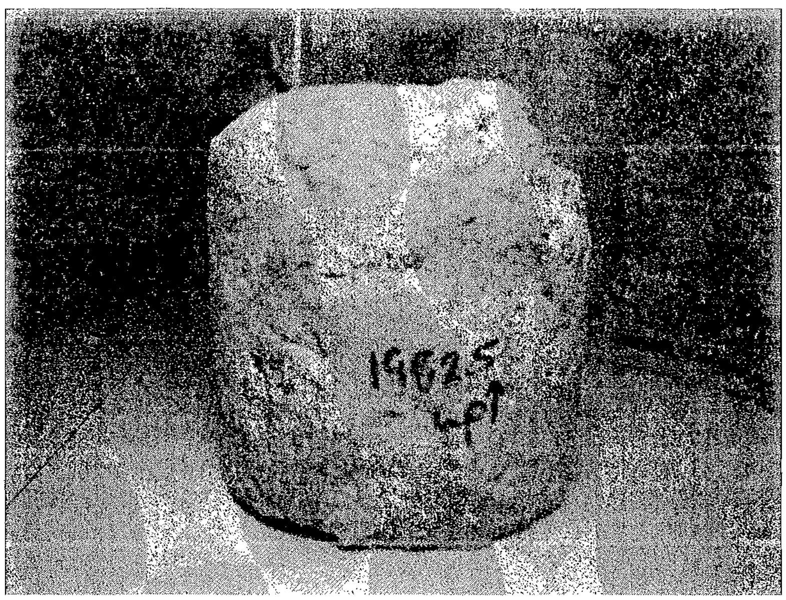
Figure No. 2-3A
City of WPB ECRWWTP, Florida
Geologic Core Samples

CDM



1880.5'

(The Core Sample was Mislabeled)



1976.5'

(The Core Sample was Mislabeled)

Figure No. 2-3B
City of WPB ECRWWTP, Florida
Geologic Core Samples

CDM

P:\10061\26918_15B\CONST\RPT\ FIG 2-3B 04/28/04 3:22 1:16:40 nunesal

1977.5'

(The Core Sample was Mislabeled)

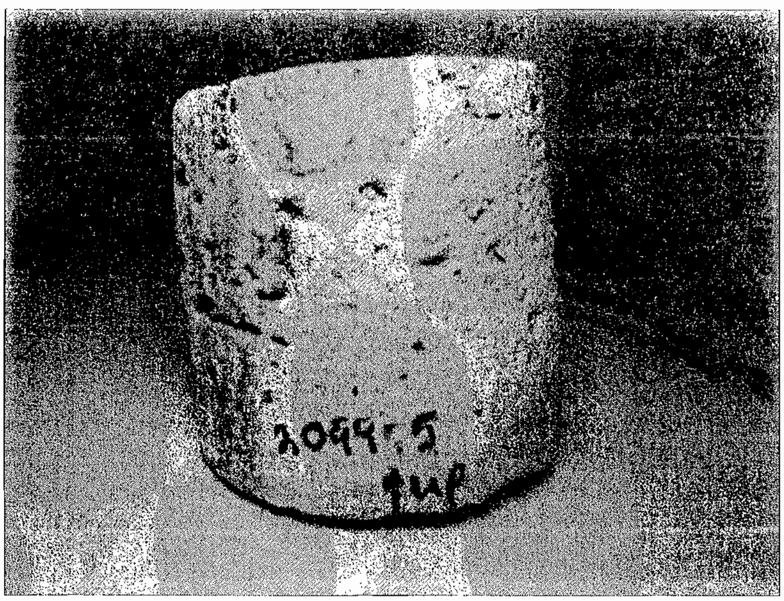
1981.0'

(The Core Sample was Mislabeled)

Figure No. 2-3C
City of WPB ECRWWTP, Florida
Geologic Core Samples

CDM

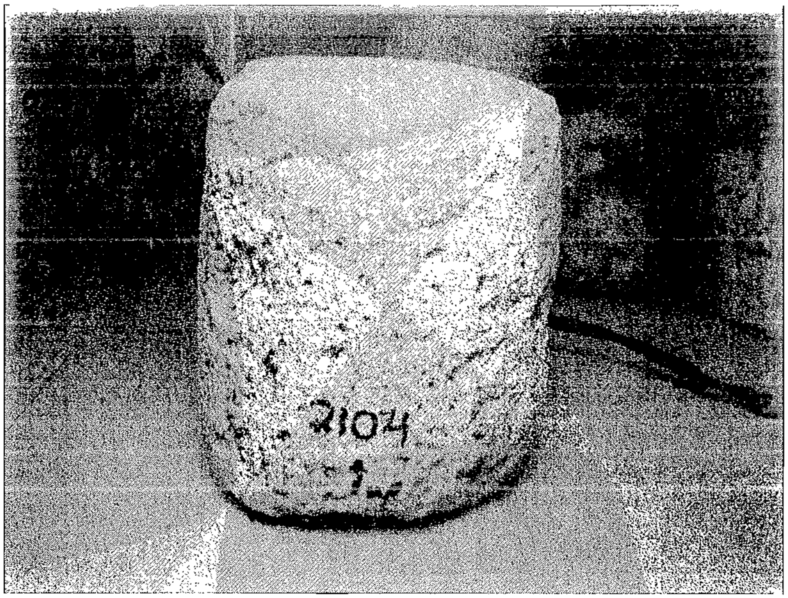
2098.0'



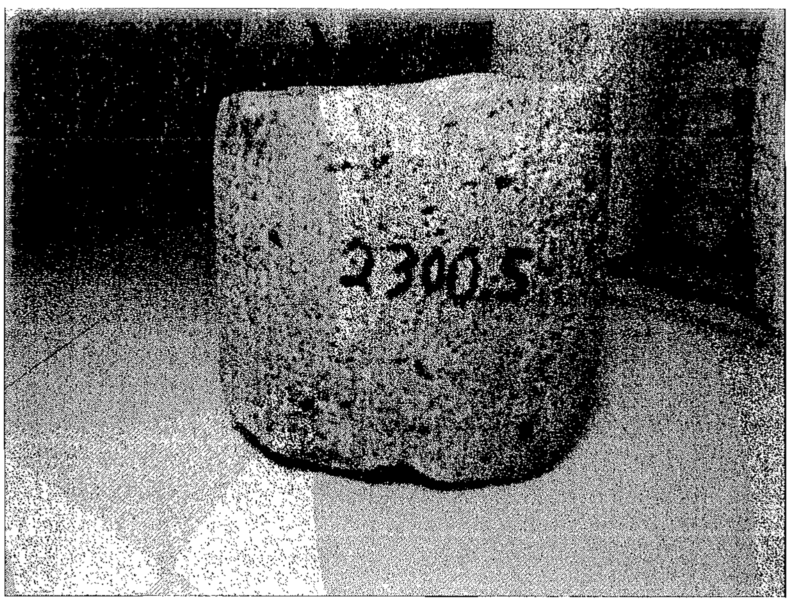
2099.5'

Figure No. 2-3D
City of WPB ECRWWTP, Florida
Geologic Core Samples

CDM



2104.0'

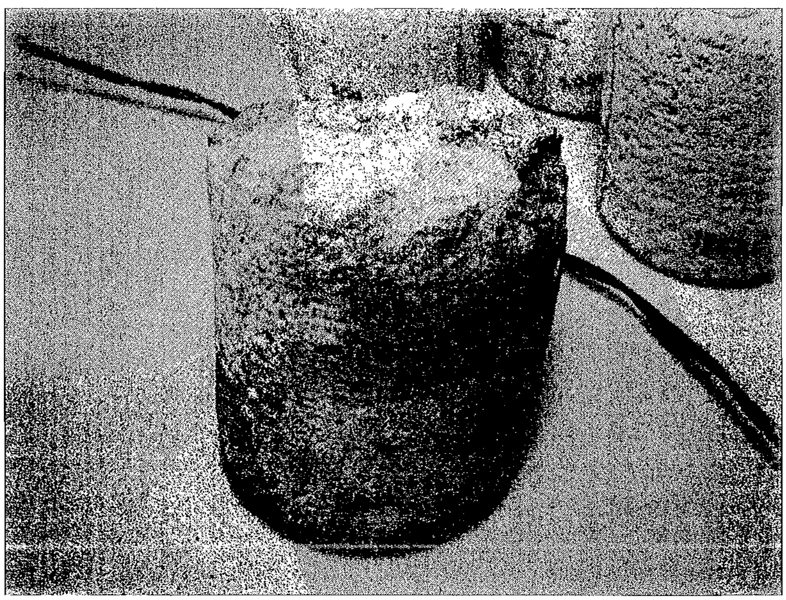


2300.5'

Figure No. 2-3E
City of WPB ECRWWTP, Florida
Geologic Core Samples

CDM

2303.1'

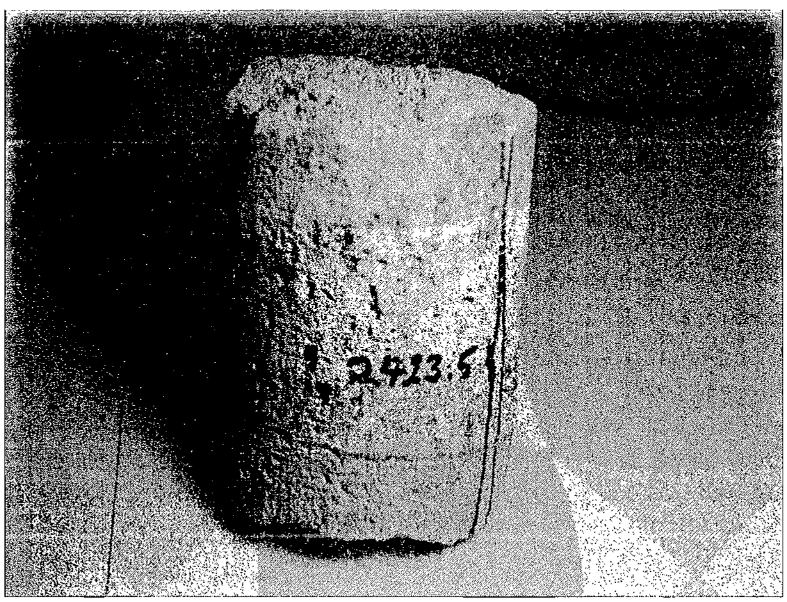


2309.0'

Figure No. 2-3F
City of WPB ECRWWTP, Florida
Geologic Core Samples

CDM

2422.1'



2423.5'

Figure No. 2-3G
City of WPB ECRWWTP, Florida
Geologic Core Samples

CDM

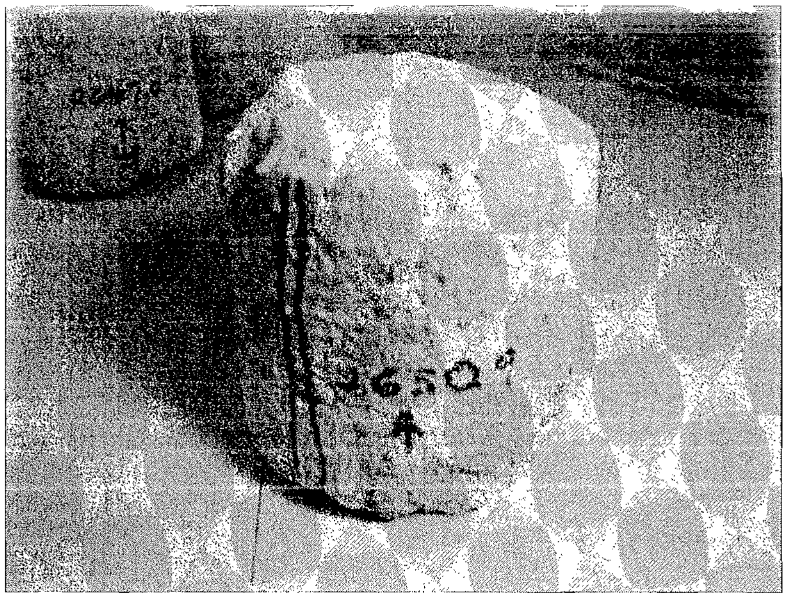
2426.6'

2647.0'

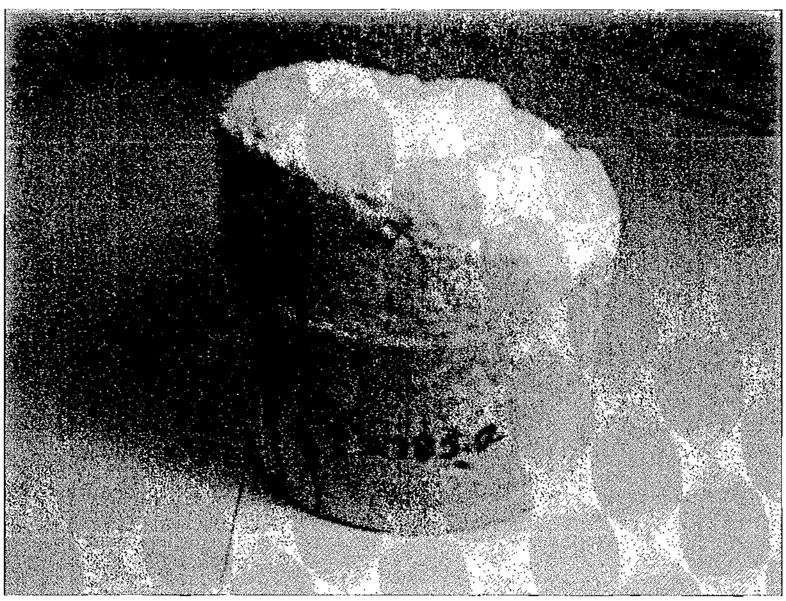
Figure No. 2-3H
City of WPB ECRWWTP, Florida
Geologic Core Samples

CDM

P:\1006:\26918_15B\CONST\RPT\ FIG 2-3H 03/02/04 1. 12 1:37:04 nunesa



2650.9'

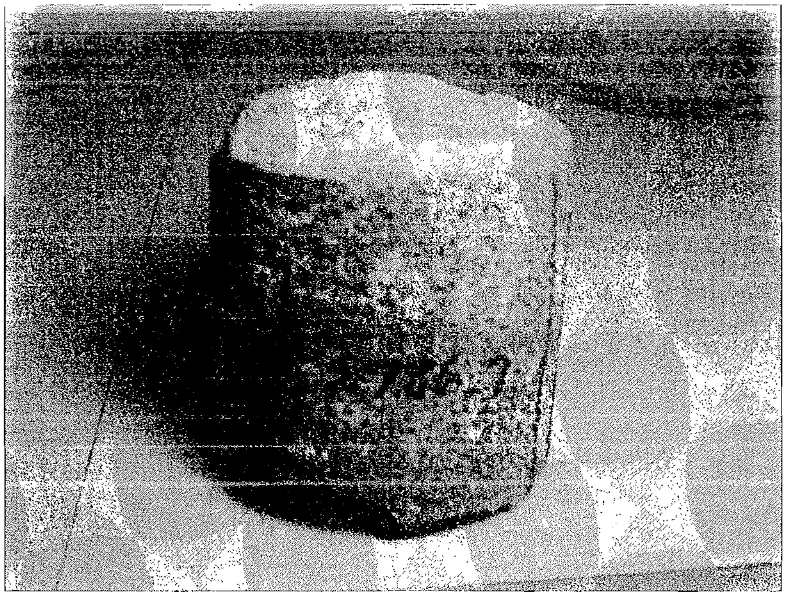


2785.2'

P:\10061\26918_15B\CONST\RPT\ FIG 2-3i 03/09/04 1 . . 14 . :4 53 nunesd

Figure No. 2-3i
City of WPB ECRWWTP, Florida
Geologic Core Samples

CDM



2786.7'

Figure No. 2-3J
City of WPB ECRWWTP, Florida
Geologic Core Sample

CDM

2.2.1 Core Description

The descriptions of the core intervals are found in **Table 2-1**, including recovery dates, depths, percentages of recovery, and formation description. From the recovered sections, samples were collected at certain depths, and sent to the AAI laboratory for analysis of permeability, porosity, and other associated properties (see **Table 2-2**). Geologic descriptions of the cores are included in Appendix B.

2.2.2 Core Testing Results

Nineteen samples were selected from the seven cores obtained at IW-7 and were submitted to AAI laboratory for analysis. Table 2-2 displays the results of the special core analysis study conducted by AAI laboratory and Appendix C includes the analysis report. The depths from which the samples were selected are shown in the third column in Table 2-2. Core No. 5, Sample No. 3 (2421.7 - 2422.5 feet below pad level (bpl)) contained two different rock types. Both types were tested, and designated samples 3A and 3B.

Due to the irregular shape and short length of the core samples, all of the requested tests (i.e., vertical permeability test, horizontal permeability test, unconfined compression test and electrical resistivity tests for formation factor and Archie's cementation exponent) could not be performed on some samples. Priority was given to obtaining samples for vertical and horizontal permeability tests.

2.2.2.1 Permeability, Specific Gravity, and Total Porosity

Permeability Tests

The permeability test results are presented in Table 2-2. Values range from 10^{-4} centimeters per second (cm/sec) to 10^{-9} cm/sec in vertical and horizontal permeability.

The vertical permeability tests were performed first on specimens maintained at received diameter and cut to lengths of 5.2 to 11.0 cm. After completing the vertical permeability tests, horizontal permeability test specimens were obtained from the samples by coring 3.3 or 5.0 cm diameter cylinders from the vertical specimens. The horizontal specimens were trimmed to lengths of 6.3 to 7.3 cm to provide flat, parallel ends. Since the vertical permeability specimens were cored upon completion of testing to obtain horizontal permeability specimens, the final moisture contents of the vertical test specimens were not measured. The dry density and degree of saturation of the vertical permeability test specimens were estimated using final moisture contents from the corresponding horizontal permeability test specimens.

The vertical permeability test specimens were air-dried, deaired under vacuum, and then saturated with deaired tap water from the bottom upward while still under vacuum. After testing, the vertical specimens were maintained submerged in water until cored for the horizontal specimens and retested for measurement of horizontal hydraulic conductivity. Each specimen was mounted in a triaxial-type permeameter

Table 2-1
Summary of IW-7 Pilot Hole
Geologic Coring Operations

Date	Core #	Depth (feet bpl)		Core Length (feet)	Recovered Length (feet)	Percent Recovered	Formation
10/2/03	1	1874	1886	12	7	58%	Avon Park Formation
10/3/03	2	1976	1986	10	5	50%	Avon Park Formation
10/5/03	3	2097	2107	10	9.25	93%	Avon Park Formation
10/7/03	4	2300	2310	10	10	100%	Avon Park Formation
10/31/03	5	2420	2430	10	7.9	79%	Avon Park Formation
11/2/03	6	2645	2655	10	6	60%	Avon Park Formation
11/5/03	7	2779	2789	12	9	75%	Avon Park Formation

bpl = below pad level

Table 2-2
Permeability Test Results
West Palm Beach Injection Well IW-7

Core No.	Sample No.	Depth Interval (feet)	D-5084 Test Method*	Test Specimen Orientation	G_s	Initial Conditions: Length (cm)	Initial Conditions: Diameter (cm)	Initial Conditions: w_c (%)	Initial Conditions: γ_d (lb/ft^3)	Initial Conditions: n	c (lb/in^2)	u_b (lb/in^2)	B Factor (%)	Average Hydraulic Gradient	Final Conditions: w_c (%)	Final Conditions: γ_d (lb/ft^3)	Final Conditions: S (%)	Hydraulic Conductivity k_{20} (cm/sec)	Hydraulic Conductivity k_{20} (ft/day)
1	1	1875.4 - 1875.7	A	Vertical	2.71	7.15	9.73	16.9	111.9	0.34	30	160	99	42	16.9†	111.9	89	1.6×10^{-5}	4.5×10^{-2}
			A	Horizontal		6.55	5	16.9	115	0.32	30	160	100	19	16.9	115	97	2.7×10^{-5}	7.7×10^{-2}
	2	1880.0 - 1880.7	A	Vertical	2.83	10.24	9.99	7	147	0.17	30	160	99	26	7.0†	147	98	1.1×10^{-7}	3.1×10^{-4}
			A	Horizontal		7.29	5.02	7	147.5	0.16	30	160	95	24	7	147.5	100	1.6×10^{-7}	4.5×10^{-4}
	3	1877.6 - 1878	A	Vertical	2.75	7.28	9.77	12.8	122.9	0.28	30	160	98	41	12.8	122.9	89	8.3×10^{-6}	2.4×10^{-2}
			A	Horizontal		6.75	5.02	12.8	125	0.27	30	160	97	28	12.8	125	95	6.6×10^{-6}	1.9×10^{-2}
2	1	1980.6 - 1981	A	Vertical	2.81	7.16	10.01	9.1	133.5	0.24	30	160	99	29	9.1†	133.5	82	1.1×10^{-5}	3.1×10^{-2}
			A	Horizontal		7.25	5.01	9.1	134.7	0.23	30	160	100	51	9.1	134.7	85	7.2×10^{-6}	2.0×10^{-2}
	2	1977.3 - 1977.8	A	Vertical	2.82	6.98	9.83	10	136.5	0.22	30	160	100	39	10.0†	136.5	98	7.0×10^{-7}	2.0×10^{-3}
			A	Horizontal		6.82	5.02	10	135.4	0.23	30	160	100	32	10	135.4	94	1.3×10^{-6}	3.7×10^{-3}
	3	1976.3 - 1976.6	A	Vertical	2.73	5.27	9.79	17.4	111.3	0.35	30	160	94**	37	17.4†	111.3	89	2.3×10^{-6}	6.5×10^{-3}
			A	Horizontal		6.79	3.25	17.4	114.9	0.33	30	160	95	33	17.4	114.9	98	5.3×10^{-6}	1.5×10^{-2}
3	1	2104.1 - 2104.5	A	Vertical	2.74	7.68	9.52	20.7	106.9	0.38	30	160	98	27	20.7†	106.9	95	8.2×10^{-5}	2.3×10^{-1}
			A	Horizontal		6.59	5.02	20.7	107.3	0.37	30	160	99	30	20.7	107.3	96	1.5×10^{-5}	4.3×10^{-2}
	2	2099.1 - 2099.5	A	Vertical	2.75	6.82	9.88	12	126.9	0.26	30	160	100	17	12.0†	126.9	93	2.0×10^{-4} ***	5.7×10^{-1} ***
			A	Horizontal		6.63	5.02	12	127.5	0.26	30	160	85**	32	12	127.5	95	8.4×10^{-6}	2.4×10^{-2}
	3	2097.5 - 2098	A	Vertical	2.72	7.31	10.01	8.1	138.3	0.19	30	160	100	38	8.1†	138.3	96	2.4×10^{-4} ***	6.8×10^{-1} ***
			A	Horizontal		7.21	5.02	8.1	139.2	0.18	30	160	90**	23	8.1	139.2	100	8.4×10^{-7}	2.4×10^{-3}
4	1	2308.7 - 2309	A	Vertical	2.78	7.11	9.96	9.1	134.2	0.23	30	160	100	35	9.1†	134.2	86	2.4×10^{-6}	6.8×10^{-3}
			A	Horizontal		7.09	5.01	9.1	137.2	0.21	30	160	100	31	9.1	137.2	95	2.4×10^{-6}	6.8×10^{-3}
	2	2302.7 - 2303.1	A	Vertical	2.73	9.88	9.8	9.5	135.3	0.21	30	160	98	23	9.5†	135.3	100	1.8×10^{-7}	5.1×10^{-4}
			A	Horizontal		6.51	5.02	9.5	134.9	0.21	30	160	87**	40	9.5	134.9	99	3.0×10^{-7}	8.5×10^{-4}
	3	2300.5 - 2300.8	A	Vertical	2.85	5.79	9.98	11.1	133.5	0.25	30	160	100	46	11.1†	133.5	95	2.1×10^{-6}	6.0×10^{-3}
			A	Horizontal		6.71	3.26	11.1	133.2	0.25	30	160	92**	37	11.1	133.2	94	2.4×10^{-6}	6.8×10^{-3}

Table 2-2
Permeability Test Results
West Palm Beach Injection Well IW-7

Core No.	Sample No.	Depth Interval (feet)	D-5084 Test Method*	Test Specimen Orientation	G_s	Initial Conditions: Length (cm)	Initial Conditions: Diameter (cm)	Initial Conditions: w_c (%)	Initial Conditions: γ_d (lb/ft^3)	Initial Conditions: n	c (lb/in^2)	u_b (lb/in^2)	B Factor (%)	Average Hydraulic Gradient	Final Conditions: w_c (%)	Final Conditions: γ_d (lb/ft^3)	Final Conditions: S (%)	Hydraulic Conductivity k_{20} (cm/sec)	Hydraulic Conductivity k_{20} (ft/day)
5	1	2423.3 - 2423.8	A	Vertical	2.86	10.64	10.05	10.7	133.2	0.25	30	160	100	22	10.7†	133.2	90	9.5×10^{-7}	2.7×10^{-3}
			A	Horizontal		6.85	5.02	10.7	134.7	0.24	30	160	99	34	10.7	134.7	95	2.3×10^{-6}	6.5×10^{-3}
	2	2426.3 - 2427	A	Vertical	2.86	11	10.03	7.1	142.4	0.2	30	160	98	20	7.1†	142.4	80	1.3×10^{-7}	3.7×10^{-4}
			A	Horizontal		6.58	5.01	7.1	145.6	0.18	30	160	85**	48	7.1	145.6	90	5.9×10^{-9}	1.7×10^{-5}
	3A	2421.7 - 2422.5	A	Vertical	2.79	5.17	9.62	11.5	129.8	0.25	30	160	100	63	11.5†	129.8	94	6.0×10^{-7}	1.7×10^{-3}
			A	Horizontal		6.33	3.26	11.5	130.4	0.25	30	160	99	36	11.5	130.4	96	6.9×10^{-7}	2.0×10^{-3}
	3B	2421.7 - 2422.5	A	Vertical	2.86	9.95	9.99	7.2	145.5	0.18	30	160	98	23	7.2†	145.5	91	5.7×10^{-7}	1.6×10^{-3}
			A	Horizontal		6.48	5.02	7.2	147.3	0.17	30	160	85**	31	7.2	147.3	97	3.8×10^{-7}	1.1×10^{-3}
6	1	2646.8 - 2647.1	A	Vertical	2.76	5.93	9.6	15.2	119.4	0.31	30	160	95	49	15.2†	119.4	95	9.6×10^{-6}	2.7×10^{-2}
			A	Horizontal		6.74	3.25	15.2	120.2	0.3	30	160	100	32	15.2	120.2	97	1.1×10^{-5}	3.1×10^{-2}
	2	2650.7 - 2651	A	Vertical	2.74	7.22	9.6	17.6	113.8	0.33	30	160	97	49	17.6†	113.8	96	3.2×10^{-5}	9.1×10^{-2}
			A	Horizontal		6.42	5.01	17.6	114.4	0.33	30	160	95	34	17.6	114.4	98	4.1×10^{-5}	1.2×10^{-1}
7	1	2784.8 - 2785.5	A	Vertical	2.81	6.9	9.97	6.5	145.2	0.17	30	160	95	28	6.5†	145.2	88	7.1×10^{-7}	2.0×10^{-3}
			A	Horizontal		7.04	5.02	6.6	147.2	0.16	30	160	100	36	6.5	147.2	96	6.6×10^{-7}	1.9×10^{-3}
	2	2786.5 - 2787	A	Vertical	2.84	8.08	9.99	9.4	137.1	0.23	30	160	98	49	9.4†	137.1	91	3.5×10^{-5}	9.9×10^{-2}
			A	Horizontal		7.01	5.01	9.4	139.8	0.21	30	160	97	14	9.4	139.8	100	8.3×10^{-5}	2.4×10^{-1}

Where: w_c = Moisture content; γ_d = Dry density; G_s = Specific gravity; n = Total Porosity; c = Average isotropic effective confining stress; u_b = Back-pressure; and S = Calculated degree of saturation using measured specific gravity.

* Method A = Constant-head test.

** B-Factor remained relatively constant for two consecutive increments of applied cell pressure.

*** Rock core contained fissures through length of specimen that resulted in relatively greater hydraulic conductivity in vertical direction.

† Vertical permeability test specimen was cored upon completion of testing to obtain horizontal permeability test specimen. The final moisture content of the vertical test specimen was not measured, and was assumed to be the same as the horizontal permeability test specimen.

and encased within a latex membrane. The specimens were confined using an average isotropic effective confining stress of 30 lb/in^2 and permeated with deaired tap water under a back-pressure of 160 lb/ in^2. Satisfactory saturation was verified by a B factor equal to or greater than 95%, or a B factor that remained relatively constant for two consecutive increments of applied cell pressure. The inflow to and outflow from each specimen were monitored with time, and the hydraulic conductivity was calculated for each recorded flow increment. The tests were continued until steady-state flow conditions were obtained, as evidenced by an outflow/inflow ratio between 0.75 and 1.25, and until stable values of hydraulic conductivity were measured.

The final degree of saturation was calculated upon completion of testing using the final dry mass, moisture content and volume, and measured specific gravity. Although some of the calculated final degrees of saturation are low (i.e. less than 95%), the B-factors indicate satisfactory saturation. The calculated final degrees of saturation are potentially affected by occluded voids within the specimens, surface irregularities, and the use of final moisture contents for vertical permeability test specimens from corresponding horizontal permeability test specimens.

Specific Gravity
The specific gravity of each sample was determined on a representative approximately 100 gram specimen ground to pass the U.S. Standard No. 40 sieve. The measured specific gravities (Gs) are presented in Table 2-2.

Porosity
The total porosity, n, of each permeability test specimen was calculated using the measured dry density, (γd), and measured specific gravity, (Gs), from the equation:

$$n = 1 [\gamma d/(Gs)(\gamma w)]$$

where γw = unit weight of water.

The calculated total porosities are presented in Table 2-2. Values ranged from 16% to 38%.

2.2.2.2 Formation Factor and Archie's Cementation Exponent

The formation factor and Archie's cementation exponent were determined by New England Research, Inc. on specimens from Core 2/Sample 1/1,981 feet and Core 3/Sample 3/2,098 feet. The results from New England Research, Inc. are presented in Appendix C.

AAI delivered two rock samples for measurement of resistivity. Both samples were carbonates cored from IW-7, one from a depth of 1,981 feet bpl (referred to as sample 1,981) and one from a depth of 2,098 feet bpl (referred to as sample 2,098).

Two samples were sub-cored from the two whole cores. Sample 1,981 was a heterogeneous, vuggy carbonate, probably dolomitized, with a grain density of 2.82

g/cc. The porosity of the sample was estimated to be 21.7%. Sample 2,098 was a uniform, slightly vuggy carbonate with a grain density of 2.69 g/cc. The porosity of the sample was estimated to be 17.3%.

Sample 1,981 was saturated with brine containing 7 grams of sodium chloride per liter. Complex impedance of the sample was measured over a frequency range of 0.01 Hz to 100 kHz. Sample 2,098 was saturated with brine containing 30 grams of sodium chloride per liter. Complex impedance of the sample was also measured over the frequency range of 0.01 to 100 kHz.

Temperature corrections were applied to the brine conductivity. A correction was also applied to "remove" parasitic impedance effects at frequencies above 10 kHz. The correction was based on a measurement made on Ottawa sand saturated with tap water.

The impedance of sample 1,981 was slightly dispersive, possibly due to clay or other mineralization of the sample. The sample contained a cementation factor of 2.56. Sample 2,098 has relatively constant impedance over the frequency range. The cementation factor for sample 2,098 is 1.98. The higher value of the cementation exponent for sample 1,981 is consistent with its larger vug porosity and implies a vug porosity to total porosity ratio of 0.4.

2.3 Geophysical Logs

Borehole geophysical surveys are performed by lowering sensing devices attached to a wireline into the borehole to measure and record various physical properties of the borehole. The geophysical logging program performed during the construction and testing of IW-7 and DZMW-7 was designed to collect information on the hydrogeology on penetrated strata, data on borehole geometry that would assist in setting and cementing casing strings and determining packer test intervals, and evaluating the integrity of the casing cements. A summary of the geophysical logs during the construction and testing of wells IW-7 and DZMW-7 is provided in **Table 2-3**. The geophysical logs collected in the pilot holes from 110 to 3,700 feet bpl are provided in the Appendix D. **Figures 2-4A** through **2-4C** displays the logs in a side-by-side format for comparison purposes.

From 110 to 1,050 feet bpl, a caliper, gamma ray, sonic, and dual induction resistivity logs were run. Below 1,000 feet bpl a full suite of logs (gamma ray, caliper, sonic, flowmeter, temperature, fluid, and dual induction resistivity) were run after completion of each segment of the pilot hole. Gamma ray and caliper logs were run on the pilot hole prior to single element packer testing and on the reamed hole before the setting of the 54, 44, 36, and 26-inch diameter casings of the injection well and the 12.75, and 6.625-inch diameter casings of the monitor well. The reamed hole gamma ray and caliper logs are provided in Appendix E. A cement bond log was run after the cementing of the 26-inch diameter injection casing and the 6.625-inch diameter monitor well casing. The cement bond logs and the cement top logs are enclosed in

Table 2-3
IW-7 Geophysical Log Summary

Depth (feet bpl)	Run No.	Date	Diameter (inches)	Type	Geophysical Log
0 to 119	1	September 10, 2003	58.5	reamed hole	Caliper and Gamma Ray
110 to 1,050	2	September 13, 2003	17.5	pilot hole	Caliper, Gamma Ray, Dual Induction, and Borehole Compensated Sonic with VDL display
80 to 1,023	3	September 18, 2003	52.5	reamed hole	Caliper and Gamma Ray
995 to 1,600	4	September 27, 2003	12.25	pilot hole	Caliper and Gamma Ray prior to Packer Test No. 1
995 to 1,730	5	September 29, 2003	12.25	pilot hole	Caliper and Gamma Ray prior to Packer Test No. 2
995 to 1,840	6	October 1, 2003	12.25	pilot hole	Caliper and Gamma Ray prior to Packer Test No. 3
995 to 2,050	7	October 4, 2003	12.25	pilot hole	Caliper and Gamma Ray prior to Packer Test No. 4
996 to 2,310	8	October 8, 2003	12.25	pilot hole	Caliper and Gamma Ray prior to Packer Test No. 5
1,000 to 2,310	9	October 9-10, 2003	12.25	pilot hole	Caliper, gamma ray, dual induction, borehole compensated sonic with VDL display, borehole televiewer, and downhole radial color television survey with rotating lens. Flowmeter, temperature, and fluid resistivity logs were run under pumping and static conditions.
1,000 to 2,210	10	October 21, 2004	42.5	reamed hole	Caliper and Gamma Ray
0 to 2,210	11	October 26, 2005	36	intermediate casing	Cement top temperature log
2,150 to 2,645	12	November 1, 2003	12.25	pilot hole	Caliper and Gamma Ray prior to Packer Test No. 6

Table 2-3
IW-7 Geophysical Log Summary

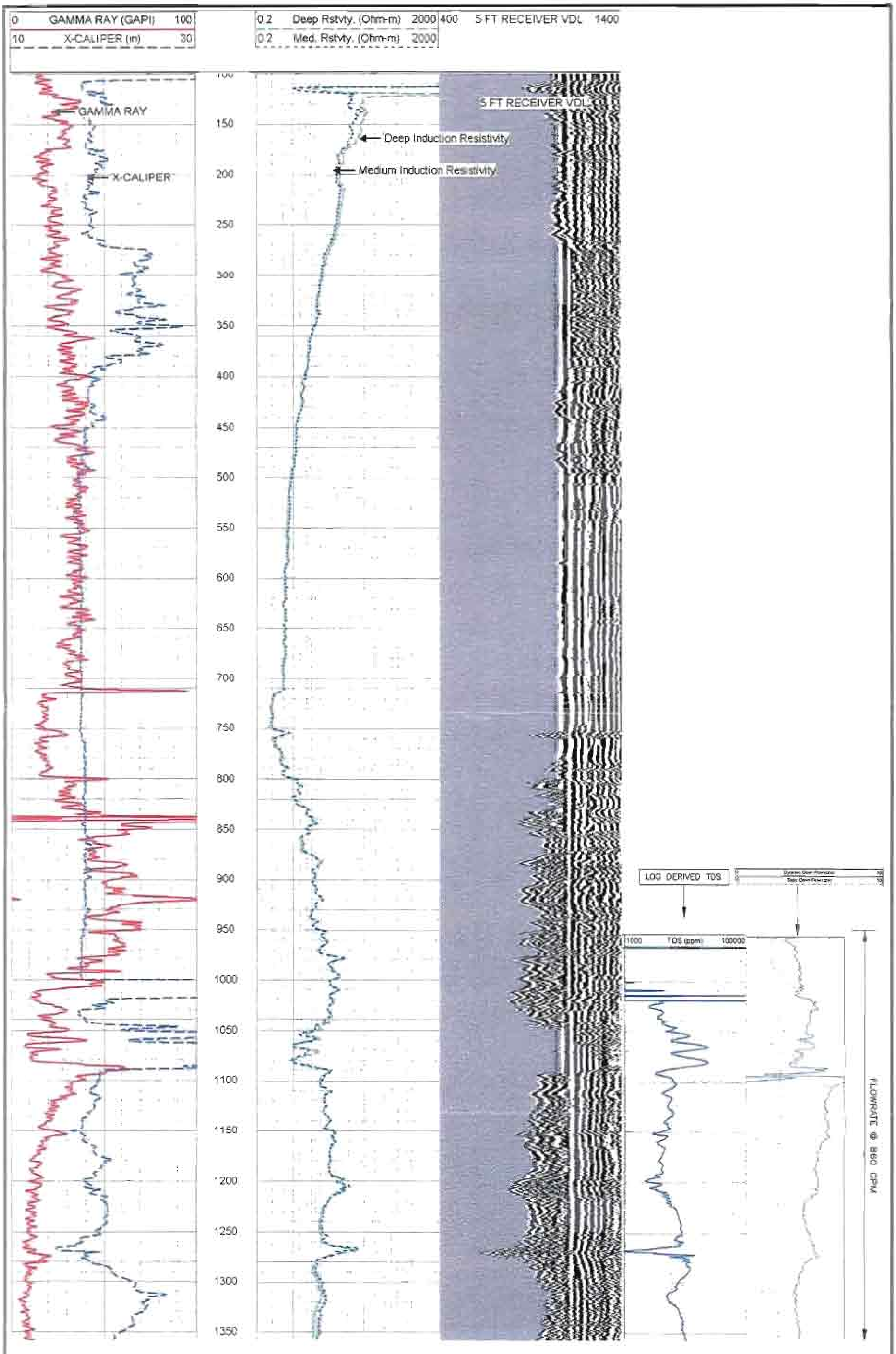
Depth (feet bpl)	Run No.	Date	Diameter (inches)	Type	Geophysical Log
2,150 to 2,745	13	November 3, 2003	12.25	pilot hole	Caliper and Gamma Ray prior to Packer Test No. 7
2,150 to 3,025	14	November 6, 2003	12.25	pilot hole	Caliper, gamma ray, dual induction, borehole compensated sonic with VDL display, borehole televiewer, and downhole radial color television survey with rotating lens. Flowmeter, temperature, and fluid resistivity logs were run under pumping and static conditions.
2,210 to 2,972	15	November 22, 2003	34.5	reamed hole	Caliper and Gamma Ray
0 to 2,962	16	December 3, 2003	26	final casing	Cement top temperature log
2,900 to 3,450	17	December 6, 2003	12.25	pilot hole	Caliper, gamma ray, dual induction, borehole compensated sonic with VDL display, borehole televiewer, and downhole radial color television survey with rotating lens. Flowmeter, temperature, and fluid resistivity logs were run under pumping and static
2,962 to 3,700	18	December 17, 2003	24	reamed hole	Cement Bond Log, caliper, gamma ray, dual induction, borehole compensated sonic with VDL display, borehole televiewer, and downhole radial color television survey with rotating lens. Flowmeter, temperature, and fluid resistivity logs were run under pumping and static conditions.

Table 2-3

IW-7 Geophysical Log Summary

Depth (feet bpl)	Run No.	Date	Diameter (inches)	Type	Geophysical Log
0 to 512	1	January 2, 2004	28	reamed hole	Caliper and Gamma Ray
500 to 1,830	2	January 8, 2004	18.5	reamed hole	Caliper, gamma ray, dual induction log, and borehole compensated sonic with VDL display
0 to 1,805	3	January 12, 2004	12.75	intermediate casing	Cement top temperature log
1,805 to 1,950	4	January 15, 2004	11	reamed hole	Caliper and Gamma Ray prior to Packer Test No. 1
1,800 to 2,150	5	January 17, 2004	11	reamed hole	Caliper, gamma ray, dual induction log, and borehole compensated sonic with VDL display
1,800 to 2,250	6	January 22, 2004	11	reamed hole	Caliper and Gamma Ray prior to Packer Test No. 2
0 to 2,250	7	January 31, 2004	6 3/4	intermediate casing	Cement top temperature log
0 to 2,200	8	April 2, 2004	6 5/8	final casing	Sector bond log and downhole radial color television survey with rotating lens

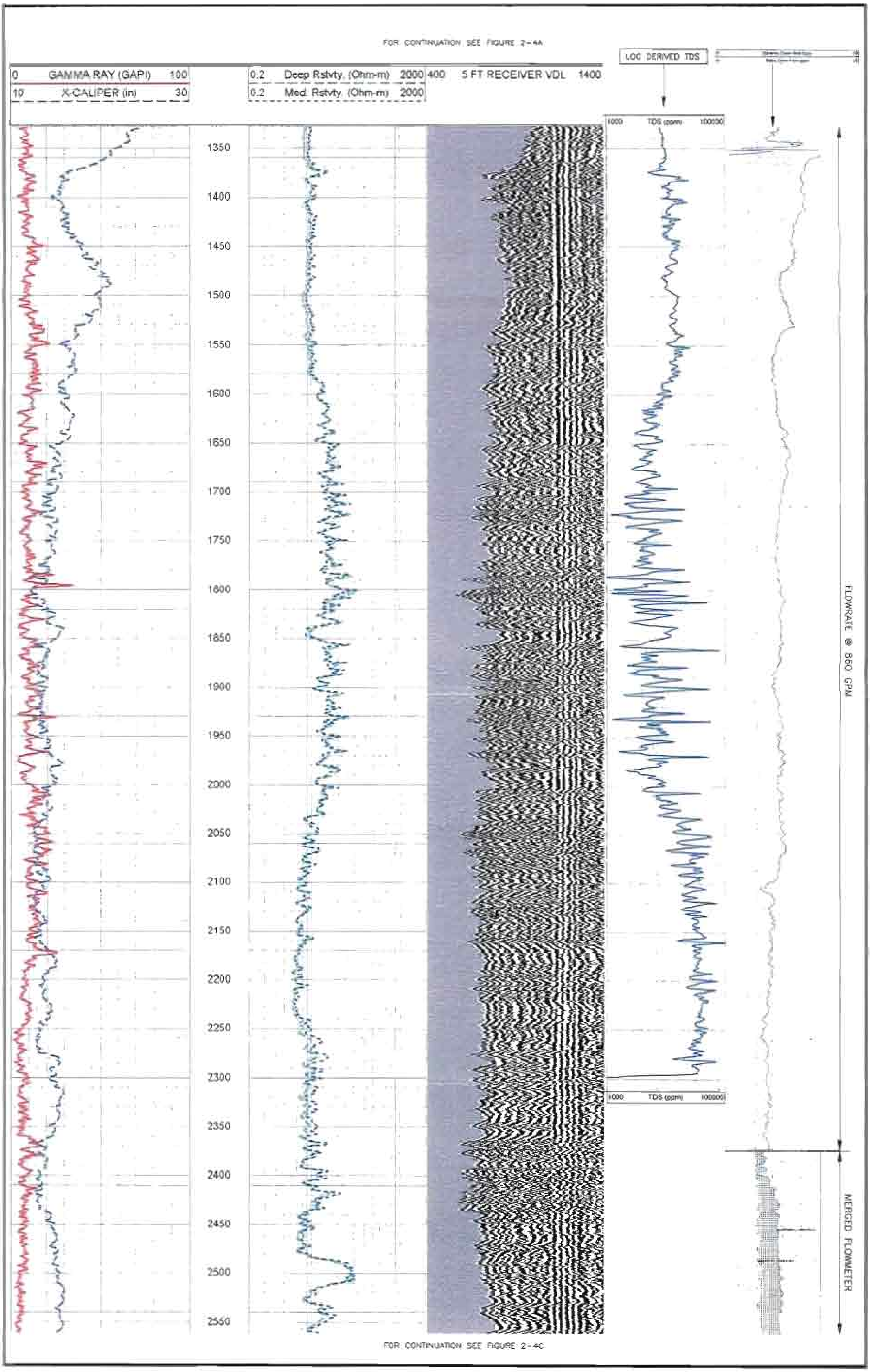
bpl = below pad level



FOR CONTINUATION SEE FIGURE NO. 2-4B

CDM

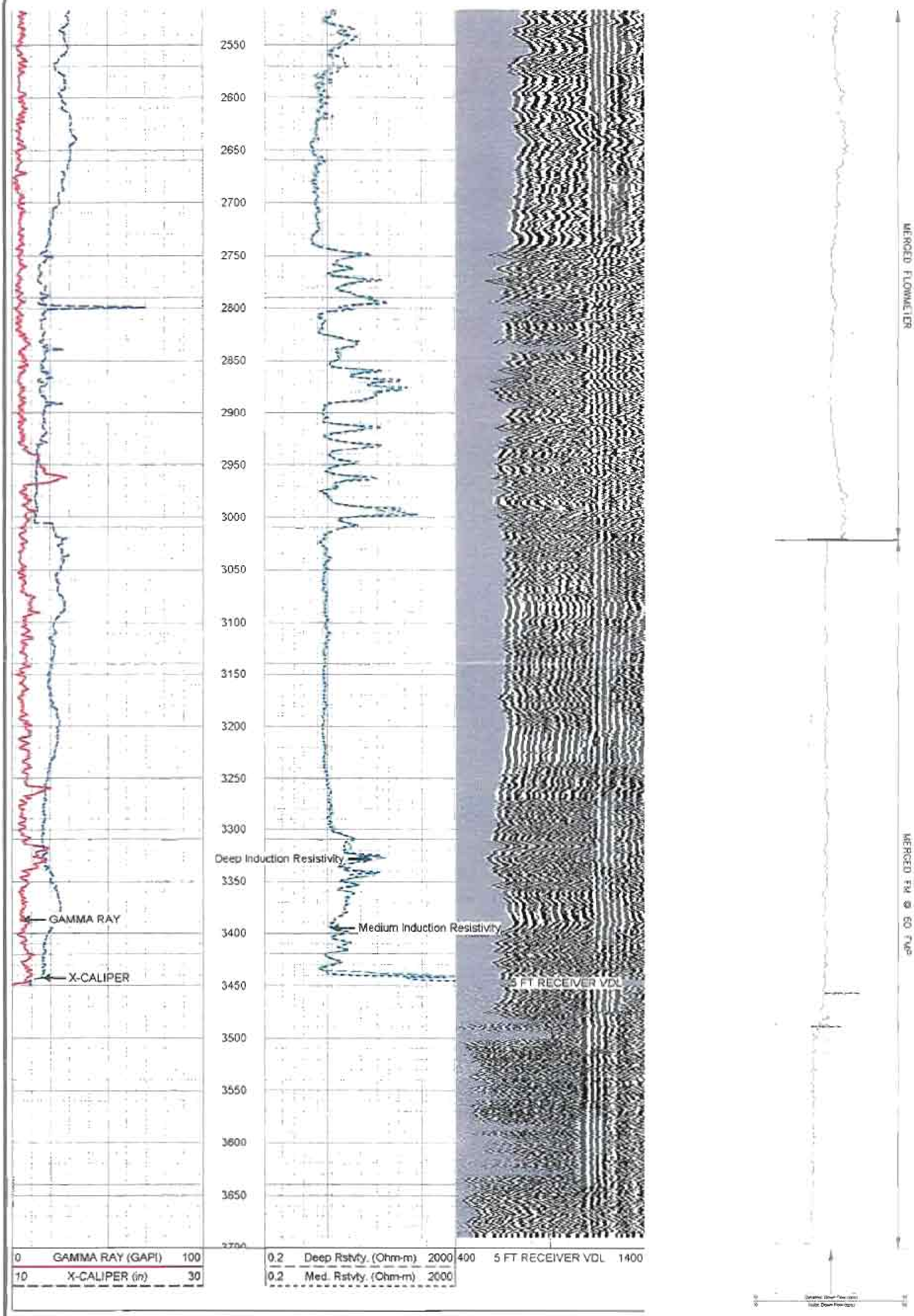
Figure No. 2-4A
City of WPB ECRWWTP, Florida
IW-7 Pilot Hole Geophysical Logs



CDM

Figure No. 2-4B
City of WPB ECRWWTP ''orida
IW-7 Pilot Hole Geophysica Logs

FOR CONTINUATION SEE FIGURE NO. 2-4B



CDM

Figure No. 2-4C
City of WPB ECRWWTP, Florida
IW-7 Pilot Hole Geophysical Logs

Appendix F. The geophysical logs were run by Youngquist Brothers, Inc. Geophysical Logging Division, and were witnessed by CDM or Palm Beach County personnel.

Television surveys were performed on the pilot hole from 1,000 feet bpl to the total depth of 3,701 feet bpl. The purpose of these surveys was to obtain information on the nature of the rocks penetrated and to evaluate the integrity of the casings. Hole conditions proved too cloudy to obtain a television picture of satisfactory clarity from 1,000 to 2,200 feet bpl. YBI attempted for two days to improve hole conditions. These attempts included flowing the well, pumping water into the well, and wiper trips. **Table 2-4** summarizes the television surveys from 2,205 to 3,701 feet bpl. The television surveys were performed by Youngquist Brothers, Inc. Geophysical Logging Division using a down-hole radial color television survey with rotating lens and a video recorder. The television surveys were witnessed in their entirety by CDM or Palm Beach County field personnel. The videotape of the television surveys were later reviewed and described in detail. The video tapes of the survey are provided in Appendix G.

Borehole televiewer logs were run from 1,500 to 2,300 feet bpl and from 2,201 to 3,025 feet bpl. These surveys were run to obtain an image of the borehole and to obtain information on the relative hardness of the formations exposed, and to identify fractures and cavernous zones. The borehole televiewer logs were performed by Youngquist Brothers, Inc. Geophysical Logging Division using their imaging tool. The televiewer logs were witnessed in their entirety by CDM or Palm Beach County field personnel. The televiewer logs are provided in Appendix G.

2.4 Water Quality Profile

To develop a profile showing how water quality changes with depth, water quality samples were collected during drilling operations and during the single element packer testing. Formation water quality samples were collected from the drill stem discharge at the end of each drill rod, beginning once the drilling operation switched from mud drilling to reverse-air drilling on September 25, 2003 at 1,016 feet bpl. As part of the testing process, water samples were collected during single element packer tests and analyzed for specific parameters. In addition, after injection well completion and development, water quality samples were collected from the open hole portion of IW-7 (the injection zone) and analyzed for parameters listed in the FDEP permit. The injection zone background water quality results are included in Appendix H. The water quality samples collected from the drill stem, the single element packer, and the injection zone were analyzed by Envirodyne, Inc. of Boca Raton, Florida.

The formation water quality samples are summarized in **Table 2-5**. The first such sample was collected at 1,050 feet bpl and successive samples were collected at approximately 30-foot intervals. The formation water quality samples were analyzed for chloride, specific conductance, ammonia, and total Kjeldahl nitrogen (TKN). There are limitations on the accuracy of the data obtained from the drill stem samples. Interpretation of this data was of limited use due to mixing of makeup and formation

TABLE 2-4

TELEVISION SURVEY

WELL: IW-7 | PROJECT NO.: 10061-26918 | PAGE: 1 of 3

SITE LOCATION: ECRWWTP | PERMIT NO.: 0048923-005-UC | CONTRACTOR: YOUNGQUIST

DEPTHS:2205-3700 | DATE: 12-17-03 | PREPARED BY: S. MAGENHEIMER

DEPTH (feet BP)	OBSERVATIONS
2205	Smooth; Pale Orange
2334-2337	Rugose
2347	Rugose Pores visible; secondary porosity.
2448	Smooth; pale orange
2450	Secondary Porosity, voids, cavities
2581	Smooth
2642	Smooth but pores and voids noticeable.
2657	Smooth
2710	Smooth, pore and voids not as well developed.
2748	Well developed voids begin
2767	Voids.
2783	Voids.
2961	Cement; dark patch at 12 o'clock casing.
2979	End of cement; formation starts.
2985	Limestone Rugose.
2995	Smooth Limestone.
2995	Rugose Limestone.
2999-3001	Flow fractures
3008	Smooth Limestone.
3017	Void
3018	Limestone W/ secondary porosity occasionally
3030-3031	secondary porosity
3045-3048	Well Developed secondary porosity
3051-3052	Voids
3057-3058	Voids
3066-3069	Voids
3074	Voids
3078-3079	Dolomite
3080	Smooth
3097-3105	Fractured Limestone

TABLE 2-4 (continued)

TELEVISION SURVEY

WELL: IW-7	PROJECT NO.: 10061-26918	
SITE LOCATION: ECRWWTP	PERMIT NO.: 0048923-005-UC	CONTRACTOR: YOUNGQUIST
DEPTHS:2205-3700	DATE: 12-17-03	PREPARED BY:S. MAGENHEIMER

DEPTH (feet BP)	OBSERVATIONS
3107-3115	Dolomite
3116-3124	Fractures & Dolomite
3125-3142	Smooth Dolomite
3142-3165	Smooth Rugose Dolomite
3191-3208	Fractures & Voids
3208-3225	Smooth
3225-3230	Fractures
3230-3245	Smooth
3245-3267	Dolomite Stringers w/ smooth limestone
3267-3272	Fractures, Voids.
3272-3278	Smooth
3278	Dolomites, stringers, voids.
3293	Dolomites, stringers
3299	Shimmer
3305	Dolomite
3308	Dolomite
3311	Shimmer
3215	Dolomite
3315-3330	Smooth
3332-3335	Shimmer
3335-3346	Rugose
3350-3356	Shimmer
3364	Void
3365-3385	Vuggy Limestone
3385-3402	Smooth Limestone
3402-3412	Vuggy Limestone
3430	Minor vugs, otherwise smooth
3440	Minor Vugs, otherwise smooth
3450	Smooth
3470	Smooth
3487-3489	Large cavern

TABLE 2-4 (continued)

TELEVISION SURVEY

WELL: IW-7 | PROJECT NO.: 10061-26918 |

SITE LOCATION: ECRWWTP | PERMIT NO.: 0048923-005-UC | CONTRACTOR: YOUNGQUIST

DEPTHS:2205-3700 | DATE: 12-17-03 | PREPARED BY: S. MAGENHEIMER

DEPTH (feet BP)	OBSERVATIONS
3490-3525	Fractures
3526	Smooth with minor vugs
3542	Medium fractures, vugs
3599	Large vugs, fractures
3624	Large vugs, fractures
3631-3642	Large vugs, fractures
3643	Smooth
3649	Large fractures, vugs
3650	Minor fractures, vugs, water begins to get cloudy
3653	Smooth
3680	Smooth, water cloudy
3683	Smooth, with minor vugs, fractures
3690	Smooth
3700	Total Depth

Table 2-5
Summary of IW-7 Pilot Hole
Formation Water Quality

Depth (feet bpl)	Chloride (mg/L)	Specific Conductance (umhos/cm)	Ammonia, as N (mg/L)	TDS (mg/L)	TKN (mg/L)	Sulfate (mg/L)
1,050	300	1,800	0.76	1,100	<2.5	NA
1,080	450	2,200	<0.020	720	2.8	NA
1,110	460	2,200	<0.020	960	<2.5	NA
1,140	710	3,300	0.69	1,600	<2.5	NA
1,170	730	2,800	0.54	1,480	<2.5	NA
1,200	490	2,400	<0.020	920	<5	NA
1,230	520	2,100	<0.020	800	<5	NA
1,260	460	2,300	<0.020	840	<5	NA
1,290	610	2,800	<0.020	960	6.5	NA
1,320	600	2,800	0.10	1,100	<5	NA
1,350	570	2,600	<0.020	1,000	<5	NA
1,380	540	2,500	<0.020	1,500	<5	NA
1,410	1,000	3,900	0.19	1,400	<5	NA
1,440	910	3,800	0.37	1,800	<5	NA
1,470	880	3,800	0.24	1,700	<5	NA
1,500	1,100	5,000	0.5	1,900	<5	NA
1,530	1,100	4,200	0.49	1,900	<5	NA
1,560	1,200	5,000	0.5	2,200	<5	NA
1,590	1,200	4,600	0.42	2,100	<5	NA
1,620	2,500	9,500	1.2	4,700	10	NA
1,650	2,400	9,000	1.3	3,400	7.5	NA
1,680	2,700	9,900	1.4	5,600	2.5	NA
1,710	3,000	12,000	1.6	6,100	3.0	NA
1,750	3,500	8,900	2.2	5,200	2.5	NA
1,770	2,800	11,000	2.0	5,100	2.1	NA
1,800	3,000	11,000	2.3	5,800	2.5	NA
1,830	3,000	12,000	2.3	5,500	2.4	NA
1,860	2,600	9,400	1.5	NA	1.5	NA
1,890	2,600	9,400	1.7	NA	1.9	NA
1,920	2,900	10,000	1.7	5,700	1.7	NA
1,950	3,000	11,000	1.8	5,300	2.6	NA
1,986	2,900	9,300	1.3	5,100	1.4	NA
2,010	2,800	10,000	1.7	5,600	1.8	NA
2,040	3,000	11,000	1.6	5,400	1.9	NA
2,070	3,100	9,800	1.2	6,400	1.3	NA
2,100	3,200	10,000	1.1	6,000	1.3	NA
2,130	3,400	10,000	1.1	4,000	1.3	NA

Table 2-5
Summary of IW-7 Pilot Hole
Formation Water Quality

Depth (feet bpl)	Chloride (mg/L)	Specific Conductance (umhos/cm)	Ammonia, as N (mg/L)	TDS (mg/L)	TKN (mg/L)	Sulfate (mg/L)
2,160	3,400	12,000	1.0	4,300	1.1	NA
2,190	4,100	11,000	1.2	4,600	1.3	NA
2,220	4,500	13,000	1.1	5,000	1.2	NA
2,250	4,500	14,000	1.5	5,000	1.5	NA
2,280	5,200	16,000	1.2	5,600	1.3	NA
2,330	5,600	16,000	0.37	15,000	2.6	NA
2,360	5,200	14,000	0.16	14,000	3.6	NA
2,390	5,200	14,000	0.032	12,000	3.2	NA
2,420	4,900	13,000	0.22	12,000	3.8	NA
2,430	5,600	14,000	0.15	13,000	2.8	NA
2,460	5,100	13,000	<0.02	8,600	2.5	NA
2,490	3,400	8,800	<0.02	5,400	5.0	NA
2,520	5,200	14,000	<0.02	8,700	1.7	NA
2,550	5,300	14,000	<0.02	8,900	3.2	NA
2,580	4,400	12,000	<0.02	12,000	3.6	NA
2,610	5,000	13,000	<0.02	7,300	3.2	NA
2,640	4,800	13,000	<0.02	6,900	3.8	NA
2,670	5,800	16,000	<0.02	6,900	2.6	NA
2,700	7,800	20,000	<0.02	12,000	2.3	NA
2,730	6,100	16,000	<0.02	7,300	4.0	NA

bpl = below pad level
NA = Not Analyzed
Formation Water Sample: chloride, specific conductance, ammonia, and TKN.

waters in the borehole during drilling. Drill stem samples yielded a mixed, and usually diluted, sample. The interval from 2,200 to 2,675 feet bpl was not productive enough to continue reverse-air drilling. Makeup water was added down to a depth of 2,675 feet bpl to maintain reverse-air drilling. More reliable water quality data were obtained from the samples collected during the packer test. The packer isolated the aquifer zones and the water samples were collected only after the water quality had stabilized as monitored by field conductivity measurements. Discussion of water quality will therefore focus primarily on the analyses from the single element packer tests.

The single element packer test water quality data are summarized in **Table 2-6**, which includes samples from the packer testing of both IW-7 and DZMW-7. The water samples collected with the single element packer were analyzed for chloride, specific conductance, ammonia, TDS, TKN, and sulfate.

The series of the first four single element packer tests (see Table 2-6 for test intervals) conducted during the construction of IW-7 support the log-derived TDS measurements. The water quality results indicate that a concentration of 10,000 milligrams per liter (mg/L) TDS occurs between a depth of 1,840 and 2,020 feet bpl in the IW-7 borehole. These depth boundaries represent the lower and upper limits, respectively, of the nearest packer test intervals. During the construction of DZMW-7, a packer test was conducted from 1,920 to 1,950 feet bpl and confirmed that the concentration of 10,000 mg/L TDS occurs between a depth of 1,950 and 2,020 feet bpl in the vicinity of injection well IW-7. Based on the data, it is interpreted that the USDW baseline occurs at a depth of 2,000 feet bpl. These data are discussed in more detail in Section 2.5.

In packer test number IW-7 #1, the concentrations of ammonia and TKN were higher than anticipated. The interval tested from 1,571 to 1,600 feet bpl. The data from the three single element packer tests below this depth indicated levels of these parameters more in line with anticipated ambient conditions. This anomaly is interpreted as resulting from natural conditions since the data below indicates that the source of the ammonia and TKN did not originate from deeper in the Floridan aquifer (i.e., the ECRWWTP injection zone).

The water quality data from packer test numbers IW-7 #5 and IW-7 #6 contain no suggestion of the upward migration of effluent. The concentrations of nutrient and salinity-related parameters are at natural background levels. TDS values ranged from 36,000 to 41,000 mg/L in the samples from these two zones. The salinity-related parameters from packer test number IW-7 #7 are consistent with invasion by effluent. The TDS concentration for the 2,716 to 2,745-foot interval was 15,000 mg/L. TKN was also higher than measured in packer test number IW-7 #6 (1 mg/L compared to 0.38 mg/L). Evaluation of confinement is discussed in detail in Section 2.6.

Table 2-6
Summary of IW-7 and DZMW-7 Pilot Hole
Packer Water Quality

Packer Test No.	Depth (feet bpl)		Chloride	Specific Conductance	Ammonia, as N	TDS	TKN	Sulfate
	From	To	(mg/L)	(umhos/cm)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
IW-7 #1	1,571	1,600	4,200	15,000	3.7	8,600	4.1	600
IW-7 #2	1,700	1,730	2,000	6,400	0.93	4,200	0.94	390
IW-7 #3	1,810	1,840	2,300	8,100	0.61	4,800	0.62	450
DZMW-7 #1	1,920	1,950	3,600	12,000	1.7	7,000	2.2	420
IW-7 #4	2,020	2,050	9,900	30,000	0.63	17,000	0.91	87
DZMW-7 #2	2,090	2,150	17,000	49,000	0.55	31,000	1.2	500
DZMW-7 #3	2,200	2,250	19,000	46,000	0.14	37,000	1.3	2400
IW-7 #5	2,280	2,310	20,000	47,000	0.19	36,000	0.34	2400
IW-7 #6	2,615	2,645	20,000	50,000	<0.02	41,000	0.38	3000
IW-7 #7	2,716	2,745	7,200	17,000	<0.02	15,000	1	1200

bpl = below pad level
Packer Tests: chloride, specific conductance, ammonia, TDS, TKN, and sulfate.

The packer test drawdown levels and flow rates were recorded to calculate specific capacity and transmissivity using the empirical relationship derived from the Jacob method where specific capacity equals transmissivity divided by 2000 (Driscoll, 1986, p. 1021). The values for each of the single element packer tests are provided in **Table 2-7** with the graphed drawdown and recovery data included in Appendix I. A value of 5,895 gallons per day per foot (gpd/ft) was calculated from packer test number IW-7 #3, which is adjacent to the upper monitoring zone for DZMW-7 and is suitable for monitoring. For the DZMW-7 lower monitoring zone, a value of 906 gpd/ft was calculated for the packer test interval from 2,200 to 2,250 feet bpl.

2.5 Evaluation of the Base of the USDW

To establish depths of the upper and lower monitor intervals for DZMW-7, an evaluation of the location of the base of the USDW at the injection well site was undertaken during construction. This is required by the Underground Injection Control construction permit and by Chapter 62-528 of the Florida Administrative Code. The interpretation of the hydrogeologic data collected related to the evaluation of the base of the USDW at IW-7 is provided below.

2.5.1 Criteria Used for Identification of the Base of the USDW

As it pertains to the Underground Injection Control program, an USDW is defined by rule as an underground aquifer containing groundwater with a TDS concentration of 10,000 milligrams per liter (mg/l) or less. The base, therefore, is the depth where TDS concentration in the groundwater exceeds 10,000 mg/l.

2.5.2 Data Used for Analysis

Data used to evaluate the location of the base of the USDW at the IW-7 site included the dual induction log, log-derived TDS presentation, fluid resistivity/temperature log, and packer test data.

2.5.3 Base of USDW Evaluation for IW-7 Site

The hydrogeologic data collected during IW-7 pilot hole construction indicate that the base of the USDW is located at approximately 2,000 feet bpl. The basis for this interpretation is discussed below:

Dual Induction Log (DIL) - The DIL indicates a conductivity inversion occurs starting at approximately 1,500 feet bpl where a trend of relatively more resistive readings begins. This trend extends to a depth of approximately 2,000 feet bpl. The DIL measures the resistivity of the formation and the fluids contained within it. Assuming the formation resistivity properties are holding relatively constant over this interval, the decrease in resistivity is equivalent to an increase in conductivity of the formation water. Increases in conductivity in formation water at this depth are normally attributable to TDS. Below 2,000 feet bpl, resistivity begins to decline indicating a down-hole transition from relatively brackish water to more saline, conductive water.

Table 2-7
Summary of IW-7 and DZMW-7 Pilot Hole
Packer Specific Capacity and Transmissivity

Packer Test No.	Depth (feet bpl) From	Depth (feet bpl) To	Pumping Rate (gpm)	Drawdown (ft)	Specific Capacity (gpm/ft)	Trans-missivity (gpd/ft)	Average Hydraulic Conductivity (ft/day)
IW-7 #1	1,571	1,600	15	127	0.12	236	1.1
IW-7 #2	1,700	1,730	51	114	0.45	895	4.0
IW-7 #3	1,810	1,840	84	28.5	2.95	5,895	26.3
DZMW-7 #1	1,920	1,950	80	32	2.50	5,000	22.3
IW-7 #4	2,020	2,050	37	170	0.22	435	1.9
DZMW-7 #2	2,090	2,150	30	90	0.33	667	1.5
DZMW-7 #3	2,200	2,250	60	132.5	0.45	906	2.4
IW-7 #5	2,280	2,310	23	154	0.15	299	1.3
IW-7 #6	2,615	2,645	22	163	0.13	270	1.2
IW-7 #7	2,716	2,745	28	214	0.13	262	1.2

bpl = below pad level
Packer Tests: chloride, specific conductance, ammonia, TDS, TKN, and sulfate.

Log-Derived TDS (Rwa) - This log was derived from DIL and sonic log porosity measurements. Calculation of formation salinity is based on the Archie equation, which relates pore water resistivity to measured formation resistivity and porosity. Please refer to Asquith (1982) for further description of the mathematical relationships. The log-derived TDS measurements are limited by the model assumptions (particularly the value of cementation and saturation exponents), so there can be variations from data collected directly by packer testing. However, the trend of the TDS log is beneficial in determining relative salinities between zones. For example, the log-derived TDS values above 1,550 feet bpl are not representative due to porosity measurements made by the sonic log. Sonic log derived porosities tend to be inaccurate when hole diameters exceed a certain diameter. In this case it appears that for the hole conditions encountered, the sonic-derived porosities are not representative at diameters in excess of 15 inches.

Below 1,550 feet bpl the data quality improves so that more representative TDS values can be derived. The calculated TDS values between 1,550 and 2,000 feet bpl were at an average value of 6,000 ppm. Below 2,000 bpl, the derived values increase to above 10,000 ppm and continue until total depth of the pilot hole.

Fluid Resistivity/Temperature (FRT) Log - From 2,284 to 2,000 feet bpl the reading for the dynamic FRT log (250 gpm) was stable at 40,000 uS. This indicates that the formation salinity is relatively stable over this interval. Starting at 2,000 feet bpl, the fluid conductivity declined with a shift at 1,850 feet bpl. From that depth the fluid conductivity was steadily declining until the casing was reached. The final reading was approximately 12,000 uS. The first trend break at 2,000 feet bpl is significant in that it coincides with shift present in the DIL.

Packer Test Data - Data from the five packer tests conducted during the construction of IW-7 and DZMW-7 support the log-derived TDS measurements. These tests were performed in order to obtain salinity data to be used to identify the base of the USDW. The water quality results indicate that a concentration of 10,000 ppm TDS occurs between a depth of 1,950 and 2,020 feet bpl in the site vicinity. These depth boundaries represent the lower and upper limits, respectively, of the nearest packer test intervals.

Based on the above data, it is interpreted that the USDW baseline occurs at a depth of approximately 2,000 feet bpl. Accordingly, based on this analysis and on the packer test data, an upper monitor interval of 1,800 to 1,850 feet bpl for DZMW-7 was selected due to it being in a permeable zone at a depth above the base of the USDW. The water quality and flow data from packer test number IW-7 #3 indicates that the proposed upper monitor interval should be suitable for this purpose. The anticipated TDS concentration of the upper monitor zone is approximately 4,800 mg/L.

The DZMW-7 lower monitor zone was selected to be from 2,200 to 2,250 feet bpl. The chosen lower monitor zone is located below the base of the USDW, in a permeable zone above the top of confinement. The evaluation of confinement is discussed in Section 2.6 of this report.

2.6 Evaluation of Confinement

A confinement analysis was performed to evaluate whether effective vertical confinement is likely present below the base of the USDW, which is present at approximately 2,000 feet bpl. The confinement analysis also includes a comparison of the likely confining characteristics of the strata below base of the USDW.

2.6.1 Bedded Rock Vertical Confinement Theory

Vertical confinement of buoyant injected fluid is provided by strata with low vertical hydraulic conductivities that are neither fractured or penetrated by other flow conduits. The relationship between the vertical hydraulic conductivity of an interval of horizontally bedded rocks (k_z) and the vertical hydraulic conductivities of individual beds (k_i) is expressed by the following equation:

$$K_z = d / (\sum d_i / k_i)$$

Where d = the thickness of the interval of rock and d_i is the thickness of the individual beds. It is not practicably possible to calculate an actual vertical hydraulic conductivity using the above equation because of the large number of individual beds with confining intervals (and thus impossibly large data requirement) and the inherent heterogeneity of hydraulic conductivity (in both the vertical and horizontal directions) within individual beds. Nevertheless, the above equation indicates that the vertical hydraulic conductivity of an interval of horizontally bedded rock is largely a function of the vertical hydraulic conductivity of the least conductive beds in the interval.

Dolomite within the Floridan aquifer system commonly has very low matrix hydraulic conductivities, typically much lower than that of adjacent limestone beds (Maliva and Walker, 1998). The vertical hydraulic conductivity of dolomites with porosities of less than 12% typically range from 1×10^{-7} cm/s (2.8×10^{-4} ft/day) to 1×10^{-10} cm/s (2.8×10^{-7} ft/day), based on core plug data from numerous South Florida injection well sites. Porosities of 12% or less in dolomite correspond to transit times on sonic logs of approximately 60 µsec/ft or less (Keys, 1989, figure 74). Low porosity dolomite beds, where unfractured and lacking other solution conduits, thus offer very good vertical confinement. At several injection well sites in south Florida, the top of the injectate-invaded zone corresponds to tight dolomitic intervals (Maliva and Walker, 2000). On the contrary, fractured dolomite beds often have extremely high transmissivity and for the principal injection intervals in the lower Floridan aquifer. Well-cemented, low porosity limestones, marls, and clays may also provide very good vertical confinement for injected fluids.

2.6.2 Criteria for Identification of Confinement Intervals

The general characteristics of high transmissivity zones in the Floridan aquifer system were described by Haberfeld (1991) and include the following:

- Greatly enlarged hole sizes on caliper logs,
- Exceedingly long transit times,
- Very low resistivities, indicating high porosity and saline water,
- Changes on temperature logs,
- Flow in or flow out zones on flowmeter logs, and
- Caverns, cavities, and fractures evident on borehole videos.

High transmissivity intervals in the Floridan aquifer system are often composed of fractured dolomite, which has very low matrix hydraulic conductivity.

Intervals likely to provide good vertical confinement have characteristics that are largely the opposite of those of high transmissivity intervals. The following criteria are characteristic of intervals interpreted as providing good vertical confinement:

- Low sonic transit times (preferable < 60 µsec/ft).
- Variable density log (VDL) patterns consisting of a strong (dark) continuous parallel bands that are either vertical, where lithology is relatively uniform, or have a "chevron" pattern where the formation consists of interbedded rock of different hardness.
- Low vertical hydraulic conductivities measured on core samples
- Borehole diameters on caliper logs close to bit size
- Relatively high resistivities, which in the middle and upper parts of the Floridan aquifer system are often indicative of tight dolomite beds.
- Absence of evidence of fractures or other flow conduits on video surveys, and borehole televiewer and fracture identification logs.
- Low macroporosity (i.e., visible pore spaces) and high degree of cementation (hardness), as observed in microscopic examination of cuttings and core samples.

Intervals were interpreted as having characteristics indicative of good vertical confinement meet the above criteria, particularly the presence of dolomite beds with low sonic transit times. Intervals interpreted as providing poor vertical confinement contain common fractures and cavernous zones, as evidenced by borehole enlargement and very long sonic transit times. Intervals that lack both tight intervals and well-developed fracturing are considered to have characteristics indicative of moderate vertical confinement.

2.6.3 Data Used for Analysis

The data used to analyze for confinement include geophysical log, lithologic, packer test, and core analysis from IW-7.

2.6.4 Confinement Analysis for IW-7 Injection Site

The strata between the base of the lowest USDW and the bottom of the injection casing in injection well IW-7 (2,000 to 2,962 feet bpl) were subdivided into four zones (I through IV, from the bottom upwards) based on their apparent vertical confinement properties. A sonic log for the injection well IW-7 pilot hole showing the confinement zone is provided in **Figures 2-5A** through **2-5C**. The properties of each confinement zone are discussed below:

Zone I, 2,675 to 2,962 feet bpl, poor vertical confinement

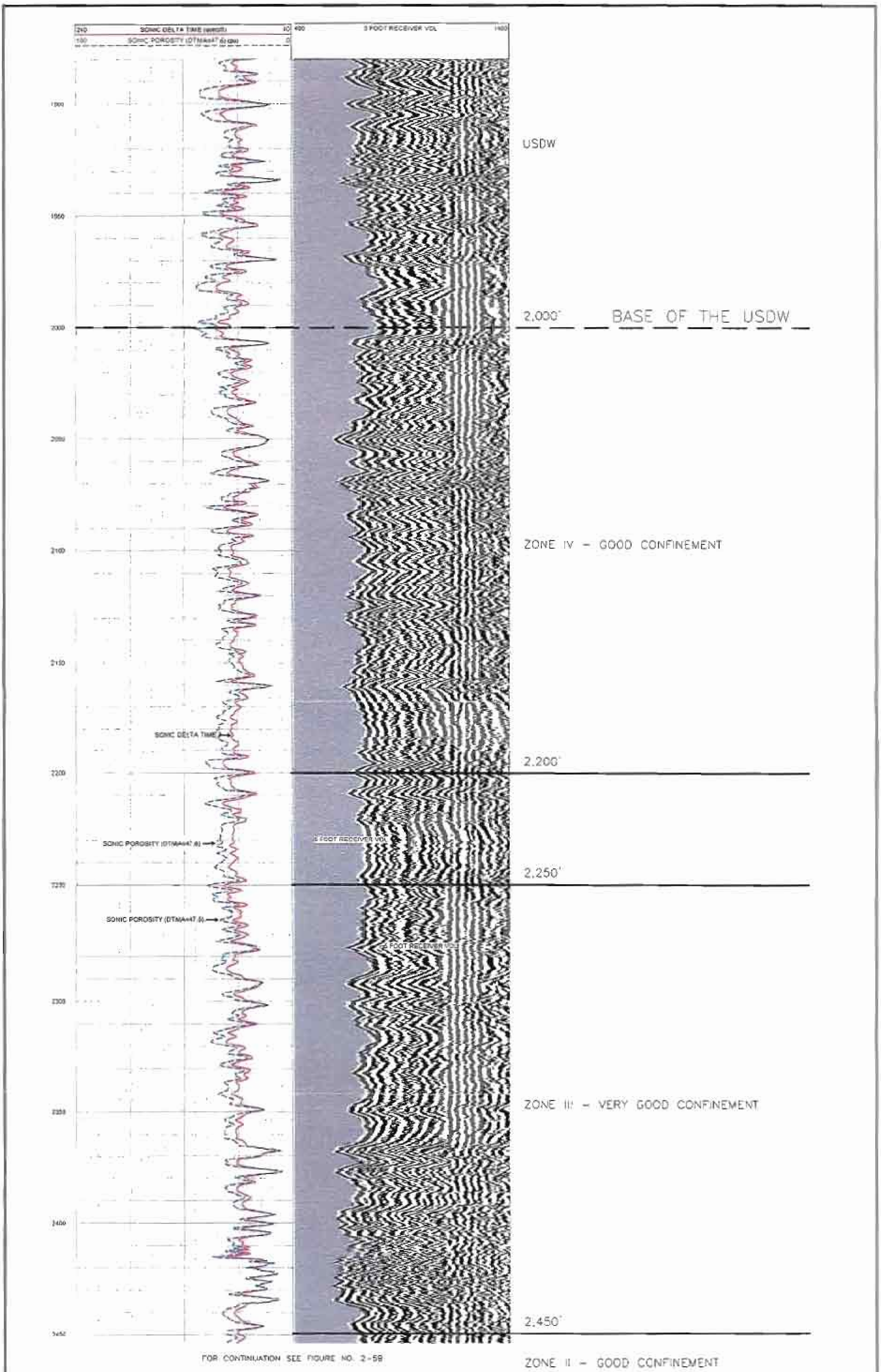
Injection zone strata. Limestone is present from 2,675 to 2,740 feet bpl and interbedded dolomite and limestone occur from 2,740 to 2,962 feet bpl. Packer test number 7 (2,716 to 2,745 feet bpl) encountered water with quality characteristics that are consistent with injectate. During the drilling of IW-7, the drilling contractor noted that the formation became pressurized at 2,675 feet bpl. Above this depth, the contractor had to add makeup water to continue reverse-air drilling for the pilot hole below the base of the intermediate casing at 2,200 feet bpl. The flow meter log indicated that essentially all of the flow recorded on the log originates from 2,790 feet bpl to the base of the pilot hole at 3,025 feet bpl.

Zone II, 2,450 to 2,675 feet bpl, good vertical confinement

Mostly limestone with minor dolomite. Sonic velocities are relatively constant in the 80 to 110 μsec/ft range, which corresponds to porosities in the 32 to 45% range. No suggestion of significant fracturing on variable density log (VDL). The limestone was generally moderately hard, as indicated by only slight borehole enlargement to 14-inches for 12 ¼-inch diameter bit as presented on the caliper log. Two core plug analyses gave vertical hydraulic conductivities of 3.2×10^{-5} to 9.6×10^{-6} cm/s (2.7×10^{-2} to 9.1×10^{-2} ft/day). The flowmeter log indicated essentially there was no flow occurring over this interval. The water quality results from packer test number 6 (2,615 to 2,645 feet bpl) indicate that the formation fluids contain concentrations of salinity and nutrient-related parameters consistent with ambient conditions.

Zone III, 2,250 to 2,450 feet bpl, very good vertical confinement

Interbedded rock (limestone and dolomite) of variable hardness without major cavernous intervals. A tight, mostly dolomite interval is present at the base of the

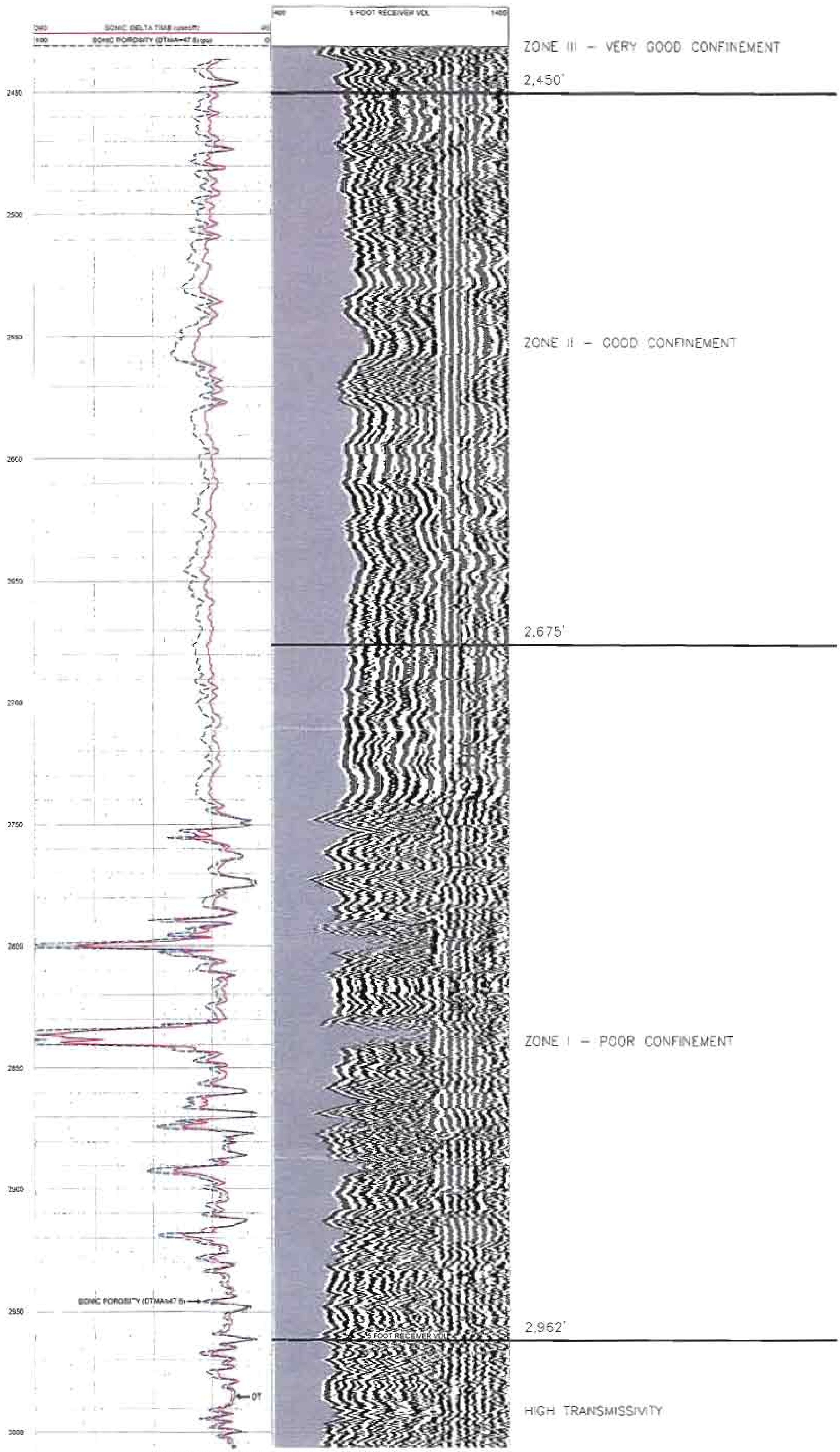


CDM

Figure No. 2-5A
City of WPB ECRWWTP, Florida
IW-7 Sonic Log

P:\10061\26918_15B\CONST\RPT\ FIG 2-5B 05/18/04

FOR CONTINUATION SEE FIGURE NO. 2-5A



FOR CONTINUATION SEE FIGURE NO. 2-5C

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Figure No. 2-5B
City of WPB ECRWWTP, Florida
IW-7 Sonic Log

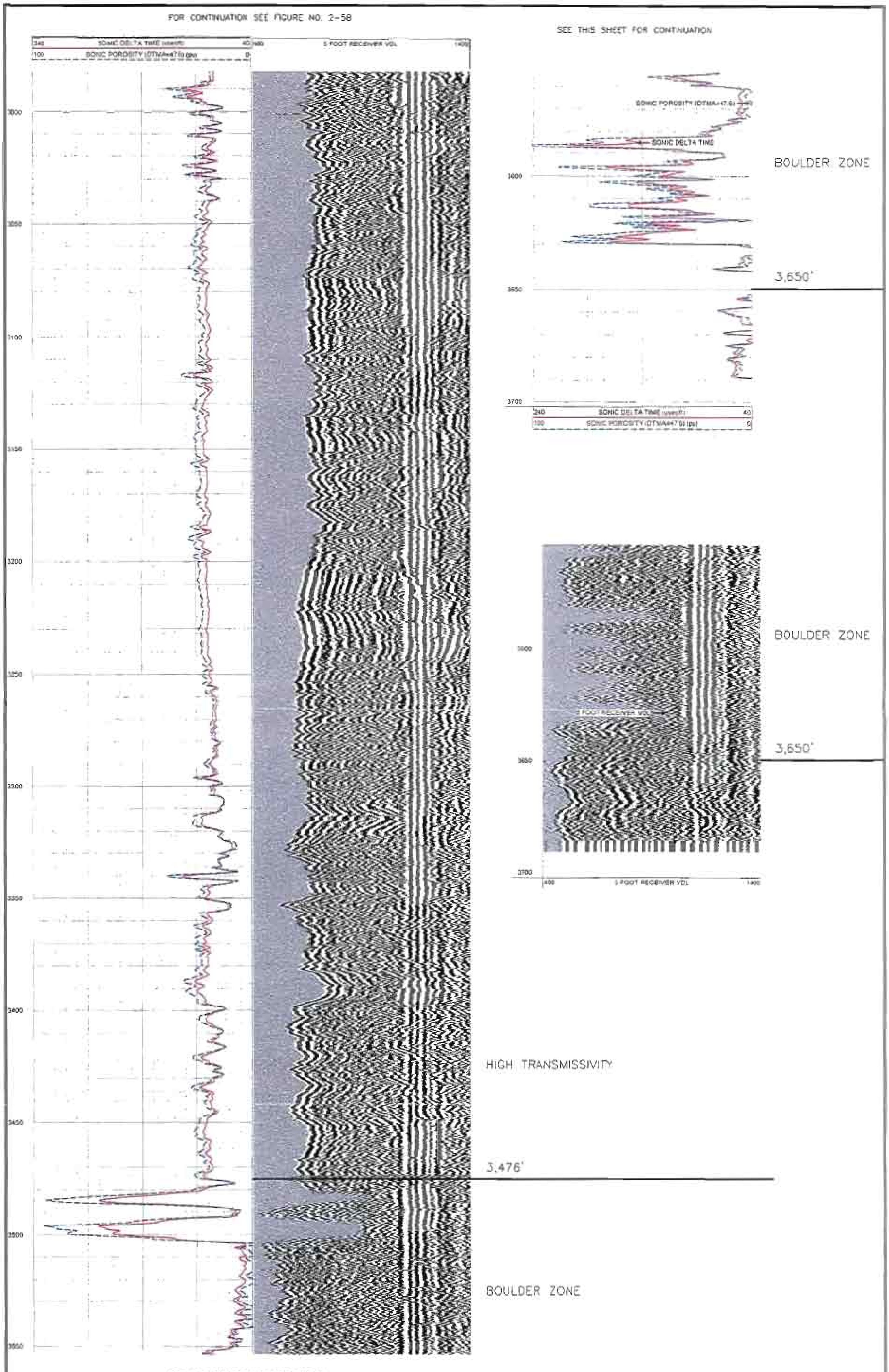

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Figure No. 2-5C
City of WPB ECRWWTP, Florida
IW-7 Sonic Log

zone (2,360 to 2,440 feet bpl) as indicated by a decrease in both borehole diameter and short sonic transit time (< 60 µsec/ft). The sonic velocities suggest porosities of 15% or less. The remainder of the zone contains scattered thin (2 to 4 feet thick) tight dolomite and/or limestone beds with sonic transit times of less than 70 µsec/ft and a corresponding increase in resistivity. Seven core samples were evaluated over this interval with permeabilities ranging from 2.1 x 10^{-6} to 1.3 x 10^{-7} cm/sec (6.0 x 10^{-3} to 3.7 x 10^{-4} ft/day). Over this interval, the flowmeter log indicated essentially there was no flow. Packer test number 5 (2,280 to 2,310 feet bpl) results indicate that the test interval contains water compositionally similar to native formation water.

Zone IV, 2,000 to 2,200 feet bpl, good vertical confinement

Mostly limestone with minor dolomite, similar to Zone II. Transit times of 60 to 95 µsec/ft. No significant fracturing is evident on VDL. Borehole diameter is no greater than 15 inches for 12 ¼-inch diameter bit indicating moderately hard formational characteristics. The three core samples evaluated over this interval had permeabilities ranging from 2.0 x 10^{-4} to 8.2 x 10^{-5} cm/sec (2.3 x 10^{-1} to 6.8 x 10^{-1} ft/day). Essentially no flow was indicated by the flowmeter log over this interval. Packer test number 4 (2,020 to 2,050 feet bpl) and number 2 from DZMW-7 (2,090 to 2,150) both yielded water compositionally similar to native formation water.

The above confinement analysis indicates that Zone III (2,250 to 2,450 feet bpl) has geophysical characteristics suggestive of tight rock and thus low vertical hydraulic conductivity. Zones II and IV exhibit good confining characteristics and are interpreted as contributing to confinement at the site. The packer test water quality data is consistent with ambient conditions to a depth of at 2,645; there is no suggestion of effluent. The strata between the base of the injection casing (2,962 feet bpl) and 2,675 feet bpl have characteristics indicative of poor vertical confinement. Packer test number 7 data indicates that this interval up to 2,716 feet bpl has been invaded by injectate.

The packer test data indicate that the top of the effluent-impacted zone occurs between the Packer test number 6 and 7 intervals (between 2,645 and 2,716 feet bpl). The top of the effluent impaired zone thus occurs at least 645 feet below the base of the lowest USDW, and based on the behavior of the pilot hole, is interpreted to occur at 2,675 feet bpl.

Section 3
Injection Zone Testing

The testing of the injection zone consisted of a 24-hour injection test as described in Section 3.1. During the injection test, the following data were recorded:

- Piezometric heads of the existing injection wells on site (IW-1 through IW-6) and DZMW-2 and DZMW-6
- Flow to the existing injection wells on site (IW-1 through IW-6)
- Flow to IW-7, injection zone pressure at the bottom of IW-7, and wellhead pressure at IW-7 (see Figures 1-5 and 1-6 for construction details)
- Barometric pressure and tidal fluctuation.

All the data (including background monitoring data) collected throughout the various phases of the injection test are included in Appendix J.

3.1 Injection Test Description

The 24-hour pre-injection background monitoring period started on Monday, June 21, 2004 at 11:00 am; the 24-hour injection test started on Tuesday, June 22, 2004 at 11:00 am; and the 24-hour post-injection background monitoring period started on Wednesday, June 23, 2004 at 11:00 am. Before the start of the pre-injection monitoring, IW-7 was temporarily connected to the existing 30-inch diameter effluent pipeline, and down-hole pressure transducers and fluid filled pressure site gauges were installed in IW-7 and DZMW-7.

Secondarily treated domestic wastewater effluent was utilized for the injection test at IW-7. During the test, the volume of effluent injected was monitored by an in-line totalizing flowmeter. The flowmeter was calibrated on March 9, 2004. Pressure was monitored using down-hole pressure transducers installed approximately twenty feet from the bottom of the IW-7 injection casing, at the IW-7 wellhead, and in the upper and lower zones of DZMW-7. The transducer equipment recorded psi values to three decimal places and was calibrated prior to installation. To confirm the transducer results, a fluid-filled pressure site gauge was also monitored for the wellhead and the upper and lower zones at DZMW-7. The calibration documentation for the flowmeter and transducer equipment is provided in Appendix J.

The target rate for the 24-hour injection test was 22.03 MGD (15,300 gpm) for a duration of at least 12 hours, as specified in the permit. A flow rate of 14,900 was attempted for the duration of the 24-hour injection test. However, the plant could not provide a minimum of 12 hours at the target flow rate due to major vibration of specific injection pumps at high flow rates, which occurred during the middle of the injection test, and periods of low flow at the plant. Moreover, the control of flow into IW-7 was performed by shutting in IW-1 through IW-6 since there is no control over the out-flow of the plant. IW-4 was kept partially open to regulate the higher out-flow periods at the plant. Ten hours into the injection test, some of the injection pumps experienced major vibration. The plant then opened IW-4, which reduced the flow rate into IW-7. For these reasons, the injection test began with approximately 15,000 gpm of flow into IW-7 and ended with 8,500 gpm. A graphic representation of the injection test flow rates is presented on Figure 3-1. The totalizer readings indicated that 16,950,000 gallons were injected in the 24-hour injection period, for an average flow rate of 11,771 gpm throughout the injection test. **Table 3-1** summarizes the background and injection test flows and pressures.

The IW-7 bottom hole pressure by the end of the injection test at 8,500 gpm increased 50 psi above the pre-injection hydrostatic pressure. The IW-7 wellhead pressure at the beginning of the injection test was measured at 92 psi at 14,800 gpm, an increase of 62 psi above the pre-injection hydrostatic pressure, which was recorded at 30 psi. The IW-7 wellhead pressure at the end of the injection test was measured at 82 psi with the transducer at 8,500 gpm, an increase of 62 psi above the pre-injection hydrostatic pressure, which was recorded at 30 psi. A graphic representation of the injection test data is presented on **Figures 3-1, 3-2, 3-3,** and **3-4**.

Effluent temperature increased in the well by nine degrees Fahrenheit five hours into the injection test and decreased approximately 1.5 degrees by the end of the injection test. The increase in temperature is due to the effluent in the pipeline is warmer than the background temperature of the injection zone. During the post-injection monitoring, temperature appears to be reaching background conditions. The individual pressure, flow, effluent temperature, barometric, and tidal data are presented in Appendix J.

3.2 Dual Zone Monitor Well Analyses

The piezometric heads in the monitor zones of the deep monitor wells on site were recorded during the background monitoring period and injection test. A graphic representation of the piezometric head data is presented on **Figure 3-5**. MW-4 monitoring tube was previously abandoned and reads no pressure. Pressure fluctuations in the injection zone during the injection test recovery period were not evident in the monitor wells. Close inspection of the data shows a slight fluctuation in the piezometric levels in MW-1 and MW-5 prior to and at the end of the injection test. However, the variation is so small it is analytically insignificant. The monitor well graphs are so flat that no analysis is possible and therefore it is concluded that there is no significant hydraulic connection between the injection zone and the monitor wells.

3.3 Injection Test Analysis

The injection zone at IW-7 exhibits a moderate to low permeability in comparison to IW-6, such that the injection of water at a rate of 14,800 gpm (21.3 MGD) at IW-7 caused an increase in pressure at the bottom of the hole of approximately 54 psi and an increase in wellhead pressure of 62 psi.

Table 3-1
Summary of IW-7 Three-Day Injection Test
(Background, Injection, and Recovery)

Description	Date	Time	IW-7					DZMW-7	
			Flow Rate (gpm)	Wellhead Pressure (psi)	Bottom Hole Pressure (psi)	Specific Capacity (gpm/ft)	Trans-missivity (gpd/ft)	Upper Zone Pressure (psi)	Lower Zone Pressure (psi)
Background Monitoring	6/21/04	11:00 AM	0	30	1,316	N/A	N/A	16.6	1.9
Injection Test	6/22/04	12:00 PM	14,800	92	1,370	119	237,191	16.6	1.8
Injection Test	6/23/04	10:00 AM	8,500	82	1,366	74	147,122	16.6	1.9
Recovery	6/24/04	11:00 AM	0	33	1,320	N/A	N/A	16.6	1.9

N/A = Not Applicable

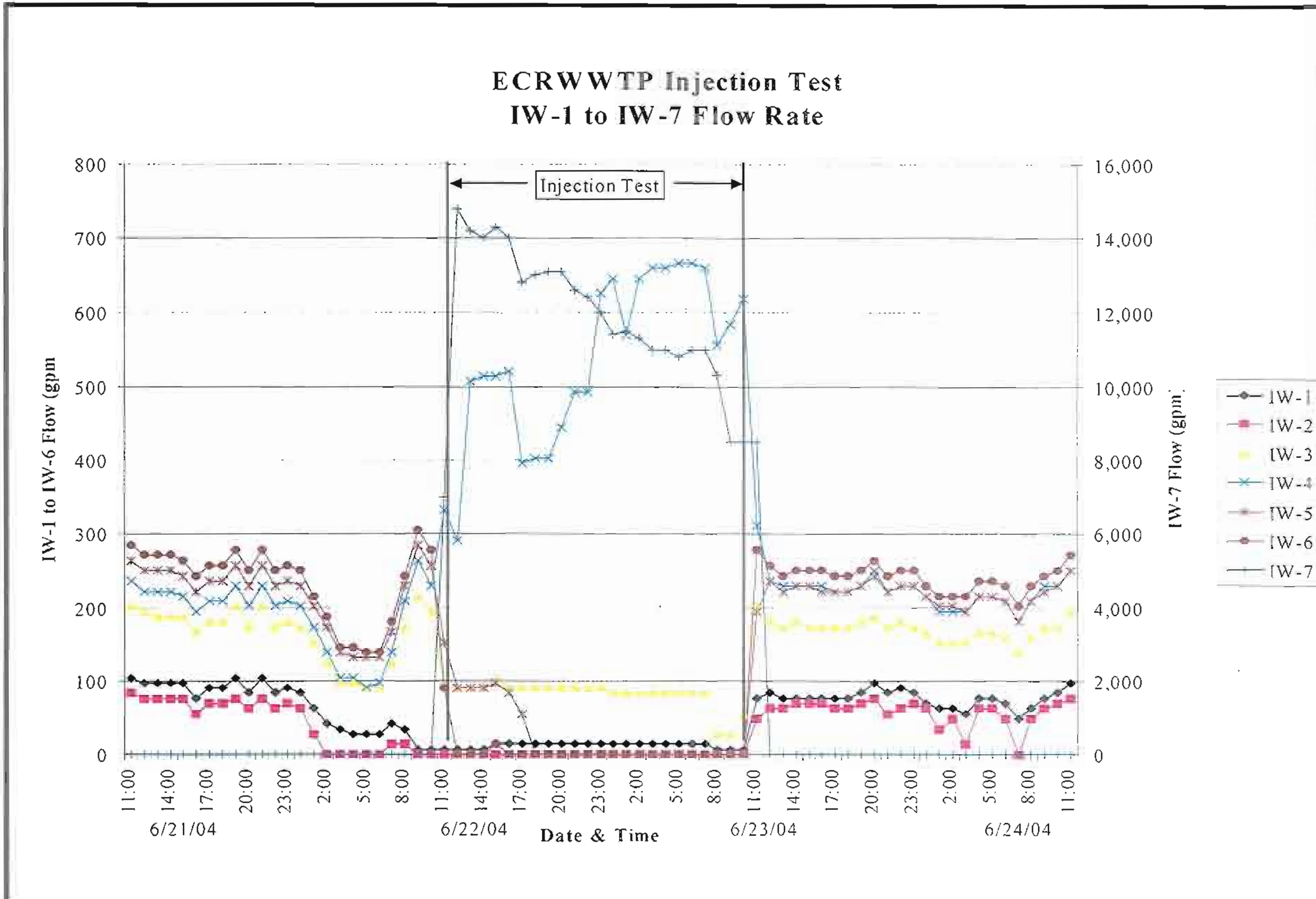

Figure No. 3-1
City of WPB ECRWWTP, Florida
IW-1 to IW-7 Flow Rate

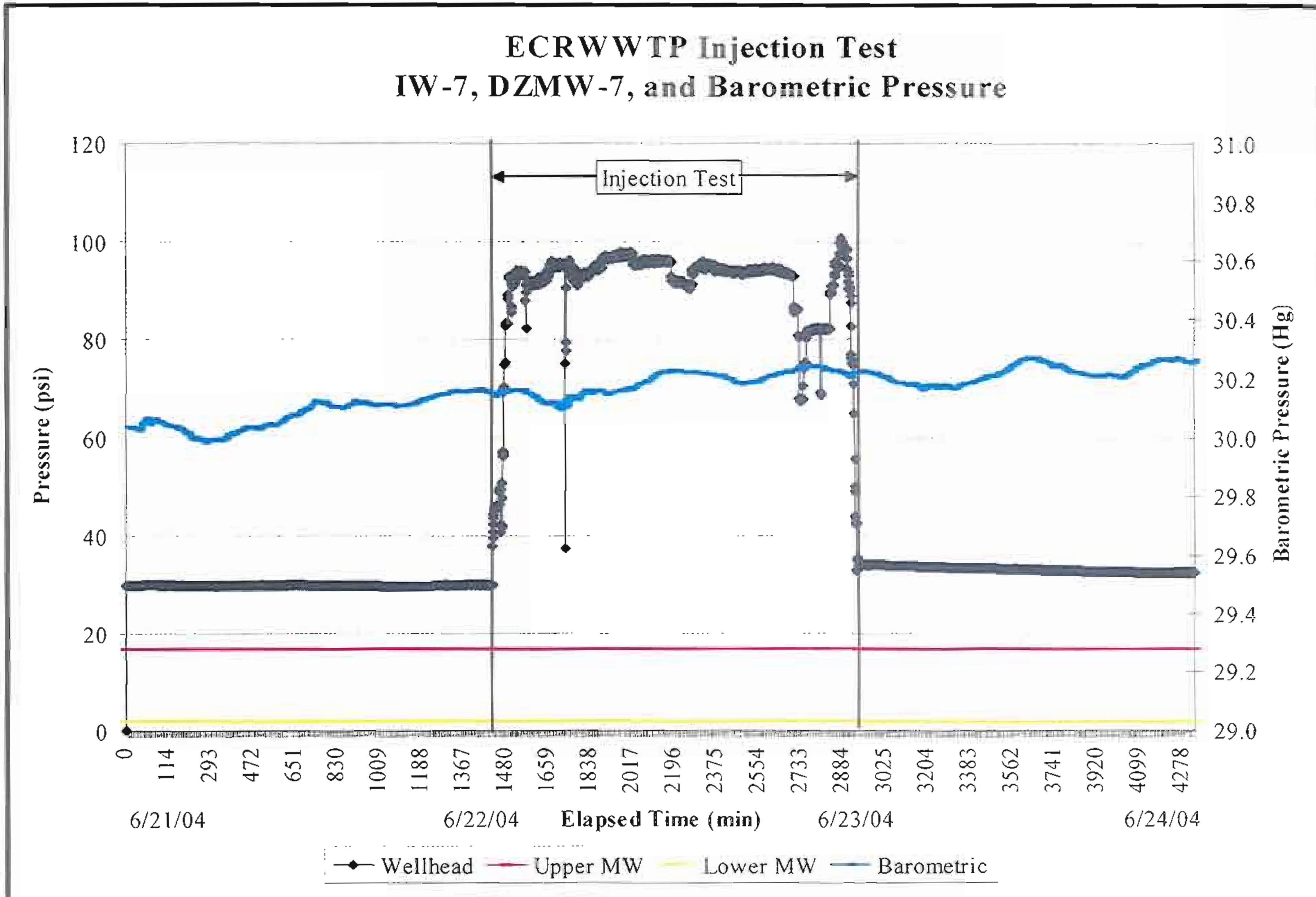

Figure No. 3-2
City of WPB ECRWWTP, Florida
IW-7 , DZMW-7, and Barometic Pressure

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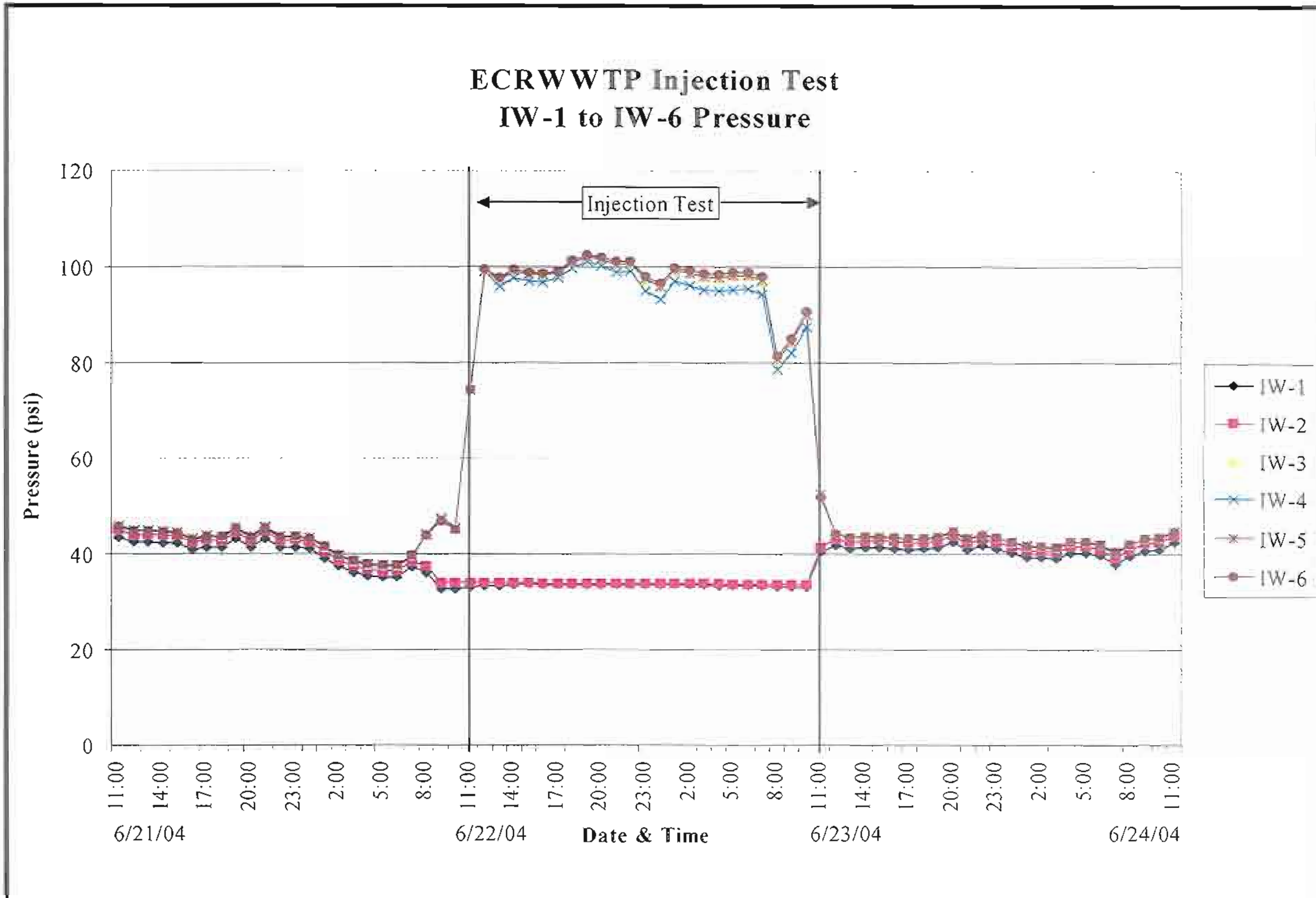

Figure No. 3-3
City of WPB ECRWWTP, Florida
IW-1 to IW-6 Pressure

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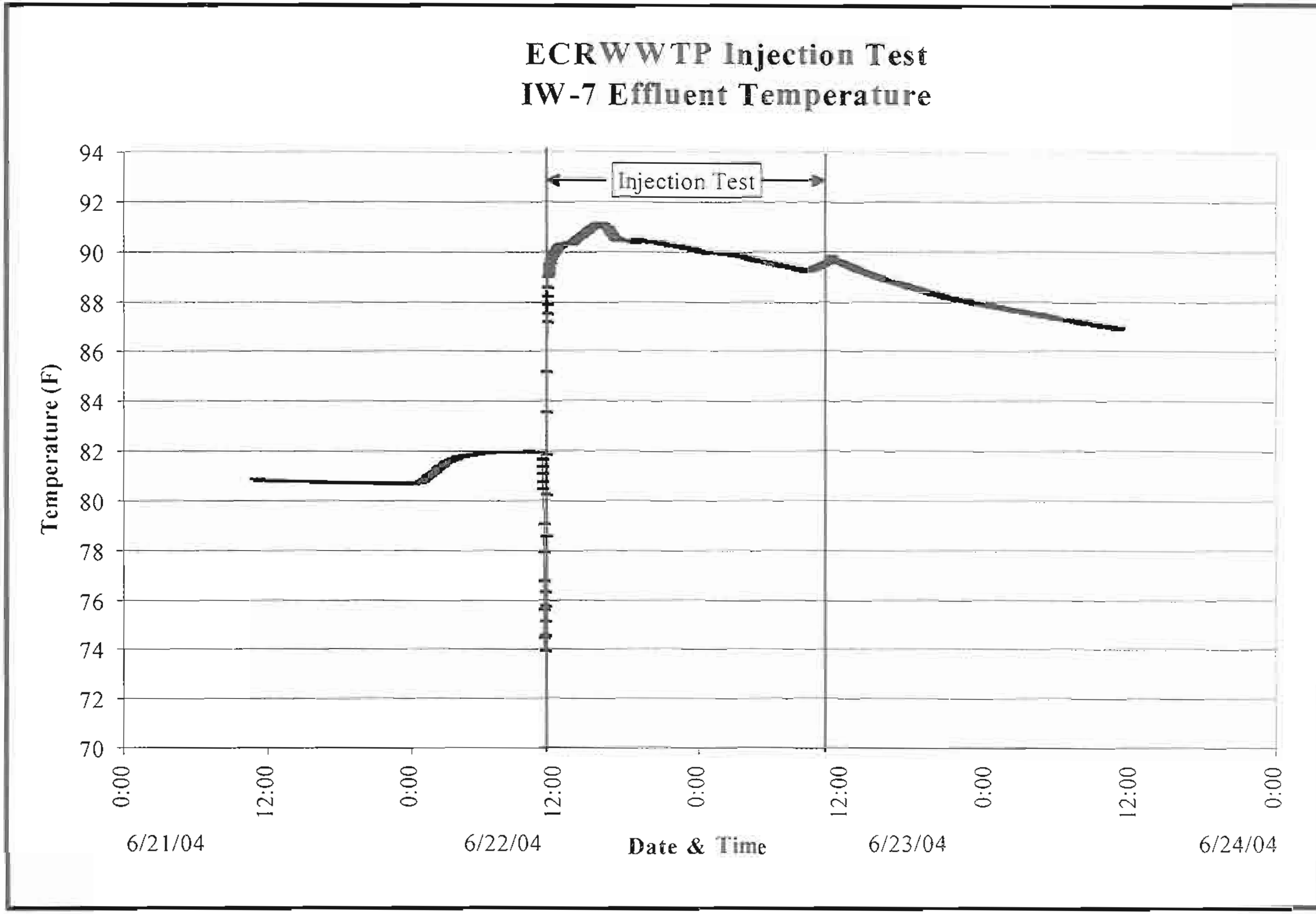

Figure No. 3-4
City of WPB ECRWWTP, Florida
IW-7 Effluent Temperature

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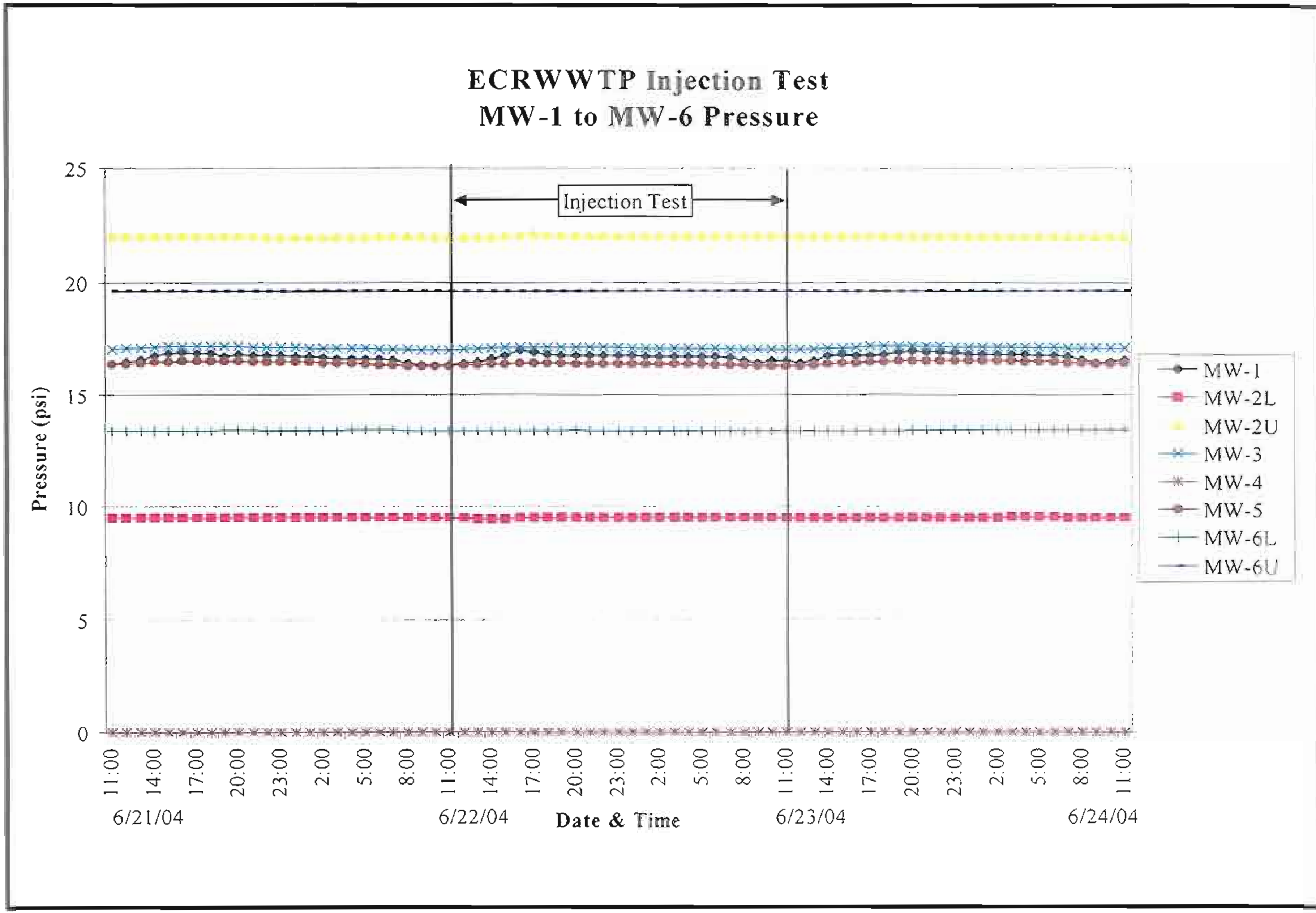


Figure No. 3-5
City of WPB ECRWWTP, Florida
MW-1 to MW-6 Pressure

CDM

For comparison, the increase in wellhead pressure in injection well IW-6 was only 28 psi during an injection test performed at 13,500 gpm (19.5 MGD) in 1996 as part of the re-rating of the well. Nevertheless, the test results indicate that the IW-7 injection zone is capable of receiving the injection volumes at a velocity of 10 ft/sec with minor stress to the aquifer. The injection test data are presented in Appendix J and were used to calculate aquifer coefficients for the injection zone.

3.3.1 Transmissivity

To quantify the injection zone's ability to receive fluid, values for transmissivity was calculated using the empirical relationship derived from the Jacob method where specific capacity equals transmissivity divided by 2000 (Driscoll, 1986, p. 1021). The equation relates flow rate and change in head to transmissivity, and takes the following form:

T = Specific Capacity * 2000

Where Specific Capacity equals flow rate (gpm) divided by the change in head induced by pumping (feet).

The resultant transmissivity value calculated using the input of 14,800 gpm and 125 feet of head increase was approximately 237,200 gpd/foot. Table 3-1 displays the calculated Specific Capacity and Transmissivity values. This value indicates a moderate to low permeable aquifer in the injection zone from 2,962 to 3,700 feet below pad level (bpl) at IW-7. The calculated transmissivity for the IW-6 injection zone, based on the down-hole pressure increase measured during a 1987 injection test, was 1.78 MGD/ft. Thus, the Boulder Zone is not as well connected in the IW-7 injection zone.

Section 4
Characteristics of Injection Zone and Confining Zone

4.1 Injection Zone – Physical Limits and Hydrologic Characteristics

4.1.1 Physical Limits

Based on the core analysis (Section 2.2), the television surveys and the geophysical logs (Section 2.3), and the water quality (Section 2.4), the proposed injection zone has been identified as being present from 2,675 to 3,650 feet below pad level (bpl), with a 50-foot rat hole from 3,650 to 3,700 feet bpl. This 975-foot injection zone comprises part of the lower Avon Park and most of the Oldsmar Formation.

Both the geophysical logs and the television survey showed that the injection zone is made up of two major sections, a poor confinement zone and a high transmissive zone (see Figure 2-1). The poor confinement zone is found between 2,675 and 2,962 feet bpl and the high transmissive zone, which contains the Boulder Zone, is present between 2,962 and 3,700 feet bpl. The geophysical logs and the television survey through the poor confinement zone indicate that this portion of the aquifer is moderately permeable. The injection casing was set through this zone. The high transmissive zone contains fractures and voids from 3,000 to 3,075 feet bpl and from 3,300 to 3,476 feet bpl. The main injection zone, the Boulder Zone, occurs 3,476 and 3,650 feet bpl.

Numerous vugs, cavities, and caverns are shown by the television survey and described in Appendix G. The definition of vugs, cavities, and caverns as used in this discussion is taken from Special Publication No. 20 (Puri and Winston, 1974) of the Florida Bureau of Geology. In that publication, a cavern is defined as an opening whose smallest dimension is more than two feet, and a cavity is defined as an opening whose largest dimension is less than two feet, but more than three inches. A vug is an opening whose largest dimension is three inches or less. To these definition, we have added a fourth, a hole is between a vug and a cavity in size and is usually about six inches in diameter.

4.1.2 Hydrologic Characteristics

The hydrologic characteristics of the injection zone were evaluated from the data collected during the injection test. The transmissivity of the injection zone was determined to be approximately 237,200 gpd/ft (see Section 3). When compared with IW-6 at ECRWWTP, this value can be described as moderate to low. However, the hydraulic conductivity (permeability) of the flow zones contributing to the transmissivity is comparable to that of the Boulder Zone of other injection sites in southeastern Florida. In other words, the relative low transmissivity of the IW-7 injection zone is due to a lesser cumulative thickness of flow zone strata. Despite its lower transmissivity, the IW-7 injection zone is capable of safely receiving the design capacity of the well.

4.2 Overlying Confining Zone

Chapter 62-528 (F.A.C.) requires that a confining zone be present above the injection zone, and that it should be able to prevent the upward migration of injected fluid from the injection zone. In practice, however, no natural soil or rock is totally impermeable and, therefore, able to totally prevent the migration of fluid from any aquifer system (Todd, 1980; Bear, 1979; Freeze and Cherry, 1979; etc.). All rocks are permeable to one degree or another; therefore, the issue addressed in this section is the degree of fluid migration rather than its complete prevention. As seen in Section 2, however, the confining layers of the confining zone are for all practical purposes impermeable. Only through monitoring can proof be obtained that migration has not reached a certain depth and thus the rules of the F.A.C. can be met.

The monitoring and packer test data indicate that after 27 years of injection at the ECRWWTP, the top of the effluent-impacted zone is still at least 645 feet below the base of the USDW. In the following subsections, the confining layer above the proposed injection zone is discussed in terms of its hydraulic characteristics. The physical limits are also discussed.

4.2.1 Physical Limits

The boundary between the injection zone and the overlying confining zone (that is, the bottom of the confining zone) was determined by the geologic cuttings, the geophysical logs and the television survey to be at a depth of about 2,675 feet bpl. The packer test data indicate that the top of the effluent-impacted zone is below 2,645 feet bpl. The top of the confining zone is placed at 2,000 feet bpl, which is the base of the USDW. At 2,675 feet bpl, a decrease in signal velocity (long transit time) was seen in the acoustic log (see Appendix D), and in the dual induction electric logs, shallow induction signals indicate an increase in porosity and permeability. The television survey also indicated an increase in secondary porosity in the form of holes and rough well walls.

The injection zone begins at 2,675 feet bpl and continues to the bottom of the well at 3,700 feet bpl. However, not all 1,025 feet of the injection zone are strictly permeable; impermeable zones were found at many intervals, and flows injected below those intervals are restricted from moving upwards toward the confining zone.

4.2.2 Hydraulic Characteristics

The confining characteristics of the dolomitic limestone overlying the injection zone are determined by the degree of calcitic cementation, the vugular and intergranular porosity and the absence or presence of fractures. The confining characteristics of the dolomite are also largely determined by the percentages of dolomite found and the degree of dolomitic cementation. The lowest porosity and permeability rock in the middle and lower Floridan aquifer are relatively pure dolomites. Dolomitic limestone tends to have porosities and permeabilities intermediate between those of pure limestone and dolomites. This relationship, however, as is also the case with the dolomitic limestone, is only applicable where the dolomite layers are unbroken and no cavities or caverns are present.

The resulting empirical relationships between transit time and porosity and between porosity and permeability developed in Section 2 from the laboratory analyses of the cores, and their comparison with the geophysical logs, can now be used and combined to better define the confining characteristic of the confining zone (see Figures 2-4 and 2-5). Hydraulic characteristics are discussed in detail in Section 2.

Section 5
Mechanical Integrity Testing (MIT)

The MIT program is designed to test two elements of the injection system: internal and external integrity. The first test, the internal mechanical integrity in the well itself, tests the condition of the injection casing. This is achieved through a series of field tests including television surveys, geophysical logs, and most important of all, a pressure test of the casing. The second test, the external mechanical integrity test, tests for leaks in both the cemented well bore and in the geologic formations penetrated by the well. This also is achieved partially through various geophysical logs, but most specifically by a radioactive tracer survey (RTS).

5.1 Injection Casing Evaluation

On November 13, 2003, CDM submitted a letter to the Underground Injection Control Technical Advisory Committee (UIC TAC) to obtain approval for the 26-inch diameter final steel injection casing seat depth. The requested depth for the casing seat was 2,962 feet bpl. The original design depth was 2,900 feet bpl. On November 22, 2003, YBI performed a caliper and gamma ray geophysical log on the 34.5-inch diameter borehole in preparation for the 26-inch diameter casing installation. From November 28 to 30, 2003, YBI installed the 26-inch diameter injection casing to 2,962 feet bpl.

From November 30 to December 3, 2003, YBI grouted the 26-inch diameter injection casing in seven cement stages. The first cement stage was performed with the pressure grout method and contained 601 cubic feet of neat cement. The second through seventh stages of cement were grouted via the tremie pipe method with 12% bentonite cement (8,540 cubic feet), for a total of 9,141 cubic feet of cement. Cement calculations indicated that it would take approximately 8,368 cubic feet, for a difference of 773 cubic feet or approximately 8.5%. A temperature log was performed after each cement stage. The top of cement was tagged at 146 feet bpl. The empty annulus space from surface to 146 feet bpl was used as a baseline for the cement bond log (CBL). On December 4, 2003, YBI tagged the cement plug inside the 26-inch diameter injection casing at 2,937 feet bpl, with the bottom of casing at 2,962 feet bpl.

On December 6, 2003, the pilot hole for the open hole portion of IW-7 reached a depth of 3,447 feet bpl. YBI cleaned out the 12.25-inch diameter pilot hole and performed geophysical logs from the bottom of the 26-inch diameter injection casing (2,962 feet bpl) to 3,447 feet bpl. The logs included caliper, gamma ray, dual induction, borehole compensated sonic with VDL display, and down-hole radial color television survey with rotating lens. The television survey was reviewed by CDM and it appeared that the Boulder Zone was not encountered in the pilot hole from the bottom of the injection casing to 3,447 feet bpl. Therefore, the pilot hole would be reamed from the bottom of the injection casing to below the design depth of 3,400 feet bpl until the Boulder Zone would be encountered. From December 7 to 16, 2003, YBI reamed the pilot hole with a 24-inch diameter bit from the bottom of the 26-inch diameter injection casing to 3,700 feet bpl. The injection zone is interpreted to be present from 2,962 to 3,650 feet bpl.

5.1.1 Television Survey

A television survey of the completed well was performed on December 17, 2003. A video tape of the entire length of the 26-inch casing and the 738 feet of open hole was produced. The survey was conducted by Kenwin Lee of Youngquist Brothers, Inc. Geophysical Logging Division. Copies of the video tape and field notes are enclosed in Appendix G.

5.1.2 Injection Casing Video

The video in the cased portion of IW-7 was viewed to evaluate the condition of the injection casing. The casing is visible and every weld can be inspected (at approximate 30-foot intervals). The video is of good quality. The only other features seen are scratches on the inside of the casing. These scratches are common-place in all wells. They are caused by the lowering and raising of the drill bit during drilling of the open hole. The evidence of scratching was seen in a few sections of the pipe. There was no significant gouging, grooving or physical damage. Such superficial scratches do not detract from the physical and mechanical integrity of the casing. Each joint is tight and clean and there are no breaks in the casing. From the television survey it was concluded that this casing is in excellent shape and the open hole is unclogged throughout its depth.

5.1.3 Pressure Test on Injection Casing

On December 19, 2003, YBI conducted the pressure test for the 26-inch diameter injection casing. FDEP was not present for the test. The purpose of the pressure test was to determine whether the injection casing has internal mechanical integrity. The regulations in Chapter 62-528 (Florida Administrative Code) call for a pressure test of a minimum one-hour duration, at a pressure of at least 1.5 times the expected operational pressure. A test tolerance of not greater than + or - 5% must be certified by the engineer of record. Since the injection pressure was expected to be less than 100 psi, it was specified that the test should be run at 150 psi and held for the required one hour with less than a 5% change. The casing pressure was measured at 153 psi with a calibrated pressure gauge at the beginning of the test. After one hour elapsed, the pressure was measured at 151.5 psi, less than 1% change, which is within the test allowance of 5% change in one hour. Results from the pressure test indicated that the injection casing was able to retain the pressurized column, and it was concluded that the mechanical integrity of the inner casing was satisfactory as defined by rule. At the end of the test, the pressure was released by bleeding of the pressure and a total of 50 gallons of water were bled. A copy of the gauge calibration certification is provided in Appendix K.

The successful completion of the pressure test and the television survey show that there is internal mechanical integrity on IW-7.

5.2 Cement Bond Evaluation

The cement bond log (CBL), used to assess the quality of the bond between the injection casing and the cement grout around the casing, is a function of casing size and thickness, cement strength and thickness, degree of cement bonding, and tool centering. The transit time of the return signal on the transit time log should be a constant for a perfectly centered logging tool.

On December 17, 2003, the CBL was conducted for the 26-inch diameter injection casing at IW-7. A copy of the CBL for IW-7 is submitted in Appendix F.

5.2.1 Transit Time

The calculation of the constant transit time includes the sonic transit times for both the casing material and the drilling fluid, which in this case is water. It is dependent on the spacing between the transmitter and receiver, as this spacing determines the length of the pathway through which the sonic signal must travel. The sonic transit times equates to a constant transit time of about 790 microseconds for the injection casing.

The transit time log shows that generally the recorded transit time ranged from 750 to 790 microseconds down to about 930 feet bpl. From 930 to 2,962 feet bpl, the recorded transit time was consistent at 790 microseconds, excluding minor blips at various depths. The logging tool fluctuations about the centerline of the cased hole are very small. The logging tool maintained a fairly good position in the casing centerline as it recorded both the CBL and the VDL. The tool contained centralizers to help maintain its center location within the injection casing.

Since the CBL tool is accurately centered, it is possible to evaluate the bond. The amplitude of the acoustic signal is a measurement of the energy lost by the signal as it passes through the casing into the cement grout. The rate of attenuation is dependent upon the percent of bonded cement, the casing diameter, and the thickness and material of the casing wall. In a casing section that is well bonded to the cement grout, the wave velocity difference between the casing and cement grout will cause significant attenuation of the acoustic signal and the returning amplitude will be relatively low. On the whole, the return signal from the injection casing is less low, than 10 millivolts. Therefore, the injection casing is qualitatively well bonded to the cement grout in the annular space. There is no indication of free pipe as shown by the logs, excluding the top portion that was purposely left as free pipe for comparison purposes on the logs. This bond was also confirmed qualitatively by the VDL.

5.2.2 Variable Density Log (VDL)

The VDL shows the sonic wave trains recorded at a receiver located on the logging tool 5 feet from the transmitter and, when associated with the CBL, can be used to confirm the quality of the cementing. Sound can transit from the transmitter to the receiver along several different travel paths, which include through the fluid within the casing, along the casing, along the cement behind the casing, and through the formations beyond the cement grout. The first travel path would show in the VDL as having a transit time of about 790 microseconds; however, this return signal from the fluid within the casing is not important in the cement evaluation and is not discussed further.

The second travel path, along the casing, is a strong indicator of the quality of the cement bond to the casing and is the primary determinant as to whether a good bond exists between the casing and the cement grout. The transit time of this path includes the time for a sonic wave train to travel from the transmitter to the casing, through the fluid, along the inner casing, and back through the fluid to the receiver.

The travel time response recorded first on the VDL is usually from the signal travel path along the steel casing. The transit time response indicated an energy loss that is usually associated with a well-cemented casing. In a well-cemented casing, most of the sound energy or sonic wave trains will be transferred to the cement or formations (Schlumberger, 1972). The variable density line for the casing response in the CBL shows good bonding, excluding the top portion that was purposely left as free pipe for comparison purposes on the logs.

The return signal from the cement grout, traveling via the third path, clearly showed an extremely faint signal (attenuation) from the cement grout on the whole from land surface to the bottom of the injection casing. This attenuation is indicative of a solid cement annulus around the casing, but even where the signal is not as sharply attenuated it is still weak enough to indicate a good cement fill in the annulus. The varying signal travel paths resulting from travel in the contact between the cement and the formations is also attenuated, indicating good cementation against the drilled walls of the formations.

In summary, the injection casing is interpreted as having a good bond with the cement grout, and the cement grout has a good bond with the formation, and as evidenced by the attenuated return from the signal travel path through the cement grout, there is cement grout throughout the annular space, excluding the top portion that was purposely left as free pipe for comparison purposes on the logs.

5.3 Radioactive Tracer Log Evaluation

The Radioactive Tracer Survey (RTS) was performed by Youngquist Brothers, Inc. Geophysical Logging Division on April 8, 2004. The test was witnessed by an FDEP representative, Mr. Joseph May, P.G., UIC TAC chair from the Southeast District. Supportive geophysical logs were run prior to the RTS on April 7, 2004, which included a temperature log that will be discussed below, and a background gamma ray log with a casing collar locator (CCL). The gamma ray background showed an API count of 20 units or less in the well except there were some small but sharp peaks were recorded at the casing bottom and at 3,265 feet bpl. Copies of the RTS logs are submitted in Appendix L.

The configuration of the RTS tool is shown on **Figure 5-1**. This is the standard configuration of the tool used by Youngquist Brothers, Inc. Geophysical Logging Division. This tool has an upper gamma ray detector above the ejector and two gamma ray detectors below the ejector, the middle and the lower detectors. The CCL is between the middle and lower gamma ray detector. The distances between detectors and ejector are shown in the drawing.

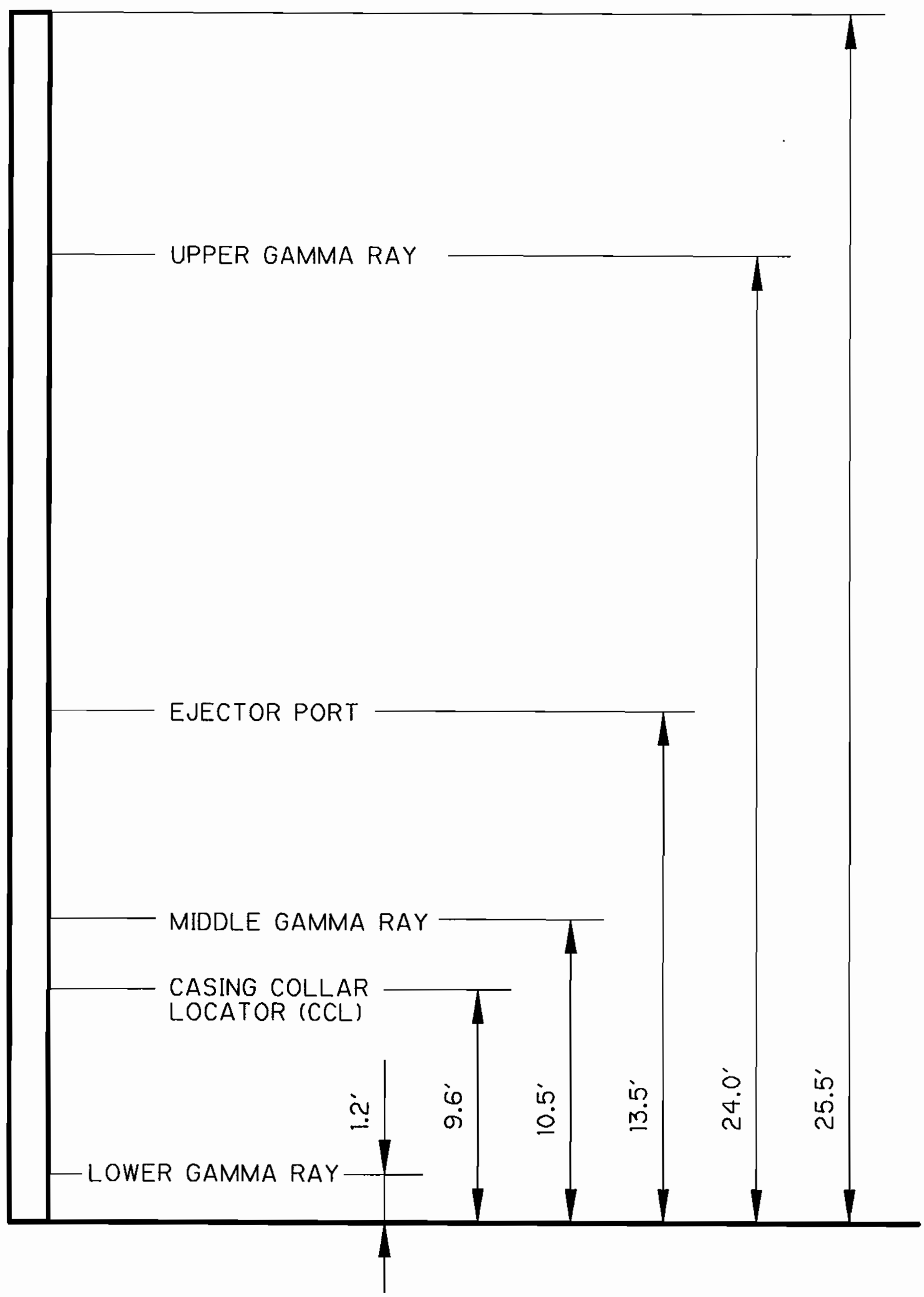
The ejector was loaded with 10.0 millicuries at land surface with Iodine 131 tracer to perform the two dynamic tests. The volume of the ejectate was decided in the field with the input and concurrence of the Department's field representative. One injectate volume would be 2.0 millicuries at a low flow velocity of 5 feet per minute(ft/min), a rate of approximately 127 gallons per minute (gpm), monitored for 60 minutes, and the second volume would be 4 millicuries at the same flow rate monitored for 30 minutes.

For the first dynamic flow test, fresh water was injected down the well at a low flow rate of 135 gpm, which is 6% more than the required 5 ft/min flow velocity (127 gpm). The ejector was positioned approximately 5 feet above the bottom of the casing, which was located with the CCL at 2,962 feet bpl, for the duration of the 60-minute test, and 2.0 millicuries were released. The middle gamma ray detector immediately detected the tracer and in less than 3 minutes, the tracer was no longer detected. The bottom gamma ray detector detected the tracer after 1 minute and 20 seconds, and in less than approximately 15 minutes, the tracer was not detected.

For the second dynamic flow test, fresh water continued to be injected down the well at a low flow rate of 135 gpm. The ejector was positioned approximately 5 feet above the bottom of the casing, which was located with the CCL at 2,962 feet bpl, for the duration of the 30-minute test, and 4.0 millicuries were released. The middle gamma ray detector immediately detected the tracer and in less than 5 minutes, the tracer was no longer detected. The bottom gamma ray detector detected the tracer after 1 minute and 40 seconds, and in less than approximately 14 minutes, the tracer was not detected.

At each dynamic flow test, the tool was brought up past the tracer eject level for a Log Out of Position (LOP) run. During both tests there was never any trace of the radioactive injectate recorded by the upper detector, thus indicating that the injectate did not move up outside the casing; thus demonstrating the mechanical integrity of the well.

After the two dynamic tests were performed, the tool assembly was lowered to the bottom of the open hole at 3,700 feet bpl, and the remaining tracer was released while pumping at 135 gpm. The well was then logged from bottom to top while continuing to pump at 135 gpm. This final log showed that most of the tracer had entered the formations within the zone between 3,460 to 3,700 feet bpl, and within 3,200 and 3,350 feet bpl the first and second tracer slugs were encountered. The mechanical integrity



CDM

Figure No. 5-1
City of WPB ECRWWTP, Florida
Radioactive Tracer Toolstring

test was then concluded. The total amount of water pumped into the well during the RTS test was approximately 33,000 gallons.

5.4 Summary

The MIT program was designed to test the internal and external integrity of IW-7 through a series of test procedures and the collection and evaluation of well construction and geophysical data. The various data collected during this program indicate that IW-7 exhibits both internal and external mechanical integrity as defined by FDEP.

The well's internal and external mechanical integrity is evidenced by the following:

- The actual cement volumes used to fill the annular space between formation and casing were or at or exceeded calculated theoretical volumes;
- The geophysical logs, including the CBL which showed good to excellent bonds between casing, cement, and formation;
- The television survey, which indicated the injection casing had no visible defects or obstructions;
- A successful casing pressure test which indicated a nominal pressure fluctuation (less than 1 percent) during the test period; and
- The successful completion of the RTS, which showed that no tracer had moved into the interval identified as the confining zone.

The data evaluated and observations made during the MIT at IW-7 demonstrate that the well exhibits satisfactory internal and external mechanical integrity as defined by FDEP.

Section 6
Well Construction and Record Drawings

6.1 Injection Well No. 7 "As-Built"

The following summarizes the construction sequence and design of IW-7. **Table 6-1** presents a chronology of the construction and testing activities. **Figure 6-1** illustrates the construction details of IW-7 and **Figure 6-2** displays the wellhead details. Signed and sealed record drawings are in Appendix M. The cement records and mill certificates are provided in Appendix N. Well inclination was measured in the pilot holes and reamed holes and copies of the inclination surveys are provided in Appendix O.

The construction of IW-7 began with the drilling of a nominal 58.5-inch diameter borehole through the strata that comprise the Surficial Aquifer System to a total depth of 119 feet below pad level (bpl). A 54-inch diameter, 0.375-inch thick steel casing was installed and grouted to 115.5 feet bpl. A total of 585 cubic feet of cement were used to grout the 54-inch diameter casing.

After installation of the 54-inch diameter casing was completed, a 17.5-inch diameter pilot hole was drilled to a depth of 1,050 feet bpl. A series of geophyiscal logs were performed on the pilot hole, as discussed in detail in Section 2.3. A 44-inch diameter, 0.375-inch thick steel casing was installed to a depth of 1,016 feet bpl after reaming of the pilot hole to a nominal diameter of 52.5 inches to a depth of 1,020 feet bpl. Well inclination, as measured in the pilot hole and reamed hole, was less than 0.5 degrees. The annular space was filled with 3,762 cubic feet of ASTM Type II neat cement.

At 1,016 feet bpl, the contractor changed drilling methods from the mud-rotary method to the reverse-air rotary method. A 12.25-inch diameter pilot hole was drilled to a depth of 2,300 feet bpl. During construction of this stage of the pilot hole, four core samples were collected. Samples were selected from each of the cores and sent to AAI in Orlando, Florida for further evaluation. Additional details regarding the core analyses can be found in Section 2.2. During construction of this stage of the pilot hole, four single element packer tests were conducted. Geophysical logs (caliper and gamma ray) were performed prior to the single element packer test. The packer testing procedure was to first develop each isolated interval. Field parameters (salinity, conductivity, and pH) were monitored during development to determine when the interval had been appropriately developed. The pump was then stopped and the water level in the interval was allowed to reach background conditions. After stabilization was achieved, the interval was pumped at a constant, sustainable rate for 4 hours. Field parameter and water levels were measured over this period. At the end of the 4-hour test, water samples were collected and sent to Envirodyne, Inc. in Boca Raton, Florida for analysis for total dissolved solids (TDS), chlorides, specific conductance, sulfate, ammonia and total Kjeldahl nitrogen (TKN). These analyses are discussed in detail in Section 2.4. Water levels were recorded for four hours after the pumping period.

Table 6-1
Drilling Program Chronology:
City Of West Palm Beach (ECRWWTP), IW-7 And DZMW-7

Date	Event
July 1, 2003	The Contractor, Youngquist Brothers, Inc. (YBI), was issued the Notice to Proceed, scheduling July 30, 2003 as the drilling start date, March 25, 2004 as the drilling completion milestone date, and June 26, 2004 as the final completion date.
September 3, 2003	Collected weekly initial water quality samples from the pad monitor wells (PMWs) located around the drilling pad.
September 9, 2003	YBI began drilling the 58.5-inch diameter borehole to 119 feet below pad level (bpl) via the mud-rotary method.
September 10, 2003	Collected weekly water quality samples from the PMWs. Caliper and Gamma Ray logs were run in the 58.5-inch diameter borehole to 119 feet bpl. The 54-inch diameter steel casing (0.375-inch wall) was installed to a depth of 115.5 feet bpl and grouted within one cement stage (585 cubic feet).
September 11, 2003	The 12.25-inch diameter pilot hole was drilled from 115.5 to 270 feet bpl.
September 12, 2003	The 12.25-inch diameter pilot hole was drilled from 270 to approximately 450 feet bpl. The pilot hole bit size was increased at approximately 180 feet bpl to 17.5-inch diameter due to the bottom hole assembly clogging from the mud. The 17.5-inch diameter pilot hole was drilled from 115.5 to 1,050 feet bpl.
September 13, 2003	Geophysical logs were performed on the 17.5-inch diameter pilot hole, which included Caliper, Gamma Ray, Dual Induction, and Borehole Compensated Sonic with VDL display.
September 14-18, 2003	The pilot hole was reamed to 52.5 inches from 115.5 to approximately 1,020 feet bpl.
September 17, 2003	Collected weekly water quality samples from the PMWs.
September 18-19, 2003	Geophysical logs were performed on the 52.5-inch diameter pilot hole, which included Caliper and Gamma Ray. The 44-inch diameter steel surface

Table 6-1
Drilling Program Chronology:
City Of West Palm Beach (ECRWWTP), IW-7 And DZMW-7

Date	Event
	casing (0.375-inch wall) was installed to a depth of 1,016 feet bpl and grouted with one cement stage (3,762 cu.ft.). After the 44-inch diameter steel surface casing was installed, YBI switched from mud-rotary drilling to reverse-air drilling.
September 25, 2003	Collected weekly water quality samples from the PMWs. Began reverse-air drilling on the 12.25-inch diameter pilot hole. A mud wafer was installed at the top of the well from pad level to approximately 217 feet bpl to keep the well from flowing after the cement plug from the 44-inch diameter casing was drilled through.
September 27, 2003	Geophysical logs were performed prior to the packer test on the 12.25-inch diameter pilot hole. Packer Test No. 1 was conducted from 1,570 to 1,600 feet bpl.
September 29, 2003	Geophysical logs were performed prior to Packer Test No. 2, which was conducted from 1,700 to 1,730 feet bpl.
October 1, 2003	Collected weekly water quality samples from the PMWs. Geophysical logs were performed prior to Packer Test No. 3, which was conducted from 1,810 to 1,840 feet bpl.
October 3, 2003	Core No. 1 was collected from 1,874 to 1,886 feet bpl with 100% recovery. Core No. 2 was collected from 1,976 to 1,986 feet bpl.
October 4, 2003	Continued drilling of the 12.25-inch diameter pilot hole. Geophysical logs were performed prior to Packer Test No. 4, which was conducted from 2,020 to 2,050 feet bpl.
October 5, 2003	Collected weekly water quality samples from the PMWs. Core No. 3 was collected from 2,097 to 2,107 feet bpl.
October 7, 2003	Core No. 4 was collected from 2,300 to 2,310 feet bpl.
October 8, 2003	Geophysical logs were performed prior to Packer

Date	Event
	Test No. 5, which was conducted from 2,280 to 2,310 feet bpl.
October 9-10, 2003	YBI cleaned out the pilot hole and geophysical logs were performed, which included caliper, gamma ray, dual induction, borehole compensated sonic with VDL display, borehole televiewer (below 1,500 ft bls), and down-hole radial color television survey with rotating lens. The logs that were run under pumping and static conditions were flowmeter, temperature, and fluid resistivity. Hole conditions proved too cloudy to obtain a television picture of satisfactory clarity. YBI attempted for two days to improve hole conditions. These attempts included flowing the well, pumping water into the well, and wiper trips.
October 11-12, 2003	YBI grouted the pilot hole in 3 cement stages (1,627 cu.ft.) to prepare for reaming hole with 42.5-inch diameter bit.
October 13, 2003	Collected weekly water quality samples from the PMWs.
October 13-16, 2003	YBI reamed 42.5-inch diameter hole.
October 15, 2003	CDM sent the 36-inch diameter intermediate steel casing seat depth (2,200 feet bpl) request letter to the UIC TAC. The requested depth for the casing seat was 2,200 feet bpl.
October 17-20, 2003	YBI reamed the 42.5-inch diameter hole to approximately 2,210 feet bpl.
October 20, 2003	Collected weekly water quality samples from the PMWs. The UIC-TAC approved the 36-inch diameter intermediate steel casing seat depth of 2,200 feet bpl.
October 21, 2003	YBI performs the caliper and gamma ray geophysical logs on the 42.5-inch diameter hole. After logging is complete, YBI began installing the 36-inch diameter intermediate casing run to 2,200 feet bpl.
October 23, 2003	YBI pressure grouts the first cement stage with 320

Table 6-1
Drilling Program Chronology:
City Of West Palm Beach (ECRWWTP), IW-7 And DZMW-7

Date	Event
	barrels (1,798 cu.ft.) 12% Bentonite cement followed by 133 barrels (748 cu.ft.) of neat cement at the bottom of the casing.
October 24, 2003	YBI tagged the first cement stage for the 36-inch diameter intermediate casing at 1,818 feet bpl with 16 feet of grout in the casing due to the pressure grouting method. YBI grouted the second cement stage by tremie pipe with 1,596 cu.ft. of 12% Bentonite cement. A temperature log was performed after the first cement stage and after every subsequent cement stage.
October 25, 2003	YBI tagged the second cement stage at 1,540 feet bpl and grouted the third and fourth cement stages by tremie pipe with 1,686 cu.ft. and 1,180 cu.ft., respectively, of 12% Bentonite cement.
October 26, 2003	YBI grouted the fifth and sixth cement stages by tremie pipe with 1,180 cu.ft. and 1,517 cu.ft., respectively, of 12% Bentonite cement.
October 27, 2003	Collected weekly water quality samples from the PMWs. YBI grouted the seventh cement stage by tremie pipe with 1,456 cu.ft. of 12% Bentonite cement. The total cumulative grout amount for the 36-inch diameter intermediate casing was 11,161 cu.ft. Cement calculations indicated that it would take approximately 8,330 cu.ft., for a difference of 2,831 cu.ft or approximately 34%. One temperature log was created, which included all seven stages.
October 28-29, 2003	YBI performed rig maintenance and let the cement cure in place.
October 30, 2003	YBI drilled a 12.25-inch diameter pilot hole from 2,200 to 2,330 feet bpl with the reverse-air rotary method.
October 31, 2003	Core No. 5 was collected from 2,420 to 2,430 feet bpl.
November 1, 2003	Packer Test No. 6 was conducted from 2,615 to 2,645 feet bpl. Geophysical logs were performed prior to the packer test on the 12.25-inch diameter pilot hole,

Table 6-1
Drilling Program Chronology:
City Of West Palm Beach (ECRWWTP), IW-7 And DZMW-7

Date	Event
	which included Caliper and Gamma Ray logs.
November 2, 2003	Core No. 6 was collected from 2,645 to 2,655 feet bpl.
November 3, 2003	Collected weekly water quality samples from the PMWs. YBI resumed the drilling of the 12.25-inch diameter pilot hole with the reverse-air rotary method beginning at 2,330 to 3,025 feet bpl.
November 4, 2003	Packer Test No. 7 was conducted from 2,716 to 2,746 feet bpl. Geophysical logs were performed prior to the packer test on the 12.25-inch diameter pilot hole, which included Caliper and Gamma Ray logs.
November 5, 2003	Core No. 7 was collected from 2,779 to 2,789 feet bpl.
November 6, 2003	YBI cleaned out the pilot hole and geophysical logs were performed, which included caliper, gamma ray, dual induction, borehole compensated sonic with VDL display, borehole televiewer, and down-hole radial color television survey with rotating lens. The logs that were run under pumping and static conditions were flowmeter, temperature, and fluid resistivity.
November 7, 2003	YBI completed the pilot hole geophysical logs and set up to grout the pilot hole in preparation for reaming the hole with a 34.5-inch diameter bit.
November 8-9, 2003	No activity at the site.
November 10, 2003	Collected weekly water quality samples from the PMWs. YBI grouted the pilot hole in 2 cement stages (1,348 cu.ft.).
November 11, 2003	YBI tagged the grout at 2,180 feet bpl inside the 36-inch diameter casing and began reaming the pilot hole with a 34.5-inch diameter bit.
November 12-13, 2003	YBI continued reaming the 34.5-inch diameter hole.
November 13, 2003	CDM sent a letter to the UIC TAC to obtain approval for the 26-inch diameter final steel casing seat depth.

Table 6-1
Drilling Program Chronology:
City Of West Palm Beach (ECRWWTP), IW-7 And DZMW-7

Date	Event
	The requested depth for the casing seat was 2,962 feet bpl.
November 14-17, 2003	YBI continued reaming the 34.5-inch diameter hole to 2,941 feet bpl. YBI performs rig maintenance during the evening shift.
November 16, 2003	Collected weekly water quality samples from the PMWs.
November 18, 2003	YBI reamed the 34.5-inch diameter hole to 2,964 feet bpl in preparation for the 26-inch diameter final casing installation. YBI waited for final casing to be delivered to the site. Casing seat depth approval was received from the UIC-TAC.
November 19-20, 2003	No activity at the site.
November 21-26, 2003	YBI waited on the 26-inch diameter final casing to arrive onsite. In the meantime, YBI welded lugs onto the casing and prepared for casing for installation.
November 22, 2003	YBI performed a caliper and gamma ray geophysical log on the 34.5-inch diameter borehole in preparation for the 26-inch diameter casing installation.
November 24, 2003	Collected weekly water quality samples from the PMWs.
November 27, 2003	YBI was not onsite due to the Thanksgiving Holiday.
November 28-30, 2003	YBI installed the 26-inch diameter final casing to 2,962 feet bpl.
November 30- December 3, 2003	YBI grouted the 26-inch diameter final casing in 7 cement stages. The first cement stage was performed with the pressure grout method and contained 601 cu.ft. of neat cement. The second through seventh stages of cement were grouted via the tremie pipe method with 12% Bentonite cement (8,540 cu.ft.), for a total of 9,141 cu.ft. of cement. A temperature log was performed after each cement stage. The top of cement was tagged by YBI at 146 feet bpl. The empty annulus space from surface to 146 feet bpl will be used as a baseline for the future cement bond log.

Table 6-1
Drilling Program Chronology:
City Of West Palm Beach (ECRWWTP), IW-7 And DZMW-7

Date	Event
December 1, 2003	Collected weekly water quality samples from the PMWs.
December 4, 2003	YBI tagged the cement plug inside the 26-inch diameter final casing at 2,937 feet bpl, with the bottom of casing at 2,962 feet bpl. YBI began drilling the 12.25-inch diameter pilot hole to 3,272 feet bpl, with an anticipated depth to 3,400 feet bpl.
December 5, 2003	YBI drilled the 12.25-inch diameter pilot hole from 3,272 to 3,447 feet bpl.
December 6, 2003	YBI cleaned out the 12.25-inch diameter pilot hole and performed geophysical logs from the bottom of the 26-inch diameter final casing (2,962 feet bpl) to 3,447 feet bpl. The logs included caliper, gamma ray, dual induction, borehole compensated sonic with VDL display, and down-hole radial color television survey with rotating lens. The logs that were run under pumping and static conditions were flowmeter, temperature, and fluid resistivity. The television survey was reviewed by CDM and it appeared that the Boulder Zone was not encountered in the pilot hole from the bottom of the final casing to 3,447 feet bpl. Therefore, the reamed hole would be drilled below the design depth of 3,400 feet bpl until the Boulder Zone would be encountered during pilot hole reaming.
December 7-11, 2003	YBI reamed the pilot hole with a 24-inch diameter bit from the bottom of the 26-inch diameter final casing to 3,494 feet bpl. The drill rig's top head drive needed repair after YBI drilled to 3,494 feet bpl.
December 9, 2003	Collected weekly water quality samples from the PMWs.
December 12, 2003	YBI performed rig maintenance on the drill rig's top head drive.
December 13-16, 2003	YBI continued reaming the hole from 3,494 to 3,695 feet bpl. The Boulder Zone was encountered during drilling from 3,447 to 3,695 feet bpl.
December 15, 2003	Collected weekly water quality samples from the

Date	Event
	PMWs.
December 17, 2003	The Florida Department of Environmental Protection (FDEP) was notified that the pressure test for the 26-inch diameter final injection casing would be tentatively scheduled for December 22, 2003. FDEP responded that they may not be onsite to witness the test and not to expect them. YBI conducted geophysical logging, which included cement bond log, caliper, gamma ray, borehole compensated sonic with VDL display, and down-hole radial color television survey with rotating lens. The logs that were run under pumping and static conditions were flowmeter, temperature, and fluid resistivity.
December 18, 2003	YBI rigged up for pressure test.
December 19, 2003	YBI conducted the pressure test for the 26-inch diameter final injection casing. FDEP was not present. The casing pressure was measured at 153 psi with a calibrated pressure gauge at the beginning of the test. After one hour had elapsed, the pressure was measured at 151.5 psi, less than 1% change.
December 20-21, 2003	YBI performed rig maintenance.
December 22, 2003	Collected weekly water quality samples from the PMWs. YBI had their subcontracted laboratory collect water quality samples of the injection zone (2,962 to 3,695 feet bpl) as part of the permit requirements. YBI demobilized from IW-7 to DZMW-7.
December 22, 2003-January 1, 2004	YBI mobilized onto DZMW-7.
December 25-28, 2003	YBI was not on site from for the holidays.
December 29, 2003	Collected weekly water quality samples from the PMWs.
January 2, 2004	YBI drilled the 28-inch diameter borehole with the mud-rotary drilling method and performed a caliper and gamma ray log to 512 feet bpl. YBI installed and

Date	Event
	grouted (1,360 cu.ft.) the 20-inch diameter surface casing to 505 feet bpl.
January 3-8, 2004	YBI drilled the 18.5-inch diameter borehole with the mud-rotary drilling method to 1,830 feet bpl.
January 5, 2004	Collected weekly water quality samples from the PMWs.
January 8, 2004	YBI circulated the hole and conducted the geophysical logging, which included caliper, gamma ray, dual induction log, and borehole compensated sonic with VDL display.
January 9, 2004	FDEP verbally approved the 12.75-inch diameter intermediate casing setting depth of 1,805 feet bpl and YBI installed gravel in the 18.5-inch diameter reamed hole from 1,805 to 1,830 feet bpl. YBI installed approximately 47 cu.ft. of gravel.
January 10, 2004	YBI conditioned the mudded 18.5-inch diameter borehole in preparation for the 12.75-inch diameter intermediate casing installation to a depth of 1,805 feet bpl.
January 11, 2004	YBI installed and pressure grouted in one stage the 12.75-inch diameter intermediate casing utilizing 1,797 cu.ft. of cement.
January 12, 2004	YBI conducted a temperature log on the 12.75-inch diameter intermediate casing. FDEP was notified that the pressure test on the intermediate casing would be conducted on January 13, 2004.
January 13, 2004	Collected weekly water quality samples from the PMWs. YBI conducted a pressure test on the 12.75-inch diameter intermediate casing utilizing the grout plug in lieu of packer equipment. The pressure gauge calibration certification documentation is enclosed. The pressure change was 1.7% from 89.5 psi to 88.0 psi. FDEP was not present for the pressure test.
January 14, 2004	YBI switched from mud to reverse-air and drilled out the cement plug, removed the gravel from 1,805 to 1,830 feet bpl, and drilled to 1,950 feet bpl in

Table 6-1
Drilling Program Chronology:
City Of West Palm Beach (ECRWWTP), IW-7 And DZMW-7

Date	Event
	preparation for packer testing from 1,920 to 1,950 feet bpl.
January 15, 2004	YBI conducted a caliper and gamma ray geophysical log from 1,805 to 1,950 feet bpl.
January 16, 2004	YBI drilled the 11-inch diameter reamed hole with reverse-air from 1,950 to 2,150 feet bpl in preparation for packer testing from 2,090 to 2,150 feet bpl.
January 17, 2004	YBI conducted geophysical logging, which included caliper, gamma ray, dual induction log, and borehole compensated sonic with VDL display.
January 18-19, 2004	YBI conducted the 60-foot Packer Test No. 2 from 1,950 to 2,150 feet bpl.
January 19-21, 2004	YBI waits for water quality results from the laboratory.
January 20, 2004	Collected weekly water quality samples from the PMWs.
January 22, 2004	CDM contacted FDEP and transmitted Packer Test Nos. 1 and 2 data, the IW-7 core analysis data, and lithologic descriptions for FDEP approval regarding the 6 5/8-inch diameter final casing seat depth. FDEP requested that the pilot hole be drilled deeper and another packer test performed at a lower zone (2,200 to 2,250 feet bpl). Water quality samples were collected at the end of the packer test and analyzed at an offsite laboratory for chloride, specific conductance, ammonia, TDS, TKN, and sulfate.
January 23, 2004	YBI conducted the 50-foot Packer Test No. 3 from 2,200 to 2,250 feet bpl, as requested by FDEP.
January 24-25, 2004	YBI waits for the water quality results from Packer Test No. 3.
January 26, 2004	Collected weekly water quality samples from the PMWs. YBI received the water quality results.
January 27, 2004	Verbal approval was issued by FDEP to set the final

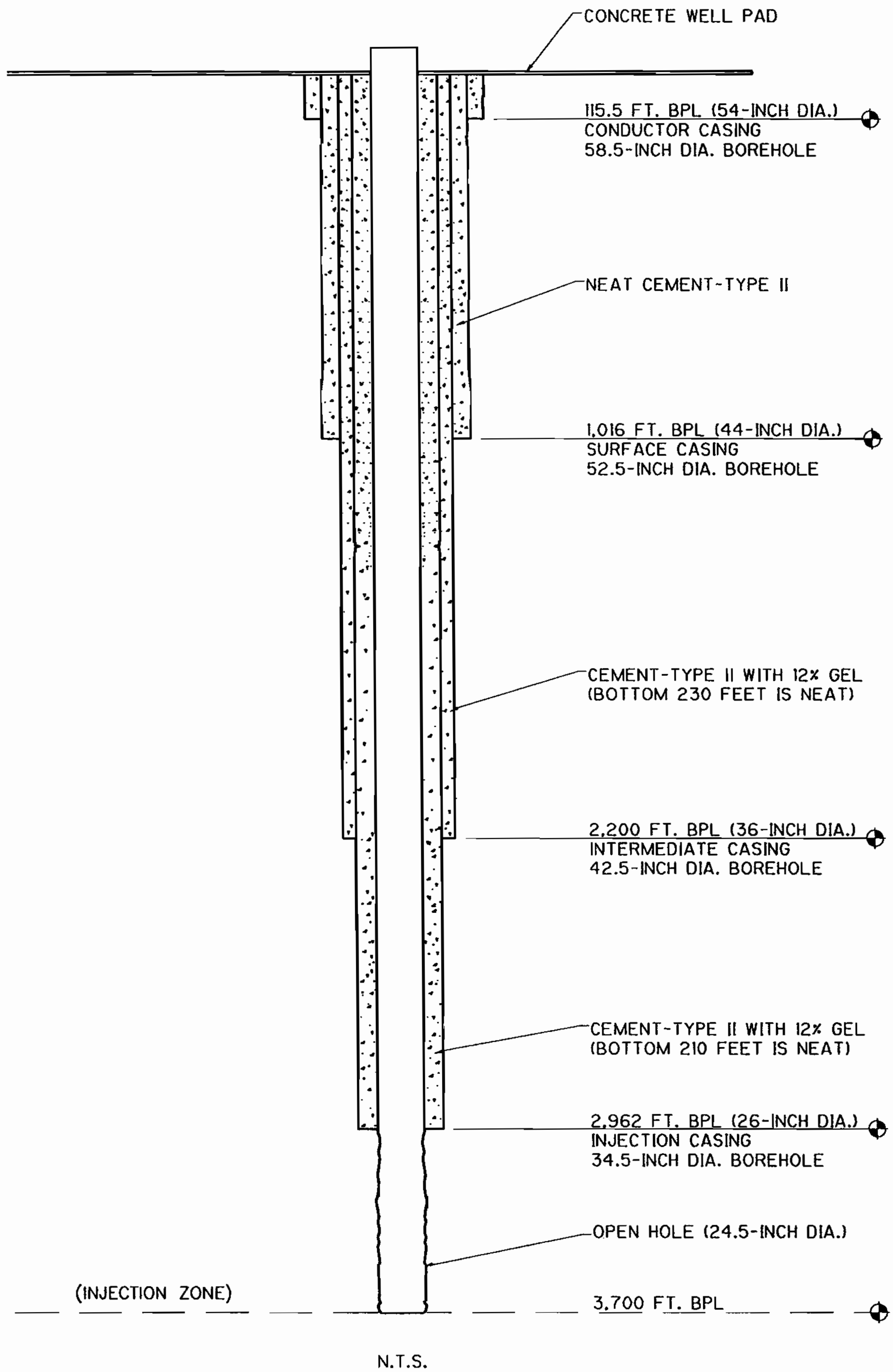
Table 6-1
Drilling Program Chronology:
City Of West Palm Beach (ECRWWTP), IW-7 And DZMW-7

Date	Event
	casing at 2,200 feet bpl based on the data collected.
January 28-31, 2004	YBI installs and cements the 6 5/8-inch diameter final casing to 2,200 feet bpl, for a lower monitor zone interval from 2,200 to 2,250 feet bpl. The casing was coated on the outside with epoxy around the weld rings from surface to 1,850 feet bpl. YBI cemented the casing with a cement basket at the bottom of the casing in four stages, totaling 205 cu.ft. of neat cement from 1,850 to 2,200 feet bpl. Temperature logs were conducted after each cementing stage.
January 31, 2004	YBI concluded the temperature logs after each stage of cement for the 6 5/8-inch diameter final casing.
February 2, 2004	Collected weekly water quality samples from the PMWs. YBI conducted the pressure test on the final casing. The pressure change was 1.1%, which was less than 5% as the permit required.
February 3, 2004	YBI mobilized onto IW-4 to drill DZMW-4 (Permit No. 0048923-007-UC).
February 9, 2004	Collected weekly water quality samples from the PMWs.
February 16, 2004	Collected weekly water quality samples from the PMWs.
February 23, 2004	Collected weekly water quality samples from the PMWs.
March 1, 2004	Collected weekly water quality samples from the PMWs.
March 9, 2004	Collected weekly water quality samples from the PMWs.
March 15, 2004	Collected weekly water quality samples from the PMWs.
March 22, 2004	Collected weekly water quality samples from the PMWs.

Table 6-1
Drilling Program Chronology:
City Of West Palm Beach (ECRWWTP), IW-7 And DZMW-7

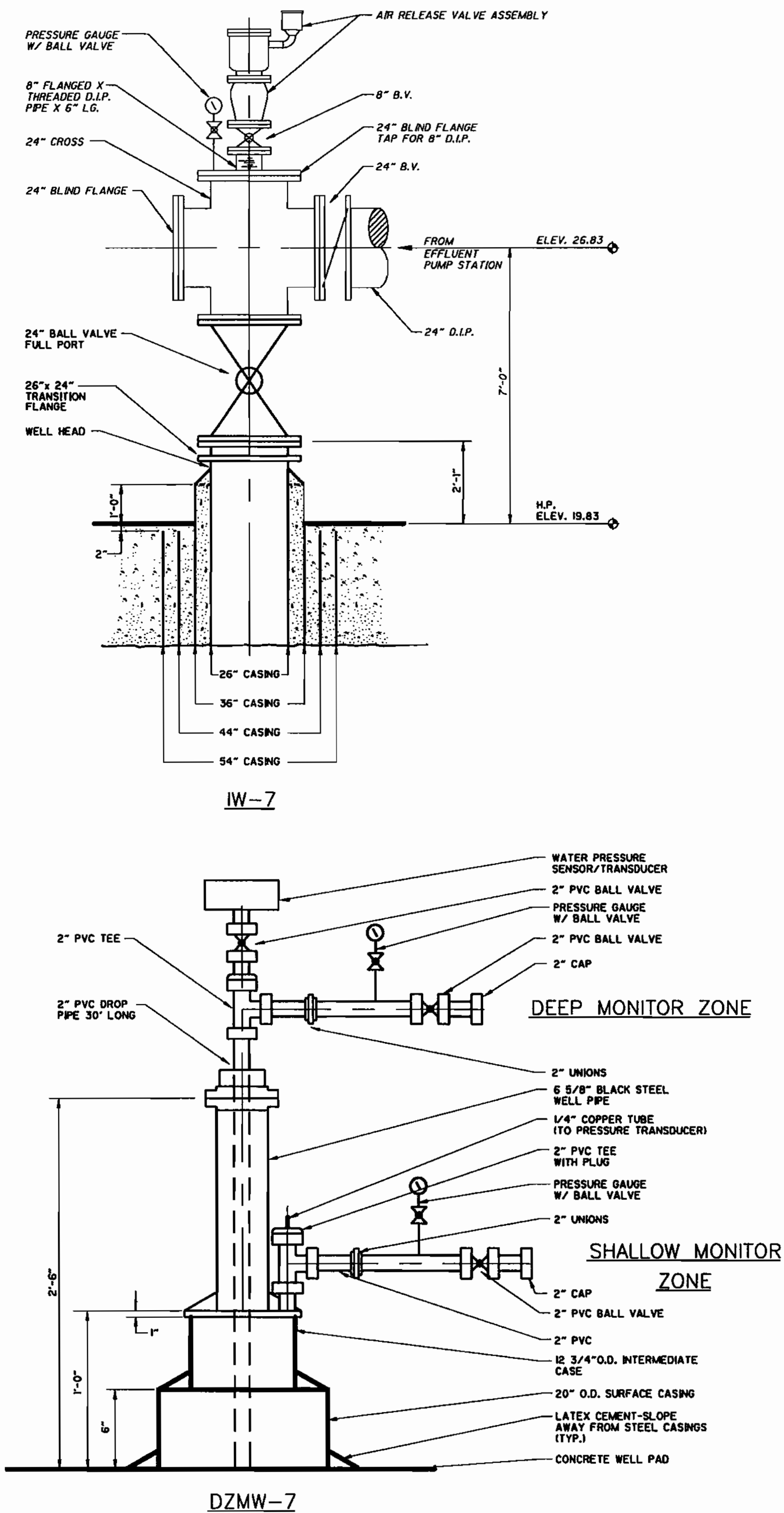
Date	Event
March 27-28, 2004	YBI was not onsite.
March 29, 2004	Collected weekly water quality samples from the PMWs.
March 29-31, 2004	No activity at the site.
April 1, 2004	YBI grouted the free pipe portion of IW-7 (in the annular space between the intermediate and final casings) and DZMW-7 (in the annular space between the surficial and intermediate casings) with 67 and 7 barrels of cement, respectively.
April 2, 2004	YBI conducted the sector bond log and video survey on the 6 5/8-inch diameter final casing at DZMW-7.
April 3-4, 2004	YBI was not onsite.
April 5, 2004	Collected weekly water quality samples from the PMWs. No activity at the site.
April 6, 2004	YBI had Envirodyne Inc. collect water quality samples from the upper and lower zones from DZMW-7 for primary and secondary analyses, as required by the permit.
April 7, 2004	No activity at the site.
April 8, 2004	YBI conducted the Radioactive Tracer Survey at IW-7 at two low flow rates.
June 21-23, 2004	YBI conducted the short term injection test with a 24-hour background monitoring period, 24-hour injection test, and a 24-hour recovery monitoring period.

Source: CDM and YBI Daily and Working Reports.



CDM

Figure No. 6-1
City of WPB ECRWWTP, Florida
IW-7 Construction Detail



P:\10061\26918_15B\CONST\RPT\ FIG 6-2 09/28/04 1: .22 5:14:36 nunesal

CDM

Figure No. 6-2
City of WPB ECRWWTP, Florida
Wellhead Details

After testing was completed, the pilot hole was grouted with 1,627 cubic feet of cement. The grouted pilot hole was reamed to a nominal 42.5 inches in diameter to a depth of 2,210 feet bpl. Well inclination measured in both the pilot hole and reamed hole, was less than 0.5 degrees. The 36-inch diameter, 0.375-inch thick steel casing was installed and cemented into place to a depth of 2,200 feet bpl. Except for the volumes used, the cement program was identical to that used on the 44-inch diameter casing. The cement volume used for the 36-inch diameter casing was 11,161 cubic feet with the bottom 230 feet of neat cement.

The third phase of the pilot hole began after the installation of the 36-inch diameter casing was complete. The 12.25-inch diameter pilot hole was drilled to a depth of 3,025 feet bpl and geophysical logging was performed. During construction of this stage of the pilot hole three core samples were collected and three single element packer tests were conducted. After the testing phase was completed for this section of the pilot hole, the pilot hole was grouted with 1,348 cubic feet of cement.

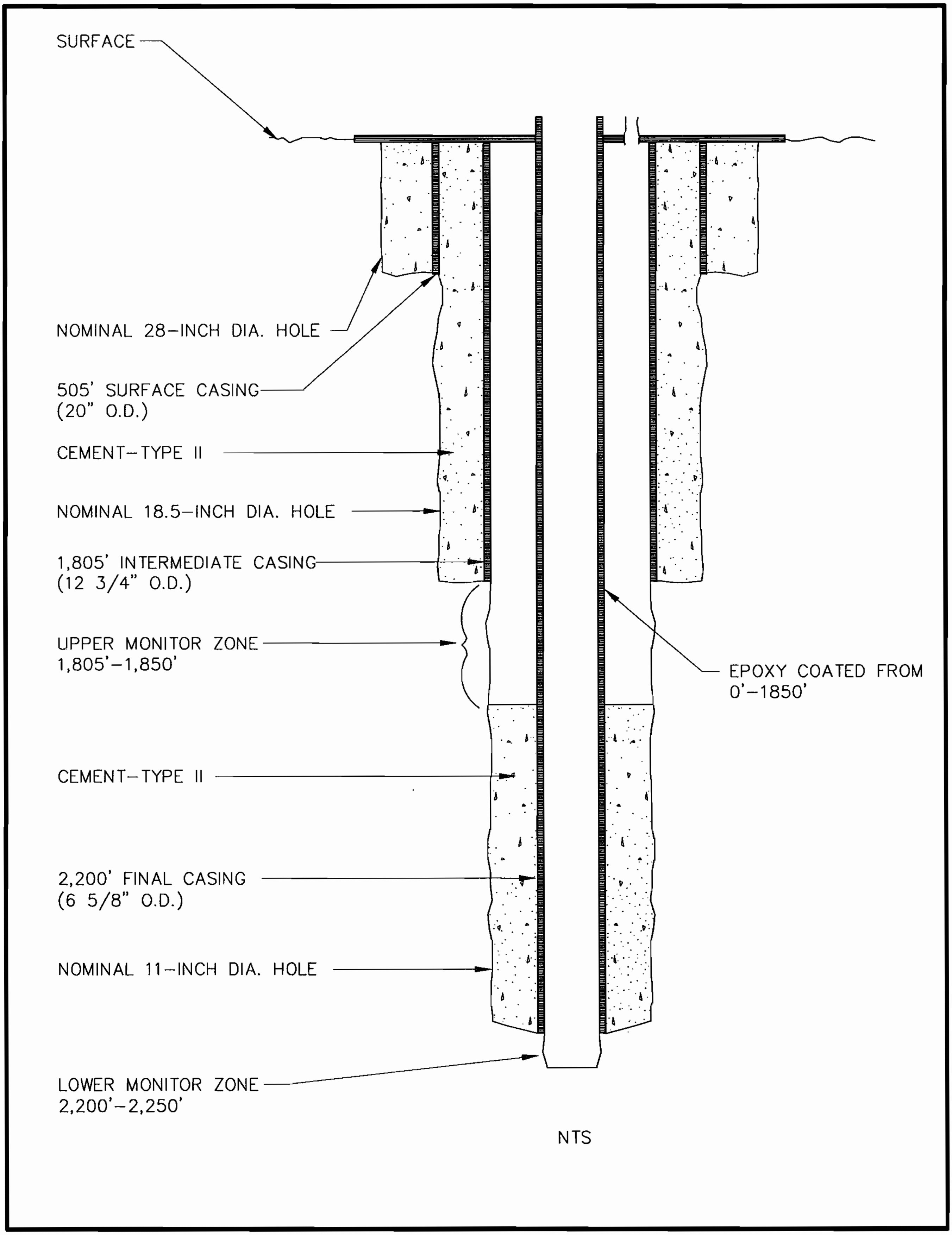
The grouted pilot hole was reamed to a diameter of 34.5 inches to a depth of 2,964 feet bpl and the injection casing was installed. Well inclination measured in both the pilot hole and reamed hole, was less than 0.5 degrees. The injection casing was 26-inch diameter, 0.500-inch thick steel casing. The casing was grouted with approximately 150 feet of free pipe at surface for cement bond log comparison. The cementing program was the same as that used for the 36-inch diameter casing except for the volumes used. A total of 9,141 cubic feet of cement was used to grout the 26-inch diameter casing and 376 cubic feet of cement was used to top off the 150-feet of free pipe. Neat cement was used on the bottom 210 feet of casing.

The fourth phase of the pilot hole began after the installation of the 26-inch diameter casing was complete. The 12.25-inch diameter pilot hole was drilled to a depth of 3,450 feet bpl and geophysical logging was performed. From the logging results it was interpreted that the Boulder Zone was not encountered. Therefore, the fifth stage of drilling consisted of reaming the 12.25-inch diameter pilot hole to 24.5 inches from 2,962 to 3,650 feet bpl with 50 feet of rat hole to 3,700 feet bpl. Geophysical logging was performed on the reamed hole. The 2,962 to 3,650-foot interval represents the injection zone for IW-7.

After completion of IW-7, a mechanical integrity test was performed. These activities consisted of an RTS and a pressure test for the 26-inch diameter injection casing. These activities were discussed in Section 5.

6.2 Dual-Zone Monitor Well No. 7 "As-Built"

Figure 6-3 illustrates the construction details of DZMW-7 and Figure 6-2 displays the wellhead details. Signed and sealed record drawings are in Appendix M. A summary of the construction sequence is provided below.



P:\10061\26918_15B\CONST\RPT\ FIG 6-3 04/27/04 1(illegible) .12 5:08:17 nunesal

CDM

Figure No. 6-3
City of WPB ECRWWTP, Florida
DZMW-7 Construction Detail

Construction of DZMW-7 began with the drilling of a 28-inch diameter borehole and the installation and grouting of the 20-inch diameter, 0.375-inch thick steel casing through the Surficial Aquifer System. A total of 1,360 cubic feet of cement was used to grout the annular space for the 20-inch diameter casing at a depth of 505 feet.

The next phase was drilling an 18.5-inch diameter borehole to a depth of 1,830 feet bpl with mud. This section of pilot hole was geophysically logged. The logs and their analyses were discussed in detail in Section 2.3. The 12.75-inch diameter, 0.375-inch thick steel casing was grouted into place to a depth of 1,805 feet bpl. A total of 1,797 cubic feet of cement was used to grout the casing annulus. A successful casing pressure test was conducted after cementing was completed. The pressure change after one hour was 1.7% from 89.5 psi to 88.0 psi, which was less than 5% as the permit required.

The drilling contractor switched drilling methods from mud rotary to reverse-air after the installation and pressure testing of the 12.75-inch diameter casing. An 11-inch diameter hole was extended to a depth of 2,250 feet bpl. Three single element packer tests were performed during this phase of construction. A suite of geophysical logs were performed from 1,805 to 2,250 feet bpl. These testing activities were discussed in detail in Section 2.

After the testing phase was complete, the 6 5/8-inch diameter, 0.500-inch thick steel casing was then installed to 2,200 feet bpl and grouted to 1,850 feet bpl. A total of 205 cubic feet of cement was used to bring the grout to this elevation. A protective coating of epoxy phenolic resin compatible with brackish saline groundwater was applied to the outside of the 6 5/8 inch outside diameter casing as shown on Figure 6-3. A successful casing pressure test was conducted after cementing was completed. A sector bond log and video survey on the casing was conducted. The pressure change after one hour was 1.1% from 90.0 psi to 89.0 psi, which was less than 5% as the permit required.

Both the upper and lower monitoring zones were developed after completion of construction operations at DZMW-7. Consistent flow rates of 125 and less than 5 gpm were attained through artesian pressure in the upper and lower zones, respectively, during development.

After completion of IW-7 and DZMW-7, a 24-hour injection test was performed. The onsite injection and monitor wells were monitored for pressure changes before, during, and after the test. This testing phase was discussed in detail in Section 3.

The last activities performed were water quality sampling of the monitoring zones. The water quality data from the monitoring zones are discussed in Section 7.

6.3 Surficial Aquifer Monitoring

Four shallow surficial aquifer monitor wells were installed and sampled on a weekly basis to detect any potential brackish water spills off the pad. The locations and designations of these wells are shown on Figure 1-7. Each well has approximately ten feet of screen with a 20/30 gravel pack extending two feet above the top of the screen. A two-foot fine sand cap was installed on top of the gravel pack and approximately three feet of grout extend from the fine sand cap to the surface. Each well was drilled to an approximate depth of 15 feet below land surface.

Sampling of the four monitoring wells was performed on a weekly basis during the construction and testing of IW-7 and DZMW-7. Laboratory analyses performed on the samples included chlorides, specific conductance, temperature, total dissolved solids, and water level. The results of the analyses indicate that there were no significant discharges of brackish/saline water off of the drilling pad during the construction and testing of IW-7 and DZMW-7. The surficial aquifer water quality data is presented in Appendix P.

Section 7
Background Water Quality

Water quality samples were collected for IW-7 and for the upper and lower monitor zones in DZMW-7 to establish background water quality conditions and to comply with FDEP construction permit conditions. These samples were collected after the injection and monitoring zones had undergone development, and were analyzed for primary and secondary drinking water standards and FDEP municipal wastewater minimum criteria parameters (62-520, Florida Administrative Code). Envirodyne, Inc. of Boca Raton, Florida, analyzed the samples. A summary of the laboratory analyses is provided in Table 7-1 and compared to the ECRWWTP effluent wastestream analysis results. The laboratory report may be found in Appendix H for IW-7 and DZMW-7.

7.1 Dual-Zone Monitor Well No. 7 Upper Zone

Based on the data collected over the reamed hole interval at DZMW-7 and the pilot hole at IW-7, the base of the USDW is interpreted to exist at approximately 2,000 feet bpl at the site. The Department issued approval on January 9, 2004 for the 12.75-inch diameter intermediate casing seat depth at 1,805 feet bpl for DZMW-7. The upper monitoring zone for DZMW-7 is located from 1,805 to 1,850 feet bpl. The background water quality data from the upper monitoring zone are summarized in Table 7-1. The background water quality data are similar to that collected during the single element packer test over the 1,810- to 1840-foot interval for the IW-7 pilot hole as discussed in Section 2. Water quality and flow data collected from DZMW-7 Packer Test No. 1 indicated that the proposed upper monitor interval should be suitable for this purpose.

The upper monitor interval will provide monitoring in the first permeable zone above the base of the USDW. The proposed upper monitor interval would be closest to the base of USDW in all of the ECR injection well system.

7.2 Dual-Zone Monitor Well No. 7 Lower Zone

The Department recommended that additional water quality data be collected during the drilling of DZMW-7 based on the IW-7 pilot hole data. An additional packer test (DZMW-7 Packer Test No. 3) was run from 2,200 to 2,250 feet bpl. After receiving Packer Test No. 3 results, CDM requested a verbal approval from the Department on setting the 6 5/8-inch diameter final casing at 2,200 feet bpl. The data from 2,200 to 2,250 feet bpl appeared to be favorable for the DZMW-7 lower monitor zone. DZMW-7 Packer Test No. 3 water quality and flow data indicated that the proposed lower monitor interval should be suitable for this purpose. A water sample collected during the packer test had a TDS concentration of approximately 37,000 ppm. The background water quality data from the lower monitoring zone are summarized in Table 7-1 and are similar to the packer test data.

The lower monitor interval will have suitable flow and water quality characteristics to monitor for changes in water quality below the base of the USDW. The lower monitor interval is the first permeable zone above the confining unit of the Floridan Aquifer System. Also, the proposed lower monitor interval does not contain high levels of nutrient-based parameters as compared to the effluent wastestream in **Table 7-1**.

7.3 Fluid Compatibility

The injection zone background quality displays similar characteristics to secondarily treated domestic wastewater effluent quality since there are six existing injection wells onsite. There is little evidence of formation water due to the invasion of secondarily treated domestic wastewater effluent in the injection zone. Therefore, a zone of mixing has already developed between the injection fluid (effluent) and the formation water in the injection zone when the proposed injection commences at IW-7.

The injection zone background quality from 2,962 to 3,700 feet bpl contains chloride and TDS levels at concentrations of 70 mg/L and 310 mg/L, respectively, which is of fresh water quality. The level of nutrients within the formation fluid is similar to secondarily treated domestic wastewater effluent. Injection into IW-7 will not lead to any immiscibility problems because these fluids are both water. In summary, the proposed injection fluid is compatible with the injection zone background quality.

The injected effluent is likely under saturated with respect to calcite and dolomite. Some minor carbonate mineral dissolution may therefore occur, which would act to enhance injection zone transmissivity.

Table 7-1
IW-7 and DZMW-7 Background Water Quality Summary

Parameter	Units	ECRWWTP Effluent Wastestream	IW-7	DZMW-7 Upper Zone (1,805-1,850 feet bpl)	DZMW-7 Lower Zone (2,200-2,250 feet bpl)
Chloride	mg/L	200	70	2,400	20,000
Total Dissolved Solids	mg/L	480	310	5,200	39,000
Specific Conductance	umhos/cm	1,125	530	7,480	46,480
Sodium	mg/L	120	140	1,300	14,000
Sulfate	mg/L	48	34	400	1,900
Nitrite	mg/L	0.13	0.044	<0.020	<0.020
Nitrate	mg/L	1.6	0.34	0.026	0.023
Nitrogen (Nitrate-Nitrite)	mg/L	1.7	0.38	0.026	0.025
Ammonia Nitrogen	mg/L	10	0.28	0.87	0.7
Total Kjeldahl Nitrogen	mg/L	10	0.69	1.1	0.84
Total Organic Nitrogen	mg/L	<0.50	<0.50	<0.50	<0.50
Total Phosphorus	mg/L	0.47	0.36	<0.010	<0.010
Total Coliform	1 cfu/100 ml	78,000	6	<1	<1
Arsenic	mg/L	<0.010	<0.010	<0.010	0.016
Barium	mg/L	<0.010	0.058	0.027	0.077
Chromium	mg/L	<0.010	0.015	<0.010	<0.010
Cadmium	mg/L	<0.0040	<0.0040	<0.0040	<0.0040
Iron	mg/L	0.36	1.2	0.25	33
Zinc	mg/L	<0.010	0.048	<0.010	0.33
Copper	mg/L	<0.010	0.079	0.031	<0.010
Manganese	mg/L	0.024	0.039	0.011	0.4
Nickel	mg/L	<0.010	0.11	<0.010	<0.010
Antimony	mg/L	<0.0010	0.0018	<0.0010	<0.0010
Lead	mg/L	0.00048	0.009	<0.00020	0.0038
Mercury	mg/L	<0.000025	<0.000025	<0.000025	0.00004
Selenium	mg/L	<0.0010	0.003	<0.0010	<0.0010
Biochemical Oxygen Demand	mg/L	<2.0	3.1	4.7	9.1
Chemical Oxygen Demand	mg/L	22	97	90	480
Color	CU	20	50	15	2,000
Fluoride	mg/L	0.42	0.95	0.84	0.43
Surfactants (as LAS, MW=340)	mg/L	0.20	0.18	0.13	0.6
Odor	TON	8	2	3	3
pH	Units	7.2	7.5	7.1	6.6
Alicarb Sulfone	ug/L	7.1	<1.0	<1.0	<1.0
Chloroform	ug/L	2.3	<0.5	<0.5	<0.5
Gross Alpha	pCi/L	9 +/- 6	27 +/- 8	7 +/- 10	37 +/- 45
Radium 226	pCi/L	0.2 +/- 0.1	1.2 +/- 0.1	2.1 +/- 0.1	6.7 +/- 0.1
Radium 228	pCi/L	0.5 +/- 0.5	<0.5 +/- 0.5	<0.5 +/- 0.5	<0.5 +/- 0.5

bpl = below pad level
NA = Not Analyzed

mg/L = milligrams per liter; CU = Color Units;
umhos/cm = micromhos per centimeter; pCi/L = picocuries per liter

Section 8
Conclusions and Recommendations

8.1 Conclusions

Previous data collected from the existing onsite injection wells at the City of West Palm Beach East Central Regional Wastewater Treatment Plant (ECRWWTP) site and the new data collected during the installation of Injection Well No. 7 (IW-7), and an associated Dual Zone Monitor Well No. 7 (DZMW-7) have provided further insight into the underlying hydrogeological strata. The lithologic and geophysical data gathered during the construction of IW-7 were evaluated in conjunction with core data to provide an understanding of the lower geological units penetrated by the well. In addition, the hydrologic data obtained from the injection test, in conjunction with other data, permitted a comprehensive evaluation of the nature and characteristics of the proposed confining zone. The hydrogeologic characteristics of the overlying confining zone indicate that there will not be any significant effect on the zones above this confining zone when effluent is injected into IW-7. The injection test data show no evidence of interconnection between the injection and overlying zones.

Numerous data were collected throughout the construction and testing of IW-7 and DZMW-7 to monitor the local hydrogeologic environment and provide that the construction and testing activities at IW-7 did not have any harmful effects. These data and the subsequent analyses enabled the development of operation and maintenance guidelines for IW-7.

Based upon CDM's evaluation of the site-specific data, the following conclusions were reached:

- The base of the USDW was identified at a depth of approximately 2,000 feet below pad level (bpl).

- The top of the injection zone at the ECRWWTP site is located at least 645 feet below the base of the USDW after approximately 27 years of deep well injection at the site.

- The injection zone is between 2,675 and 3,650 feet bpl, and the bottom of the injection casing is at 2,962 feet bpl. It is anticipated that the primary interval for injection at IW-7 is a cavernous zone at a depth between 3,485 to 3,650 feet bpl. The water quality data and geophysical log responses for the IW-7 pilot hole indicate that secondarily treated domestic wastewater effluent from the existing onsite injection wells has migrated into the strata below 2,962 feet bpl. The native formation water was not evident from the injection zone background quality results.

- Effective vertical confinement is provided by dolomite and dolomitic limestone present below the base of the USDW. There appears to be three distinct confining layers overlying the injection zone: a good confining layer from 2,000 to 2,200 feet bpl, a very good confining layer from 2,250 to 2,450 feet bpl, and a good confining layer from 2,450 to 2,675 feet bpl. The lowest vertical permeability measured in the cores obtained in this interval during pilot hole construction was on the order of 10^{-7} cm/sec at depths of 1,880, 1,977.3, 2,302.7, 2,423.3, 2,426.3, 2,421.7, and 2,784.8 feet bpl. Other zones in the interval also showed very low vertical permeability. These low permeability zones, in combination with the more than 625 feet of homogeneous non-fractured limestone and dolomite, give extensive confinement to the waters below the USDW.

IW-7 Construction Phase

- The 26-inch diameter, 0.500-inch wall steel injection casing, set at 2,962 feet bpl, has a good cement-to-casing bond and cement-to-formation bond. The mechanical integrity criteria set forth in the rules governing injection well construction were successfully met at the IW-7 site. These criteria included pressure testing of the inner casing and the performance of a radioactive tracer survey. The results of the tests performed at IW-7 indicate that the well satisfies the criteria.

- The salinity-related parameters analyzed from packer test number IW-7 #7 showed levels that are consistent with being invaded by effluent. The TDS value for the 2,716 to 2,745-foot interval was 15,000 mg/L. TKN was also higher than measured in packer test number IW-7 #6 (1 mg/L compared to 0.38 mg/L). The injection zone background quality displays similar characteristics to secondarily treated domestic wastewater effluent quality since there are six existing injection wells onsite.

- The 26-inch diameter injection casing is set at 2,962 feet bpl, approximately 287 feet below the base of the confining zone. The 36-inch intermediate casing is set at 2,200 feet bpl, which is 200 feet below the base of the 10,000 mg/L USDW line.

- Well inclination, as measured by the pilot hole and reamed hole, was measured at less than 0.5 degrees, which is within the allowable deviation of one degree. After testing of each pilot hole was complete, that pilot hole was grouted to the previous casing seat before reaming operations began.

- The Surficial Aquifer monitoring program samples collected from the pad monitor wells confirmed that well construction activities had no impact on the Surficial Aquifer.

Well Development and Injection Testing Phase

- There was no evidence for the upper or lower monitoring zones of DZMW-2, DZMW-6, and DZMW-7 being impacted by injection into the Boulder Zone of the lower Floridan Aquifer. There was no increase in piezometric head recorded in the upper and lower monitoring zones during the injection test which could be attributed to injection pressure effects.

- The target rate for the 24-hour injection test was 22.03 MGD (15,300 gpm) for the duration of at least 12 hours as specified in the permit. A flow rate of 14,900 was attempted for the duration of the 24-hour injection test due to plant operations. However, the plant could not provide a minimum of 12 hours at the target flow rate due to major vibration of specific injection pumps at high flow rates, which occurred during the middle of the injection test, and periods of low flow at the plant. The bottom hole pressure at the end of the injection test was 54 psi or 125 feet of head above the pre-test hydrostatic pressure. The injection test was performed at a rate of approximately 14,800 gpm. The resultant transmissivity value calculated using the input of 14,800 gpm and 125 feet of head increase was approximately 237,200 gpd/foot utilizing the Jacob's method. The transmissivity of the injection zone in IW-7 is relatively low in comparison to the IW-6 transmissivity of 1,783,000 gpd/ft.

- The injection zone is capable of receiving the design capacity of 22.03 MGD (15,300 gpm) of treated effluent. This is indicated by only the nominal increase of injection pressure noted during the injection test at a rate of 21.3 MGD (14,800 gpm).

8.2 Recommendations

Based on the conclusions discussed in Section 8.1 which were drawn from the available data, IW-7 meets all of the regulatory requirements for a Class I injection well as defined by FDEP. Thus, it is recommended that the IW-7 Class I construction permit should be modified to allow operational testing.

The recommended maximum daily average injection rate for inclusion in the permit should be 22.03 MGD, which provides an injection velocity of 10 feet per second. The recommended maximum wellhead injection pressure over and above the static piezometric pressure for inclusion in a five-year operation permit should be 100 psi.

The operation and maintenance manual provided in Appendix Q identifies the operation and maintenance required for IW-7. It is recommended that the monitoring guidelines in the manual become the actual requirements of the permit and that the reporting criteria and forms included in the manual be used for reporting and monitoring purposes.

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