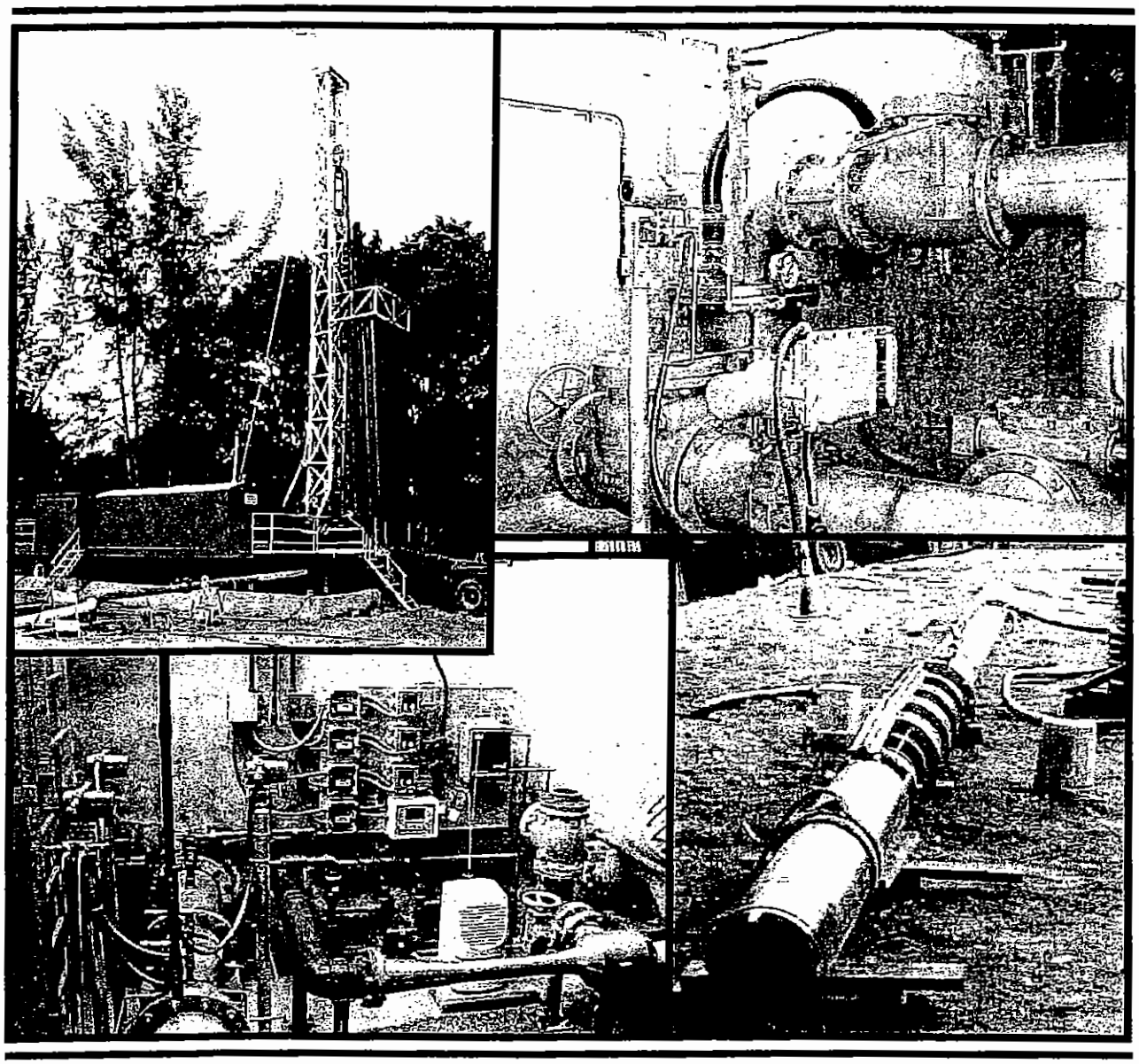
Eastern Hillsboro Canal
(Palm Beach County System 9)

Class V Injection Facility No. 46



Palm Beach County
Water Utilities Department

Eastern Hillsboro Canal - WTP #9
Aquifer Storage and Recovery Well
PBCWUD Project No. 98 – 66B

Well Construction Report and
Operational Testing Request

August 2003

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TABLE 2-1
FLORIDAN AQUIFER MONITORING WELL (FAMW)
SUMMARY OF CONSTRUCTION DETAILS

Casing Details				Cementing Details			
ID	Type	Diameter (inches)	Depth (feet)	Stage No.	Type	Volume (cubic feet)	Tag Depth (feet bpl)
Conductor	Steel	34	35	NA	Vibrated	NA	NA
Surface	Steel	24	220	1	Neat	810	0
Intermediate	Steel	14	1,005	1	Neat	810	464
				2	Neat	770	0
Final	Fiberglass	6 5/8	1,007	1	2% Bentonite	27	997
				2	Neat	24	975
				3	Neat	216	632
				4	Neat	378	66
				5	Neat	30	0

Following completion of geophysical logging, the pilot borehole was reamed to 1,016 feet bpl with a 22 ½-inch reamer assembly. After circulating to condition the borehole and remove all of the drill cuttings, the drilling tools were removed from the borehole. Caliper and borehole compensated sonic logging was subsequently conducted on the borehole, followed by the installation of 1,005 feet of 14-inch OD steel intermediate casing having a 0.375-inch wall thickness as specified. The beveled casing joint ends were welded together. Centralizers were welded to the casing to ensure more uniform grouting. The annular space between the borehole and the casing was grouted to land surface with 1,580 cubic feet of API Class B Portland neat cement in two stages. Following the first stage of cementing a physical tag using tremmie pipe in the annular space and a cement top log (temperature) was performed to determine the depth of the top of cement.

Following cementing, a 12 ¼-inch bit was used to advance the pilot borehole to 1,650 feet bpl. Deviation surveys were performed at 60 foot intervals during drilling as well as the collection of 14 additional conventional cores. A summary of the core analysis is provided in **Table 2-2**. Following completion of the pilot borehole, the drilling fluid was circulated and the borehole was conditioned for geophysical logging. Geophysical logging (SP, caliper, resistivity, borehole compensated sonic, and gamma ray logs) was then performed.

At the completion of geophysical logging, packer testing of the pilot borehole commenced. Three straddle packer tests and two single packer tests were performed to evaluate the hydrology of the formation and determine the injection/monitoring

interval. The packers were placed on depth, inflated with nitrogen to isolate the interval, the test pump installed, and the interval developed. Static water levels were obtained prior to the start of pumping. A 4-hour pumping test was then performed followed by a 3-hour recovery period. Prior to the end of the pumping test, water samples were collected and analyzed for the specified parameters. The packer test and water quality data is provided in **Appendix H. Table 2-3** provides a summary of the packer test data.

TABLE 2-3
FLORIDAN AQUIFER MONITORING WELL (FAMW)
SUMMARY OF PACKER TESTS

Test Number	Interval	Pumping Rate (gpm)	Specific Capacity (gpm/ft)	Chlorides (mg/L)	TDS (mg/L)
1	1,596.5 – 1,626.6	99.5	2.73	2,400	4,600
2	1,310 – 1,340	92.0	1.71	2,100	4,100
3	1,310 – 1,340	89.4	1.92	2,300	4,200
4	1,005 – 1,198	71.0	6.76	2,200	4,300
5	1,005 – 1,041	92.6	18.9	2,200	4,200

Note: Packer test number 3 was performed on the same interval as packer test number 2 following a 250 gallon acid stimulation.

Following packer testing the borehole was developed clean and geophysical logging (video, borehole televiewer, static and dynamic fluid resistivity, temperature, and flowmeter) was performed. Based on information provided from lithologic and geophysical logs, cores, and packer testing results, the casing setting depth of 1,007 feet bpl was selected for the final casing. On November 12, 2001 approval for the casing seat request, injection zone/monitoring interval, and plug back depth was received from the Florida Department of Environmental Protection (FDEP), Underground Injection Control Division.

Once plug back and final casing seat approval was received from the FDEP, the monitor well was plugged back to 1,232 feet bpl with 399 cubic feet of API Class B Portland neat cement in four stages.

At the completion of the plug back operations, the monitoring interval was developed clean and the step-rate and constant-rate pumping tests were performed. The pumping tests were completed prior to the setting of the 6 5/8-inch final casing (in the 14-inch intermediate casing) to accommodate a larger diameter pump (6-inch) and higher flow volumes. Between the step-rate pumping test and the constant-rate pumping test,

Figure 2-1 shows the FAMW well schematic.

Construction Sequence –Floridan Aquifer Storage and Recovery (ASR) Well

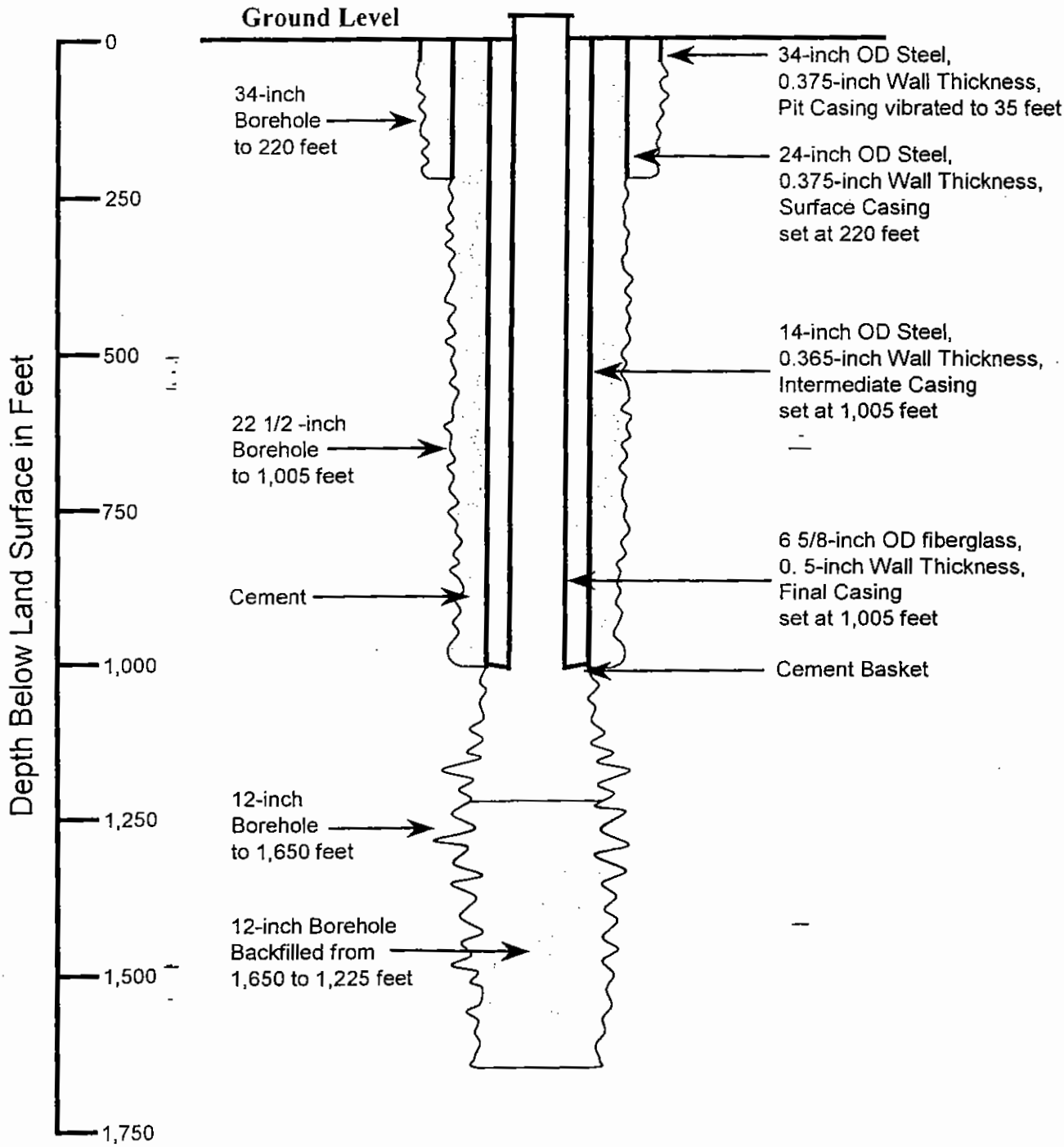
Prior to drilling, 40 feet of 48-inch OD carbon steel conductor casing was vibrated to 35 feet below land surface. Once in place, pilot hole drilling, utilizing the mud rotary method, was initiated on October 2, 2001. A 44-inch by 12 1/4-inch staged bit was used to clean the conductor casing to 40 feet bpl and center the initial pilot borehole in the casing. The center punch was removed from the borehole and a 12 ¼-inch bit was used to complete the pilot hole to 250 feet bpl. Lithologic samples were collected at 10 foot intervals during pilot borehole drilling operations.

Upon completion of the pilot borehole, the well was circulated clean of drill cuttings, conditioned, and the drill pipe and bit were removed from the borehole. Geophysical logging (caliper, SP, resistivity, gamma ray) was performed.

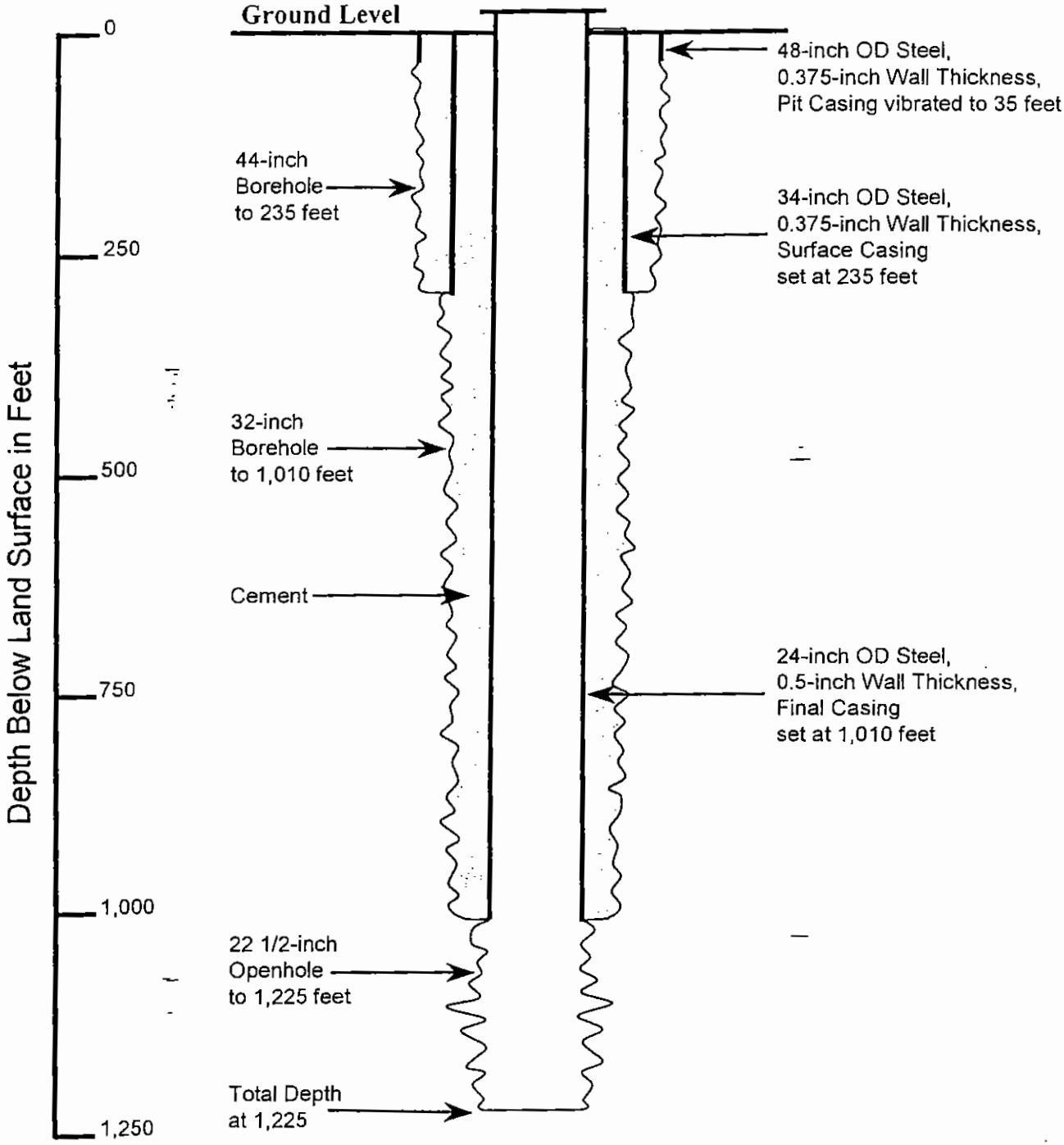
Following geophysical logging, the borehole was reamed with a 44-inch bit to 250 feet bpl. After circulating to remove all of the drill cuttings, the borehole was conditioned and the drilling tools were removed. Caliper logging was subsequently conducted on the borehole, followed by the installation of 240 feet of 34-inch OD steel surface casing. The beveled casing joint ends were welded together. Centralizers were welded to the casing beginning at 20 feet from the bottom of the casing and at 40 foot intervals thereafter to ensure more uniform grouting. The annular space between the borehole and the casing was pressure grouted on October 19, 2001 with 1,323 cubic feet of API Class B Portland neat cement in one stage. A summary of the ASR construction details is shown in **Table 2-6.**

TABLE 2-6
FLORIDAN AQUIFE STORAGE AND RECOVERY WELL
SUMMARY OF CONSTRUCTION DETAILS

Casing Details				Cementing Details			
ID	Type	Diameter (inches)	Depth (feet)	Stage No.	Type	Volume (cubic feet)	Tag Depth (feet bpl)
Conductor	Steel	48	35	NA	Vibrated	NA	NA
Surface	Steel	34	235	1	Neat	1323	0
Final	Steel	24	1,010	1	Neat	905	901
				2	Neat	729	424
				3	Neat	621	128
				4	6% Bentonite	176	36
				5	Neat	41	19.5
				6	Neat	41	3



EASTERN HILLSBORO CANAL - WTP #9
FLORIDAN AQUIFER MONITOR WELL
CONSTRUCTION DIAGRAM
Figure 2-1



EASTERN HILLSBORO CANAL - WTP #9
AQUIFER STORAGE & RECOVERY WELL CONSTRUCTION DIAGRAM
Figure 2-2

In order to conduct the step-rate pumping test, a test pump was installed in the ASR well. A 12-inch diameter discharge line leading to a 10-inch by 12-inch orifice manometer was used to calculate flow rates. Incremental pumping rates of approximately 1,400 gpm, 1,900 gpm, 2,900 gpm and 3,130 gpm were utilized for the step-rate pumping test. The static water level of the well was approximately 28 feet above land surface before testing began. Water levels were measured in the well during each pumping rate until a near equilibrium drawdown within the well occurred. The well was pumped for approximately one hour at each respective pumping rate. The drawdown data was used in conjunction with the pumping rates to obtain specific capacity values for the well. The results of the step-rate pumping test are shown in **Table 2-8.**

TABLE 2-8
FLORIDAN AQUIFER STORAGE AND RECOVERY WELL
SUMMARY OF STEP-RATE PUMPING TEST

Flow Rate (gpm)	Water Level (feet relative to ground level)	Drawdown (feet)	Specific Capacity (gpm/ft)
1,400	-12	40	35.0
1,940	-37	65	29.8
2,900	-91	119	24.4
3,130	-102	130	24.1

ASR Well Acidization

The ASR well was acidized in an effort to increase its specific capacity and to develop more defined flow zones. Prior to acidization, the specific capacity was estimated to be approximately 24.1 gpm/ft at a pumping rate of approximately 13000 gpm from data collected during the ASR step-rate pumping test. Following acidization the specific capacity increased to approximately 62.9 gpm/ft at a pumping rate of 3,400 gpm.

Acid treatment was performed by IWP using 6,000 gallons of 36 percent hydrochloric acid. The acid was pumped using HydroChem's bulk hauler pump at a rate of approximately 45 gpm through a temporary sealed wellhead assembly and 1,019 feet of 2 3/8-inch diameter tremmie. The temporary wellhead had a primary access port for the tremmie, a gas bleed port, a water injection port, and a pressure gage. During acid pumping, potable water was simultaneously pumped into the well at a rate of 15 gpm. The pressure gauge and pumping rates were continually monitored and the pressure at the wellhead did not exceed 40 psi.

The final rate was continued for the remainder of the 24-hour testing period. The drawdown data was used in conjunction with the pumping rates to obtain specific capacity values for the ASR well. Transmisivity values were determined for various methods using AQTESOLV, a computer program for pump test analysis. The results of the constant-rate pumping test are shown in **Table 2-9.**

TABLE 2-9
FLORIDAN AQUIFER STORAGE AND RECOVERY WELL
SUMMARY OF CONSTANT-RATE PUMPING TEST

Flow Rate (gpm)	Water Level (feet relative to pad level)	Drawdown (feet)	Specific Capacity (gpm/ft)	Transmissivity (gpd/ft)
1,800	5	23	78.3	NA
3,000	-16	44	68.2	NA
3,400	-26	54	63.0	142,000

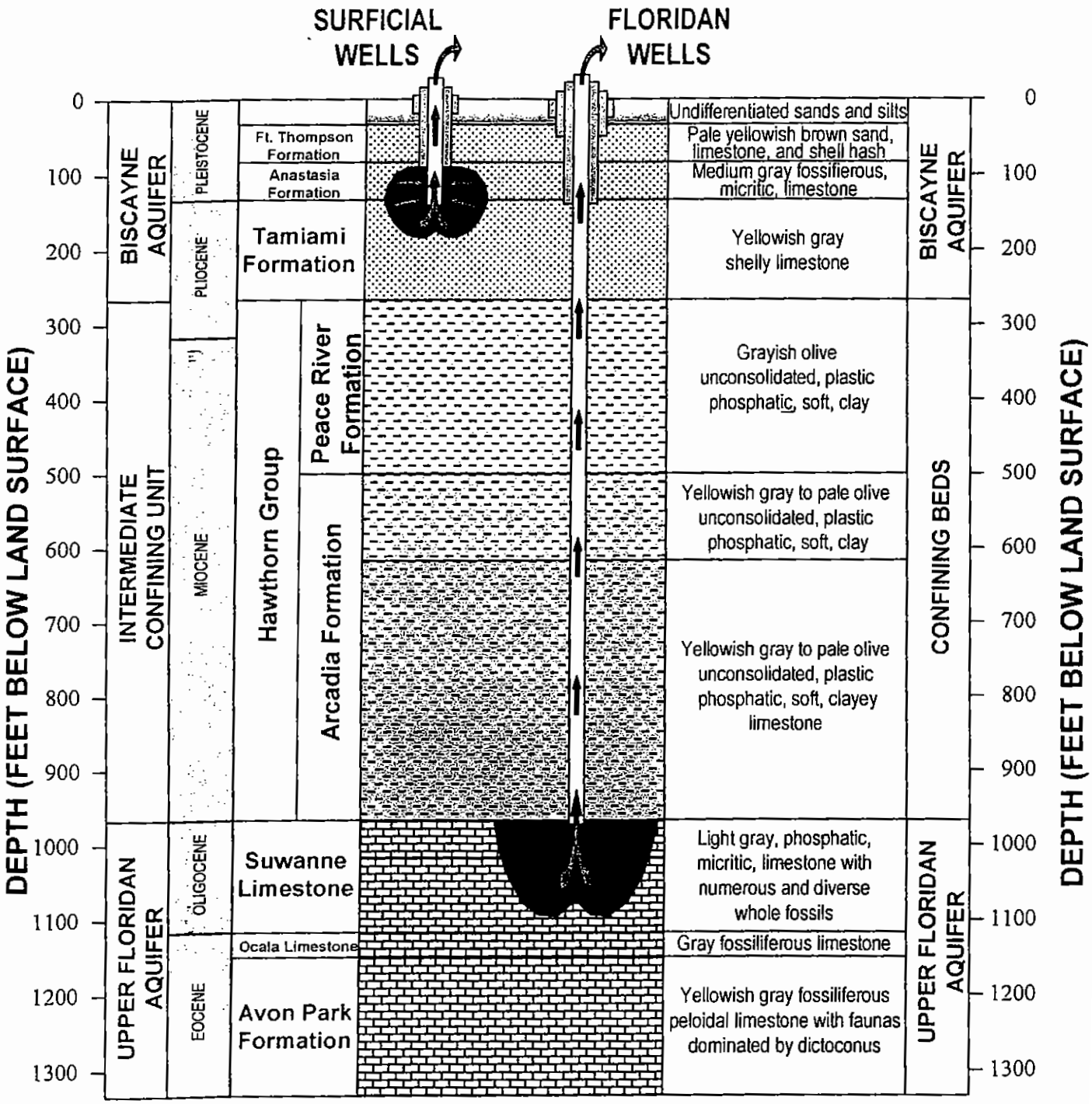
The effectiveness of the acid stimulation can be seen by examination of the pre and post acid stimulation specific capacity data. Prior to performing the acid stimulation the specific capacity of the ASR well ranged from 29.8 gpm/ft at 1,940 gpm to 24.1 gpm/ft at 3,130 gpm. Following the acid stimulation the specific capacity ranged from 78.3 gpm/ft at 1,800 gpm to 63.0 gpm/ft at 3,400 gpm. The increase in specific capacity corresponds to approximately 265 percent.

Final Water Sample

Following completion of the constant-rate pumping test, water samples were collected from the ASR well by laboratory personnel from Envirodyne, Inc. These samples were analyzed for primary and secondary drinking water standard constituents, as specified in the FDEP construction permit. The laboratory results for this sampling event are contained in Appendix J.

Cement Bond Log

A cement bond log (CBL) was run in the final casing of the ASR well to evaluate the strength and continuity of the cement to the casing and cement to formation bond as required under Special Condition 3.1.6) of the construction permit. This log detects potential voids in the grout sheath around the casing by measuring the acoustic properties of the cemented casing. Below are the details of the CBL results. Copies of these logs are contained in **Appendix C** of this report.



EASTERN HILLSBORO CANAL - WTP #9
GENERALIZED GEOLOGY and HYDROLOGY
Figure 3-1

Generally, the flow rate was observed to increase as depth increased throughout the pilot borehole. Water quality was also observed to worsen as depth increased.

Well Development

Upon completion of the plug-back of the FAMW and open hole drilling in the ASR well, the open hole of each well was developed by air-lift surging and turbine pumping. During development, sand content was recorded. Development was terminated when the sand content decreased appreciably from the initial concentrations at the desired flow rate of approximately 3,500 gpm.

WATER QUALITY

Constant-Rate Pump Test Water Sample Analysis

Upon completion of the pumping portion of the constant-rate test in both the ASR and FAMW wells, a final construction water quality sample was collected. These water samples represents the open hole interval from 1,005 feet bpl to 1,225 feet bpl (the storage/monitor interval). The laboratory results indicated there were no exceedances of primary drinking water standards in water collected from the completed ASR storage interval and the FAMW monitoring interval. Analyses of selected cations and anions indicate the water in the upper Floridan aquifer is brackish. A summary of the laboratory results is presented in **Table 3-2**.

TABLE 3-2
FINAL CONSTRUCTION WATER QUALITY SUMMARY

Parameter	Units	FAMW Well Concentration	ASR Well Concentration	MDL
Chloride	mg/L	2,300	2,100	10
Total Dissolved Solids	mg/L	4,400	4,400	10
Conductivity (lab)	umhos/cm	8,200	8,300	--
Sulfate	mg/L	1,000	470	100
pH		7.6	7.6	0.01
Calcium Hardness	mg/L	320	350	5
Total Hardness	mg/L	819	803	10
Total Alkalinity	mg/L	140	150	1
Arsenic	mg/L	BDL	BDL	0.01
Iron	mg/L	0.1	0.077	0.01
Phosphate	mg/L	BDL	0.039	0.01
Sodium	mg/L	1,300	1,500	100

Section 4
Cycle Testing Plan

Upon FDEP and PBCHD approval, cycle testing of the ASR system will commence. Cycle testing will be conducted to evaluate the performance of the well during injection, storage and recovery, and to fulfill the requirements within the FDEP and PBCHD construction permits. It is anticipated that recharge and recovery rates will be at 3,500 gpm equivalent to 5.0 mgd. Cycle testing will include two cycles. The first cycle will be used to evaluate the system performance at the designed injection and recovery rates, to observe injection pressures, to build the fresh water "bubble", and to monitor the effects of injection and recovery on water quality. The second cycle will be used to continue "bubble" development and evaluate the effects of a simulated storage interval. **Table 4-1** summarizes the cycle testing plan.

TABLE 4-1
CYCLE TESTING PLAN

Cycle Number	Recharge Rate (gpm)	Recharge** Days	Recharge Volume (mg)	Storage Days	Recovery Volume (mg)
1	3500	90	453.6	Variable	*
2	3500	90	453.6	0	*

"*" Signifies that water will be recovered until chloride concentration exceeds 1,000 mg/L.

"**" Signifies that recharge amounts may vary based upon the months which the cycles occur.

Cycle Durations:

During the cycle testing, recovery efficiencies (recovery volume/recharge volume) will be calculated for each cycle. It is anticipated that recovery efficiencies will progressively increase throughout each of the cycles. Cycle 1 will consist of one 90-day recharge period (with variable storage time) to determine the injection rate/pressure relationship, establish a baseline effect of recharge water on the storage zone, and to observe the effects of storage on water quality and recovery efficiencies. The variable storage time for Cycle 1 will depend upon the water needs during the peak season. Peak season begins in March and runs through June. A 60-day storage period is anticipated, however, storage may be cut short due to supply and demand. Cycle 2 will consist of one 90-day recharge period with no storage period to further build the "bubble". These cycles will approximate the injection and storage periods which will be utilized during normal operations (presumably after a bubble of sufficient size has

Data to be inserted

Data to be inserted