VERRASTRO

ENGINEERING REPORT
on the Preliminary Results of the

FLORIDA KEYS AQUIFER STORAGE AND RECOVERY TEST PROGRAM AT STOCK ISLAND

FLORIDA KEYS
AQUEDUCT AUTHORITY

For The
FLORIDA KEYS AQUEDUCT AUTHORITY
Key West, Florida

Prepared by
CH2M HILL

SEF19915.W4
March 1992

Engineers
Planners
Economists
Scientists

March 6, 1992

SEF19915.W4

Dr. Harley Young, P.E.
Florida Department of
Environmental Regulation
2269 Bay Street
Fort Myers, FL 33901-2896

CERTIFIED MAIL
RETURN RECEIPT REQUESTED

Dear Dr. Young:

Subject: Engineering Report on the Preliminary Results of the Florida Keys Aquifer Storage and Recovery Test Program at Stock Island, Florida

On behalf of the Florida Keys Aqueduct Authority (FKAA), enclosed is a copy of the Engineering Report on the Preliminary Results of the Florida Keys Aquifer Storage and Recovery (ASR) Test Program at Stock Island, Florida. This report is presented in fulfillment of the requirements of Permit Numbers UC44-196505 and UC44-196507 for the construction of an ASR well and a drainage well at the site.

If we can be of any further assistance, please contact Rich Schoeck of the FKAA at (305) 296-2454 or me at (305) 426-4008.

Sincerely,

CH2M HILL

Peter J. Kwiatkowski
Project Manager

pk/100107A0.DFB
cc: Richard Schoeck/FKAA
Paul Mitchell/FKAA
Albert Muniz/CH2M HILL/DFB
Ken Williams/CH2M HILL/KWF
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Vince Melee/FDER/Fort Myers
Don White/FDER/West Palm Beach

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Executive Summary

The Phase I investigation of Aquifer Storage and Recovery (ASR) feasibility at the Stock Island site has been completed with encouraging results. Coring and drilling conducted at the observation borehole during Part I of this program indicated that the unconsolidated sand/gravel zone used for ASR purposes at Marathon was not present at Stock Island. However, a limestone interval from approximately 680 to 716 feet below land surface (bls) has been identified as a potential zone for storage of potable water. This interval is confined above by approximately 430 feet of low-permeability sediments, which would tend to impede vertical flow of the more buoyant injected waters from within the storage interval. The borehole was advanced to a depth of 750 feet bls but lower confinement was not identified in the drill cuttings.

A 16-inch-diameter ASR well was constructed with steel casing from land surface to 680 feet bls. The borehole was plugged back with neat cement from 750 to 716 feet bls; therefore the open-hole interval from 680 to 716 feet bls is the target ASR zone. Geophysical logging and specific capacity testing were conducted to determine preliminary hydraulic characteristics of this zone. Results of this testing indicate a specific capacity of approximately 3.2 gallons per minute per foot (gpm/ft) and an approximate transmissivity of 6,400 gallons per day per foot (gpd/ft). Based on the fluid resistivity log conducted during the first short-term pumping test, the native aquifer water is saltwater.

CH2M HILL recommends that the Florida Keys Aqueduct Authority (FKAA) proceed with cycle testing of this ASR zone. FKAA staff have previously indicated that they will perform design and construction of an ASR surface facility, complete with pump and appurtenances to facilitate ASR cycle testing. Based on the data collected to date, a 6-inch-diameter line and 300 gallons per minute (gpm) capacity submersible pump should be sufficient to handle the expected flow capacities. When these surface facilities are in place, an 8-hour constant-rate pumping test should be conducted to better estimate aquifer characteristics within the storage interval. Water samples should be obtained during this test and analyzed for primary and secondary drinking water standard parameters. This data can be used to determine the necessary water quality parameters to be analyzed for optimal cycle testing.

Cycle testing should consist of a minimum of three cycles (5 million gallon volumes each) of injection and recovery as follows:

- Cycle 1—Inject and recover approximately 5 million gallons of potable water. No storage is planned. Recovery should begin immediately after the injection cycle and continue until background water quality is reached. This cycle will evaluate the mixing properties of the storage zone and attempt to determine if upconing of saltwater from below is occurring.

- Cycle 2—This cycle is the first of two cycles to evaluate improvement in water quality with successive equal-volume cycles. Inject and immediately recover 5 million gallons of potable water with no planned storage until the 250 milligram per liter (mg/l) chloride level is obtained. The purpose of this cycle is to evaluate the improvement in water quality and to estimate formation plugging potential.

- Cycle 3—This cycle will be run similarly to Cycle 2. It will further evaluate and compare the results to previous cycles.

At the conclusion of these cycle tests, the data should be evaluated to determine the feasibility of ASR in Stock Island. If results of cycle testing indicate ASR is feasible at Stock Island, additional cycle tests involving storage periods of approximately 30 to 60 days should be conducted to determine the effects of density stratification within the aquifer. Concurrently, a disinfection facility should be designed and constructed so that potable water could be recovered back to the distribution system.

Introduction

Aquifer Storage and Recovery (ASR) is the storage of treated drinking water underground when excess supplies are available, thus creating an "underground storage reservoir". In the Florida Keys, this water will be recovered for potable use for emergency and seasonal demands.

Phase I of ASR for the Florida Keys Aqueduct Authority (FKAA) involved a review of data and documents available for the Florida Keys area. The results of this review indicated that subsurface conditions existed that could be favorable for ASR. Subsequently, Phase II was initiated to collect specific hydrogeologic data in the vicinity of the Marathon Pump Station. The data and information gathered during Phase II identified an interval at approximately 400 feet in depth that appeared favorable for ASR. Based on this favorable data, a test ASR facility was implemented in Phase III at Marathon.

The Phase III investigation at Marathon included constructing and testing an observation well (OW-1) and an aquifer storage and recovery well (ASR-1). Data obtained included well construction information, lithologic and core descriptions, water quality data for native and injected waters, and results of cycle testing. Cycle test results indicated that more than 70 percent of injected water could be retrieved successfully before reaching the 250 mg/l drinking water standard for chlorides. Additionally, recovery percentages increased with successive cycles at the same volume. Based on this encouraging data, a test program at Stock Island, similar to that completed as Phase III at Marathon was recommended.

This report presents the information and data collected during drilling and testing of an observation well (OW-1) and an aquifer storage and recovery well (ASR-1) at the Stock Island site. Data presented includes well construction information, lithologic and core descriptions, geophysical logs, specific capacity tests, and recommendations for continued study.

Construction and Testing Activities

Phase I Construction

Site Description

The Stock Island ASR site is located at the Florida Keys Aqueduct Authority's (FKAA) Reverse Osmosis (RO) Plant in Section 35, Township 67 South, and Range 25 East. The ASR well is located at latitude 81° 44 feet 2 inches N, and longitude 24° 33 feet 30 inches W. Figure 1 shows the location of the project site and Figure 2 shows the locations of the observation well (OW-1), the ASR well (ASR-1), and the shallow drainage well (DW-1). ASR-1 is located 109 feet away from OW-1 and 63 feet from DW-1.

General Information

Construction permits, presented in Appendix A, were granted by the Florida Department of Environmental Regulation (FDER) on August 26, 1991, for construction of an ASR well and a shallow drainage well at Stock Island, Florida. On July 15, 1991, Youngquist Brothers Inc. of Fort Myers, Florida was given notice-to-proceed for Phase I construction of the ASR project at Stock Island for FKAA. Drilling equipment was mobilized to the site and set up at the designated location of OW-1 on July 19, 1991. Well completion diagrams of ASR-1 and DW-1 are provided in Appendix B and construction details are described below. Figure 3 shows the wellhead details for each of these wells. A chronological sequence of construction events and daily reports are presented in Appendix C.

Observation Well No. 1

Construction of OW-1 commenced with the setting of a 12-inch-diameter steel surface casing to a depth of 32 feet below land surface (bls). From the base of the surface casing, an 8-inch-diameter pilot hole was drilled to 345 feet bls using mud-rotary circulation methods. Formation samples were collected at 10-foot intervals to 345 feet during drilling to identify the lithology encountered. Detailed lithologic descriptions of the cuttings from OW-1 and ASR-1 are presented in Appendix D. Based on the existence of the sand/gravel zone at Marathon from 390 to 430 feet bls, it was determined that continuous coring would be attempted from approximately 350 to 500 feet bls. Information gathered during the coring would more accurately delineate the storage interval and determine its hydrogeologic characteristics, in addition to determining confinement above and below the zone. Specialized coring equipment, manufactured by Christensen, Inc., was used in

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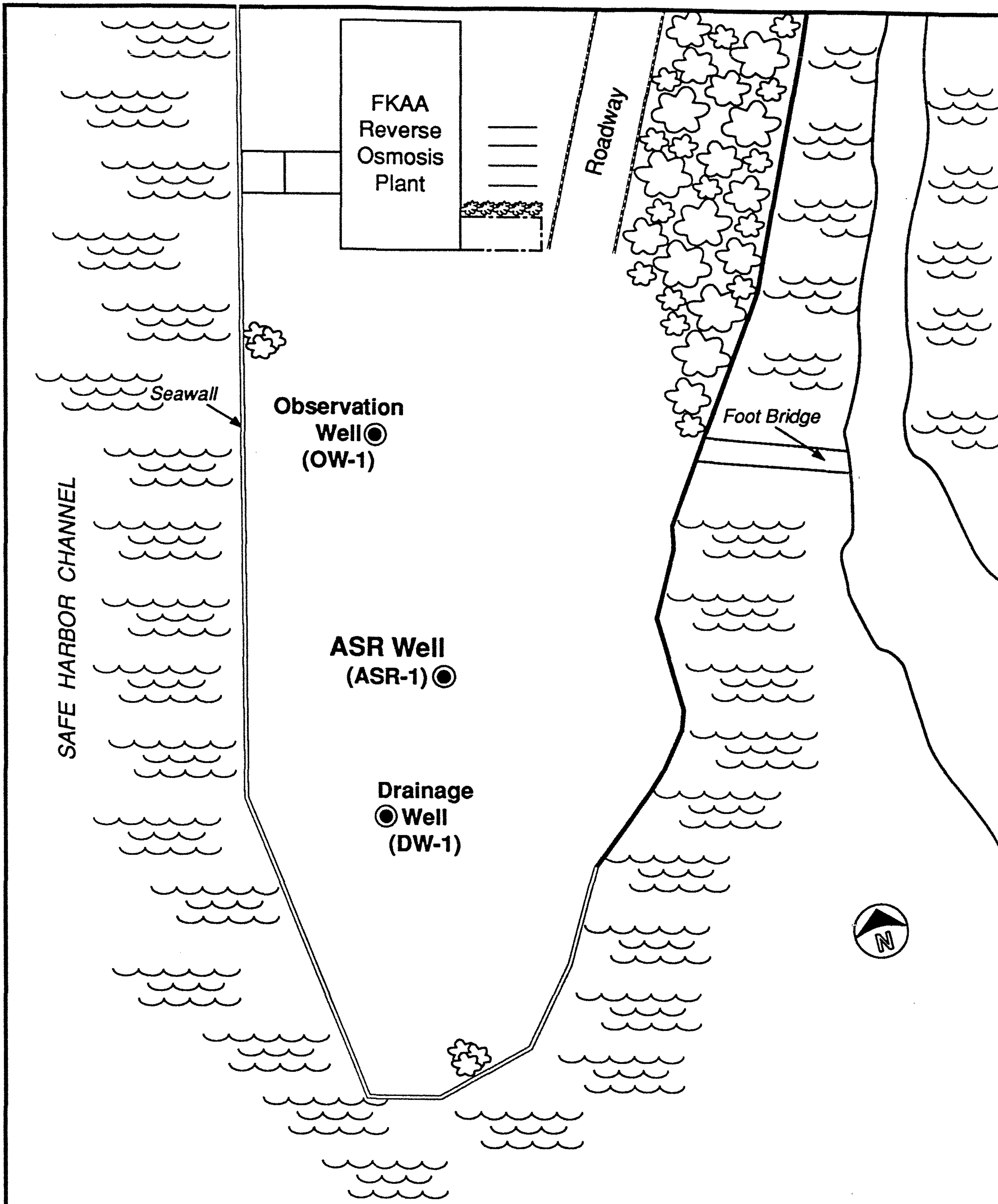

Well Distances
ASR-1 to OW-1: 109 ft
ASR-1 to DW-1: 63 ft

FIGURE 2
Site Layout

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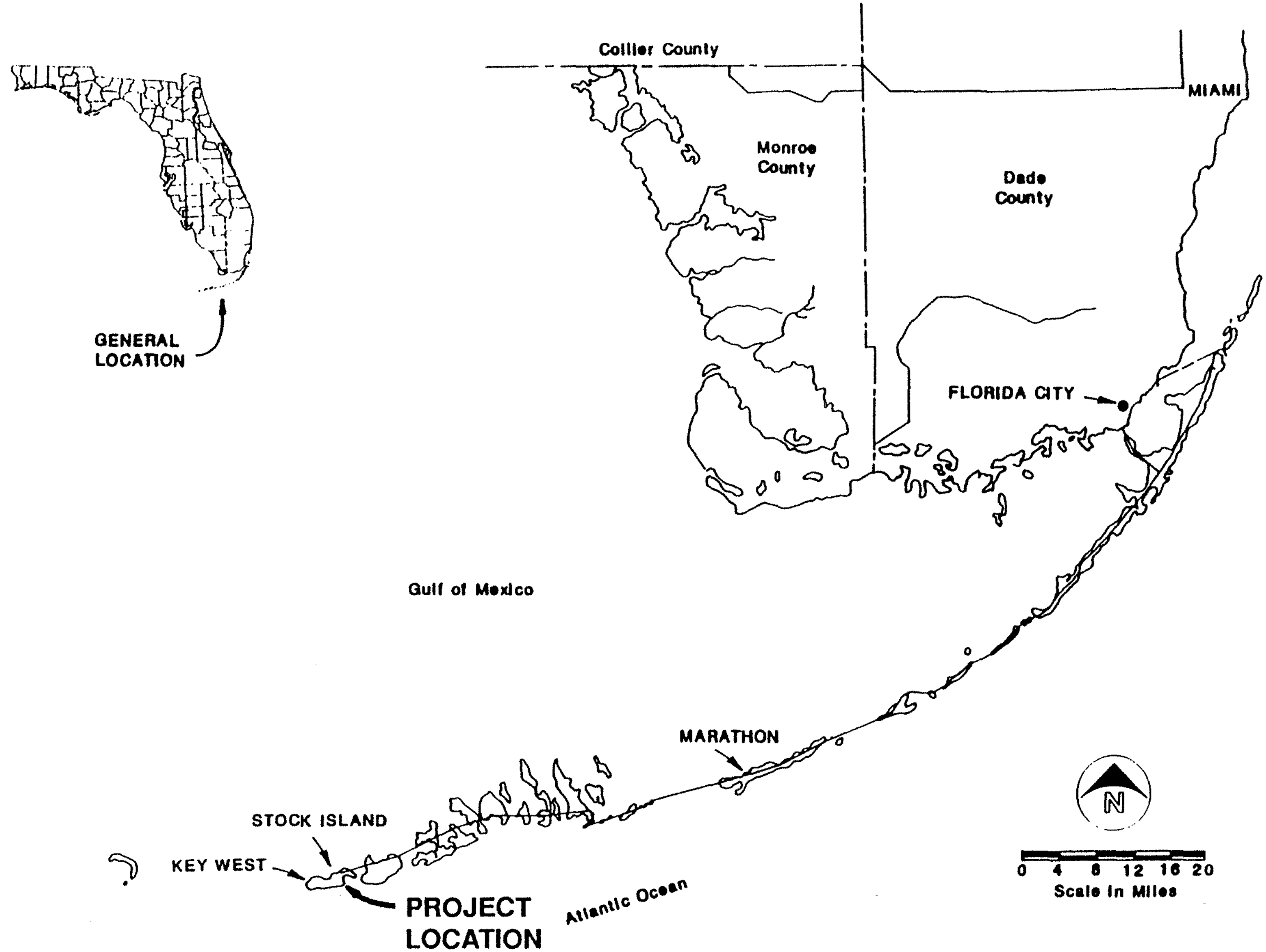

FIGURE 1
Project Location Map

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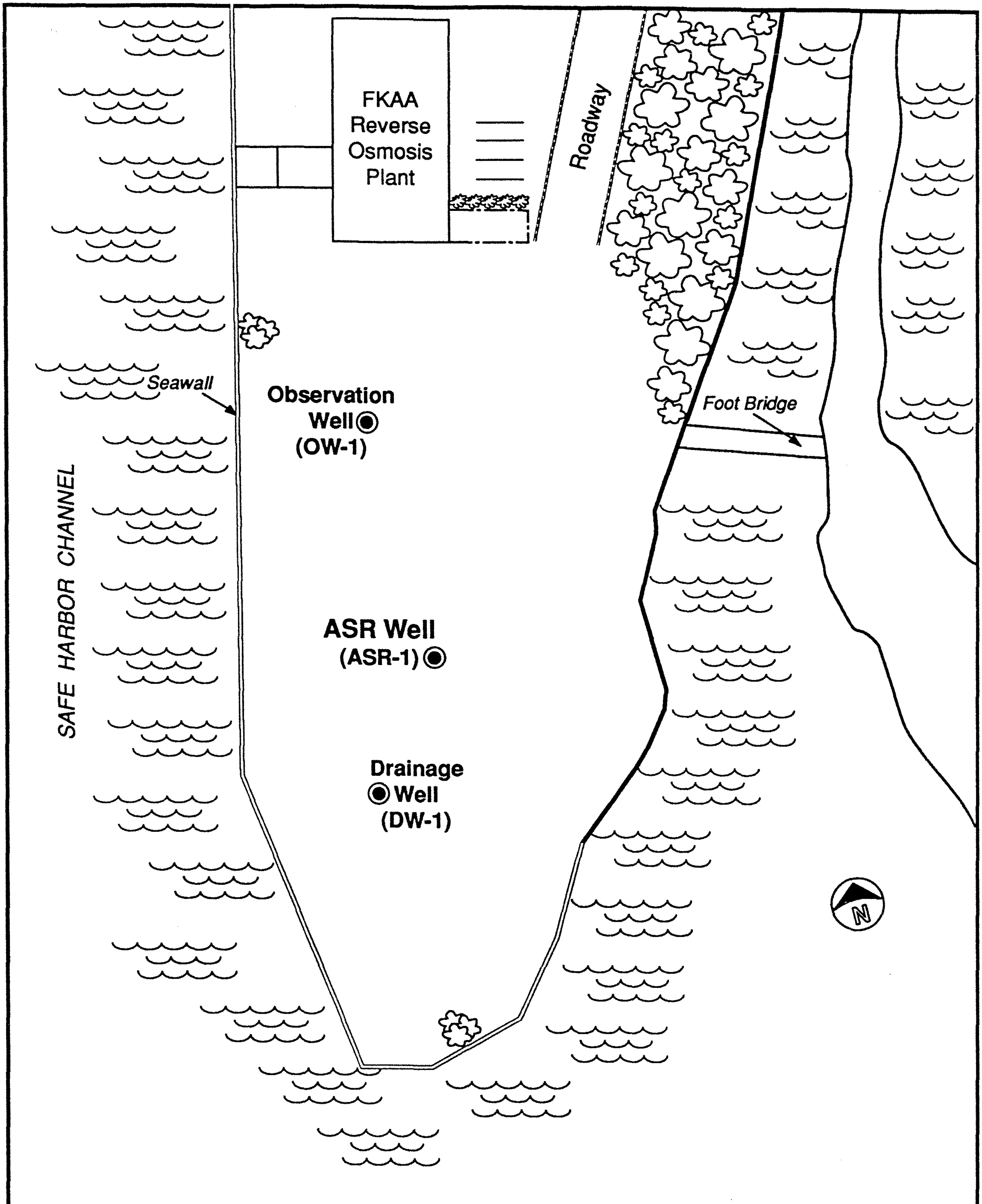

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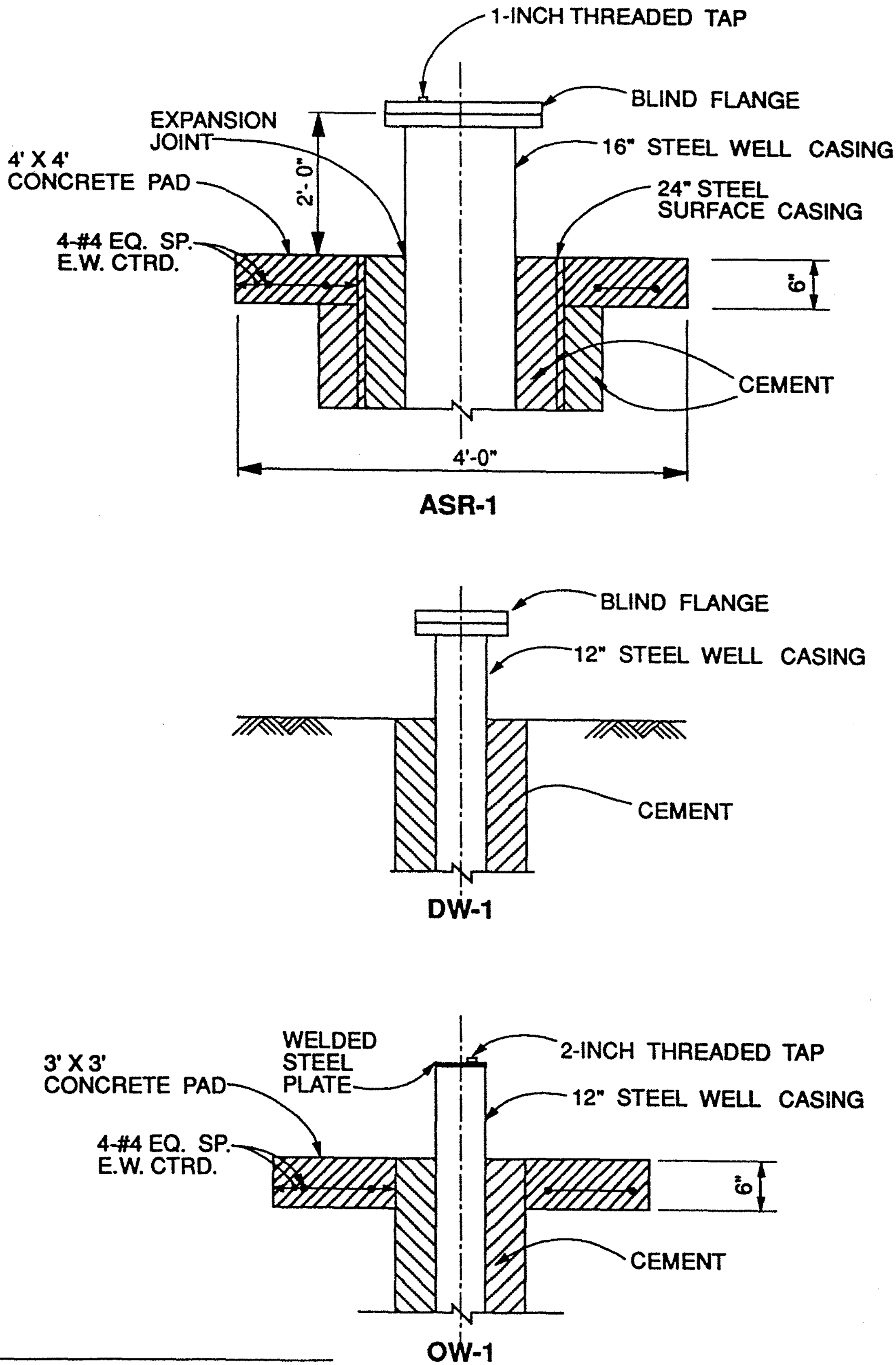

LEGEND

ASR - 1 = Aquife Storage and Recovery Well
DW - 1 = Drainage Well
OW - 1 = Observation Well

FIGURE 3
Wellhead Details for ASR-1, DW-1 and OW-1

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an effort to retrieve cores of unconsolidated materials, as previously identified at Marathon.

Coring was conducted on July 31 and August 1, 1991, beginning at an approximate depth of 350 feet bls. A total of 140.7 feet of core was attempted, with recovery measured at 138.4 feet (98.4 percent recovery). A detailed description of the cores is presented in Appendix E. Further details are contained in the Coring section of this report.

Results of the coring determined that the sand/gravel zone identified at Marathon did not exist at the Stock Island site. At this point, drilling was continued in the hope of finding a deeper zone suitable for ASR. The test hole was advanced from 490 to 680 feet bls, with cuttings obtained and analyzed every 5 feet. At a depth of 680 feet, a limestone unit initially identified as the Arcadia formation was delineated. This formation continued to a depth of 729 feet bls, where mud circulation was lost. Reverse-air drilling was attempted to advance the test hole further, but this technique proved unsuccessful in the uncased hole due to cave-in of the overlying formation.

The mud-rotary drilling technique used at OW-1 did not allow hydraulic testing of the potential ASR zone within the Arcadia Formation. It was therefore decided that work would begin at ASR-1 to determine hydraulic characteristics of the Arcadia Formation, and evaluate this data in relation to its use as an ASR zone. FDER was informed of this change in the targeted ASR zone in a letter from CH2M HILL dated September 9, 1991, and is also contained in Appendix A.

Further work on OW-1 was suspended and ultimately discontinued pending initial cycle testing. The wellhead was completed by welding a steel plate on the 12-inch-diameter casing with a two-inch threaded tap. A 3-foot square, reinforced concrete pad was poured around the well to complete the wellhead as shown in Figure 3.

Drainage Well

DW-1 was constructed by installing and cementing in place a 12-inch-diameter steel casing to a depth of 27 feet bls. The casing was cemented in place with 26 sacks of neat cement by the pressure-grout method. Following casing installation, the cement plug was drilled out, and a nominal 8-inch-diameter borehole was advanced inside the casing to a total depth of 121 feet bls. The well completion diagram for DW-1 is contained in Appendix B. Lost circulation zones were encountered at 40 feet and 114 feet bls, which facilitated disposal of pumping test waters described in the Pumping test section of this report. The drainage well was completed with a blind flange as shown in Figure 3.

ASR Well No. 1

On September 10, 1991, drilling of ASR-1 began with an 8-inch-diameter tricone roller bit using mud circulation. Using a staged reaming bit with nominal diameters of 14 and 28 inches, the borehole was reamed to a depth of 30 feet bls for installation of a 24-inch-diameter steel surface casing. After cementing the surface casing with 35 sacks of neat cement by the pressure-grout method, an 8-inch-diameter pilot hole was drilled to 750 feet bls inside the surface casing. The lithology of this borehole was described by inspecting cuttings collected at 10-foot intervals to 350 feet, and 5-foot intervals to 750 feet bls. Static geophysical logs including gamma ray, caliper, long and short normal resistivity (LSN), and spontaneous potential (SP) were run to a depth of 750 feet bls on September 27, 1991 (Table 1). Core data from OW-1, lithologic samples from both OW-1 and ASR-1, and geophysical logs from ASR-1 were used to select a casing setting depth of 680 feet bls. Geophysical logs performed on ASR-1 are contained in Appendix F. The pilot hole was then reamed with a 22-1/2-inch-diameter bit to a depth of 680 feet.

Sixteen-inch-diameter steel casing (1/2-inch wall thickness) was set from land surface to a depth of 680 feet bls, and cemented in place with 163 sacks of neat cement and 723 sacks of 12-percent bentonite cement. The well completion diagram for ASR-1 is provided in Appendix B. Copies of casing mill certificates and the casing tally are included in Appendix G. A total of nine cement stages was used to cement the well to land surface. The first stage was performed by pressure grouting, and the remaining eight stages through dual tremie pipes in the annulus between the casing and the borehole. A summary of casing and cement quantities used to construct ASR-1, DW-1, and OW-1 is presented in Table 2.

After allowing the cement to cure for 24 hours, the cement plug was drilled out and the borehole was reamed with a 14-inch-diameter bit using reverse-air drilling techniques to 715 feet bls. At this depth, the drill string was removed from the borehole, and a vertical turbine pump was installed. Set up of the turbine pump involved the installation of approximately 100 feet of pump column, a pump head, and an engine.

A 4-hour pumping test with dynamic geophysical logs (fluid velocity, temperature, and fluid resistivity) was conducted to determine hydraulic characteristics of the interval from 680 to 715 feet bls. Following this testing, the pump and geophysical probe were removed, and the drill string was reinstalled to extend the 14-inch-diameter borehole to 750 feet bls. The short-term pumping test and flow logs described above were repeated for the 680 to 750 feet testing interval. Based on this data, described in detail in the Pumping Test section of this report, the borehole was plugged back with 70 sacks of neat cement for a final ASR interval of 680 to 716 feet bls. The ASR well was disinfected with a 5 parts per million (ppm) chlorine solution for 24 hours. Following disinfection, at least one casing volume of water was evacuated from the well to remove the chlorine

Table 1
Geophysical Logging Schedule
ASR-1

Well No.	Date	Interval (feet-bls)	Nominal Borehole Diameter (inches)	Geophysical Log	Remarks
ASR-1	09/27/91	0-750	8	Natural Gamma Ray Caliper LSN SP	Borehole fluid = saltwater
ASR-1	11/01/91	680-715	14	Fluid Velocity Caliper Temperature Fluid Resistivity	Borehole fluid = saltwater
ASR-1	11/05/91	680-750	14	Fluid Velocity Temperature Caliper	Borehole fluid = saltwater

Note:
LSN = Long and Short Normal
SP = Spontaneous Potential
bls = below land surface

Table 2
CASING AND CEMENT SCHEDULE
STOCK ISLAND, FLORIDA

WELL	CASING DIAMETER (inch)	CASING TYPE	WALL THICKNESS (Inch)	CASING DEPTH (feet)	DATE CEMENTED	CEMENT TYPE	CEMENT VOLUME (sacks)	CEMENT FILL (feet)	COMMENTS
ASR WELL	24	Steel	1/2	29.5	9/10/91	Neat	40	Land Surface	First Stage
	16	Steel	1/2	680	10/19/91	Neat	162		First Stage
						12% Bentonite	200	251	First Stage
					10/20/91	12% Bentonite	79	99	Second Stage
					10/21/91	12% Bentonite	29	51	Third Stage
					10/23/91	12% Bentonite	108	68	Fourth Stage
					10/23/91	12% Bentonite	77	44	Fifth Stage
					10/24/91	12% Bentonite	52	29	Sixth Stage
					10/24/91	12% Bentonite	52	48	Seventh Stage
					10/24/91	12% Bentonite	111	75	Eighth Stage
					10/25/91	12% Bentonite	15	15	Ninth Stage
OBSERVATION WELL	12	Steel	3/8	32	7/23/91	Neat	25	22	First Stage
					7/24/91	Neat	1	3	Second Stage
DRAINAGE WELL	12	Steel	1/4	27	9/05/91	Neat	25	Land Surface	First Stage

solution. ASR-1 was developed with air-lift methods for one hour until clear, sand-free formation water was produced. The well was completed with a blind flange and a 1-inch threaded tap. A 4-foot square, reinforced concrete pad was poured to complete the wellhead as shown in Figure 3.

Lithostratigraphic Description

The lithostratigraphic description is based on evaluation of previously reported data, examination of drilling cuttings and core samples from drilling operations at ASR-1 and OW-1, and the results of geophysical logs that were run during well construction. Correlation of these data shows that the formations and depths of lithologic contacts did not vary appreciably across the site. Strata encountered at the site range in age from Miocene to more recent Pleistocene deposits. Figure 4 presents the major stratigraphic units encountered while drilling ASR-1 and OW-1, well construction of ASR-1, brief lithologic descriptions, and graphically prepared geophysical logs. Lithologic logs for ASR-1 and OW-1 are presented in Appendix D. The geophysical logs conducted at ASR-1 are contained in Appendix F and include natural gamma ray, caliper, spontaneous potential (SP), and long and short normal (LSN) electric logs.

The following lithostratigraphic description of ASR-1 and OW-1 is presented in order of geologic time, from the oldest formation to the youngest.

Miocene Series—Hawthorn Group—Arcadia Formation

The Hawthorn Group is variable in lithology and generally consists of interbedded sand, silt, clay, dolostone, and limestone, with a characteristically high phosphate content (Johnson, 1984). The early Miocene Arcadia Formation is the name applied to the lower Hawthorn Group carbonate section of South Florida (Scott, 1988). The Arcadia Formation is a slightly phosphatic limestone and dolostone, with some clay and chert (Johnson, 1984). Scott (1988) suggested a shallow marine carbonate platform as the depositional environment for the Arcadia Formation.

The top of this formation at the site was determined to be 678 feet bls, based on drill cuttings and geophysical logs. At the site, the Arcadia Formation consists of alternating hard and soft layers of white, chalky limestone and tan, fossiliferous, dolomitic limestone. This formation extended to at least a depth of 750 feet bls, as delineated on the gamma log and from drill cuttings. The natural gamma log indicates a sharp increase in gamma counts at a depth of 678 feet. Sharp peaks on gamma logs frequently indicate lithologic contacts or changes. The LSN log showed an increase in electrical response indicating relatively high resistivity and porosity. The caliper log showed an increase in hole diameter at an approximate depth of 730 feet which corresponds to a lost circulation zone encountered at OW-1.

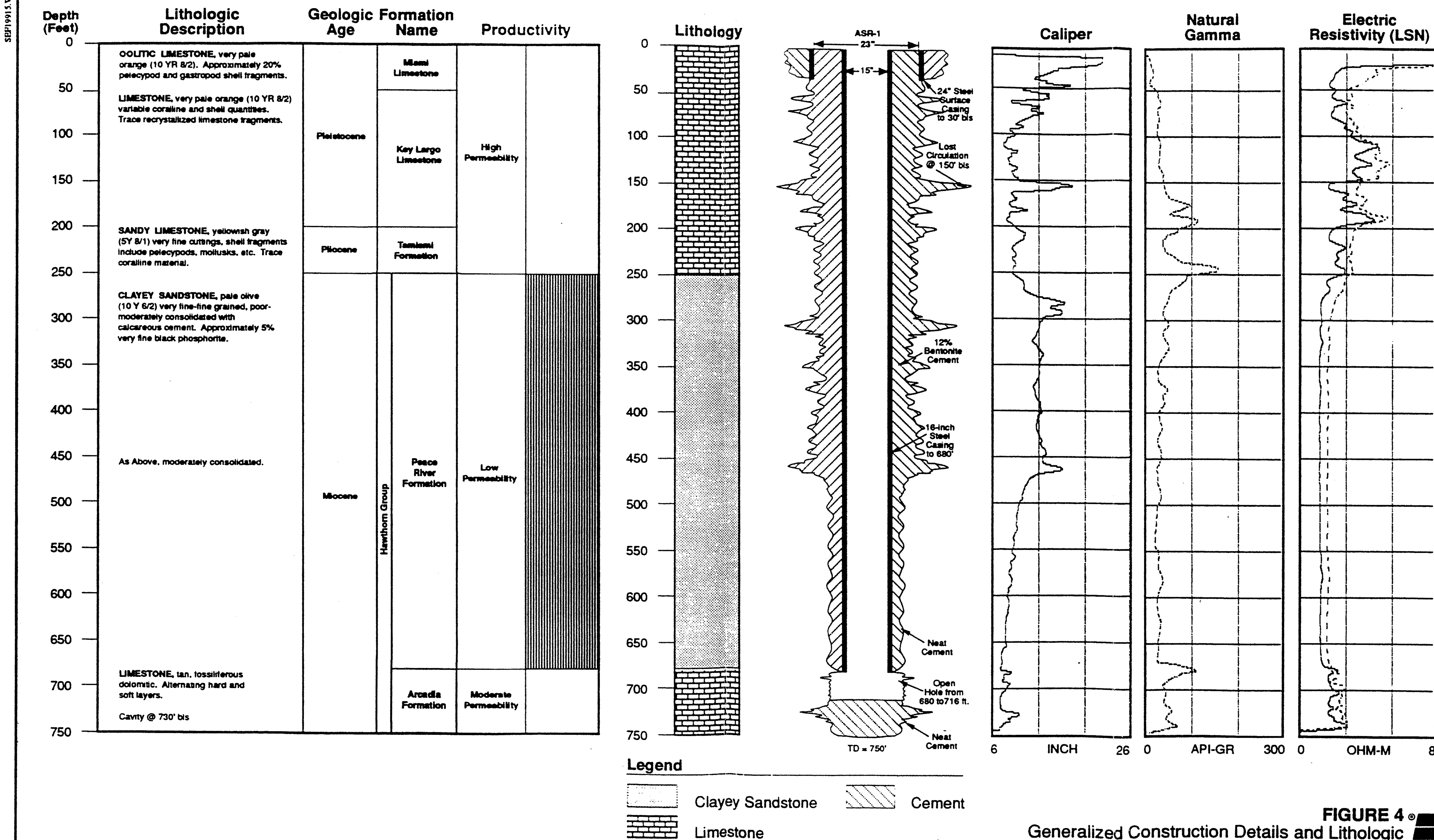

FIGURE 4
Generalized Construction Details and Lithologic Features for the ASR Well in Stock Island, Florida

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Miocene Series—Hawthorn Group—Peace River Formation

The Peace River Formation is the name for the upper Hawthorn Group sediments in southern Florida (Scott, 1988). It consists of poor-to-moderately consolidated clastics that are calcareous to dolomitic, clayey, phosphatic sands and clayey sands. The Peace River Formation overlies the Arcadia Formation, together constituting the Hawthorn Group. At the ASR-1 and OW-1 boreholes, the top of the Peace River Formation occurs at a depth of approximately 245 feet bls. The formation appears as a yellowish-gray, poor-to-well consolidated calcareous, clayey sandstone, with round- to subangular-grained sand in a calcareous cement. Trace black grains of phosphorite were also part of the matrix which result in a relatively uniform response on the natural gamma ray log. The formation occurs from 245 to approximately 678 feet bls as determined by a change in drilling characteristics at these depths, and as shown on the caliper log. Characteristic high gamma counts, reflecting higher phosphate content and formation contacts, are also found on the natural gamma ray log at depths of 245 and 678 feet bls. The LSN and SP logs show little variation in signal response with depth throughout this formation, indicating its uniformity. The thickness of the formation is approximately 433 feet at the site. Additional lithologic data from 348 to 489 feet bls at OW-1 is presented in the Coring section of this report and Appendix E.

Pliocene Series—Tamiami Formation

The Tamiami formation, as reported by Parker and Cooke (1944), is primarily composed of white- to cream-colored calcareous sandstone, sandy limestone, and intermittent beds of quartz sand. The formation boundaries at the project site were based on lithologic descriptions and gamma ray and SP response. At the site, the formation is a greenish-gray clayey sandstone that occurs from approximately 200 to 245 feet bls. The base of the Tamiami formation was distinctly marked by an increase in gamma ray activity at 245 feet bls. The LSN log showed an increase in resistivity throughout this interval. The SP log shows definite inflections at depths of approximately 200 and 245 feet, delineating the top and bottom of the formation. The caliper log at ASR-1 indicated a relatively stable hole diameter of approximately 9 inches throughout this interval.

Pleistocene Series—Key Largo Limestone

The Key Largo Limestone is a predominantly coralline reef rock and crops out from Soldier Key in Biscayne Bay to Bahia Honda (Schroeder et al., 1958). The Key Largo Limestone varies in thickness from 75 to over 200 feet (Lane, 1986). At the project site, this formation is a very pale-orange to white, hard and cavernous, solution-riddled, coralline limestone with varying quantities of shell and recrystallized limestone. It rests conformably on the Tamiami Formation and is approximately 150 feet thick. A uniform response on the SP log was observed from 50 to 200 feet bls. The LSN log at ASR-1 indicated relatively higher resistivity with significant porosity because of the hard, cavernous limestone encountered during drilling. At a depth of approximately 150 feet bls, the long and short normal signatures converge, indicating increased porosity. This geophysical signature correlates well with the lost circulation zone encountered at a depth of approximately 150 feet during mud-rotary drilling. The caliper log indicated a relatively more fractured lithology than that in the older formations. The caliper log indicates that the largest hole diameters (approximately 23 inches) occur at depths of 49 and 158 feet bls within this formation. The gamma log is relatively stable, except at depths of approximately 180 and 190 feet where gamma counts increased.

Pleistocene Series—Miami Limestone

The Miami Limestone is a very permeable, tidal-shoal deposit which is usually cross-bedded (Hoffmeister, 1974). It underlies the Atlantic coastal ridge in Dade and Broward counties, floors Florida Bay, and crops out again from Big Pine Key to Key West overlying the Key Largo Limestone (Parker and Cooke, 1944). At the site, it is characterized by a very-pale orange and white oolitic limestone, layered with significant quantities of shells and shell fragments. The shell fraction is dominated by pelecypods, with some gastropods and mollusks. Some coralline material is also present, and is usually recrystallized. The formation extends from land surface to an approximate depth of 50 feet bls. The caliper log shows a jagged appearance typical of fractured limestone formations. Slight inflections in the natural gamma ray and SP logs may also indicate the formation change between the Miami Limestone and the overlying Key Largo Limestone.

Coring

Coring was conducted at the OW-1 borehole to obtain detailed lithologic data of the planned ASR zone and confining units. Coring at the OW-1 borehole was conducted through the 4-inch-diameter drill string with wireline apparatus. This coring apparatus, manufactured by Christensen Mining Products Inc., can be distinguished from conventional coring techniques in that it is equipped with core catchers designed to retrieve cores of unconsolidated sediments. A total of 140.7 feet of core was attempted from approximately 348 to 489 feet bls. This resulted in 138.4 feet of recovery (98.4 percent) through the cored interval. A summary of the coring sequence with depth sampled, length attempted and recovered, and lithologic descriptions is presented in Appendix E.

In summary, the cores indicated an interval of poor-to-well consolidated sandstone with a calcareous, clayey matrix with some pelecypod shells and moldic porosity from 348 through 489 feet bls. These sediments are correlated with the Peace River Formation of the Hawthorn Group. Cores obtained indicated that the sand/gravel layer used as the ASR zone at the FKAA Marathon ASR facility was not present at Stock Island. Therefore, drilling was continued to locate another potential ASR zone as described previously.

Pumping Tests

Background Information

Two short-term (4- to 8-hour) pumping tests were conducted at the ASR well. These tests were conducted in conjunction with geophysical logging to delineate the most suitable hydraulic zone for ASR implementation. These tests were also used to estimate the specific capacity and therefore expected drawdown levels during future operation. A vertical turbine pump with approximately 100 feet of drop pipe was placed in ASR-1 and connected to a 6-inch-diameter discharge line hardpiped to DW-1. A Rockwell turbine flow meter/totalizer was connected in line with the discharge line to record flow measurements during the test.

First Short-Term Pumping Test

The first short-term pumping test was conducted at ASR-1 on November 1, 1991. The test was conducted on the open-hole interval from 680 to 715 feet bls. This test consisted of operating the vertical turbine pump for 4 hours at a rate of approximately 170 gallons per minute (gpm). During this test, a drawdown of approximately 53 feet was observed. Geophysical logs were also run during this test to determine flow characteristics of the interval. Geophysical logs included temperature, fluid resistivity, caliper and fluid velocity and are also contained in Appendix F. Analysis of this first flow log indicates that most of the flow originated from the upper portions of the open-hole interval from 680 to 700 feet bls. The temperature log showed a slight decrease in water temperature across the tested interval. A relatively constant fluid resistivity of approximately 0.3 ohm-meters indicates that the native aquifer fluid is saltwater.

Second Short-Term Pumping Test

The second short-term pumping test was conducted at ASR-1 on November 5, 1991. The test was conducted on the open-hole interval from 680 to 750 feet bls. This test consisted of operating the vertical turbine pump for 4 hours at a rate of approximately 700 gpm. Results of this test indicated a drawdown of approximately 77 feet at this flow rate. Dynamic geophysical logs were also run during this short-term test to determine flow characteristics of the interval. Inspection of this second flow log indicates a significant flow zone at an approximate depth of 730 feet bls. This depth corresponds to a fracture noted on the caliper log conducted after pilot hole drilling. Below this depth to 750 feet bls, the flow log does not indicate significant flow production. A relatively even distribution of flow from small producing intervals was observed from 680 to 715 feet bls.

The temperature log showed very little change across the tested interval. Slight deflections on the temperature log were noted at depths of 683, 692, and 732 feet bls, indicating potential flow zones. These depths also correspond to fractures delineated on the caliper log—especially at 683 and 732 feet bls. The fluid resistivity log was not conducted over this interval because the previous log showed no change over the tested interval and none was expected—given the strongly saline water within the aquifer. A second step rate conducted during this test at 450 gpm showed a corresponding drawdown of 45 feet.

Results

A summary of the hydraulic data determined from the preliminary specific capacity testing is presented in Table 3. Specific capacity data are presented in units of gallons per minute per foot (gpm/ft). From this data, it is apparent that the zone from 680 to 715 feet bls has a lower specific capacity (3.2 gpm/ft) than the interval from 680 to 750 feet bls (9.1 to 10.0 gpm/ft). The greater specific capacity in the 680 to 750 feet bls interval may be related to the large fracture observed on the caliper log (Appendix F) at an approximate depth of 730 feet bls.

Estimates of transmissivity were made from a method presented by Driscoll (1986) relating specific capacity and aquifer conditions according to the equation:

$$T = 2000\ Q/s$$

where:

T = Transmissivity (gpd/ft)
Q = Pumping rate (gpm)
s = Drawdown in the pumping well (ft)

From this equation, estimates of transmissivity for the two short-term pumping tests would be 6,400 and 18,200 gpd/ft, respectively, reflecting, in part, the increase in transmissivity associated with the greater length of the tested interval.

Table 3
Summary of Hydraulic Data from
Specific Capacity Tests at ASR-1
Stock Island, Florida

Date	Flow Rate (gpm)	Drawdown (feet)	Interval Tested (feet btoc)	Specific Capacity (gpm/ft)	Estimated Transmissivity (gpd/ft)
11/01/91	170	53	680 - 715	3.2	6,400
11/05/91	700	77	680 - 750	9.1	18,200
11/05/91	450	45	680 - 750	10.0	20,000

Notes:

gpm = gallons per minute
btoc = below top of casing
gpd/ft = gallons per day per foot

Recommendations

CH2M HILL recommends that the FKAA proceed with cycle testing of this ASR zone. FKAA staff have previously indicated that they will perform design and construction of an ASR surface facility, complete with pump and appurtenances to facilitate ASR cycle testing. Based on the data collected to date, a 6-inch-diameter line and 300 gallons per minute (gpm) capacity submersible pump should be sufficient to handle the expected flow capacities. When these surface facilities are in place, an 8-hour constant-rate pumping test should be conducted to better estimate aquifer characteristics within the storage interval. Water samples should be obtained during this test and analyzed for primary and secondary drinking water standard parameters. This data can be used to determine the necessary water quality parameters to be analyzed for optimal cycle testing.

Cycle testing should consist of a minimum of three cycles (5-million-gallon volumes each) of injection and recovery as follows:

- Cycle 1—Inject and recover approximately 5 million gallons of potable water. No storage is planned. Recovery should begin immediately after the injection cycle and continue until background water quality is reached. This cycle will evaluate the mixing properties of the storage zone and attempt to determine if upconing of saltwater from below is occurring.

- Cycle 2— This cycle is the first of two cycles to evaluate improvement in water quality with successive equal-volume cycles. Inject and immediately recover 5 million gallons of potable water with no planned storage until the 250 milligram per liter (mg/l) chloride level is obtained. The purpose of this cycle is to evaluate the improvement in water quality and to estimate formation plugging potential.

- Cycle 3—This cycle will be run similarly to Cycle 2. It will further evaluate and compare the results to previous cycles.

At the conclusion of these cycle tests, the data should be evaluated to determine the feasibility of ASR in Stock Island. If results of cycle testing indicate ASR is feasible at Stock Island, additional cycle tests involving storage periods of approximately 30 to 60 days should be conducted to determine the effects of density stratification within the aquifer. Concurrently, a disinfection facility should be designed and constructed so that potable water could be recovered back to the distribution system.

Summary and Conclusions

Phase I construction at Stock Island has been completed with the drilling, testing, and installation of two wells: a 16-inch-diameter ASR well (ASR-1) to a depth of 716 feet, and a 12-inch-diameter drainage well (DW-1) to a depth of 121 feet. Final construction of the observation well (OW-1) was suspended pending results of cycle testing.

Coring performed at OW-1 from approximately 350 to 490 feet below land surface (bls) showed that the unconsolidated sand/gravel layer functioning as the ASR zone at Marathon did not occur at the Stock Island site. Therefore, drilling was continued in search of another suitable zone. Such a zone was found at a depth of approximately 680 feet bls, where a tan, dolomitic limestone was encountered.

Geophysical logging and hydraulic testing indicate that the selected limestone interval from 680 to 716 feet bls has a specific capacity of approximately 3.2 gallons per minute per foot (gpm/ft) and contains saltwater. These hydraulic characteristics are similar to those of the unconsolidated sand/gravel zone at the Marathon ASR site, which has shown that storage of potable water within a saline aquifer is possible.

From an ASR perspective, this site is somewhat different than Marathon. The storage zone is limestone, which is similar to all other operating ASR systems in Florida except Marathon. The Stock Island site also has uncertain lower confinement. Testing will be required to determine a suitable recovery flow rate that will not cause upconing of saltwater from below, and the associated recovery efficiency characteristics with successive cycles.

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