City of Naples Well Completion Report for Aquifer Storage and Recovery Well No. 2

March 2011

HAZEN AND SAWYER
Environmental Engineers & Scientists

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Hazen and Sawyer, P.C.
Boca Corporate Center
2101 NW Corporate Boulevard, Suite 301
Boca Raton, Florida 33431
(561) 997-8070
Fax: (561) 997-8159

March 9, 2011

Robert Middleton
Utilities Director
CITY OF NAPLES
380 Riverside Circle
Naples, Florida 34102

City of Naples
ASR Test Well No. 2
Well Completion Report

Dear Mr. Middleton:

Enclosed please find a copy of the Well Completion Report summarizing the construction and testing activities of Aquifer Storage and Recovery (ASR) Well No. 2 (i.e., ASR-2) and Monitor Well Nos. 1 and 2. We sincerely appreciate the opportunity to assist the City of Naples with this challenging project.

As always, please feel free to call should you have any questions.

Very truly yours,
HAZEN AND SAWYER, P.C.

Albert Muniz, P.E. / Project Director
Vice President

c: David Graff / City of Naples
Ben Copeland / City of Naples
Justin Frederiksen / City of Naples
Ken Kemlage / City of Naples
H&S – 41000-004.4.7
Jim Wheatley / H&S – WTA
Eric Stanley / H&S
John Koroshec / H&S

Acknowledgements

On behalf of Hazen and Sawyer, we would like to sincerely thank all of the individuals who assisted in making this project a success. We would especially like to thank the following:

City of Naples

Mr. William Moss / City Manager
Mr. Robert Middleton / Utilities Director
Mr. Justin Frederiksen / Deputy Utilities Director
Mr. David Graff / Project Manager
Mr. Ben Copeland / Budget and CIP Manager
Mr. Ken Kemlage / Water Reclamation Facility Superintendent
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Ms. Zayli Perez

Florida Department of Environmental Protection

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Mr. Joseph Haberfeld

South Florida Water Management District / Big Cypress Basin

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Mr. Max Guerra

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EXECUTIVE SUMMARY

The City of Naples is seeking alternative water supplies in an effort to reduce potable water consumption since irrigation demands have been the largest demand on the City's potable water system. To reduce the stress on the potable water system and reduce the City's per capita consumption, the City has moved forward with development of alternative water supplies. This initiative is being implemented in conjunction with regulators to ensure permit compliance. The City's alternative water supply plan consists of a strategy that includes close coordination with the Big Cypress Basin and the South Florida Water Management District (District), as well as the Florida Department of Environmental Protection (FDEP).

This element of the overall alternative water supply program consists of development of an aquifer storage and recovery (ASR) system that includes ASR wells, monitor wells and appurtenances. The ASR system, which will use both reclaimed water and canal surface water, is a critical component of the City's Integrated Water Supply Plan. One ASR well, identified as ASR-1, has been constructed as part of Phase 1. The second phase included construction and testing of a second ASR well (i.e., ASR-2) and two monitor wells. Monitor Well No. 1 (MW-1) is a dedicated storage zone monitor well as requested by FDEP while Monitor Well No. 2 (MW-2) is designed to monitor the first permeable zone near the 10,000 mg/L total dissolved solids (TDS) interface. A summary of the drilling and testing of ASR-2, MW-1 and MW-2 is presented in this well completion report

The City of Naples was issued a Water Use Permit (WUP) No. 11-00017-W on June 12, 2003 and expired on June 12, 2008. A renewal WUP application was prepared and submitted to the District in June 2008. To date, two requests for additional information have been issued by the District and responded to by the City. A key component of the WUP is the implementation of an alternative water supply program to assist with reduction of potable water consumption. The proposed alternative water supply program consists of development of an ASR system that utilizes both reclaimed water and excess surface water. The District accepted the City's water supply strategy and issued a 20-year WUP on June 21, 2010. The WUP expires on June 23, 2030.

This project represents completion of the second phase of the City's reclaimed water ASR program which will assist the City in addressing irrigation demands. Supplemental water (i.e., surface water) from the Golden Gate Canal is also planned to further enhance recycling of excess waters. Excess reclaimed water and excess surface water are presently discharged to tide and lost as a resource. Discharge to tide will be reduced and possibly eliminated as a result of this program. In addition, the decrease of potable water use will extend the useful life of the wellfields and water treatment facilities.

Conclusions from the construction and testing of the second ASR Well (ASR-2) are as follow:

- The fresh water raw water sources located in the Tamiami Formation extend to a depth of approximately 175 feet below land surface at the project site
- The first brackish aquifer, known as the Hawthorn Zone 1, is present from a depth of approximately 320 to 420 feet below land surface. This aquifer contains brackish water and is not used by the City of Naples for raw water supply
- The deepest production horizon, known as the Lower Hawthorn, exists between depths of approximately 670 to 740 feet below land surface. This zone is highly brackish and is not used by the City for raw water supply purposes
- The 10,000 mg/L total dissolved solids interface was estimated to occur between the depths of 760 to 780 feet below land surface based on information collected via geophysical logging and straddle packer tests. The 10,000 mg/L total dissolved solids interface is the base of a potential underground source of drinking water (USDW). This depth is important as FDEP has separate criteria for regulating systems completed below USDWs
- A presence of the potential storage zone was confirmed to exist between depths of 1,080 and 1,350 feet below land surface during drilling and testing of ASR-2 and MW-1. This zone has been targeted as a potential storage horizon as it contains water with total dissolved solids greater than 10,000 mg/L and there appears to be separation between the targeted storage horizon and the USDW
- Adequate confinement appears to be present between the base of the USDW and the top of the potential storage zone based on additional packer test data, and collection and analysis of rock cores
- The storage zone has adequate hydraulic conductivity to allow injection and recovery at rates from 700 gpm (~1 mgd) to possibly 1,400 gpm (~2 mgd) based on results of the step drawdown test. Specific capacity of ASR-2 was slightly less than ASR-1, ranging from 71 gpm/ft to 60 gpm/ft at pumping rates of 660 and 2,000 gpm, respectively. The specific capacity of ASR-1 ranged from 124 to 115 gpm/ft at pumping rates of 700 and 1,400 gpm, respectively
- The 72-hour pumping test, which used ASR-2 as the pumping well, suggests that the proposed storage zone has a low to moderate transmissivity. Transmissivity was estimated to range from 35,000 to 200,000 gpd/ft
- The 24-inch diameter final casing successfully passed a casing pressure test and demonstrated mechanical integrity for an ASR type well

- The storage zone contains water with a total dissolved solids concentration in excess of 25,000 mg/L

- The cost for the construction and testing of ASR-2, MW-1 and MW-2 was within the contract amount

- A storage zone monitor well (i.e., MW-1) was successfully constructed by converting the existing exploratory well into a dedicated single zone monitor well as required by FDEP. The well monitors the proposed storage zone between 1,080 to 1,350 feet

- A single zone monitor well to monitor the first permeable zone near the USDW was successfully constructed as required by FDEP. This monitor well (i.e., MW-2) monitors a horizon between 670 and 740 feet

- A permit to construct additional Class V ASR wells was submitted and approved by FDEP

- A request to commence development of the storage zone using reclaimed water was submitted and approved by FDEP

The following recommendations are suggested based on the information collected and evaluated to date:

- Continue with construction of surface facilities to allow testing of the storage zone at ASR-1. The temporary facilities should also include wellheads at the monitor wells and ASR-2 which will allow monitoring of water levels and collection of water samples during storage zone development at ASR-1

- Continue with implementation of the reclaimed water / surface water ASR system in a phased approach to allow for go / no-go checkpoints based on data collection

- Continue with implementation of the City's integrated water resources plan in support of the City's overall strategy to develop alternative water supplies

- Continue with the funding partnership with the South Florida Water Management District / Big Cypress Basin

Chapter 1.0
Introduction

1.1 Scope of Work

The City of Naples is seeking alternative water supplies in an effort to reduce potable water consumption since irrigation demands have been the largest demand on the City's potable water system. To reduce the stress on the potable water system and reduce the City's per capita consumption, the City has moved forward with development of alternative water supplies. This initiative is being implemented in conjunction with regulators to ensure permit compliance. The City's alternative water supply plan consists of a strategy that includes close coordination with the Big Cypress Basin and the South Florida Water Management District (District), as well as the Florida Department of Environmental Protection (FDEP).

This element of the overall alternative water supply program consists of development of an aquifer storage and recovery (ASR) system that includes ASR wells, monitor wells and appurtenances. The ASR system, which will use both reclaimed water and canal surface water, is a critical component of the City's Integrated Water Supply Plan. One ASR well, identified as ASR-1, has been constructed as part of Phase 1. The second phase included construction and testing of a second ASR well (i.e., ASR-2) and two monitor wells. Monitor Well No. 1 (MW-1) is a dedicated storage zone monitor well as requested by FDEP while Monitor Well No. 2 (MW-2) is designed to monitor the first permeable zone near the 10,000 mg/L total dissolved solids (TDS) interface. A summary of the drilling and testing of ASR-2, MW-1 and MW-2 is presented in this well completion report.

1.2 Background

The City of Naples was issued a Water Use Permit (WUP) No. 11-00017-W on June 12, 2003. The permit has an expiration date of June 12, 2008. A renewal WUP application was prepared and submitted to the District in June 2008. To date, two requests for additional information have been issued by the District and responded to by the City. A key component of the WUP is the implementation of an alternative water supply program to assist with reduction of potable water consumption. The proposed alternative water supply program consists of development of an ASR system that utilizes both reclaimed water and excess surface water. The District accepted the City's water supply strategy and issued a 20-year WUP on June 21, 2010. The WUP expires on June 23, 2030.

As previously mentioned, the City of Naples is implementing a reclaimed water ASR system to meet irrigation demands which will result in reduction of potable water use. Supplemental water (i.e., surface water) from the Golden Gate Canal is also planned to further enhance recycling of fresh water resources. Excess reclaimed water and excess surface water are presently discharged to tide and lost as a resource. This project will optimize use of resources and provide replacement water for irrigation. Discharge to tide will be reduced and possibly eliminated as a result of this program. In addition, the decrease of potable water use will extend the useful life of the wellfields and water treatment facilities.

Implementation of the City's water supply plan to use reclaimed water and excess surface water as replacement water to meet irrigation demands is well underway. The first ASR well has been constructed and permitting to allow construction and testing of additional ASR wells was successfully completed. A request to commence development of the storage zone was approved by FDEP on January 28, 2011. Reclaimed water is currently available and construction of surface facilities to allow testing to commence using reclaimed water is underway. In addition, it is anticipated that the surface water component will be available within 3 to 5 years. Testing using reclaimed water is anticipated to start in 2011. Future testing will incorporate storage of excess surface water from the Golden Gate Canal in addition to available reclaimed water. Milestones for implementation of the various programs initiated by the City are presented below:

- Integrated Water Supply Plan – Approved by Resolution on October 2, 2008

- Expansion of reclaimed water distribution system – Ongoing

- Implementation of a reclaimed water / surface water ASR program

    - Construction of exploratory well – Completed (August 2007)
    - Construction of ASR Well No. 1 – Completed (March 2010)
    - Design of additional ASR wells – Completed (February 2010)
    - Permitting of three additional Class V ASR wells – Completed (August 23, 2010)
    - Construction of ASR Well No. 2, Monitor Well No. 1, and Monitor Well No. 2 – Completed (January 2011)
    - Construction of reclaimed water surface facilities – Anticipated completion March 2011
    - Approval from FDEP to commence development of the storage zone – Completed (January 28, 2011)
    - Design and construction of surface water ASR facilities – Ongoing, Preliminary Design Report Completed January 2011
    - Permitting of Golden Gate Canal withdrawals from District – Ongoing
    - Anticipated completion of reclaimed water ASR program – 2014

- Investigation of stormwater ASR – Initiated

Construction and testing of the first two ASR wells and monitor wells completes the first two phases of the City's integrated water resources plan to implement strategies for prudent use of resources and meet future demands. Other ongoing and upcoming activities associated with this project are described below:

1. Finalize the permitting with the District to allow withdrawals from the Golden Gate Canal
2. Continue with design and permitting for construction of intake structure and transmission piping to transport water from the Golden Gate Canal to the City's WWTP
3. Begin operational testing of ASR-1 using the existing irrigation distribution system
4. Begin operational testing of ASR-2 using the existing irrigation distribution system

It should be noted that the City has entered into a partnering agreement with the Big Cypress Basin / District as part of the District's grant program associated with development of alternative water supplies. To date, the City has met all milestones and the program continues to move forward successfully.

The above describes near-term activities that are planned by the City to implement an ASR system to address irrigation demands and reduction in potable consumption. An important aspect of this second phase was the collection of additional data (i.e.., cores and further assessment of the storage zone) to address permit related issues. Design criteria used for construction of the City's ASR system included identification of a storage zone below the any potential underground source of drinking water (USDW), providing separation between the storage zone and the USDW, and selection of a storage zone that will optimize recovery efficiency. The proposed plan to further evaluate the storage zone includes the following:

- Conduct a series of cycle tests of the entire proposed storage zone and evaluate recovery efficiency. If recovery efficiencies are acceptable to the City, FDEP, and engineer, proceed with additional cycle testing and storage zone development.

- Conduct operational testing of ASR-1 and ASR-2 to provide confirmation of system performance and serve as the basis for final permitting of the ASR system

1.3 Purpose

The purpose of this report is to summarize the construction and testing activities of the second ASR well (i.e., ASR-2) and the two monitor wells (i.e., MW-1 and MW-2) located at the City's water reclamation facility. Drilling sequence, testing results, geology encountered, and storage zone information (i.e., water quality and estimated hydraulic characteristics) is summarized. Copies of permits and applicable regulatory correspondence are also included. This information will be used in support of future permits and as a record of construction and testing activities.

Chapter 2.0
Well Construction and Testing

2.1 Well Construction

Construction and testing of ASR-2, MW-1 and MW-2 was performed in accordance with the Contract Documents titled "City of Naples Aquifer Storage and Recovery (ASR) Test Well No. 2" City of Naples Bid # 018-10. The bid was approved by the City Council on March 17, 2010.

Construction of ASR-2 well and associated monitor wells commenced with the issuance of a Notice-to-Proceed (NTP) on May 20, 2010. Per the NTP letter, the successful contractor, Youngquist Brothers Incorporated (YBI), was notified to commence work as of May 24, 2010. In addition, the contractor was instructed to reach substantial completion within 180 calendar days (November 20, 2010) and final completion within 210 calendar days (December 20, 2010). While construction and testing of MW-1 proceeded expeditiously as allowed by FDEP, the overall project was delayed several weeks awaiting approval from FDEP to allow drilling and testing of MW-2 and ASR-2.

Figure 1 shows the general location of the project site while Figure 2 shows the site location. A site layout of the water reclamation facility is presented in Figure 3. Figure 3 also shows the distances between wells. Monitor Well No. 1, which included conversion of the existing exploratory well (Figure 4), into a dedicated storage zone monitor well, was the first well constructed for this phase of the ASR program. The exploratory well was the initial well constructed at the plant site while ASR-1 was the second well constructed. Both of these wells were constructed under a separate contract and are considered to comprise Phase 1 of the overall program. Construction details of ASR-1 are shown in Figure 5 for information purposes. An as-built diagram of MW-1 is presented in Figure 6. Upon completion of MW-1, the contractor remobilized and constructed MW-2 to monitor the first permeable zone at or near the USDW. Figure 7 shows the construction details for MW-2. The second ASR well (i.e., ASR-2) was the final well constructed under the abovementioned contract. Construction details of ASR-2 are shown in Figure 8. During well construction, geophysical logging and testing was performed in general accordance with the contract documents. Table 1 presents a summary of the key dates during the construction and testing of MW-1, MW-2 and ASR-2.

The drilling of ASR-2 generally proceeded as identified in the project specifications. The project specifications identified an outline of a drilling plan with the intention of making modifications to the plan as site specific conditions warranted. The plan included setting casing at selected depths to maintain the borehole integrity during drilling and to facilitate the proposed testing.

To consistently record down-hole depth, well measurements were recorded in terms of depth below land surface and / or elevations. Actual depths of casings are identified in the record drawings. Construction and testing of the wells generally proceeded as follows:

Monitor Well No. 1 (MW-1)

- Mobilize necessary equipment to convert the existing exploratory well to a dedicated storage zone monitor well
- Remove wellhead
- Perform geophysical logging
- Drill nominal 16-inch diameter (i.e., 14-¾ inch bit) hole to a depth of 1,350 feet
- Perform geophysical logging
- Set 6-⅝ inch FRP casing to a depth of 1,080 feet (FRP casing has an outside diameter of 6.590 inches, an inside diameter of 5.430 inches, and a wall thickness of 0.580 inches)
- Perform geophysical logging
- Install cement basket and cement FRP casing using neat cement from bottom to land surface
- Perform geophysical log
- Drill out well to 1,350 feet and develop as necessary
- Perform geophysical logging
- Collect background water sample and analyze for primary and secondary drinking water parameters including priority pollutants
- Install wellhead
- Demobilize and restore site to original conditions

Monitor Well No. 2 (MW-2)

- Mobilize necessary equipment to drill Lower Hawthorn monitor well
- Set pit casing as needed
- Drill nominal 12-¼ inch diameter pilot-hole to a depth of approximately 450 feet
- Perform geophysical logging
- Ream pilot-hole to approximately 450 feet in depth
- Perform geophysical logging
- Set 16-inch diameter steel casing to a depth of 431 feet
- Drill nominal 12-¼ inch diameter pilot-hole to a depth of 740 feet
- Perform geophysical logging
- Ream nominal 16-inch diameter hole to approximately 670 feet in depth
- Set 6-⅝ inch FRP casing to a depth of 670 feet (FRP casing has an outside diameter of 5.870 inches, an inside diameter of 5.430 inches, and a wall thickness of 0.220 inches)
- Drill nominal 6-inch diameter borehole to a depth of approximately 740 feet and develop monitor zone as necessary
- Perform geophysical logging

- Collect background water sample and analyze for primary and secondary drinking water parameters including priority pollutants
- Install wellhead
- Demobilize and restore site to original conditions

Aquifer Storage and Recovery Well No. 2 (ASR-2)

- Mobilize equipment and perform necessary site work including installation of pad monitor wells
- Drill a nominal 14-¾ inch diameter pilot-hole to approximately 450 feet below land surface using the mud rotary drilling method
- Perform geophysical logging
- Ream borehole to nominal 42-inch diameter to a depth of 430 feet below land surface
- Perform geophysical logging
- Set and cement 34-inch diameter (0.375-inch wall thickness) steel surface casing to a depth of 430 feet below land surface
- Drill 14-¾ inch diameter pilot-hole and core to a depth of 1,500 feet below land surface using reverse-air drilling method
- Perform geophysical logging
- Conduct straddle packer tests
- Ream pilot-hole to nominal 34-inch diameter to a depth of 1,080 feet below land surface.
- Set and cement 24-inch diameter (0.500 inch wall thickness) seamless steel final casing to a depth of 1,080 feet below land surface
- Conduct casing pressure test
- Re-drill 14-¾ inch diameter pilot-hole to a depth of 1,350 feet below land surface using reverse-air drilling method
- Perform geophysical logging
- Cement pilot-hole to approximately 1,350 feet below land surface
- Drill a nominal 24-inch diameter borehole to approximately 1,350 feet below land surface using the reverse-air method
- Develop well
- Perform step drawdown test
- Perform geophysical logging
- Perform 72-hour pump test
- Collect background water samples
- Disinfect well and install wellhead
- Demobilize and restore site

Information collected during the construction and testing of MW-1, MW-2 and ASR-2 was forwarded to FDEP and the City with progress reports that were submitted on a weekly basis during the construction phase of the project. A copy of FDEP permit information is included in Appendix No. 1. Appendix No. 2 contains copies of District well completion reports prepared by YBI. A summary of key dates is presented in Table 1.

2.2 Data Collection

Data was collected during the construction and testing of MW-1, MW-2 and ASR-2 using various methods and procedures as described in this Section. Geophysical logging was performed by Youngquist Brothers, Inc., Geophysical Logging Division. Water analyses was performed Sanders Laboratories, which is a certified laboratory.

Daily progress and activities were monitored and recorded during construction and testing. The Engineer prepared daily progress reports during well construction along with weekly summaries. The Contractor prepared independent daily reports. Conditions encountered during drilling were observed and noted. Activities related to the installation of well casings, cementing or other materials, as well as their quantities, were recorded. Detailed descriptions of test procedures and data collection were described and recorded. Copies of the daily and weekly progress reports were transmitted on a weekly basis to the Fort Myers and Tallahassee offices of FDEP.

2.3 Geologic Samples

Samples of drilled cuttings were collected and analyzed from the drilling of MW-1, MW-2 and ASR-2. Circulation time (the time required for drilled cuttings to reach the surface) was calculated on a regular basis to ensure that accurate sample depths were recorded. After initial examination, the Engineer's on-site personnel described the samples. A geologic description of each sample was entered into a log. The cuttings were classified in accordance with the scheme of Dunham (1962). A generalized hydrogeologic column and descriptions of each sample are included in Appendix No. 3. Two sets of drill cuttings were bagged in 5-foot intervals. After the wells were complete, the Contractor sent one set of these samples to the Florida Bureau of Geology in Tallahassee, Florida.

2.4 Casing

Casing heat numbers stamped on the casing were verified in the field with the mill certificates prior to running casings in the hole. Copies of the casing mill certificates are presented in Appendix No. 4. Cementing plans for each casing string were proposed by the Contractor and reviewed by the Engineer prior to cementing. After accepting the proposed plan, casing was set and cemented. A summary of cementing was included in the weekly progress reports. The casing schedule for construction of the abovementioned wells is presented in Table 2.

2.5 Geophysical Logs

Geophysical logging was used to obtain information of underground conditions at various stages during the construction and testing of MW-1, MW-2 and ASR-2. In general, geophysical logging was conducted at the completion of each stage of borehole drilling. These logs assisted in identifying the geologic formations encountered, quantifying water quality with respect to depth, identifying confining sequences and production horizons. The geophysical logs performed, including a brief description of the information provided by the logs, are as follows:

- X-Y Caliper – Identification of borehole diameter and geometry

- Gamma Ray – Measurement of the natural gamma ray radiation of the formation, used as a tie-in between logs
- Dual Induction Log (resistivity log) – Identifies differentiation between limestone and dolomite beds, and, along with the gamma ray log, is useful in the correlation of lithologic units
- Borehole Compensated Sonic Variable Density Log (VDL) – Identification of the confining sequences, as well as identification of zones that could cause problems during cementing
- Flow Meter Surveys – Determination of where fluid may be entering or exiting the borehole
- Temperature – Provides a profile of static and dynamic temperature of the borehole, may be useful in determining fluid movement
- Fluid Resistivity – Provides information related to the salinity
- Televisions Survey – Determination of where structural features (bedding planes, fractures, vugs and voids) are located

Geophysical logs were transmitted to FDEP members on a weekly basis during construction once the logs were available. Copies of the logs can be found in CD format in Appendix No. 5. A summary of the geophysical logs is presented in Table 3. Information obtained from the geophysical logs was reviewed along with geologic samples to prepare a hydrogeologic profile of the formations encountered. Figure 9 presents a generalized hydrogeologic section from data collected.

2.6 Video Logs

Video surveys were made with the camera lens in two positions; down-hole with a radial view and up-hole with a horizontal rotating position. Air development and / or artesian flow were used to displace suspended solids from the well prior to performing the television survey. The open-hole survey allowed for visual inspection of formations encountered in the borehole, as well as to observe potential fractures and water-producing zones. Acceptable picture clarity was obtained in the surveys.

2.7 Coring

Rock cores were collected during various stages of drilling at ASR-2 to collect additional information of the subsurface conditions. Cores were collected at specific intervals as estimated from data collected at ASR-1 and MW-1. This data was collected to support demonstration of confinement between the base of the Underground Source of Drinking Water (USDW) and the targeted storage horizon. A copy of the core data is contained in a report prepared by Ardaman & Associates (dated November 30, 2010) and included in Appendix No. 6. Table 4 presents a summary of results from the core testing.

2.8 Packer Tests

Straddle packer tests were performed on the 14-¾ inch diameter pilot-hole of ASR-2. Packer tests were conducted at intervals to support demonstration of confinement, to determine water quality so as to define the base of the USDW, and to identify potential zones of interest.

Packer testing was performed by setting two inflatable packers (plugs) at a selected depth and pumping from the interval between the packers. The packers were used to isolate zones to perform drawdown and recovery tests. The straddle packer intervals were selected based on reviewing and interpreting information from geophysical logs, lithology, and other packer tests. A total of eight (8) straddle packer tests were performed at ASR-2.

The packers were lowered into the pilot-hole to the selected interval on the 6-⅝ inch (outside) diameter drill pipe, inflated and seated against the formation. A 4-inch diameter submersible pump was lowered into the drill pipe approximately 200 feet to introduce stress on the isolated interval. Prior to starting the tests, each zone was developed free of any drilling fluids by means of air lifting and pumping until the specific conductance stabilized. The isolated zone was then allowed to recover from development before beginning the pumping test. During drawdown and recovery, water level measurements were obtained using a data logger attached to a pressure transducer (In-situ Hermit 3000). The method of analysis used on the data collected and recorded during the packer tests was the Modified Non-Equilibrium Formula derived by Cooper and Jacob (1946). The equation of the Cooper-Jacob method is as follows:

$$T = \frac{264Q}{\Delta s}$$

T = coefficient of transmissivity (gallons per day / foot)
Q = pumping rate (gallons per minute)
Δs = change in drawdown over one log cycle (feet)

The calculated hydraulic conductivity from the packer tests are presented in Table 5. The packer data plots are presented in Appendix No. 7. Based on the stabilization of the fluid specific conductance prior to starting the packer tests and the drawdown characteristics of the data shown in this Appendix, the hydraulic conductivity values presented from the packer tests are considered valid.

2.9 Water Quality

Water samples obtained during the packer tests were analyzed in the field for temperature and conductivity. These water samples, which were collected during the drawdown phase of the packer tests, were also sent to an independent laboratory for additional analysis. The samples were analyzed and the results are presented in Appendix No. 7. A compilation of the packer test water quality data is presented in Table 6. Log derived water graphs for ASR-1, ASR-2 and MW-1 were prepared and compare to the packer test water quality test. The graphs show good correlation with the water quality data collected during packer testing.

2.10 Casing Pressure Test

On February 22, 2010, the 24-inch diameter final casing at ASR-2 was pressurized to 169.00 pounds per square inch (psi). The pressure test was started at 9:35 AM. Mr. Rhodes from FDEP was onsite to witness the casing pressure test. Pressure readings were recorded at five minute increments for a period of one hour. The final pressure reading after 60 minutes was 168.50 psi. FDEP allows a variance of up to 5% of the initial pressure which would allow an increase or decrease of 8.45 psi during the one hour test period. The actual pressure change observed at the end of 60 minutes was 0.50 psi or 0.33%, which is within the allowable 5% limits. Results of the casing pressure test are included in Appendix No. 8 along with a copy of the pressure gauge calibration certificate.

2.11 Pumping Test

A step drawdown test was conducted on November 18, 2010 to obtain information on the selected storage zone. The testing included collection of background water levels, pumping water levels, and recovery water levels. A copy of the test data is included in Appendix No. 9. Test data is presented in both tabular and graphical form.

The step drawdown test consisted of four steps whereby the well was pumped at rates of approximately 660, 1,000, 1400, and 2,000 gallons per minute (gpm). Drawdown measurements were collected and the specific capacity of ASR-2 was estimated as shown below:

STEP DRAWDOWN TEST RESULTS		
Pumping rate (gpm)	**Drawdown** (feet)	**Specific Capacity** (gpm/ft)
660	9.311	70.9
1,000	14.894	67.1
1,400	22.146	63.2
2,100	33.480	59.7

In addition to the step drawdown test, a 72-hour withdrawal test was conducted from November 19, 2010 through November 24, 2010, to estimate the transmissivity of the storage zone. The test consisted of a 24-hour background period, and a 72-hour pumping period followed by a 24-hour recovery period. Water levels were recorded at MW-1, MW-2 and ASR-1 while pumping from ASR-2 during the testing. Table 7 presents a summary of the aquifer testing results.

The withdrawal test was conducted at a constant pumping rate of approximately 1,320 gpm for a period of 72 hours. Drawdown was observed to be 21.104 feet suggesting a specific capacity for ASR-2 of 62.6 gpm/ft. Based on the data collected, transmissivity of the storage zone is estimated to range from 35,000 to 200,000 gpd/ft. This estimate for transmissivity was calculated using the Modified Non-Equilibrium Formula derived by Cooper and Jacob (1946). Values for storage coefficient were estimated to be around 0.0005. The data collected during the 72-hour pump test is included in Appendix No. 9.

2.12 Background Water Quality

In addition to the water quality collected during the drilling and testing of wells MW-1, MW-2 and ASR-1, representative background water samples were collected to establish baseline conditions.

Copies of the laboratory results are included in Appendix No. 10. Table 8 presents select background water quality parameters.

2.13 Construction Costs

The City of Naples bid the referenced work in one bid package. Bids were advertised on February 2, 2010, and a pre-bid meeting was held on February 16, 2010. One addendum was issued on February 25, 2010, to clarify questions raised during the pre-bid meeting. The bid opening was held on March 4, 2010, and a recommendation letter was submitted on March 9, 2010, recommending award of the contract to Youngquist Brothers, Inc. in the amount of $1,250,000.00. The City Council approved award of the contract on March 17, 2010. Additional discussions with FDEP resulted in the need for an additional monitor well to monitor a permeable zone at or near the USDW and modification of the existing exploratory well to a dedicated storage zone monitor well. Hence, the contract was amended per a memorandum dated May 12, 2010. The amendment increased the total contract price by $280,000.00. As previously noted, a Notice-to-Proceed was issued on May 24, 2010 (City Bid No. 018-10; City Project Number 10K53). A final completion date, based on 210 calendar days, was set for December 20, 2010.

A summary of the original and modified contracts is provided below:

Original contract

Contractor	Youngquist Brothers, Inc.
Part 1 – Construction of MW-1	$200,000.00
Part 3 – Construction of ASR-2	$1,000,000.00
Part 2 – Allowance	$50,000.00
Total Bid	$1,250,000.00

Modified Contract:

Contractor	Youngquist Brothers, Inc.
Part 1 – Construction of MW-1[1]	$238,000.00
Part 2 – Construction of MW-2[2]	$242,000.00
Part 3 – Construction of ASR-2	$1,000,000.00
Part 2 – Allowance	$50,000.00
Total Bid	$1,530,000.00

1 – Existing exploratory well was deepened to a dedicated storage zone monitor well
2 – Additional monitor well added to monitor a permeable zone at or near the USDW
Contractor – Youngquist Brothers, Inc.

Below is a summary of the project financials which incorporate the final project close-out change order:

Contract Amount	$1,530,000.00
Actual Amount[1]	$1,520,378.60
Balance	$ 9,621.40 (under budget by -0.63%)

[1] – Based on final pay request

2.12 Project / Program Schedule

The City of Naples issued a NTP for construction of two monitor wells and one ASR well on May 24, 2010. The contract noted that work was to be completed within 210 days of issuance of the NTP, or by December 20, 2010. Substantial completion was to be completed by November 20, 2010, which is within 180 days of issuance of the NTP.

YBI was able to mobilize immediately upon receipt of the NTP. It should be noted that FDEP required additional permits for construction of the second monitor well and ASR well which resulted in a delay of 57 calendar days. Thus, per the final closeout change order, the date for Substantial Completion was changed from November 20, 2010 (i.e., 180 days) to January 16, 2011 (i.e., 237 days). The date for final completion was also revised from December 20, 2010 (i.e., 210 days) to February 15, 2011 (i.e., 267 days). Substantial completion was achieved on January 16, 2011 as planned. Demobilization and site restoration was concluded on January 24, 2011, which represented final completion.

This project is second component of a multi-phase ASR program that the City of Naples is implementing to develop a reclaimed water / surface water ASR system. Completion of this project represents closure of one element of the City's water supply plan to use reclaimed water and excess surface water as replacement water to meet irrigation demands and reduce potable water use. Initial development of the storage zone will be conducted using reclaimed water while future testing will incorporate storage of excess surface water from the Golden Gate Canal.

Milestones for implementation of the various programs initiated by the City are presented below:

- Integrated Water Supply Plan – Approved by Resolution on October 2, 2008
- Expansion of reclaimed water distribution system – Ongoing
- Implementation of a reclaimed water / surface water ASR program
    - Construct exploratory well – Complete

- Construct ASR Well No. 1 – Complete
- Construction of Monitor Well No. 1 – Complete
- Construction of Monitor Well No. 2 – Complete
- Construction of ASR Well No. 2 – Complete
- Permitting of additional Class V ASR wells – Complete
- Construction of surface facilities for ASR system – Ongoing
- Design and construction of surface water ASR facilities from the Golden Gate Canal – Ongoing, Pre-design completed in January 2011; Final design due July 2012
- Initiate development of the ASR storage horizon using reclaimed water pending
- Anticipated completion of reclaimed water ASR program – 2014

- Investigation of stormwater ASR – Initiated

Chapter 3.0
Subsurface Conditions

3.1 Generalized Geologic Setting

Information obtained during drilling and testing of the second ASR well and two monitor wells were used in conjunction with previous data collected to formulate the general geologic setting at the project site. The geophysical logging, drill cuttings, cores, packer testing and withdrawal testing data collected were used to confirm the presence of a suitable confining sequence and to determine the targeted storage zone. The data collected show similarity with the underground conditions encountered at the project site at other wells. A summary of the data evaluation and analysis are presented in this section.

The stratigraphic sequence underlying the City of Naples water reclamation facility site was determined from microscopic analysis of drill cuttings, correlation with geophysical logs run on pilot-holes drilled for the ASR-1, ASR-2, MW-1 and MW-2, and comparison with similar projects in southwest Florida. The stratigraphic units penetrated by the site wells were, from the surface downward, the undifferentiated Quatenary Deposits (Pleistocene to Holocene), the Tamiami Formation (Pliocene), the Hawthorn Group consisting of the Peace River Formation and the Arcadia Formation (Micoene), and the Suwannee Limestone (Oligocene). A lithologic description of the cuttings from MW-1, MW-2 and ASR-2 is included in Appendix No. 3. Copies of the geophysical logs, which were previously submitted with weekly reports, are included in Appendix No. 5 and contain a CD of the logs.

<u>Pleistocene to Holocene Series</u>

Undifferentiated Quaternary Sediments – The undifferentiated sediments at the project site are characterized by yellowish brown to light gray, organics, fine to medium-grained quartz sand and shell. The undifferentiated sediments extend from land surface to an approximate depth of 60 feet at the project site.

<u>Pliocene Series</u>

Tamiami Formation – The Tamiami Formation at the site is characterized by brownish gray sandy limestone, shelly sandstone, and quartz sandstone. The Tamiami Aquifer is layered and contains several horizons that can be used for water supply purposes. This aquifer is present from depths of approximately 40 feet to 130 feet in the area of the City's wellfields. The deeper portions of the Tamiami Aquifer are commonly known as the Lower Tamiami and are the primary unit used by the City for water supply. The Coast Ridge Wellfield withdraws from a horizon between 48 feet to 96 feet in depth, while the East Golden Gate

Wellfield withdraws from a production zone between 37 feet to 137 feet below land surface. An important aspect of the Lower Tamiami is the natural separation that exists between the upper water table aquifer and the Lower Tamiami; and between the Lower Tamiami and the deeper Sandstone Aquifer and a production horizon known as Hawthorn Zone 1. The unit is indicated by a low uniform gamma ray responses noted in the geophysical logs. The contact of the sandy limestone in the Tamiami Formation with the underlying greenish clay of the Hawthorn Group is distinctive. Evaluation of data suggests that the Tamiami Formation extends from approximately 60 feet to 175 feet below land surface at the project site.

Miocene Series

Hawthorn Group – The Hawthorn Formation contains both the Peace River Formation and the underlying Arcadia Formation. At the ASR test well site, the Hawthorn Group is characterized by greenish-gray calcareous sandy clay, clayey-sand, and light brownish-gray sandy limestone. The unit is indicated by a consistent, moderate gamma ray signature with a sharp peak in the gamma ray response at the base of the unit at approximately 790 feet. There is a distinct change in lithology from light-colored sandy limestone of the overlying Tamiami Formation to greenish clay at the top of the unit at around 175 feet. The base of the Hawthorn Group is estimated to be around 790 feet below land surface.

The slightly brackish Hawthorn Zone 1 production horizon is present at the project site between the approximate depths of 320 feet and 420 feet. This aquifer is used in some parts of the region for water supply purposes, but there are no wells within several miles of the project site. The City of Naples does not use the brackish Hawthorn Zone 1 production zone for water supply purposes. Additional separation is present between the Hawthorn Zone 1 production zone and the Lower Hawthorn production zone. The brackish Lower Hawthorn production zone extends from 670 feet to 740 feet at the project site and is not used for water supply purposes by the City. This production zone is used for water supply purposes by others in the area, but all users are located several miles from the project site. Underlying the Hawthorn Group is the Suwannee Limestone which extends from approximately 790 feet to the total depth of the ASR test well (i.e., 1,500 feet).

Oligocene Series

Suwannee Limestone – The Suwannee formation at the project site is characterized by shelly sandy clay. The top of the unit is indicated by a shift in the gamma ray log to higher counts, and by a reduction in borehole size, indicated by the caliper log, at approximately 790 feet. The reduction in borehole size appears to be related to the greater competency of the Suwannee formation relative to the overlying Arcadia Formation. The base of the Suwannee formation was not established as the pilot-hole only extended to 1,500 feet.

A summary of the estimated geologic formations conditions encountered at the City of Naples water reclamation facility from data collected during construction and testing of ASR-1, ASR-2, MW-1, and MW-2 is presented below:

FORMATION NAME	INTERVAL		APPROXIMATE THICKNESS
	from	to	
Undifferentiated Quaternary Deposits	0	~ 60	60
Tamiami Formation	~ 60	~175	115
Hawthorn Group	~ 175	~790	615
Suwannee Limestone	~ 790	1,500 ?	710 ?

Note: All numbers are in feet below land surface

3.2 Hydrogeologic Setting

There are several production horizons in the area surrounding the project site. The primary and closest raw water supply source is the Tamiami Formation. This unit is the primary source for raw water supply for the City of Naples and other neighboring utilities. Production from this horizon is low to moderate. Water quality is generally fresh, but may become brackish near the Gulf of Mexico.

A production zone known as the Hawthorn Zone 1 is moderately productive and also used in some areas for water supply purposes. This production zone is found at the project site from approximately 320 to 420 feet below land surface. The zone is artesian and contains water that is considered brackish. The City of Naples does not use this zone for raw water supply.

Near the base of the Hawthorn Group is a production horizon known as the Lower Hawthorn. The zone can be brackish to almost saline. At the project site, the zone has moderate to high productivity and is artesian. Concentrations of total dissolved solids (TDS) are near 10,000 mg/L in this horizon at the project site. The 10,000 mg/L TDS interface is important as this marks the location of the lowermost potential underground source of drinking water (USDW). The base of the USDW is defined as water having a TDS concentration of less than or equal to 10,000 mg/L.

A potential storage zone below the USDW was further defined during this phase of the City's ASR program. A flow log, similar to the one conducted during testing of ASR-1, was conducted at ASR-2. This log was used to further estimate the yield from the targeted storage zone. The flow log at ASR-2 in conjunction with other logs was analyzed to estimated flow zones. It was observed that some intervals which show increased porosity did not appear to be productive. A copy of the flow log and caliper log is included in Appendix No. 5.

The flow log conducted on November 14, 2010, is included in Appendix No. 5 presents a summary of the flow zone for the 22 ½ inch reamed hole. Logging was performed while pumping at a rate of approximately 1,300 gpm. As indicated in the percent flow figure, about 10 percent of the flow occurs between the base of the casing at 1,080 feet and 1,140 feet. Approximately 40 percent of the flow occurs between 1,135 feet and 1,160 feet. The next flow zone appears between approximately 1,200 feet and 1,240 feet. This interval contributes about 40 percent of the total flow. The remainder of the flow appears to occur between 1,290 and the bottom of the borehole at 1,350 feet. It should be noted that the feature from approximately 1,140 to 1,160 feet did not result in major flow, suggesting that this feature is not indicative of a highly fractured formation that yields significant amounts of water. Data from the temperature logs and fluid resistivity logs correlate well with the observed production zones. While the sonic porosity log indicates that the interval from 1,080 to 1,140 appears to have higher porosity, the productive interval appears to begin around 1,135 feet and extends to approximately 1,160 feet based on the temperature and flow logs. It is noted that the porosity is not necessarily indicative of hydraulic conductivity as evidenced by the fact that the flow log shows production at depths slightly below 1,140 while the porosity appears higher between 1,080 and 1,140 feet.

Based on the above findings and discussions with FDEP, a potential storage zone between 1,080 and 1,350 feet has been selected for further testing and analysis. A depth of 1,080 feet was chosen for the final casing seat to take advantage of an interval located just below this depth with relatively high porosity as indicated by the sonic porosity log. In addition, natural separation appears to exist between this depth and the estimated base of the potential USDW. Hence, based on data collected and discussions with FDEP, a well completion strategy consisting of setting final casing strings to 1,080 feet with an open hole to 1,350 feet was employed.

3.3 Water Quality

A key factor in the design of the reclaimed water ASR system was identifying the base of the USDW. Water samples were collected from isolated sections of the borehole during straddle packer testing. The water samples from the packer tests were analyzed for selected parameters to establish background water quality and to identify the 10,000 mg/L TDS interface. Table 6 summarizes the results of the laboratory analyses from the packer tests collected from ASR-2 and from the previously constructed ASR well (i.e., ASR-1).

The base of the USDW was identified by performing water quality analysis on samples obtained from packer tests and geophysical log interpretation. Data compiled from geophysical logs, including the dual induction log, was useful in determining the base of the USDW. This data along with the log derived water quality log appears to place the base of the USDW somewhere between 760 feet and 780 feet below land surface. This data was confirmed by the water quality results of the packer test conducted in ASR-1 between 785 and 805 feet that yielded a TDS concentration of 12,000 mg/L. The packer test conducted at ASR-2 between 806 and 823 feet showed a slightly lower TDS value which is most likely due to the influence of the highly productive Lower Hawthorn productive zone which contains brackish water. The log derived log shows some mixing, but generally shows the USDW occurring at a slightly shallower depth. A copy of the log derived water quality graph from ASR-1, ASR-2 and MW-1 is included in Appendix No. 5. Figure 9 shows the location of the USDW with respect to the production zones.

3.4 Confinement Analysis

The approach to the evaluation of vertical confinement at the City of Naples water reclamation facility site included review of available borehole geophysical, and analysis of geological data and open-hole testing data. This information was used to identify intervals from 760 feet (i.e., base of the USDW) to 1,080 feet that exhibited confining properties. The vertical confinement provided by each interval was then evaluated. Particular attention was paid to locating beds of limestone, dolomite, clay or marl that have low vertical hydraulic conductivities and are not penetrated by fractures and/or solution cavities. Such tight beds provide the primary vertical confinement of the injected fluids.

3.4.1 Identification of Confining Units

The presence of satisfactory confining sequences between 760 and 1,080 feet below land surface was established during the drilling of ASR-1. A letter previously submitted to the FDEP documented the presence of this confinement on site. This letter from the Engineer is dated December 7, 2009, and is referred to as “the 24-inch diameter casing seat request”. Comparison of information collected during drilling and testing of ASR-2 has confirmed the presence of confinement as previously documented. In fact, a series of cores were collected and analyzed, and packer testing was performed at ASR-2 to clearly establish the presence of a suitable confinement. Packer test data are summarized in Table 5, while core results are presented in Table 6.

3.4.2 Geophysical Logs

The geophysical logs for ASR-2, MW-1, and previously constructed ASR-1 were examined in detail for the presence of units of rock that could provide vertical confinement for injected fluids. A combination of sonic, caliper and resistivity logs were used to identify well-cemented limestone and / or dolomite beds that would be expected to have low matrix porosities and hydraulic conductivities. The television survey was used to locate fractures and / or cavernous zones that could be conduits for vertical fluid flow. Information on the orientation and thickness of beds was also obtained from the television survey.

The development and conditioning of the wells prior to logging is not an issue for the sonic, caliper, gamma ray, temperature, and resistivity logs as these logs were designed to and are often run in mudded boreholes. Fine scale features, such as bed contacts, are readily distinguishable on the television survey, which indicates that borehole conditions did not have a significant adverse effect on log quality.

Flow meter, temperature, and fluid resistivity / conductivity logs provide information on the location of flow zones into wells and on changes in the salinity of formation waters. These logs did not provide useful information concerning vertical confinement. Flow meter logs provide limited value for identifying individual beds with low vertical hydraulic conductivities because a single zone of high hydraulic conductivity very often dominates the flow for the entire tested interval.

3.4.3 Characterization of Well Cuttings

Cuttings collected during the drilling of MW-1, MW-2, and ASR-2 (land surface to 1,350 feet) were examined in detail for lithology. The cuttings were grab samples collected at 5-foot intervals during the construction of the well. The lithology of the limestone cuttings was characterized using the limestone classification scheme of Dunham (1962). The most common grain types were silt to fine-sand sized rounded carbonate grains that are described as either peloids (fecal pellet-shaped grains of indeterminate origin) or as bioclasts (transported fossil fragments). The mineralogy of the samples (calcite versus dolomite) was confirmed by reaction with dilute hydrochloric acid. Dolomite was classified according to crystal size as being either microcrystalline (crystals are not visible with the low-powered microscope), finely crystalline (1/64 to 1/16 mm) or medium crystalline (1/16 to 1/4 mm).

3.4.4 Packer Test Data

Straddle packer test data collected during the drilling of ASR-2 were designed to collect water quality data and for information on the hydraulic conductivity. The straddle packer data collected to evaluate hydraulic characteristics were analyzed using the Cooper and Jacob (1946) modification of the Theis (1935) non-equilibrium equation (i.e., the straight line method). The hydraulic conductivity values calculated from both the pumping and recovery phase data for each test were similar.

A total of eight packer tests were conducted at ASR-2. The packer tests were designed to collect information on hydraulic characteristics and / or to collect depth specific water quality data. The packer tests conducted from 1,075 to 1,125 feet, 1,125 to 1,225, and 1,225 to 1,350 feet were intended to estimate yield in an effort to estimate the specific yield of intervals within the storage zone. Results from the packer testing are presented in Appendix No. 7. A summary of the packer test water quality results is presented in Table 6.

It should be noted that the hydraulic conductivity values calculated from the packer test data are largely a function of horizontal hydraulic conductivities. Packer test data thus tend to overestimate vertical hydraulic conductivities. For example, a packer test performed on an interval containing one or more high hydraulic conductivity horizontal beds inter-bedded between very low hydraulic conductivity beds would give a high hydraulic conductivity value whereas the interval would have a very low vertical hydraulic conductivity. Table 5 summarizes the hydraulic conductivity derived from the packer tests.

Packer test data collected between the estimated USDW and the targeted storage zone indicated good confining characteristics. Additional data obtained from cores further confirmed the degree of confinement present.

3.4.5 Criteria for Identification of Confinement Units

Beds or intervals of rock that are likely to offer good vertical confinement were identified using the following criteria:

- Low sonic transit times
- Variable density log (VDL) pattern consisting of straight parallel vertical bands, where lithology is relatively uniform, or a "chevron" pattern of continuous parallel bands, where the formation consists of inter-bedded rock with differing densities and/or degrees of consolidation. Fractured rock typically has an irregular VDL log pattern
- Low hydraulic conductivities calculated using packer pump test data
- A high degree of cementation as observed in microscopic examination of cuttings and core samples
- Borehole diameters on caliper logs close to the bit size.

- Absence of evidence of fractures on the television survey
- Core data

3.4.5.1 Confinement Intervals

An analysis of confinement was performed to evaluate units that provide separation between the proposed storage zone and the USDW. This analysis was conducted using the confinement properties of the strata between the base of the USDW (760 to 780 feet) and 1,080 feet (i.e., the top of the storage zone).

Interval from 750 to 1,000 feet below land surface – This interval consists predominantly of light-colored limestone. Wackestones and packstones are the most common lithologies. The wackestones and packstones are interbedded with beds of carbonate-mud rich lithologies (fossiliferous mudstones and grainstones). The borehole television log indicates that the beds are horizontal and range in thickness from approximately 0.5 to 10 feet. The bedding appears to consist of stacked sequences of carbonate sand-rich (wackestones and packstones) and carbonate mud-rich (packstones to mudstones) limestones. The mudstone and wackestone beds, which have low macroporosities and are well cemented, can provide better vertical confinement than the thicker grainstone and packstone beds.

Hydrologic conductivities calculated from packer tests performed during the construction of ASR-1 and ASR-2 ranged from 3.2×10^{-3} to 3.1×10^{-4} cm/sec. Vertical hydrologic conductivities derived from the cores collected at ASR-2 ranged from 1.0×10^{-3} to 6.0×10^{-9} cm/sec. Hydrologic conductivities in these ranges indicate the existence of good confinement over the interval.

Interval from 1,005 to 1,150 feet below land surface – This interval consists of interbedded light-colored limestones and dolomites. Grainstones and packstones are the most common lithologies. The grainstones and packstones are interbedded with beds of carbonate-mud rich lithologies (fossiliferous mudstones and wackestones). The borehole television log indicates that the beds are horizontal and range in thickness from approximately 0.5 to 10 feet. The bedding appears to consist of stacked sequences of carbonate sand-rich (grainstones and packstones) and carbonate mud-rich (packstones to mudstones) limestones. The mudstone and wackestone beds, which have low macroporosities and are well cemented, can provide better vertical confinement than the thicker grainstone and packstone beds.

Hydrologic conductivities calculated from packer tests performed during the construction of ASR-1 and ASR-2 ranged from 1.8×10^{-3} to 8.0×10^{-4} cm/sec. Vertical hydrologic conductivities derived from the cores collected at ASR-2 ranged from 1.3×10^{-4} to 6.8×10^{-8} cm/sec. The hydrologic conductivity values shown above suggest the presence of good confinement over the interval tested.

3.4.5.2 Confinement Summary

A comparison of data collected from ASR-1, ASR-2, MW-1 and MW-2 were analyzed to evaluate the presence of adequate confinement at the project site for the intended use (i.e., reclaimed water ASR). More specifically, the drilling and testing plan for ASR-2 was designed to collect additional information to further define confinement (i.e., cores and additional packer tests) at the City's water reclamation facility site. This information was useful in confirming the presence of suitable confinement between the base of the USDW and the top of the proposed storage zone at 1,080 feet. A total of eighteen (18) rock cores were collected and five additional packer tests were performed over this interval during this project. The test results indicate the presence of good confinement between the USDW and the storage zone.

Chapter 4.0
Conclusions and Recommendations

4.1 Conclusions

The purpose of this report is to summarize the construction and testing activities of the second ASR well (ASR-2) and the two monitor wells (MW-1 and MW-2) located at the City of Naples Water Reclamation Facility. This information will be used in support of future permits and as a record of construction and testing activities.

Conclusions from the construction and testing of the ASR Test Well No. 2 (ASR-2) are as follows:

- The fresh water raw water sources located in the Tamiami Formation extend to a depth of approximately 175 feet below land surface at the project site. The City of Naples uses the Tamiami Formation for water supply

- The first brackish aquifer, known as the Hawthorn Zone 1, is present from a depth of approximately 320 to 420 feet below land surface. This aquifer contains brackish water and is not used by the City of Naples for raw water supply

- The deepest production horizon, known as the Lower Hawthorn, exists between depths of approximately 670 to 740 feet below land surface. This zone is highly brackish and is not used by the City for raw water supply purposes

- The 10,000 mg/L total dissolved solids interface was estimated to occur somewhere between the depths of approximately 760 to 780 feet below land surface based on information collected via geophysical logging and straddle packer tests. The 10,000 mg/L total dissolved solids interface is the base of any potential USDW. This depth is important as FDEP has separate criteria for regulating ASR systems completed below the USDW

- A potential storage zone was identified to exist between depths of 1,080 and 1,350 feet below land surface. This zone has been targeted as a potential storage horizon as it contains water with total dissolved solids greater than 10,000 mg/L and there appears to be separation between the targeted storage horizon and the USDW

- Adequate confinement appears to be present between the base of the USDW and the top of the potential storage zone based on packer test data

- The storage zone has adequate hydraulic conductivity to allow injection and recovery at rates from 700 gpm (~1 mgd) to possibly 1,400 gpm (~2 mgd) based on results of the step drawdown test. The specific capacity at ASR-2 was estimated to range between 70.9 to 59.7 gpm/ft at pumping rates of 660 and 2,000 gpm, respectively

- The 24-inch diameter final casing at ASR-2 successfully passed a casing pressure test and demonstrated mechanical integrity for an ASR type well

- The storage zone contains water with a total dissolved solids concentration over 25,000 mg/L

- The construction and testing was completed under the contract amount and slightly over schedule

4.2 Recommendations

The following recommendations are suggested based on the information collected and evaluated to date:

- Commence development of the storage zone using reclaimed water as source water

- Continue with implementation of the reclaimed water / surface water ASR system in a phased approach to allow for go / no-go checkpoints based on data collection

- Continue with implementation of the City’s integrated water resources plan in support of the City’s overall strategy to develop alternative water supplies

- Continue with the funding partnership with the South Florida Water Management District / Big Cypress Basin

- As needed, expand the ASR wellfield to optimize use of reclaimed and surface water to meet future irrigation demands

TABLES

TABLE 1 - Summary of Key Dates

City of Naples ASR Phase 2

INDENTIFICATION	DESCRIPTION	DATE
Project Start	Notice-to-Proceed	May 24, 2010
Monitor Well No. 1 (MW-1)	Set 6 ⅝" FRP casing to 1,080 feet	June 7, 2011
	Collect background water samples	June 17, 2010
Monitor Well No. 2 (MW-2)	Set 16" casing to 431 feet	August 30, 2010
	Set 6 ⅝" FRP casing to 670 feet	September 11, 2010
	Collect background water samples	September 14, 2010
ASR Test Well No. 2 (ASR-2)	Set 34" casing to 430 feet	September 25, 2010
	Set 24" casing to 1,080 feet	October 28, 2010
	Conduct aquifer withdrawal test	November 20, 2010
	Collect background water samples	November 22, 2010
	Conduct casing pressure test	December 3, 2010
Final Completion	Complete construction	January 31, 2011

TABLE 2 - Casing Schedule

City of Naples ASR Phase 2

CASING RUN	DIAMETER (inches)		DEPTH (feet)	MATERIAL	WALL THICKNESS (inches)
	Inside	*Outside*			
ASR Test Well No. 2 (ASR-2)					
Pit Casing (pulled)	41.250	42.000	8	Steel	0.375
Surface Casing	33.250	34.000	430	Steel	0.375
Final Casing	23.000	24.000	1,080	Steel	0.500
Total Well Depth	---	---	1,350	---	---
Monitor Well No. 1 (MW-1)					
Pit Casing	23.250	24.000	29	Steel	0.375
Surface Casing	15.250	16.000	334	Steel	0.375
Final Casing	5.430	6.590	1,080	FRP	0.580
Total Well Depth	---	---	1,350	---	---
Monitor Well No. 2 (MW-2)					
Pit Casing (pulled)	23.250	24.000	8	Steel	0.375
Surface Casing	15.250	16.000	431	Steel	0.375
Final Casing	5.430	5.870	670	FRP	0.220
Total Well Depth	---	---	742	---	---

TABLE 3 - Geophysical Logging Schedule

City of Naples ASR Phase 2

CONSTRUCTION PHASE	INTERVAL	DATE	GEOPHYSICAL LOGS
Monitor Well No. 1 (MW-1)			
MW-1 (Existing exploratory well)	0 to ~ 612 feet	26-May-10	X-Y capliper, Gamma ray, and Televsion survey
MW-1 (Existing exploratory well)	0 to ~ 1,350 feet	06-Jun-10	X-Y capliper, Gamma ray, Borehole compensated sonic w/ variable density, Dual induction LL3, Spontaneous potential, Fluid Conductivity, Temperature, and Television survey
MW-1 (Existing exploratory well)	0 to ~ 1,350 feet	06-Jun-10	Log derived water quality
MW-1 (Existing exploratory well)	1,080 feet	07-Jun-10	Cement bond log
MW-1 (Existing exploratory well)	1,080 feet	08-Jun-10	Temperarture logs after each cement stage
MW-1 (Existing exploratory well)	1,080 feet	11-Jun-10	Cement bond log
MW-1 (Existing exploratory well)	1,080 to 1,350 feet	10-Jun-10 & 25-Jun-10	Television survey
Monitor Well No. 2 (MW-2)			
12-1/4 inch pilot-hole	0 to ~ 450 feet	27-Aug-10	X-Y capliper and Gamma ray
26-inch reamed hole	0 to ~ 435 feet	30-Aug-10	X-Y capliper and Gamma ray
16-3/4 & 9-3/4 inch hole	0 to ~ 742 feet	10-Sep-10	X-Y capliper, Gamma ray, Borehole compensated sonic w/ variable density, Dual induction LL3, Spontaneous potential, Fluid Conductivity, and Temperature
6-5/8 inch final hole	0 to ~ 742 feet	11-Sep-10	Cement bond log
6-5/8 inch FRP casing	640 feet	12-Sep-10	Temperarture logs after each cement stage
6-5/8 inch final hole	0 to ~ 742 feet	13-Sep-10	Cement bond log
6-5/8 inch final hole	0 to ~ 742 feet	13-Sep-10	Television survey
Aquifer Storage and Recovery Well No. 2 (ASR-2)			
12-1/4 inch pilot-hole	0 to ~ 450 feet	20-Sep-10	X-Y capliper, Gamma ray, Dual induction LL3, and Spontaneous potential
42-inch reamed hole	0 to ~ 435 feet	25-Sep-10	X-Y capliper and Gamma ray
12-1/4 inch pilot-hole	0 to ~ 1,120 feet	08-Oct-10	X-Y capliper, Gamma ray, Borehole compensated sonic w/ variable density, Dual induction LL3, Spontaneous potential, Temperature, Log derived water quality, and Television survey
12-1/4 inch pilot-hole	0 to ~ 1,120 feet	10-Oct-10	Television survey
34-inch reamed hole	0 to ~ 1,083 feet	27-Oct-10	X-Y capliper and Gamma ray
24-inch casing	1,080 feet	29-Oct-10	Temperarture logs after each cement stage
12-1/4 inch pilot-hole	0 to ~ 1,350 feet	03-Nov-10	X-Y capliper, Gamma ray, Borehole compensated sonic w/ variable density, Dual induction LL3, Spontaneous potential, Temperature, Log derived water quality, flow, and cement bond
12-1/4 inch pilot-hole	0 to ~ 1,350 feet	04-Nov-10	Television survey
24-inch hole	1,080 to 1,350 feet	14-Nov-10	X-Y capliper, Gamma ray, Borehole compensated sonic w/ variable density, Dual induction LL3, Spontaneous potential, Temperature, and Flow
24-inch hole, final hole	0 to 1,350 feet	15-Nov-10	Television survey

TABLE 4 - Estimated Hydraulic Conductivity from Cores

City of Naples ASR Phase 2

INTERVAL (depth in feet)			WELL	HYDRAULIC CONDUCTIVITY	
				Vertical Conductivity (cm/sec)	Horizontal Conductivity (cm/sec)
810.00	to	810.33	ASR-2	1.7×10^{-5}	1.3×10^{-5}
811.00	to	811.33	ASR-2	6.0×10^{-9}	9.2×10^{-9}
813.00	to	813.33	ASR-2	1.3×10^{-8}	2.1×10^{-8}
815.00	to	815.33	ASR-2	4.8×10^{-8}	6.7×10^{-8}
965.00	to	965.33	ASR-2	1.3×10^{-4}	1.9×10^{-4}
981.00	to	981.33	ASR-2	1.0×10^{-3}	4.1×10^{-5}
985.00	to	985.33	ASR-2	8.6×10^{-5}	1.2×10^{-4}
989.00	to	989.33	ASR-2	9.0×10^{-4}	2.5×10^{-3}
991.00	to	991.33	ASR-2	5.4×10^{-4}	9.9×10^{-4}
994.00	to	994.33	ASR-2	9.3×10^{-6}	1.7×10^{-5}
996.00	to	996.33	ASR-2	2.3×10^{-7}	8.3×10^{-7}
1,013.00	to	1,013.33	ASR-2	1.3×10^{-4}	3.4×10^{-4}
1,015.00	to	1,015.33	ASR-2	4.6×10^{-6}	1.3×10^{-3}
1,024.00	to	1,024.33	ASR-2	2.3×10^{-6}	8.2×10^{-6}
1,025.00	to	1,025.33	ASR-2	1.3×10^{-6}	3.1×10^{-5}
1,068.00	to	1,068.33	ASR-2	4.3×10^{-6}	6.8×10^{-5}
1,115.00	to	1,115.33	ASR-2	7.0×10^{-8}	6.4×10^{-8}
1,116.00	to	1,116.33	ASR-2	6.8×10^{-8}	6.9×10^{-8}

TABLE 5 - Estimated Hydraulic Conductivity from Packer Testing

City of Naples ASR Phase 2

INTERVAL	WELL	PUMPING RATE (gpm)	DRAWDOWN (feet)	SPECIFIC CAPACITY (gpm/ft)	ESTIMATED HYRDAULIC CONDUCTIVITY	
					Drawdown (cm/sec)	Recovery (cm/sec)
806 -823	ASR-2	27	95.542	0.283	0.00034	0.00025
944 - 960	ASR-2	47	122.540	0.384	0.00031	0.00036
978 - 994	ASR-2	73	71.098	1.027	0.00099	0.00097
1,012 - 1,028	ASR-2	66	77.240	0.854	0.00080	0.00041
1,030 - 1,046	ASR-2	74	75.051	0.986	0.00170	0.00089
1,075 - 1,125[A]	ASR-2	85	72.235	1.177	N / A	N / A
1,125 - 1,225[A]	ASR-2	86	5.376	15.997	N / A	N / A
1,225 - 1,350[A]	ASR-2	87	5.411	16.078	N / A	N / A

gpm = gallons per minute

gpm / ft = gallons per minute per foot

cm / sec = centimeters per second

A = packer test performed to assess specific capacity of interval

TABLE 6 - Water Quality from Packer Testing

City of Naples ASR Phase 2

INTERVAL	WELL	WATER QUALITY			PURPOSE OF TEST
		Chloride (mg/L)	TDS (mg/L)	(µmhos/cm)	
785 - 805	ASR-1[B]	6,400	12,000	16,600	To assess hydraulics and water quality
806 - 823	ASR-2	4,560	9,070	13,200	To assess hydraulics and water quality
900 - 920	ASR-1[B]	12,800	23,400	32,400	To assess hydraulics and water quality
944 - 960	ASR-2	13,500	22,000	35,000	To assess hydraulics and water quality
978 - 994	ASR-2	14,000	24,600	35,700	To assess hydraulics and water quality
1,005 - 1,025	ASR-1[B]	14,200	24,900	34,600	To assess hydraulics
1,012 - 1,028	ASR-2	14,700	25,500	36,700	To assess hydraulics and water quality
1,030 - 1,046	ASR-2	14,600	26,900	36,800	To assess hydraulics and water quality
1,075 - 1,125[A]	ASR-2	12,500	18,800	30,100	To assess hydraulics
1,105 - 1,125	ASR-1[B]	14,500	25,600	35,600	To assess hydraulics
1,125 - 1,225[A]	ASR-2	15,100	25,500	35,800	To assess hydraulics
1,225 - 1,350[A]	ASR-2	17,600	28,800	42,600	To assess hydraulics

A - tests conducted to estimate specific yield of storage zone

B - result from previously constructed ASR Well No. 1

TABLE 7 - Aquifer Testing Results

City of Naples ASR Phase 2

ACTIVITY	PUMPING WELL	PUMPING DATA		
		Rate (gpm)	Drawdown (feet)	Specific Capacity (gpm/ft)
Step Drawdown Test	ASR-2	660	9.311	70.9
	ASR-2	1,000	14.894	67.1
	ASR-2	1,400	22.146	63.2
	ASR-2	2,000	33.480	59.7
72-hour Pump Test	ASR-2	1,320	21.104	62.5

TABLE 8 - Background Water Quality Results

City of Naples ASR Phase 2

PARAMETER	UNITS	WELL			
		ASR-1 1,080' - 1,350'	**ASR-2** 1,080' - 1,350'	**MW-1** 1,080' - 1,350'	**MW-2** 670' - 742'
Chloride	mg/L	17,800	15,600	14,900	4,350
TDS	mg/L	28,600	25,400	26,900	7,980
Conducitivty	µmhos/cm	47,500	43,500	31,600[A]	12,800
Arsenic	mg/L	0.0040	0.0026	0.0026	0.0020
Sodium	mg/L	11,000	9,700	9,100	2,700
Sample Date	---	03/27/10	11/22/10	06/17/10	10/08/10

A - This value appears to be an apparent lab error and is most likely a transposition error and should be 41,600.

FIGURES

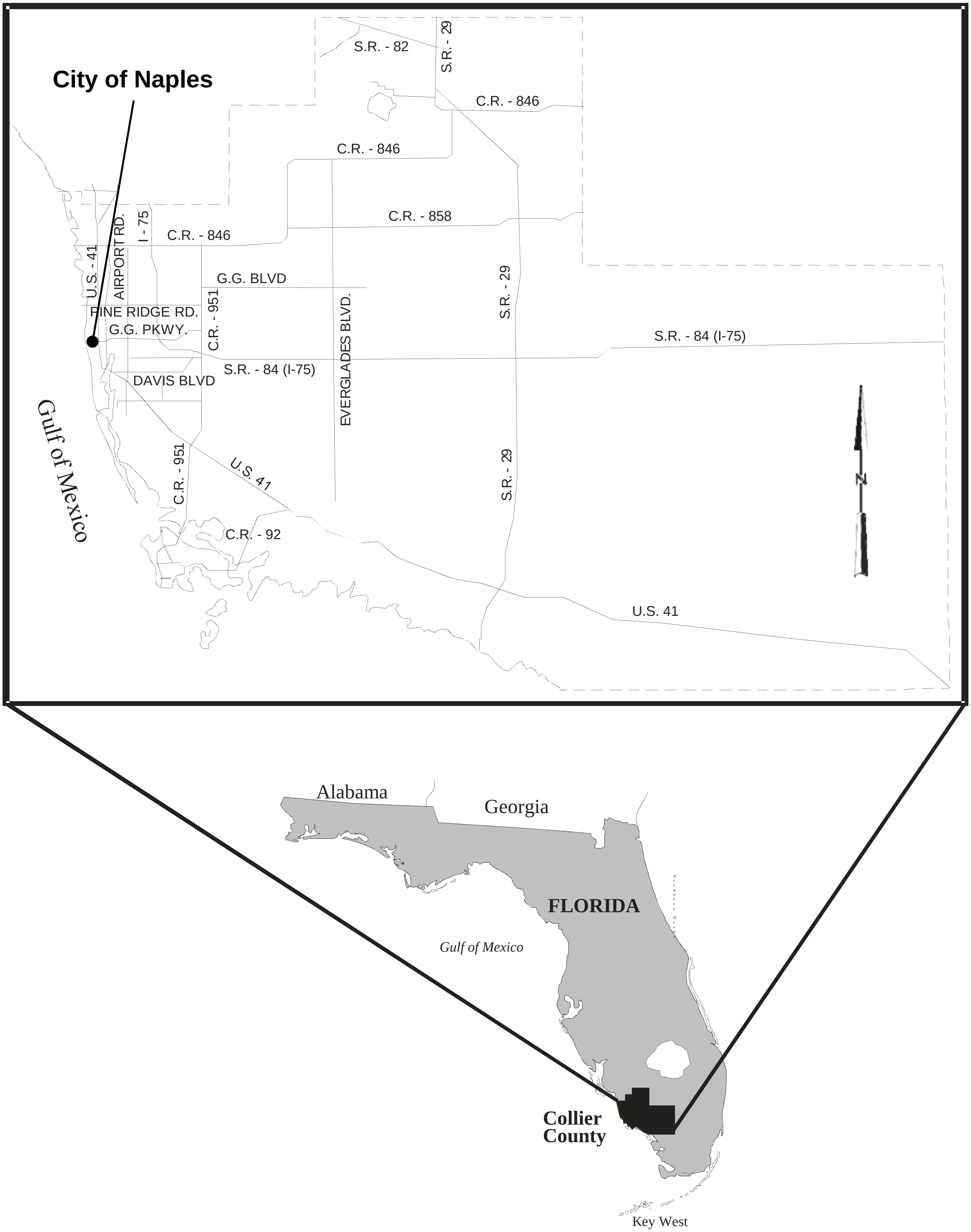

Figure 1
General Location Map

HAZEN AND SAWYER
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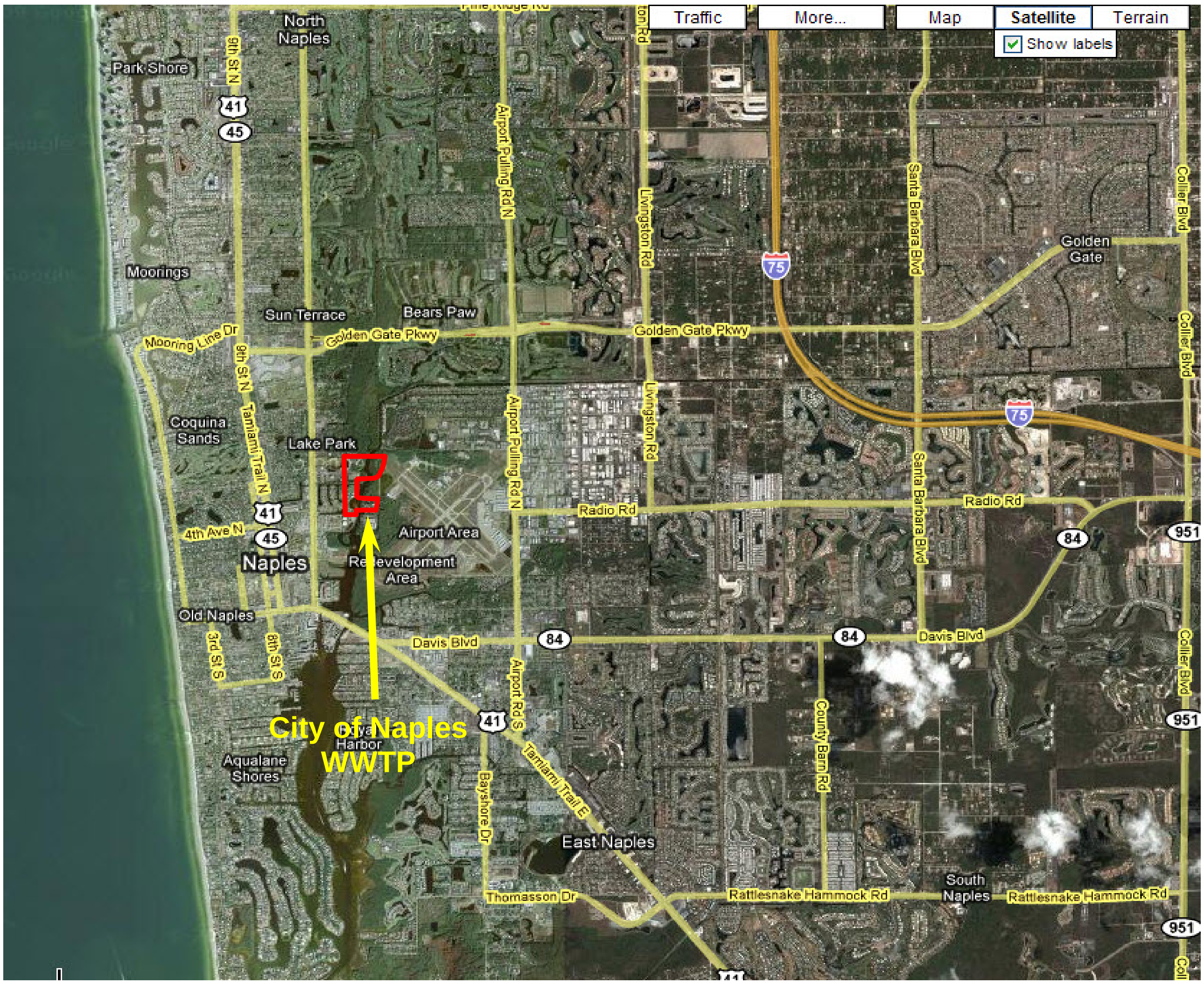
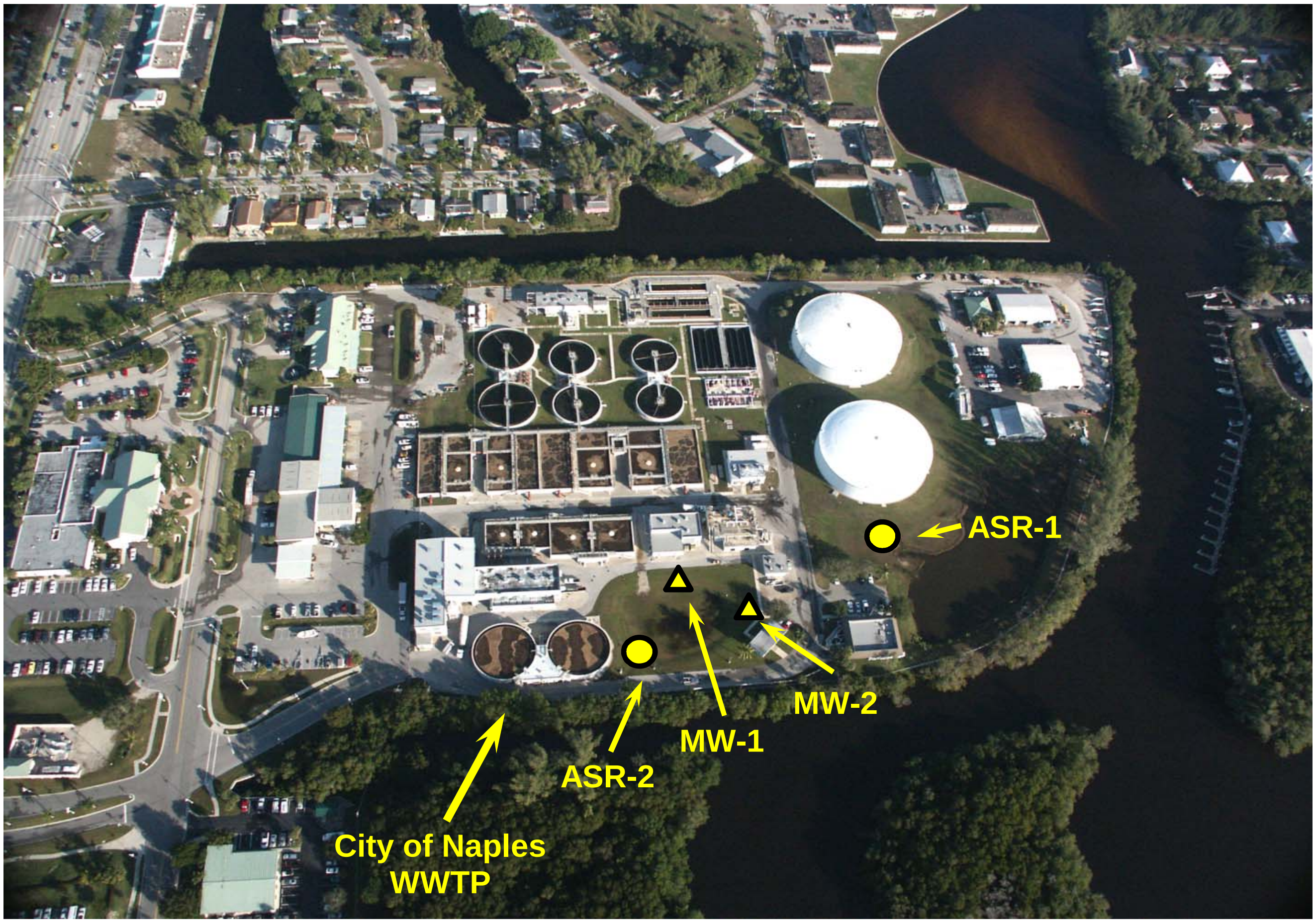


Figure 2
Site Location Map

HAZEN AND SAWYER
Environmental Engineers & Scientists



Distances from Well to Well (in feet)

	ASR-1	ASR-2	MW-1	MW-2
ASR-1	---	339.2	256.1	198.8
ASR-2	339.2	---	116.5	140.4
MW-1	256.1	116.5	---	86.8
MW-2	198.8	140.4	86.8	---

Figure 3
Site Layout

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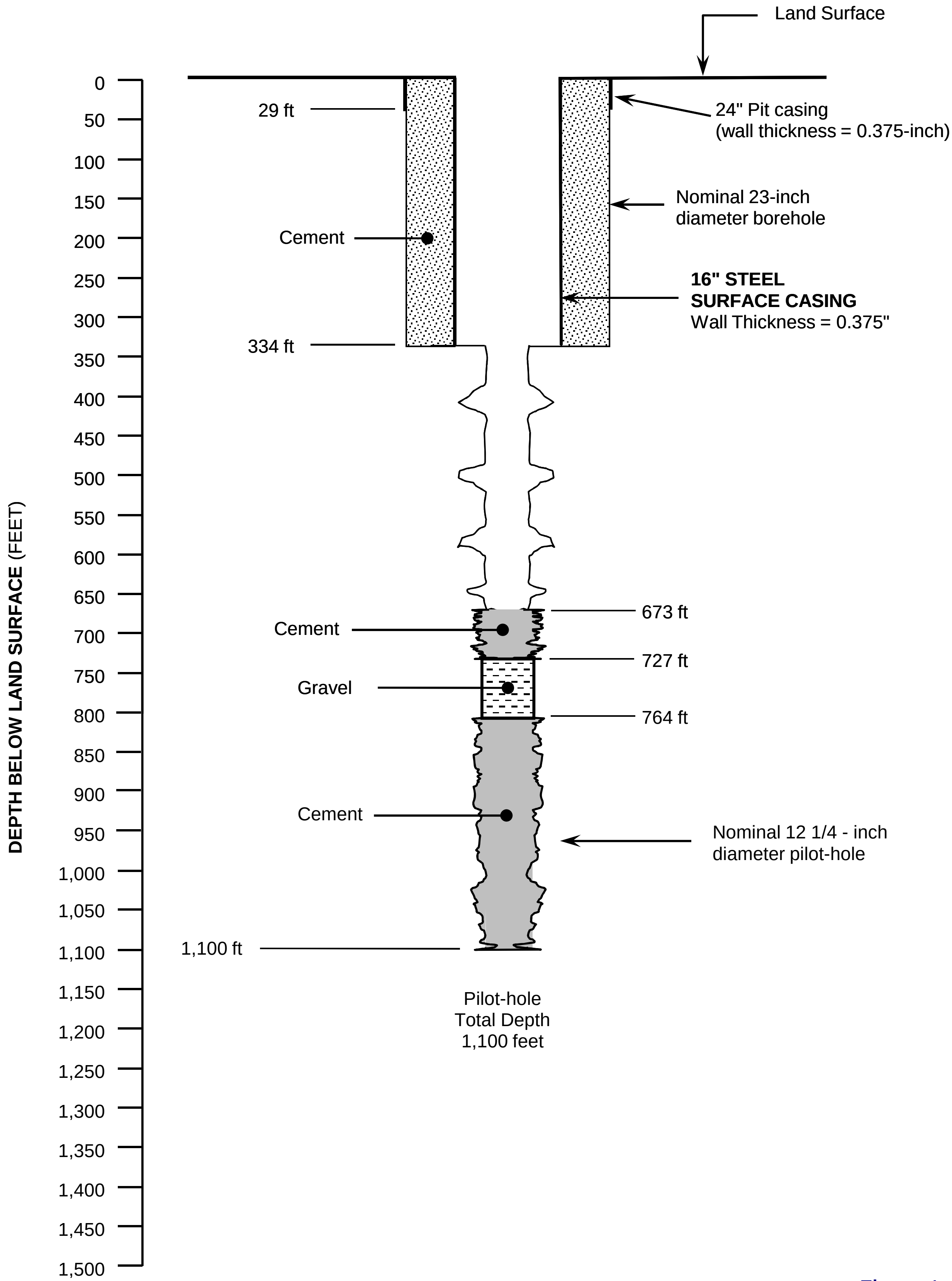

Figure 4
Exploratory Test Well
Construction Details

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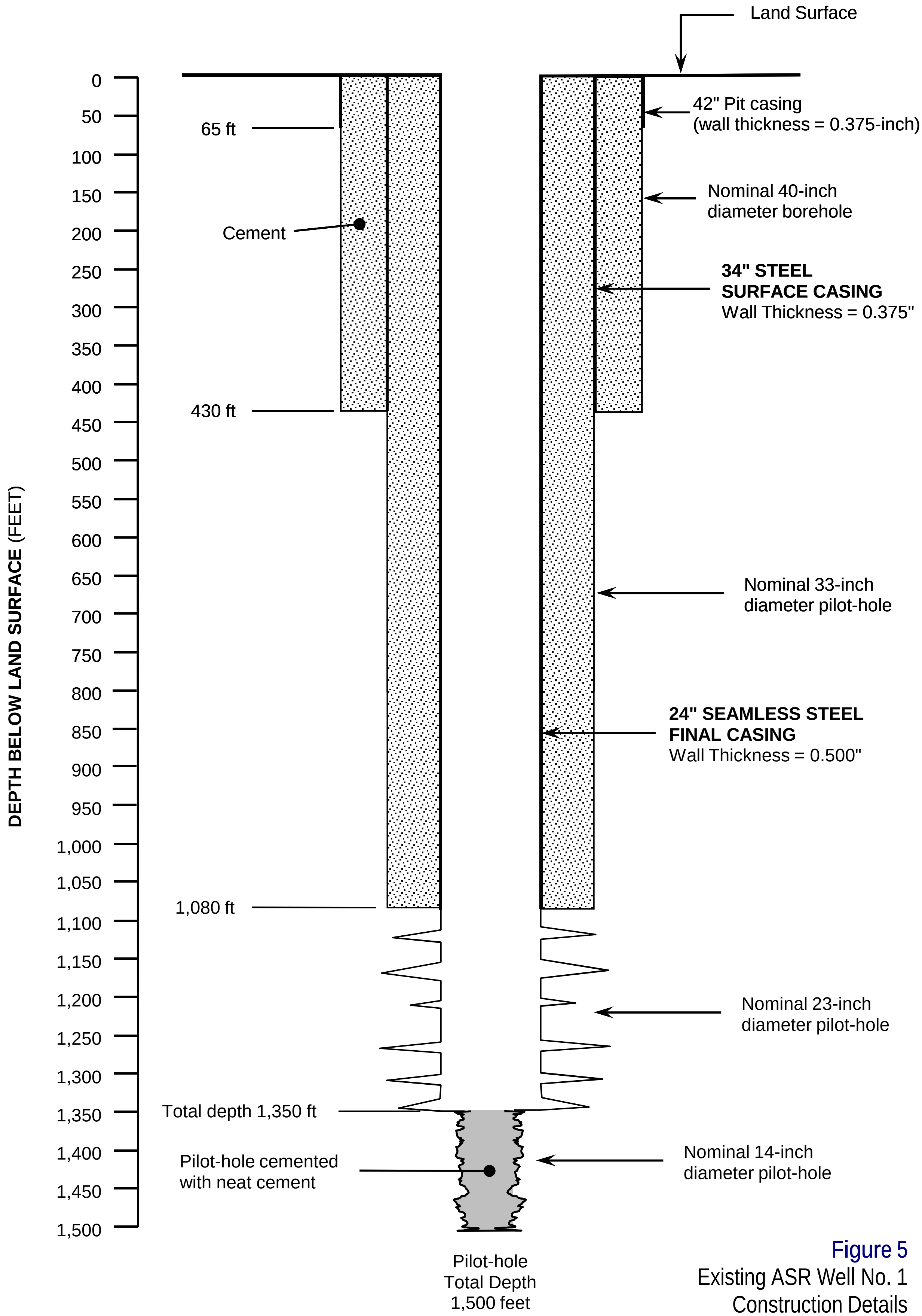

Figure 5
Existing ASR Well No. 1
Construction Details

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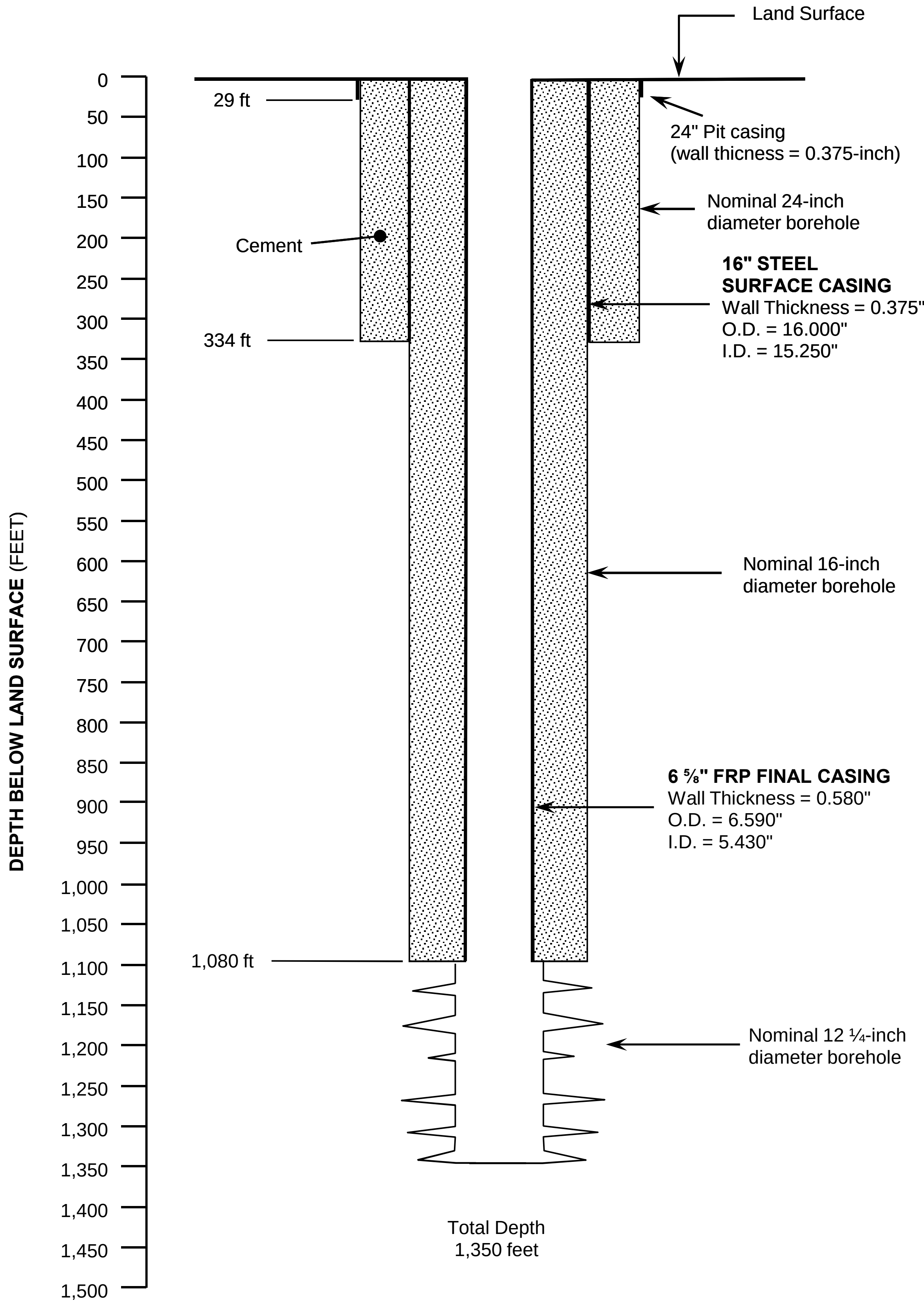

Figure 6
Monitor Well No. 1
Construction Details

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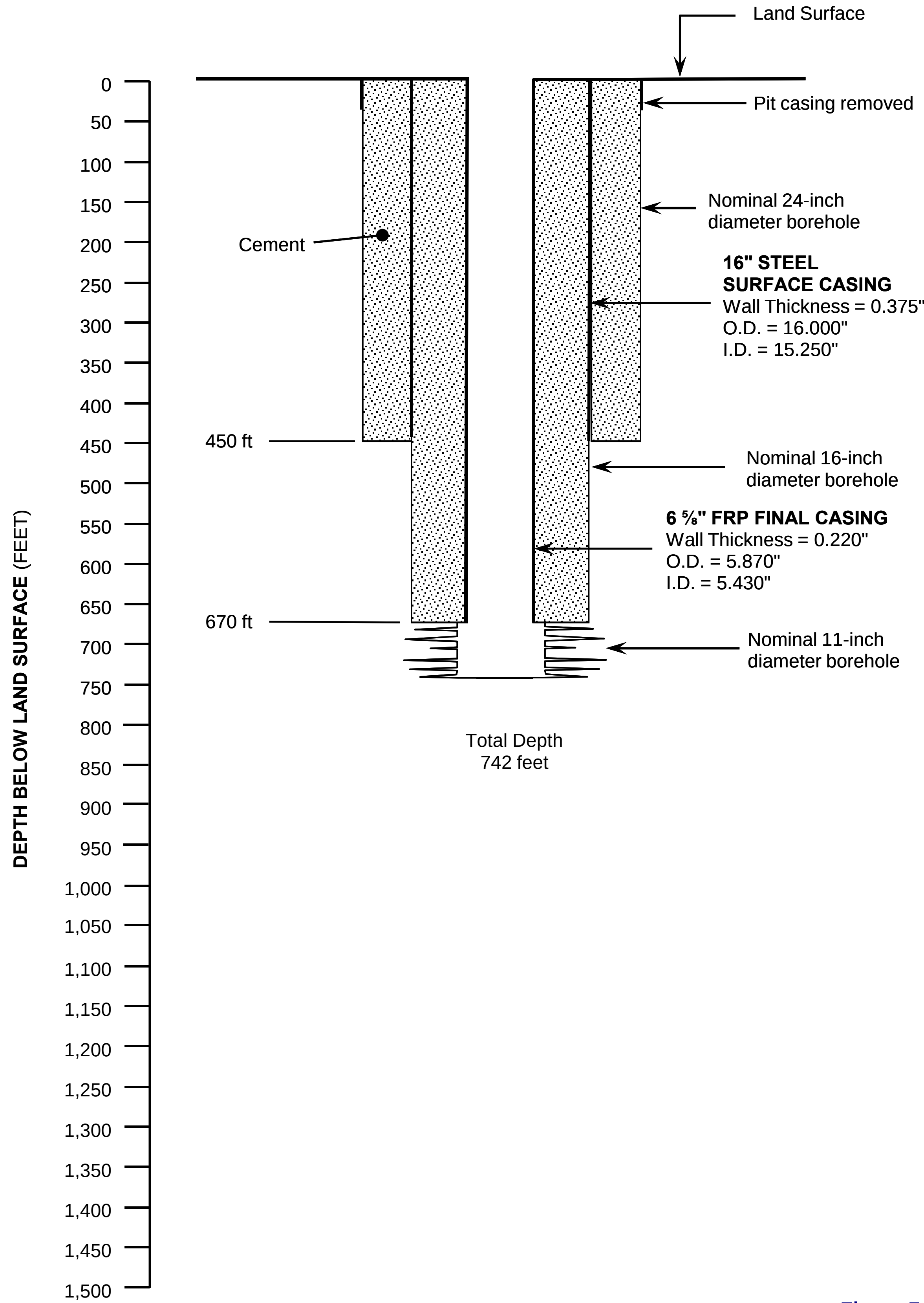

Figure 7
Monitor Well No. 2
Construction Details

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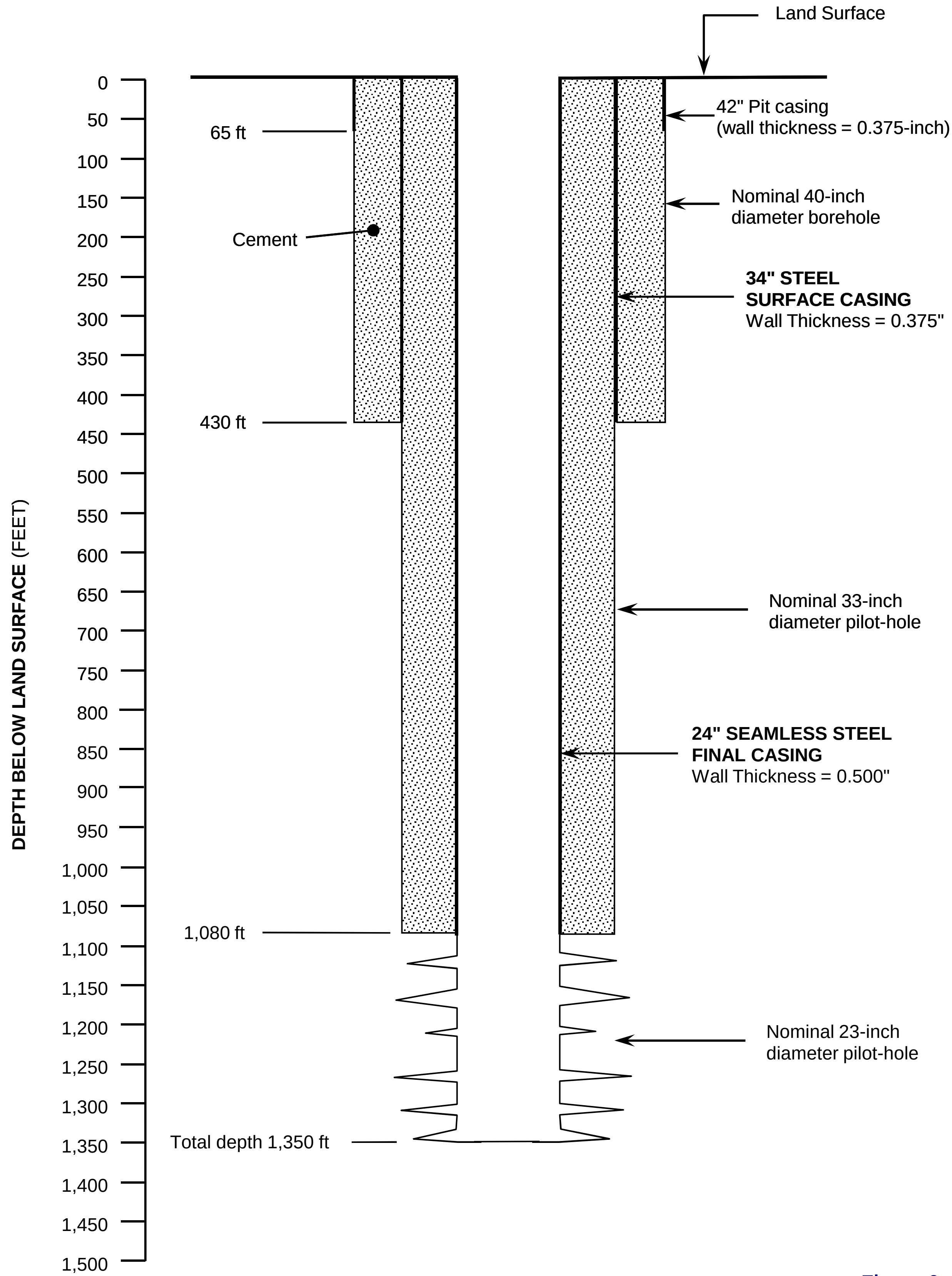

Figure 8
ASR Well No. 2
Construction Details

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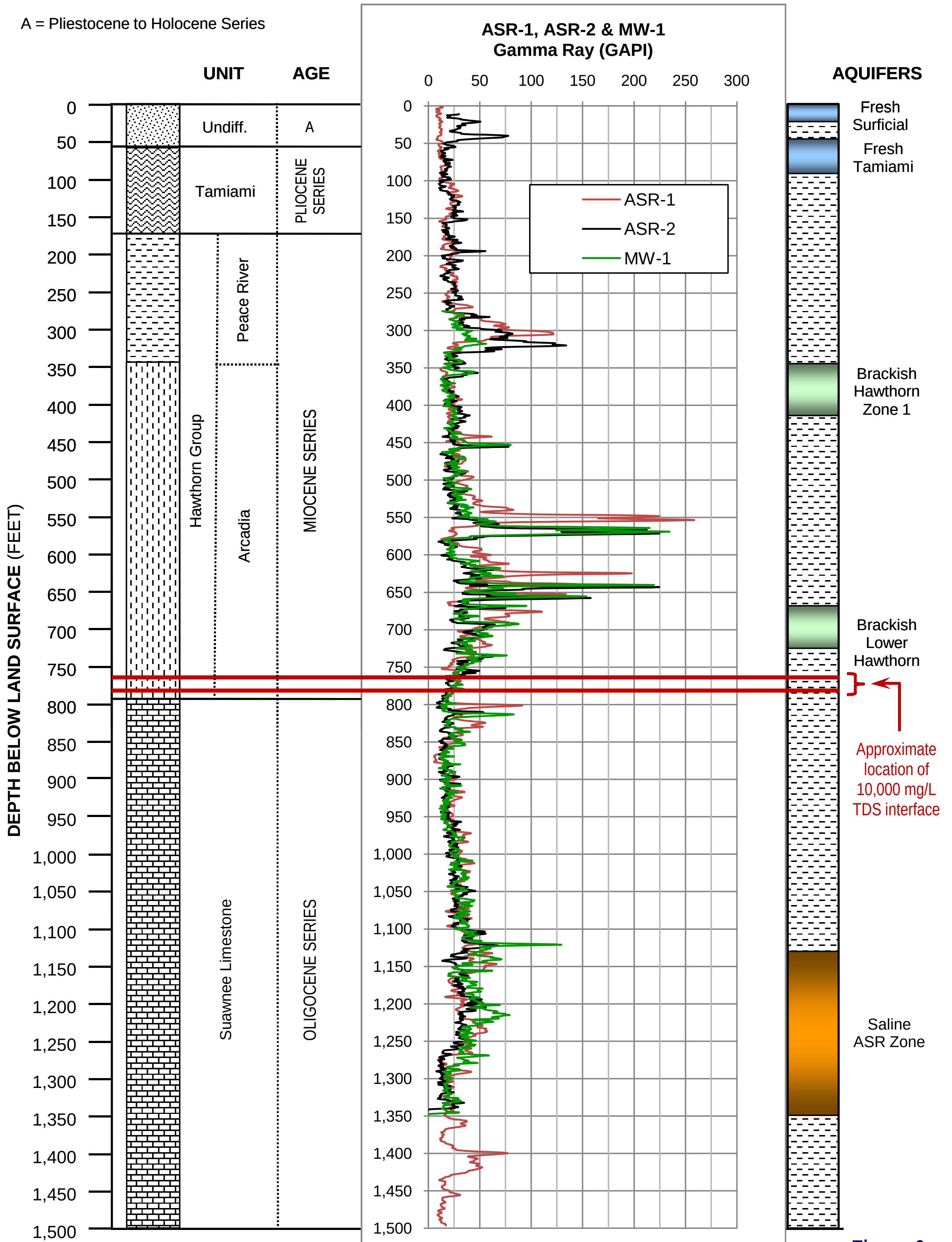

Figure 9

Generalized Hydrogeologic Section from ASR and Monitor Wells

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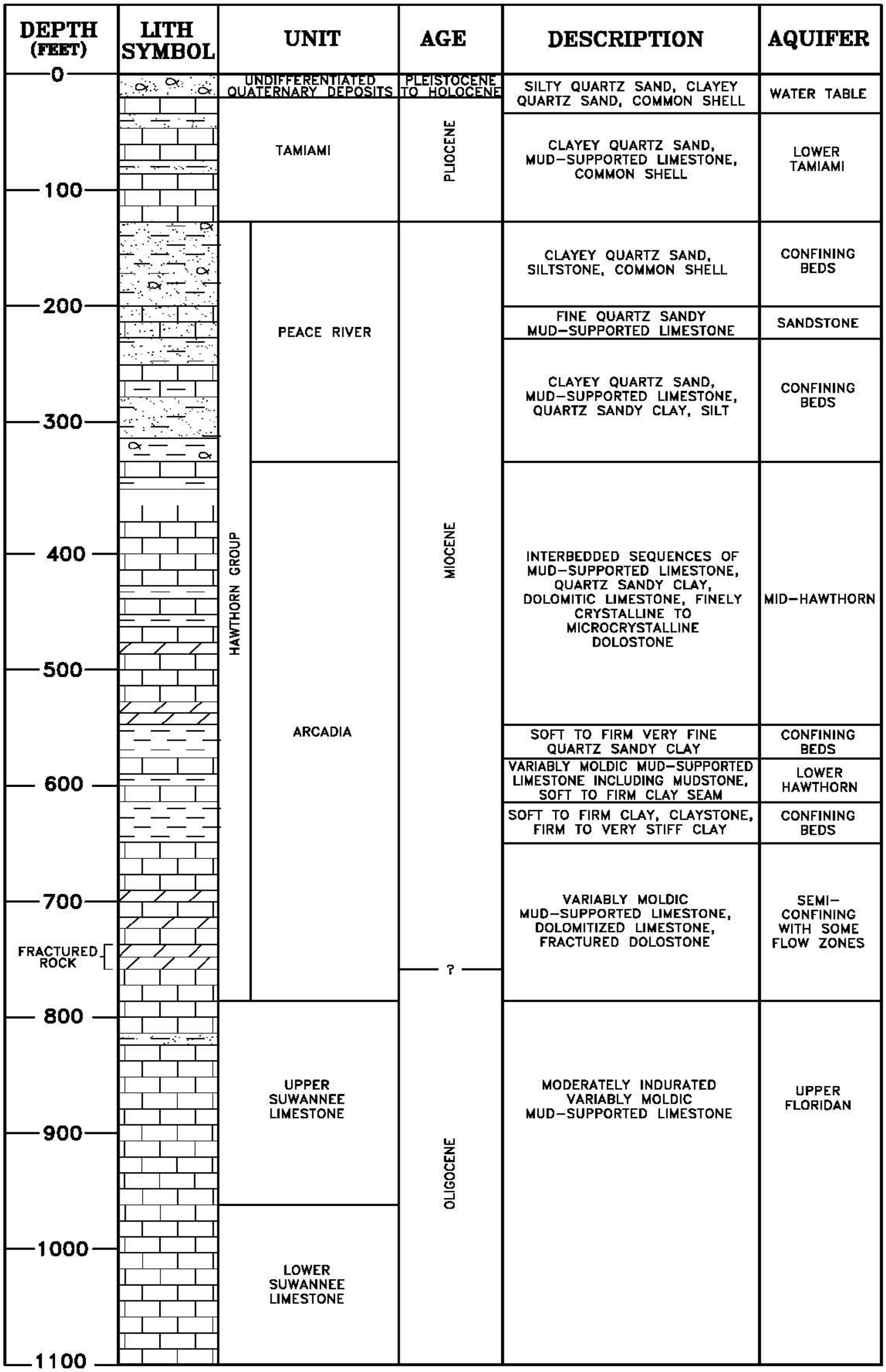

Source: City of Naples - Integrated Water Resources Plan Final Report (Tetra Tech); July 2008
ASR Well EW-1

Figure 10
Generalized Geologic Column
from Exploratory Test Well

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