

**CITY OF CLEARWATER
GROUNDWATER REPLENISHMENT FEASIBILITY STUDY**

FINAL REPORT

PREPARED FOR:

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EXECUTIVE SUMMARY

INTRODUCTION

In an effort to reduce discharge of reclaimed water to open waters and more fully utilize their reclaimed water, the City of Clearwater (City) is investigating the feasibility of replenishing aquifer systems in the City with highly purified reclaimed water from the Northeast Water Reclamation Facility (NEWRF). The City authorized Tetra Tech and Legette, Brashears & Graham, Inc. (LBG) to develop a Groundwater Replenishment (GWR) Feasibility Study. This GWR Feasibility Study builds upon findings from the GWR Preliminary Feasibility Study that are summarized to the City in a letter report dated September 15, 2009. This feasibility study includes reclaimed water sampling, groundwater sampling, and modeling that was used to update the recommendations and cost opinions from the preliminary feasibility study.

The NEWRF is located in the northeast portion of the City, off of State Road (S.R.) 580 and consists of advanced wastewater treatment using biological nutrient removal and high level disinfection. The NEWRF is currently permitted to discharge up to 13.5 MGD annual average daily flow (AADF) for public access reuse or to a surface discharge into Tampa Bay via the East WRF. Influent flows to the NEWRF from January 2009 to June 2010 averaged approximately 5.2 MGD. This GWR Feasibility Report is based on providing 3 MGD of highly purified water for injection into the groundwater. Based on the projected recovery of the treatment processes, this will result in approximately 3.8 MGD of effluent from the NEWRF being diverted to the proposed advanced treatment process for purification.

The preliminary feasibility study reviewed the use of both direct and indirect aquifer recharge. Direct aquifer recharge was determined to be more beneficial due to the limitations of indirect aquifer recharge. Direct aquifer recharge consists of the purified reclaimed water being injected directly into the aquifer that is being recharged through the use of injection (recharge) wells.

Aquifer recharge wells are defined as Class V injection wells in Rule 62-528.300 of the Florida Administrative Code (F.A.C), and include recharge wells, salt water intrusion barrier wells, subsidence control wells, and connector wells. Per Rule 62-528.300, F.A.C., recharge wells are “used to replenish, augment, or store water in an aquifer” and salt water intrusion barrier wells are “used to inject water into a fresh water aquifer to prevent the intrusion of salt water into the fresh water.” Per Chapter 62-528, F.A.C., wells injecting into an underground source of drinking water (USDW) must meet all primary and secondary drinking water standards.

A summary of the regulatory requirements for groundwater recharge is provided in Table ES-1.

Table ES-1. Groundwater Recharge Requirements				
	62-600 (Domestic Wastewater Facilities)		62-610 (Reuse of Reclaimed Water and Land Application)	
TDS	<10,000 mg/L (G-II Aquifer)	<500 mg/L	>3,000 mg/L	<3,000 mg/L
Treatment	Secondary	Secondary	Secondary	Secondary
Reliability	Class I	Class I	Class I	Class I
Disinfection	High	Full	High	Full
Primary DWS	Yes	Yes	Yes	Yes
Secondary DWS	Yes	Yes	Edge of ZOD ⁸	Yes
Filtration	Before Disinfection ¹	Before Disinfection ¹	Before Disinfection ⁴	Before Disinfection ⁴
Total Nitrogen (TN)	10 mg/L ⁵	10 mg/L ⁵	10 mg/L ⁵	10 mg/L ⁵
Total Organic Carbon (TOC)	BPJ	5 mg/L and 9 mg/L ²	BPJ	3 mg/L and 5 mg/L ⁶
Total Organic Halogen (TOX)	BPJ	0.2 mg/L and 0.3 mg/L ³	BPJ	0.2 mg/L and 0.3 mg/L ⁷
Testing Program	Not discussed	Min 2-Year, Full Scale	BPJ	1 Year Pilot

¹ 62-600.540(2)(b), ² 62-600.540(3)(b)(1), ³ 62-600.540(3)(b)(2), ⁴ 62-610.563(2)(b), ⁵ 62-610.563(2)(c), ⁶ 62-610.563(3)(d)
⁷ 62-610.563(3)(e), ⁸ 62-610.560(3)(c)

DWS = Drinking Water Standards as established in Rules 62-550.310 and 62-550.320, F.A.C.

ZOD = Zone of Discharge

BPJ = Best Professional Judgment

Regulations for GWR include the requirement that the treatment process shall provide multiple barriers for organics and pathogens and that additional pollutant reduction for parameters reasonably expected to pose a risk to public health due to acute or chronic toxicity shall be provided.

The Southwest Florida Water Management District (SWFWMD) published a report called “Feasibility of Using Reclaimed Water for Aquifer Recharge” (MWH, 2009) that “evaluates if indirect or direct aquifer recharge could be used to create improvements to the aquifer and provide the opportunity for future, additional groundwater withdrawals to be developed consistent with the District’s water use permitting (WUP) rules”. To meet the requirements for full treatment for direct aquifer recharge, the SWFWMD report recommended the following treatment processes following advanced wastewater treatment:

- Microfiltration
- Reverse Osmosis
- Advanced Oxidation/UV Disinfection

These treatment processes are similar to those used at the Orange County Water District (OCWD) GWR System, which is the largest planned indirect potable reuse project in the world. The OCWD GWR system treats reclaimed water from the Orange County Sanitation District in Orange County, California to be used for groundwater replenishment and as a saltwater barrier. Therefore, these treatment processes are the basis of the purification process proposed in this feasibility study. In addition to the

primary treatment processes, post-treatment of the purified water will be necessary. Post treatment will, at a minimum, consist of alkalinity and calcium addition for stabilization and an oxygen removal process to help prevent the mobilization of metals in the aquifer.

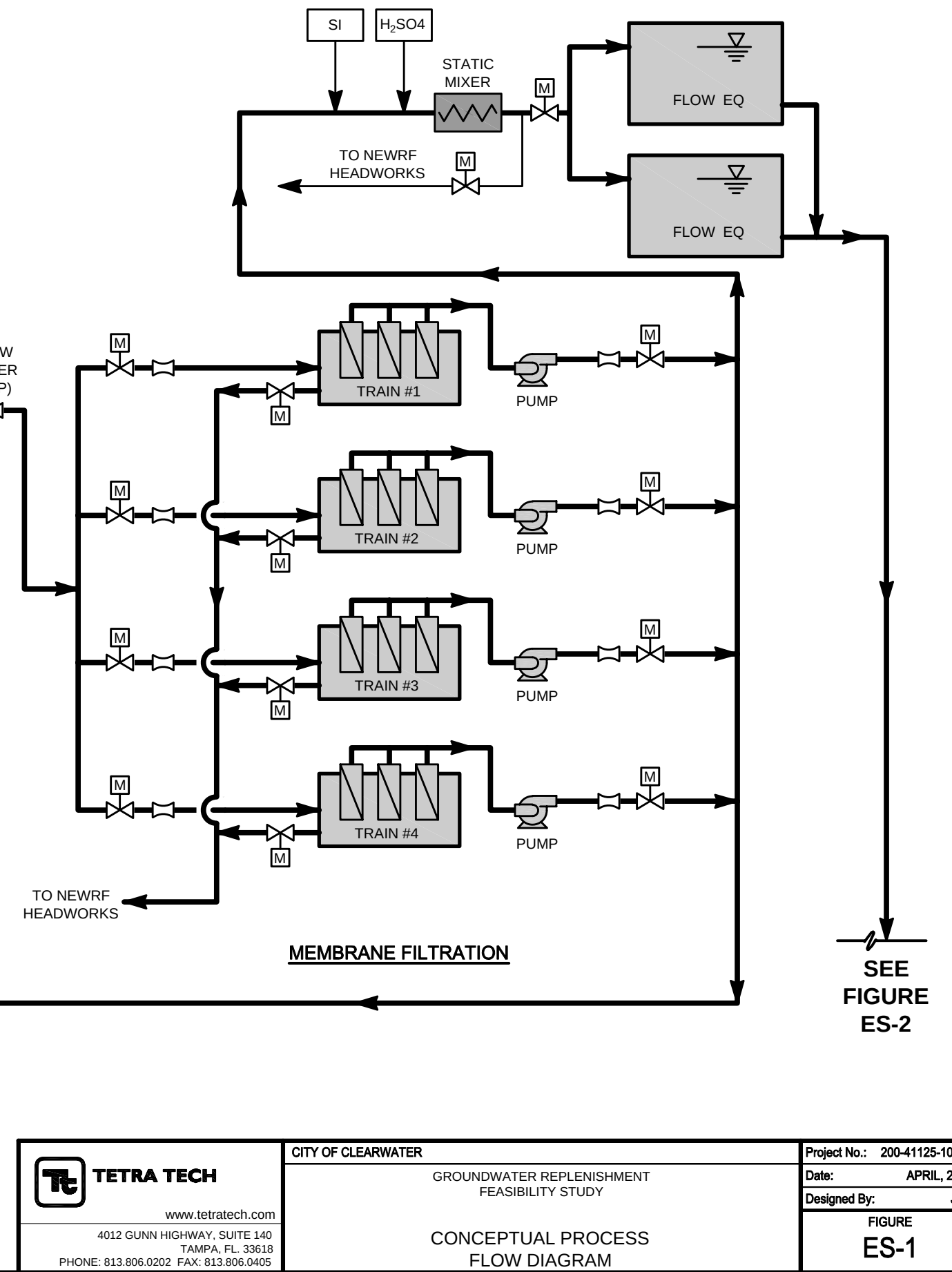
PROPOSED GWR PURIFICATION PROCESS

The proposed GWR purification process is based on providing 3 MGD of purified water for injection that:

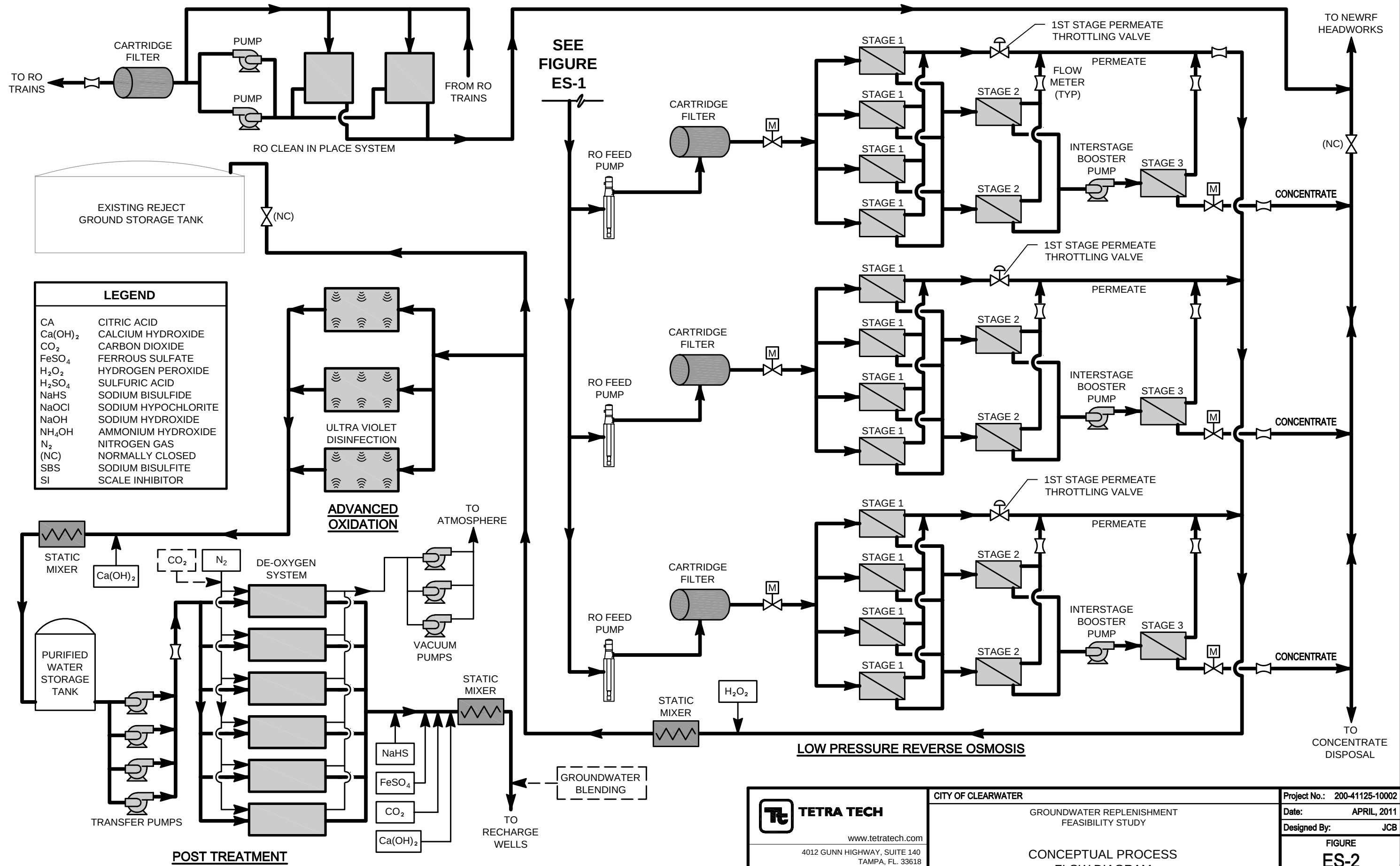
- meets drinking water standards;
- provides multiple barriers for contaminants;
- has been treated to reduce the risk due to acute or chronic toxicity (microconstituents);
- is stable;
- has been treated to reduce the potential for the mobilization of arsenic and other metals in the groundwater;
- and meets all other requirements for direct aquifer recharge as outlined in the FDEP regulations.

The major process components are shown in the process flow diagram provided in Figure ES-1 and ES-2 and include:

- Chemical Pretreatment
 - o Ammonium hydroxide addition to convert the free chlorine in the reclaimed water to chloramines
- Membrane Filtration
 - o Strainers to protect the membrane elements from damage from abrasive materials such as sand or grit
 - o Membrane trains
 - o Permeate Pumping
 - o Backpulse system for periodic backwashing of the membrane elements.
 - o Membrane cleaning
- Reverse Osmosis
 - o Chemical Pretreatment including sulfuric acid (pH adjustment) and scale inhibitors
 - o Equalization tank to balance out the fluctuations in flow from the MF system
 - o Membrane feed pumps
 - o Cartridge filtration
 - o Membrane trains
 - o RO membrane cleaning system
- Advanced Oxidation
 - o Hydrogen peroxide addition
 - o UV oxidation
- Post Treatment
 - o Storage and pumping



4/27/2011 3:49:54 PM - P:\200-41125-10002 - CLEARWATER GWR FEASIBILITY\CAD\CONCEPTUAL\PILOT PDR\ES-1 AND ES-2 PROCESS FLOW DIAGRAM.DWG - BUNDY, JON



- o Dissolved oxygen removal (membrane contactors)
- o Stabilization
 - Calcium hydroxide addition
 - Carbon dioxide addition
 - Sodium bisulfide addition
 - Ferrous sulfate addition
- Five (5) recharge wells

Table ES-2 provides a summary of the capital and O&M cost opinions developed. A detailed breakdown of the cost and assumptions used in developing the costs is provided in Section 6 of this report.

Table ES-2. Conceptual Cost Opinion Summary for GWR Facilities	
Capital Cost Opinion	\$28,580,000
O&M Cost Opinion	\$1,960,000/year
Capital Cost per Thousand Gallons ¹	\$2.28/kgal
O&M Cost per Thousand Gallons	\$1.79/kgal
Total Cost per Thousand Gallons ¹	\$4.07/kgal

1. Based on 20 years and 6%.

HYDROGEOLOGIC EVALUATION

This feasibility study is concentrated on direct beneficial aquifer replenishment of purified reclaimed water through the use of injection (recharge) wells. The recharge wells are proposed to be constructed on and near the City's NEWRF site. Based on available aquifer characteristics and groundwater quality data, the projected injection zone for the recharge wells at this time is within the underground source of drinking water (USDW) in lower Zone A of the Floridan aquifer, which would require a one year pilot test to meet regulations. A number of hydrogeologic aspects were evaluated for this report, including hydrogeologic conditions, groundwater flow modeling, travel-time modeling, geochemical analysis, concentrate management, permitting needs, preliminary design and recommendations related to future hydrogeologic activities.

Based on this geochemical analysis from available data and the proposed treatment processes for the water to be recharged, there is minimal probability for the mobilization of arsenic in the groundwater system. Site specific data collection and testing is necessary to further verify that the aquifer can be recharged with purified water and not cause unacceptable metals mobilization.

The recharge wells will be permitted as Class V, Group 2 injection wells. The next phase of the feasibility assessment for this project should include construction and testing of a lower Zone A test well to collect the data needed to provide a more reliable evaluation of the number of recharge wells needed, the injection rates, and the injection pressures. Zone A monitoring wells and core sampling should also be constructed for this testing program. Data collected from this testing program will be used to perform a more detailed modeling analysis to evaluate the hydraulic and transport effects of the

recharge water and to assist in final design and permitting. Preliminary design consists of five recharge wells into lower Zone A and a number of monitoring wells in both upper and lower Zone A. The recharge wells will likely be near the center line of City owned/controlled property and the monitoring wells will be near property boundaries.

The RO treatment component of the plant will require disposal of approximately 530,000 gpd of concentrate. If deep well injection is selected as the option for disposal of concentrate from the NEWRF RO treatment process, the injection well planned for the City's two RO Water Treatment Plants could be utilized for disposal of this relatively small amount of reject water.

PILOT GWR PURIFICATION SYSTEM

A preliminary design for a pilot GWR purification system was developed and is provided in Section 7 of this report. It is anticipated that the pilot GWR purification system will run for at least 12 months and will meet the following objectives:

- Demonstrate the effectiveness of the selected treatment processes for Regulatory Compliance.
 - o Demonstrate ability to meet drinking water standards.
 - o Demonstrate ability to provide multiple barriers for viruses and pathogenic organisms.
 - o Collect and test samples for mutagenicity.
- Collect data relative to electrical power and chemical costs for verification of full scale treatment costs.
- Confirm the design criteria for the full-scale treatment processes.
- Evaluate effectiveness of differing post treatment process technologies and configurations.

The pilot unit will include the same unit processes of the proposed full-scale treatment system. The cost opinion for 12-months of piloting includes the cost for building ancillary equipment and the cost for a 12-month lease of the major equipment.

Table ES-3 provides a breakdown of the cost opinion for the purification pilot system and exploratory well testing.

Table ES-3. Purification Pilot System and Exploratory Well Testing Preliminary Opinion of Probable Construction Costs¹	
Description	Costs
Purification Pilot System	\$702,000
Test Recharge Well/Underground Injection Control Permit	\$161,000
Monitoring Well	\$132,000
Wire-Line Test Cores	\$100,000
Total	\$1,095,000

1. Conceptual costs for equipment lease or purchase and installation. Costs do not include pilot system operation and maintenance costs, including chemicals, electric power, membrane replacement, and membrane cleaning. Pilot program sampling, water quality analysis, and engineering services are also not included.

PUBLIC OUTREACH

Public outreach is a critical part of an indirect potable reuse project. Successfully implementing this type of project requires a clear understanding of how it will initially be perceived, how to describe its value, and how to conduct an effective outreach program. FDEP regulations include a requirement for opportunities for public meetings and require the implementation of public education and public participation programs during the planning stages of the program. The public education and public participation programs are required to be described in detail in the engineering report. Additionally, FDEP regulations require written notification to affected public water supply utilities within the area to be affected by the proposed project.

The City of Clearwater is committed to the development of a public outreach program that begins during the design of the City's Groundwater Replenishment Project and continues through the construction of the project. During this feasibility study, a public outreach collaborative workshop was conducted for City staff on July 16th, 2010 at the city's Public Works classroom. The recommendations from the public outreach workshop are intended to help the City efficiently and cost-effectively implement an outreach process so that a strong foundation for future outreach efforts is developed.

FUTURE STEPS AND RECOMMENDATIONS

Based on the findings of this evaluation, this project continues to appear to be a technically feasible alternative to more fully utilize the City's water resources. In addition, the TMDLs for Tampa Bay may necessitate the reduction or elimination of surface water discharge from the City's East and Northeast WRFs or expensive upgrades to those treatment plants to reduce the nitrogen and phosphorus discharges. A groundwater replenishment system would help the City to reduce the discharges to Tampa Bay. Verification and refinement of the proposed facilities will be a step-wise approach as the City continues to move forward with a groundwater replenishment program. Additional reclaimed water and groundwater sampling to better characterize each, along with pilot testing, construction of preliminary monitoring wells, and an exploratory well will be the next steps in confirming the treatment process and post treatment requirements for the groundwater replenishment process as well as confirming the rate of injection.

As the City moves forward with developing this groundwater recharge system the following future steps will be required prior to full-scale implementation.

- **Pilot Testing** – Based on the groundwater samples taken, the TDS of the proposed injection zone is greater than 500 mg/L. Therefore, pilot testing for a minimum of 12 months will be required by FDEP prior to issuing a permit for injection of the recharge water. Included in the pilot testing would be the design of the pilot unit, bidding and construction of the pilot unit, development of a pilot test plan and protocol, operation of the pilot unit and sampling during pilot testing operations.

- **Reclaimed Water Sampling-** Analysis of the existing reclaimed water quality will be required to confirm the design parameters presented in this study as well as observe variations in the water quality in the reclaimed water. A proposed reclaimed water sampling plan was provided in Section 3.
- **Preliminary Monitoring Wells** – Construction monitoring wells in locations where the permanent monitoring wells are anticipated to be located, will allow for sampling of the groundwater around the injection zone to further characterize the groundwater. The monitoring wells could also be used to extract cores from the local formation for testing.
- **Groundwater Sampling** – Additional groundwater sampling will be required to further characterize the groundwater in the injection zone. The preliminary monitoring wells and the existing inactive test ASR well at the NEWRF can be used to pull groundwater samples. Groundwater quality with respect to minerals and metals will be important to fully characterize as the implementation of a groundwater replenishment program continues.
- **Exploratory Well** – An Underground Injection Control (UIC) permit will be required to drill an exploratory well. The exploratory well could be located at one of the proposed recharge well locations so it could be converted to a recharge well following construction of the purification process. The exploratory well could be used to do both aquifer performance testing and injection testing.
- **Underground Injection Control (UIC) Permit for Recharge Wells** – Permits will be required from FDEP and the SWFWMD for drilling/operating recharge wells for groundwater recharge. Involving regulatory agencies early in the planning process can help streamline the permitting process. The UIC permit process for the recharge wells should be started following injection testing on the exploratory well.
- **Purification WTP Permitting** – Following piloting of the purification process, the permitting process for construction the purification process should begin. A permit for disposal of the concentrate should also be applied for at the same time.
- **Preliminary Design** – A preliminary design report will fully define the process design of the groundwater replenishment system, serving as the basis of design and providing documentation for permitting applications.
- **Public Participation** – Public education and input early in the process can help with public acceptance and support of the project. Items that can be included in a public participation plan include surveys, public notices, e-mails and mail-outs, flyers and fact sheets, public meetings, websites, and media liaisons. A public education/information center could be included as part of the pilot testing program as a way for the public to learn more about the proposed process and the testing done by the City prior to implementation. Public education and input will also continue

through each step of the project to keep the public informed throughout the development of the groundwater replenishment system

A proposed work flow chart outlining the various steps in implementing the groundwater replenishment program is provided in Figure ES-3.

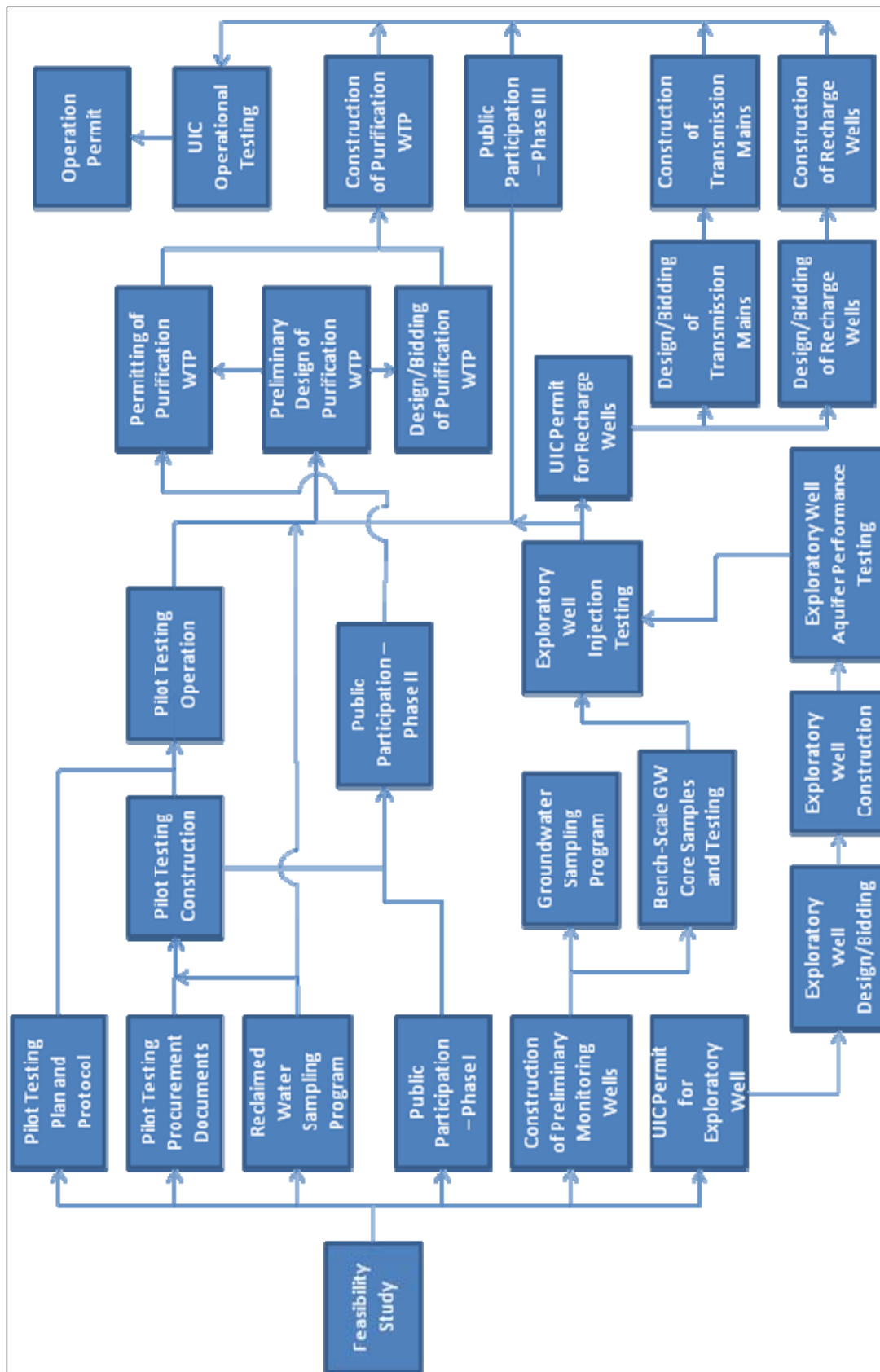


Figure ES-3. Program Implementation Flow Chart

1.0 INTRODUCTION

1.1 PURPOSE

In an effort to reduce discharge of reclaimed water to open waters and more fully utilize their reclaimed water, the City of Clearwater (City) is investigating the feasibility of replenishing aquifer systems in the City with highly purified reclaimed water from the Northeast Water Reclamation Facility (NEWRF). The City authorized Tetra Tech and Legette, Brashears & Graham, Inc. (LBG) to develop a Groundwater Replenishment (GWR) Feasibility Study. This GWR Feasibility Study builds upon findings from the GWR Preliminary Feasibility Study that are summarized to the City in a letter report dated September 15, 2009. The preliminary feasibility study was based on a number of assumptions relative to the quality of the reclaimed water and quality of the receiving groundwater that were used to initially develop the program scope and costs. This feasibility study includes reclaimed water sampling, groundwater sampling, and modeling that will be used to update the recommendations and cost opinions from the preliminary feasibility study. This feasibility study also includes a preliminary design of a pilot GWR purification system and the development of a public information program. A summary of the tasks included in the GWR Feasibility Study include the following:

- Characterization of the reclaimed water.
- Characterization of the groundwater quality in the replenishment area.
- Groundwater modeling.
- Updated preliminary plans, equipment list, and cost opinions from the preliminary feasibility study.
- Development of a pilot purification system preliminary design.
- Potential impact of proposed numeric nutrient criteria on the City's surface water discharge of reclaimed water.
- Development of a water quality monitoring program.
- Development of public information program recommendations.

1.2 BACKGROUND

1.2.1 Northeast Water Reclamation Facility (NEWRF)

The NEWRF is located in the northeast portion of the City, off of State Road (S.R.) 580 and has a rated capacity of 13.5 million gallons per day (MGD). The existing NEWRF consists of primary sedimentation, a 4-stage Bardenpho process for biological nutrient removal, secondary clarifiers, rapid sand filters; and chlorine disinfection. Sodium hypochlorite is added to the filtered water for chlorination and the treated effluent is stored in a 5 million gallon (MG) reclaimed water storage tank. A 3.5 MG reject water storage tank is also located on-site. Chlorinated effluent from the 5 MG reclaimed water storage tank is pumped into the City's reuse system or to the City's East Water Reclamation Facility (East WRF) where it is combined with effluent from the East WRF. The combined effluent is dechlorinated and the dissolved oxygen is boosted before

being pumped to an outfall that discharges to Old Tampa Bay. Influent flows to the NEWRF from January 2009 to June 2010 averaged approximately 5.2 MGD, with a low of 3.9 MGD and a high of 7.5 MGD. The existing site plan for the NEWRF is provided in Figure 1-1.

This GWR Feasibility Report is based on providing 3 MGD of highly purified water for injection into the groundwater. Based on the projected recovery of the treatment processes, this will result in approximately 3.8 MGD of effluent from the NEWRF being diverted to the proposed advanced treatment system for purification.

1.2.2 Direct Aquifer Recharge

The preliminary feasibility study reviewed the use of both direct and indirect aquifer recharge. Direct aquifer recharge was determined to be more beneficial due to the limitations of indirect aquifer recharge (land application of reclaimed water such that it will indirectly recharge an aquifer by allowing the recharged water to pass through different medium before it reaches the aquifer that is being recharged). Direct aquifer recharge consists of the reclaimed water being injected directly into the aquifer that is being recharged through the use of recharge wells.

1.3 REGULATORY REVIEW

1.3.1 State Regulations

State of Florida regulations that address groundwater recharge and indirect potable reuse are documented in the Florida Administrative Code (F.A.C.). Chapters of the F.A.C. that are applicable to these types of recharge and reuse projects include:

- Chapter 62-4 Permits
- Chapter 62-40 Water Resource Implementation Rule
- Chapter 62-110 Exceptions to the Uniform Rules of Procedure
- Chapter 62-520 Groundwater Classes, Standards, and Exemptions
- Chapter 62-521 Wellhead Protection Rule
- Chapter 62-522 Groundwater Permitting and Monitoring Requirements
- Chapter 62-528 Underground Injection Control
- Chapter 62-532 Water Well Permitting and Construction Requirements
- Chapter 62-550 Drinking Water Standards, Monitoring, and Reporting
- Chapter 62-600 Domestic Wastewater Facilities
- Chapter 62-610 Reuse of Reclaimed Water and Land Application
- Chapter 62-620 Wastewater Facility and Activities Permitting
- Chapter 62-699 Treatment Plant Classification and Staffing

1.3.2 Classification of Groundwater

For groundwater recharge projects, it is important that the classification of the groundwater targeted to receive the recharge water be identified as that will determine the level of treatment necessary for the recharge water. Per Chapter 62-520, F.A.C., all groundwater of the State of Florida falls within one of five classes, Class F-1, G-I, G-II, G-III, or G-IV. These groundwater classifications are described in Table 1-1.

Table 1-1. Groundwater Classifications	
Classification	Description
F-I	Potable water use, groundwater in a single source aquifer described in Rule 62-520.460, F.A.C., with a total dissolved solids content of less than 3,000 mg/L and was specifically reclassified as Class F-I by the Environmental Regulation Commission (boundaries are in Flagler County)
G-I	Potable water use, groundwater in a single source aquifer that has a total dissolved solids content of less than 3,000 mg/L and was specifically reclassified by the Commission
G-II	Potable water use, groundwater in aquifers with a total dissolved solids content of less than 10,000 mg/L, unless otherwise classified by the Commission
G-III	Non-potable water use, groundwater in unconfined aquifers with a total dissolved solids content of 10,000 mg/L or greater; or with a total dissolved solids content of 3,000-10,000 mg/L and either has been reclassified by the Commission as having no reasonable potential as a future source of drinking water, or has been designated by the Department as an exempted aquifer pursuant to subsection 62-528.300(3), F.A.C.
G-IV	Non-potable water use, groundwater in confined aquifers with a total dissolved solids content of 10,000 mg/L or greater

Chapter 62-528, F.A.C. defines an underground source of drinking water (USDW) as an aquifer which supplies drinking water for human consumption, is a Class F-I, G-I or G-II groundwater, or contains a total dissolved solids (TDS) concentration less than 10,000 mg/L, and is not an exempted aquifer. Per Chapter 62-528, F.A.C., any water injected into a USDW must meet all primary and secondary drinking water standards. The recommended injection zone for the GWR project is the lower Zone A, which is classified as a G-I groundwater.

1.3.3 Injection Well Classifications

Chapter 62-528, F.A.C. provides the definition of injection wells and classifies them as Class I, Class II, Class III, Class IV, or Class V. Typically:

- Class I wells are municipal and industrial disposal wells injecting into a non-USDW
- Class II wells are injection wells utilized in the oil and gas industry
- Class III wells are generally used in the mining industry
- Class IV wells are hazardous waste wells, and
- Class V wells are injection wells not included in Class I, II, III, and IV wells and include wells such as aquifer recharge wells, desalination process wells, stormwater wells, and aquifer storage and recovery (ASR) wells.

Of the various classifications of injection wells, Class V wells are applicable for the proposed Groundwater Recharge project. Class V wells are subdivided into nine groups for permitting purposes. Group 2 includes aquifer recharge wells.

1.3.4 Aquifer Recharge

Aquifer recharge wells are defined as Class V injection wells in Rule 62-528.300, F.A.C. Aquifer recharge wells include recharge wells, salt water intrusion barrier wells, subsidence control wells, and connector wells. Per Rule 62-528.300, F.A.C., recharge wells are “used to replenish, augment, or store water in an aquifer” and salt water intrusion barrier wells are “used to inject water into a fresh water aquifer to prevent the intrusion of salt water into the fresh water.”

1.3.5 Part V of Chapter 62-610, F.A.C. (Groundwater Recharge and Indirect Potable Reuse)

Part V of Chapter 62-610, F.A.C. (Reuse of Reclaimed Water and Land Application) describes the regulations for groundwater recharge and indirect potable reuse systems. These regulations are presented in the following sections. Reclaimed water from treatment facilities are allowed to be utilized for groundwater recharge and indirect potable reuse provided the reclaimed water meets the treatment requirements and the treatment facility producing the reclaimed water has a design average daily flow of equal to or greater than 0.1 million gallons per day (mgd).

1.3.5.1 Groundwater Recharge

Per 62-610.550, F.A.C., groundwater recharge systems include:

1. Injection of reclaimed water into Class F-I, G-I, or G-II groundwaters, as described in Rule 62-610.560, F.A.C.
2. Rapid-rate land application systems, as described and regulated by Part IV of Chapter 62-610, F.A.C.
3. Use of reclaimed water to create barriers to the landward or upward migration of salt water within Class F-I, G-I, or G-II groundwaters, as described in Rule 62-610.562, F.A.C. Rapid-rate land application or injection facilities may be used for salinity barrier control.

4. Discharge to surface waters which are directly connected to Class F-I, G-I, or G-II groundwaters, as described in Rule 62-610.555, F.A.C.

As presented earlier, Class F-I, G-I, and G-II groundwaters are designated for potable water use and Class G-III and G-IV groundwaters are designated for non-potable water use. Per Rule 62-610.560, the injection of reclaimed water into Class F-I, G-I, or G-II groundwater shall be considered groundwater recharge.

1.3.5.2 Indirect Potable Reuse

Per 62-610.550, F.A.C., indirect potable reuse systems involve the planned use of reclaimed water to augment surface water resources which are used or will be used for public water supplies. Indirect potable reuse systems include:

- Discharges to Class I surface waters, as described in Rule 62-610.554, F.A.C.
- Discharges to other surface waters which are directly or indirectly connected to Class I surface waters, as described in Rule 62-610.555, F.A.C.

There is a discrepancy in the Chapter 62-610, F.A.C. definition of indirect potable reuse and in the definition used nationally. The National Water Research Institute (NWRI) defines indirect potable reuse as the augmentation of a drinking water source (surface water or groundwater) with recycled water followed by an environmental buffer prior to drinking water treatment.¹

Per Chapter 62-610, F.A.C., indirect potable reuse systems only include discharges to surface waters.

1.3.6 Aquifer Recharge Requirements

Per Chapter 62-528.610(2), F.A.C. Operation Requirements for Class V Wells, domestic wastewater effluent or reclaimed water quality shall meet the criteria established in Rules 62-600.420(1)(d)2 and 62-600.540(2) and (3), or 62-610.560, F.A.C., as appropriate. Additionally, as stated previously, per Chapter 62-528, F.A.C., wells injecting into a USDW must meet all primary and secondary drinking water standards.

1.3.7 Source Water Treatment

In many cases, the source water for recharge and reuse projects is treated water from domestic wastewater treatment facilities. Per 62-600.420, F.A.C., the treatment levels for these facilities are described in Table 1-2.

Table 1-2. Treatment Requirements	
Treatment Level	Requirements
Secondary	20 mg/L CBOD5 and 20 mg/L TSS
Advanced	5 mg/L CBOD5, 5 mg/L TSS, 3 mg/L TN, and 1 mg/L TP
Full	20 mg/L CBOD5, 5 mg/L TSS, 3 mg/L TOC, 0.2 mg/L TOX, 10 mg/L TN, and Primary and Secondary Drinking Water Standards

In addition, the disinfection requirements for these systems are shown in Table 1-3.

Table 1-3. Disinfection Levels¹	
Disinfection Level	Requirement
Low	2400 Fecal Coliform Values/100 mL sample
Basic	200 Fecal Coliform Values/100 mL sample
Intermediate	14 Fecal Coliform Values/100 mL sample
High ²	25 Fecal Coliform Values/100 mL sample
Full	0 Total Coliform Values/100 mL sample

¹ Rule 62-600.440

² 75% of all samples must be non-detect for fecal coliform

Depending on the specifics of a proposed groundwater recharge system, the requirements for permitting and demonstration can vary. For recharge systems, the classification of the affected groundwater supply is a starting point to identifying the set of regulatory requirements for a proposed project.

1.3.8 Groundwater Recharge Requirements

Groundwater recharge in Florida occurs naturally or through engineered systems such as Class V injection wells and rapid infiltration basins (RIBS). Class V injection wells generally inject nonhazardous fluid into or above an underground source of drinking water (USDW) and can include aquifer storage and recovery (ASR) wells, domestic waste wells, stormwater drainage wells, lake level control wells, air conditioning return flow wells, and swimming pool drainage wells.

Per 62-600.540(2)(d), F.A.C., "Effluent or reclaimed water shall, at a minimum, meet the Class G-II groundwater quality standards as established in Rule 62-520.420, F.A.C." Per 62-610.560(2), F.A.C., "Reclaimed water injected into Class G-II groundwater containing 3,000 mg/L or less of total dissolved solids or into Class G-I or F-I groundwater shall meet the full treatment and disinfection requirements contained in Rule 62-610.563(3), F.A.C. A summary of the regulatory requirements for groundwater recharge is provided in Table 1-4.

Table 1-4. Groundwater Recharge Requirements				
	62-600 (Domestic Wastewater Facilities)		62-610 (Reuse of Reclaimed Water and Land Application)	
TDS	<10,000 mg/L (G-II Aquifer)	<500 mg/L	>3,000 mg/L	<3,000 mg/L
Treatment	Secondary	Secondary	Secondary	Secondary
Reliability	Class I	Class I	Class I	Class I
Disinfection	High	Full	High	Full
Primary DWS	Yes	Yes	Yes	Yes
Secondary DWS	Yes	Yes	Edge of ZOD ⁸	Yes
Filtration	Before Disinfection ¹	Before Disinfection ¹	Before Disinfection ⁴	Before Disinfection ⁴
Total Nitrogen (TN)	10 mg/L ⁵	10 mg/L ⁵	10 mg/L ⁵	10 mg/L ⁵
Total Organic Carbon (TOC)	BPJ	5 mg/L and 9 mg/L ²	BPJ	3 mg/L and 5 mg/L ⁶
Total Organic Halogen (TOX)	BPJ	0.2 mg/L and 0.3 mg/L ³	BPJ	0.2 mg/L and 0.3 mg/L ⁷
Testing Program	Not discussed	Min 2-Year, Full Scale	BPJ	1 Year Pilot

¹ 62-600.540(2)(b), ² 62-600.540(3)(b)(1), ³ 62-600.540(3)(b)(2), ⁴ 62-610.563(2)(b), ⁵ 62-610.563(2)(c), ⁶ 62-610.563(3)(d)
⁷ 62-610.563(3)(e), ⁸ 62-610.560(3)(c)

DWS = Drinking Water Standards as established in Rules 62-550.310 and 62-550.320, F.A.C.

ZOD = Zone of Discharge

BPJ = Best Professional Judgment

Both 62-600 F.A.C. and 62-610 F.A.C. includes the requirement that the treatment process shall provide multiple barriers for organics and pathogens and that additional pollutant reduction for parameters reasonably expected to pose a risk to public health due to acute or chronic toxicity (Rule 62-610.562(3)(b), FAC) shall be provided.

Along with public perception, one of the obstacles in using treated municipal wastewater effluent for groundwater recharge is the concern of the impacts of emerging contaminants including trace organics (potential endocrine disrupting compounds, pharmaceutically active compounds, and Nitrosodimethylamine (NDMA)), some trace inorganics, and microbes. Reverse osmosis has shown to be effective at efficiently removing selected organic wastewater indicators, such as endocrine disrupting compounds and pharmaceutically active compounds (Asano et al, 2004). Trace levels of microconstituents can still exist with a single treatment system, thus multiple barriers of treatment are important for adequate removal of these compounds.

The Southwest Florida Water Management District (SWFWMD) published a report called “Feasibility of Using Reclaimed Water for Aquifer Recharge” (MWH, 2009) that “evaluates if indirect or direct aquifer recharge could be used to create improvements to the aquifer and provide the opportunity for future, additional groundwater withdrawals to be developed consistent with the District’s water use permitting (WUP) rules”. To meet the requirements for full treatment for direct aquifer recharge, the SWFWMD report

recommended the following treatment processes following advanced wastewater treatment:

- Microfiltration
- Reverse Osmosis
- Advanced Oxidation/UV Disinfection

These treatment processes are similar to those used at the Orange County Water District (OCWD) GWR System, which is the largest planned indirect potable reuse project in the world. The OCWD GWR system treats reclaimed water from the Orange County Sanitation District in Orange County California to be used for groundwater replenishment and as a saltwater barrier. Therefore, these treatment processes are the basis of the purification process proposed in this feasibility study. In addition to the primary treatment processes, post-treatment of the purified water will be necessary, which will, at a minimum, consist of alkalinity and calcium addition for stabilization and an oxygen removal process to help prevent the mobilization of metals in the aquifer. Design criteria for the treatment processes at the OCWD GWR System, membrane projections, geochemical modeling results, and manufacturer recommendations will be used as a basis for sizing and costing equipment for this feasibility report. Actual design requirements would need to be further developed through treatability studies and pilot testing as the City continues to develop a groundwater replenishment system.

2.0 NEWRF RECLAIMED WATER CHARACTERIZATION

In order to characterize the reclaimed water quality that will supply the purification process for process verification, sizing and performance projections, the existing permit requirements and historical water quality from monthly operating reports were reviewed and summarized. The City performed additional sampling on the reclaimed water for parameters that are not sampled as part of their routine monitoring that should be considered when projecting design criteria for the anticipated purification process.

2.1 NEWRF PERMIT REQUIREMENTS

The NEWRF is currently permitted to discharge up to 13.5 MGD annual average daily flow (AADF) for public access reuse or up to 13.5 MGD AADF (18.5 MGD combined AADF with the East WRF) to a surface discharge into Tampa Bay via the East WRF. The effluent at the NEWRF is required to meet the guidelines stipulated in the FDEP discharge permit summarized in Table 2-1.

Table 2-1. NEWRF FDEP Discharge Permit Requirements						
Parameter	Units	Max/Min	Annual Average	Monthly Average	Weekly Average	Single Sample
Flow ^{1,2}	MGD	Max	13.5	Report	-	-
BOD, Carbonaceous ^{1,2} 5-day, 20°C	mg/L	Max	5.0	6.25	7.5	10.0
Solids, Total Suspended ¹	mg/L	Max	5.0	6.25	7.5	10.0
Nitrogen, Total (as N) ¹	mg/L	Max	3.0	3.75	4.5	6.0
Solids, Total Suspended ²	mg/L	Max	-	-	-	5.0
pH ^{1,2}	SU	Range	-	-	-	6.5 to 8.5
Coliform, Fecal, % less than detection ^{1,2}	Percent	Min	-	75	-	-
Coliform, Fecal ^{1,2}	#/100mL	Max	-	-	-	25
Oxygen, Dissolved (DO) ¹	mg/L	Min	-	-	-	4.0
Total Residual Chlorine (For Disinfection) ²	mg/L	Min	-	-	-	1.0
Total Residual Chlorine (For Dechlorination) ¹	mg/L	Max	-	-	-	0.01
Copper, Total Recoverable ¹	ug/L	Max	-	-	-	3.7
Dichlorobromomethane ¹	ug/L	Max	43	-	-	-
Chronic Whole Effluent Toxicity ¹	Percent	Min	-	-	-	100

1. Denotes water quality requirements for surface water discharge.

2. Denotes water quality requirements for public access reuse discharge.

2.2 NEWRF HISTORICAL EFFLUENT MONITORING

The City of Clearwater collects effluent water quality samples on a daily basis for use in reporting to FDEP. The City has provided Tetra Tech with monthly operating reports (MORs) for the NEWRF from January 2007 to June 2010. The average, 5th and 95th percentile data for each parameter was calculated from this data as a basis for the estimated design parameters of the facilities. A summary of the water quality data for selected parameters of interest is provided in Table 2-2.

Table 2-2. NEWRF Effluent Monitoring Data (January 2007 to June 2010)			
Parameter	Average Concentration (mg/L)	5% Percentile Concentration (mg/L)	95% Percentile Concentration (mg/L)
Chloride	225	192	259
pH (Units)	7.5	6.9	8
Turbidity (NTU)	0.67	0.40	1.04
Cl ₂ Residual	2.8	2	3.6
TSS	1.12	0.5	2.3
Temperature (Degrees C)	26.6	22	30
TKN	1	0.66	1.36
NH ₃	0.03	0	0.065
NO _x	1.47	0.5	2.76
Total Nitrogen	2.47	1.35	3.8
Total Phosphorous	0.65	0.16	1.2
CBOD ₅	2.3	2	3.9
Dissolved Oxygen	9.5	7.9	11.6

2.3 NEWRF RECLAIMED WATER SAMPLING

The City has conducted more extensive sampling of the reclaimed water that includes many of the FDEP regulated drinking water contaminants. The City provided Tetra Tech with the laboratory results from these sampling events. In addition to these reclaimed water samples, the City and Tetra Tech recently sampled the reclaimed water for several additional parameters in order to more fully characterize the reclaimed water. The water quality parameters sampled included general water quality parameters for physical, mineral and inorganic constituents for process verification, sizing, performance and projections as well as blending and stability considerations. A summary of the water quality parameters from all of these sampling events and the results are presented in Table 2-3.

Table 2-3. NEWRF Effluent Water Quality Sampling Results ¹				
Parameter	Average (mg/L)	Range (mg/L)	Number of Samples	Drinking Water MCL
Metals				
Sodium	132	98 to 151	4	160 mg/L
Calcium	110	--	1	--
Magnesium	15	--	1	--
Iron	0.034	0.026 to 0.048	4	0.3 mg/L
Potassium	11	--	1	--
Aluminum	--	BDL to 0.097	4	0.2 mg/L
Copper	0.0019	0.0013 to 0.0025	3	1 mg/L
Zinc	0.015	0.012 to 0.018	3	5 mg/L
Other Regulated Metals ²	BDL ⁵	BDL ⁵	3	--
Inorganics				
Chloride	219	190 to 277	4	250 mg/L
Alkalinity (as HCO ₃ ⁻)	232	--	1	--
Sulfate	71	45 to 102	4	250 mg/L
Nitrate	2.2	0.2 to 3.4	3	10 mg/L
Nitrite	BDL	BDL	3	1 mg/L
Arsenic	0.002	0.0011 to 0.0034	3	0.01 mg/L
Fluoride	0.46	0.43 to 0.48	3	2 mg/L
Silica	23	--	1	--
Aggregates				
Color (CPU)	--	BDL to 10	3	15 CPU
Odor (TON)	9	4 to 17	3	3 TON
Surfactants	--	BDL to 0.078	3	--
TDS	665	520 to 840	4	500 mg/L
Other				
pH (Unitless)	7.7	7.6 to 7.8	3	6.5 – 8.5
Temperature (°C)	28.3	26.4 to 29.7	3	--
Ammonia	BDL	--	1	--
Total THM's	0.10	0.094 to 0.11	3	0.08 mg/L
VOC's & SOC's ³	BDL ⁶	BDL ⁶	3	--
Herbicides/Pesticides ³	BDL ⁷	BDL ⁷	3	--
Radionuclides (pCi) ⁴	BDL ⁸	BDL ⁸	3	--
NDMA (ng/L)	3.5	--	1	--
1,4 Dioxane	BDL	--	1	--

- Table includes data from five (5) sampling events on 6/24/2008, 5/21/2009, 8/24/2010, 9/29/2010, and 10/27/10
- Includes Antimony, Barium, Beryllium, Cadmium, Chromium, Lead, Manganese, Mercury, Selenium and Silver.
- List of VOC's, SOC's, Herbicides, and Pesticides analyzed is presented in Appendix A
- Radionuclides include Gross Alpha, Radium 226, and Radium 228
- All analytes measured BDL except for Cadmium (1 ug/L on 6/24/08 and 2.4 ug/L on 5/21/09) and Manganese (1.3 ug/L on 5/21/09 and 2.9 ug/L on 8/24/09)
- All analytes measured BDL except for Dalapon (1.0 ug/L on 6/24/08 and 1.4 ug/L on 8/24/10)
- All analytes measured BDL except for Atrazine (0.14 ug/L on 6/24/08)
- All analytes measured BDL except for Radium 226 (0.07 ± 0.1 pCi on 6/24/09)

2.4 COMPREHENSIVE RECLAIMED WATER SAMPLING PLAN

In the next phase of the Groundwater Replenishment Program, it is recommended that a more comprehensive sampling program be implemented by the City in order to more fully characterize the reclaimed water that will supply the groundwater replenishment purification process. This sampling program could be performed during the pilot testing program and will more fully define the reclaimed water quality and help identify water quality parameters of concern. The sampling program would be implemented at the NEWRF.

The proposed reclaimed water quality monitoring program is summarized in Table 2-4 below with additional details provided in Tables 2-5 through 2-13. The purpose of the proposed sampling program is to provide a baseline of water quality data in the effluent from the NEWRF to support the future design and permitting of the purification treatment process and recharge system. Samples should be taken on the discharge line from the reclaimed water pump station. The parameters to be analyzed, the frequency of sampling, and the type of sample (grab or composite) are described in Table 2-4 and the following tables.

The water quality parameters in this sampling program include additional sampling of general water quality parameters for physical, mineral and inorganic constituents for process verification, sizing, performance and projections as well as blending and stability considerations. The additional sampling will provide additional details on the range of these parameters observed in the reclaimed water. In addition to these parameters, we have included sampling of the parameters in the primary and secondary drinking water standards to determine if the reclaimed water meets the standards for full treatment and disinfection in Rule 62-610.563 (3) (b), F.A.C and, if not, to verify that the proposed treatment should be able to achieve compliance. Sampling has also been proposed to determine the concentrations of total organic halides (TOX) and total organic carbon (TOC) in the reclaimed water relative to the requirements set forth in Rule 62-610.563 (3) (d) and (e), F.A.C. A list of pharmaceutically active compounds has also been included due to the increasing concern of these compounds in wastewater effluent. Additional parameters, if any, that may be required to be sampled to demonstrate compliance with Rule 62-610.563 (3) (c) and (f), F.A.C, would be determined in cooperation with FDEP and SWFWMD.

In the next phase of the program it is anticipated that pilot testing of the proposed treatment process will be performed to satisfy the requirements of Rule 62-610.564 F.A.C. (if TDS in the receiving groundwater is less than 3,000 mg/L TDS) and to provide the City and public with a high degree of confidence that the proposed treatment process can provide a high level of removal for all of the constituents in the reclaimed water.

Table 2-4. Proposed Reclaimed Water Quality Monitoring Program			
Monitored Parameters	Type of Sample¹	Sampling Frequency	Reference
pH	Continuous	Continuous	-
Chlorine Residual	Continuous	Continuous	-
Turbidity	Continuous	Continuous	-
Total Coliforms	Grab	Daily	-
TSS	24-Hr Composite	Daily	-
TOC	24-Hr Composite	Weekly ²	-
BOD	24-Hr Composite	Weekly ²	-
General Physical	Grab or 24-Hr Composite	Weekly for 14 Weeks ² , then Monthly	Table 2-6
General Mineral	24-Hr Composite	Weekly for 14 Weeks ² , then Monthly	Table 2-7
Regulated Inorganic Chemicals I	24-Hr Composite	Weekly for 14 Weeks ² , then Monthly	Table 2-8
Regulated Inorganic Chemicals II	24-Hr Composite	Monthly	Table 2-9
Regulated Organic Chemicals	Grab or 24-Hour Composite	Quarterly	Table 2-10
Unregulated Organic Chemicals	Grab or 24-Hour Composite	Quarterly	Table 2-11
Pharmaceutically Active Compounds	Grab or 24-Hour Composite	Quarterly	Table 2-12
Radioactivity	24-Hour Composite	Quarterly	Table 2-13
Disinfectants/Disinfection Byproducts	Grab	Quarterly	Table 2-14

Notes: 1. All samples taken from the reclaimed water main on-site.
2. Weekly samples taken on succeeding days so that all days of the week are sampled twice.

Table 2-5. General Physical		
Parameters	Method ¹	Reportable Detection
TSS	2540 D	-
Oil and Grease	5520 C	-
Foaming Agents	55440 C	0.02 mg/L
Turbidity	2130 B	0.05 NTU
UV %T-254	5910 B	0.1%
Conductivity	2510 B	1 µm/cm
Temperature – Field	2550 B	-
Odor	2150 B	0 TON
Color	2120 B	3 Units
SDI	D4189 (ASTM)	-
ORP	2580 B	-
Chlorophyll a	10200 H	--

1. Standard Methods, unless otherwise noted.
2. ASTM

Table 2-6. General Mineral		
Parameters	Method ¹	Reportable Detection
Calcium	3500 – CaB	0.003 mg/L
Magnesium	3500 – MgB	0.0005 mg/L
Potassium	3500 – KB	0.005 mg/L
Alkalinity	2320 B	Lab
Total Sulfide	4500 – S ²⁻	Lab
Strontium	3500 – SrB	0.03 mg/L
Ammonia	4500 – NH ₃	Lab
Silica	4500 – SiB	0.3 mg/L
Boron	200.7 (EPA)	0.1 mg/L
Bromide	4500 – BrB	0.1 mg/L
Total Dissolved Solids	2540 C	Lab
Total Phosphorous	4500 – P	Lab
Dissolved Phosphorous	4500 – P	Lab

1. Standard Methods, unless otherwise noted.
- Lab: Detection limit dependent upon equipment and method.

Table 2-7. Regulated Inorganic Chemicals I			
Parameters	Method¹	Reportable Detection	Drinking Water MCL, mg/L
Aluminum	200.8	1 µg/L	0.2
Barium	200.8	1 µg/L	2
Chloride	300.0	0.5 mg/L	250
Copper	200.8	1 µg/L	1
Fluoride	200.0	0.1 mg/L	2.0
Total Iron	200.7	1 µg/L	0.3
Dissolved Manganese	200.7	1 µg/L	--
Total Manganese	200.8	1 µg/L	0.05
Dissolved Iron	200.8	1 µg/L	--
Nitrate	4500NO ₃ ⁻ (Standard Methods)	0.1 mg/L	10
Silver	200.7	1 µg/L	0.1
Sodium	200.7	0.1 mg/L	160
Sulfate	300.0	0.5 mg/L	250
Zinc	200.8	1 µg/L	5
Nitrite	4500 – NO ₂ ⁻ (Standard Methods)	5µg/L	1

1. EPA, unless otherwise noted.

Table 2-8. Regulated Inorganic Chemicals II			
Parameter	Method¹	Drinking Water MCL	Reportable Detection
Antimony	200.8	6 µg/L	0.5 µg/L
Arsenic	200.8	10 µg/L	1 µg/L
Asbestos (fibers> 10 um in length)	100.2	7 MFL	0.20 MFL
Beryllium	200.8	4 µg/L	0.5µg/L
Cadmium	200.8	5 µg/L	1 µg/L
Chromium	200.7	100 µg/L	1 µg/L
Cyanide	335.3	200 µg/L	5 µg/L
Mercury	200.8	2 µg/L	0.1 µg/L
Nickel	200.8	100 µg/L	1 µg/L
Perchlorate	314.0	-- ²	2.5 µg/L
Selenium	200.8	50 µg/L	1 µg/L
Thallium	200.8	2 µg/L	0.5 µg/L

1. EPA, unless otherwise noted

2. Proposed for regulation

Table 2-9. Regulated Organic Chemicals				
Parameter	Molecular Weight	Method ¹	Drinking Water MCL	Reportable Detection
Volatile Organic Chemicals				
Benzene	78.12	524.2	1 ug/L	0.5 ug/L
Carbon Tetrachloride	153.82	524.2	3 ug/L	0.5 ug/L
1,2-Dichlorobenzene	147.01	524.2	600 ug/L	0.5 ug/L
1,4-Dichlorobenzene	147.01	524.2	75 ug/L	0.5 ug/L
1,2-Dichloroethane	98.96	524.2	3 ug/L	0.5 ug/L
1,1-Dichloroethene	98.96	524.2	7 ug/L	0.5 ug/L
cis-1,2-Dichloroethene	96.94	524.2	70 ug/L	0.5 ug/L
trans-1,2-Dichloroethene	96.94	524.2	100 ug/L	0.5 ug/L
Methylene Chloride (dichloromethane)	84.93	524.2	5 ug/L	0.5 ug/L
1,2-Dichloropropane	112.99	524.2	5 ug/L	0.5 ug/L
Ethylbenzene	106.17	524.2	700 ug/L	0.5 ug/L
Chlorobenzene	112.56	524.2	100 ug/L	0.5 ug/L
Styrene	104.16	524.2	100 ug/L	0.5 ug/L
Tetrachloroethene	165.83	524.2	5 ug/L	0.5 ug/L
Toluene	92.15	524.2	1,000 ug/L	0.5 ug/L
Total Organic Halide (TOX)	--	450.1	0.3 mg/L ²	--
1,2,4-Trichlorobenzene	181.45	524.2	70 ug/L	0.5 ug/L
1,1,1-Trichloroethane	133.41	524.2	200 ug/L	0.5 ug/L
1,1,2-Trichloroethane	133.41	524.2	5 ug/L	0.5 ug/L
Trichloroethene	131.39	524.2	3 ug/L	0.5 ug/L
Vinyl Chloride	62.50	524.2	1 ug/L	0.5 ug/L
Total Xylenes (m,p,&o)	106.17	524.2	10,000 ug/L	0.5 ug/L
Non-Volatile Synthetic Organic Chemicals (SOCs)				
Alachlor	269.77	507	2 ug/L	0.05 ug/L
Atrazine	215.69	507	3 ug/L	0.1 ug/L
Bentazon	240.28	515.4	--	1 ug/L
Benzo(a)pyrene	252.32	550.1	0.2 ug/L	0.1 ug/L
Carbofuran	221.26	531.1	40 ug/L	1 ug/L
Chlordane	409.78	508	2 ug/L	0.1 ug/L
2,4-D	221.04	515.4	70 ug/L	0.5 ug/L
Dalapon	142.97	515.4	200 ug/L	1 ug/L

Table 2-9. Regulated Organic Chemicals				
Parameter	Molecular Weight	Method¹	Drinking Water MCL	Reportable Detection
1,2-Dibromo-3-chloropropane	280.8	504.1	0.2 ug/L	0.01 ug/L
bis (2-ethylhexyl) adipate	370.57	525.2	400 ug/L	2 ug/L
bis (2-ethylhexyl) phthalate	390.56	525.2	6 ug/L	2 ug/L
Dinoseb	240.22	515.4	7 ug/L	0.5 ug/L
Diquat	184.24	549.1	20 ug/L	4 ug/L
Endothall	186.16	548.1	100 ug/L	45 ug/L
Endrin	380.91	508	2 ug/L	0.03 ug/L
Dibromomethane	173.85	504.1	0.05 ug/L	0.01 ug/L
Glyphosate	169.07	547	700 ug/L	25 ug/L
Heptachlor	373.32	508	0.4 ug/L	0.01 ug/L
Heptachlor Epoxide	389.32	508	0.2 ug/L	0.01 ug/L
Hexachlorobenzene	284.79	525.2	1 ug/L	0.1 ug/L
Hexachlorocyclopentadiene	272.77	525.2	50 ug/L	0.1 ug/L
HCH-gamma (Lindane)	290.83	525.2	0.2 ug/L	0.1 ug/L
Methoxychlor	345.66	525.2	40 ug/L	0.1 ug/L
Molinate	187.31	525.2	20 ug/L	0.1 ug/L
Oxamyl	219.26	531.1	200 ug/L	2 ug/L
Pentachlorophenol (PCP)	266.34	515.4	1 ug/L	0.1 ug/L
Picloram	241.46	515.4	500 ug/L	0.5 ug/L
PCB-1016	--	508	0.5 ug/L	0.5 ug/L
PCB-1221	--	508	0.5 ug/L	0.5 ug/L
PCB-1232	--	508	0.5 ug/L	0.5 ug/L
PCB-1242	--	508	0.5 ug/L	0.5 ug/L
PBB-1248	--	508	0.5 ug/L	0.5 ug/L
PCB-1254	--	508	0.5 ug/L	0.5 ug/L
PCB-1260	--	508	0.5 ug/L	0.5 ug/L
Simazine	201.66	507	4 ug/L	0.1 ug/L
Thiobencarb	257.78	507	--	0.5 ug/L
Toxaphene Mixture	--	508	3 ug/L	1 ug/L
2,3,7,8-TCDD (Dioxin)	321.97	1613B	30 pg/L	5 pg/L
2,4,5-TP (Silvex)	269.51	515.4	50 ug/L	0.5 ug/L

1. EPA, unless otherwise noted.

2. Rule 62-563 (3) (e) for groundwater <3000 mg/L TDS.

Table 2-10. Unregulated Organics			
Parameters	Molecular Weight	Method	Reportable Detection
1,4 Dioxane	88.12	Purge and Trap GC/MS	1 µg/L
n-Nitroso dimethylamine (NDMA)	74.08	Isotopic Dilution – GC/MS/MS-C1	2 ng/L
1,2 Dibromoethane (EDB)	187.87	504 (EPA)	--
1,1 – Dichloroethene	96.94	6210 D (Standard Methods)	--
Acetone	58.08	1624 (EPA)	--
Formaldehyde	30.03	1667 (EPA)	--
Ethylene Glycol	62.1		--
sec-Butylbenzene	134.2	524.2 (EPA)	--

Table 2-11. Pharmaceutically Active Compounds		
Parameters	Molecular Weight	Reportable Detection
Bezafibrate	361.8	--
Chloramphenicol	322.0	0.005 ug/L
Chlorotetracycline	478.9	0.05 ug/L
Clorfibric acid	214.6	--
Diclofenac	296.1	--
Dilantin	252.3	0.002 ug/L
Doxycycline	444.4	0.05 ug/L
Gemfibrozil	250.3	--
Ibuprofen	206.3	0.05 ug/L
Levothyroxine (Synthroid)	798.9	0.002 ug/L
Naproxen	230.3	230.3 ug/L
Oxytetracycline	460.4	0.5 ug/L
Penicillin G	372.5	0.002 ug/L
Penicillin V	388.5	0.002 ug/L
Prednison	358.4	0.002 ug/L
Salicyclic acid	138.1	0.05 ug/L
Tetracycline	444.1	0.5 ug/L
Theophylline	180.2	0.005 ug/L
Triclocarbon	315.6	0.005 ug/L
Triclosan	289.5	0.05 ug/L
Acetaminophen	151.2	0.005 ug/L
Antipyrine	188.2	0.001 ug/L
Atenolol	266.3	0.001 ug/L
Azithromycin	749.0	0.005 ug/L
Bacitracin	1,488	1 ug/L
Caffeine	194.2	0.05 ug/L
Carbadox	262.2	0.005 ug/L

Table 2-11. Pharmaceutically Active Compounds		
Parameters	Molecular Weight	Reportable Detection
Carbamzepine	236.1	0.001 ug/L
Ciprofloxacin	331.4	0.05 ug/L
Cotinine	392.5	0.001 ug/L
DEET	191.3	0.005 ug/L
Dexamethasone	392.5	0.005 ug/L
Diazepam	284.8	0.001 ug/L
Diltiazem	451.0	--
Enrofloxacin	184.8	0.05 ug/L
Erythromycin	451.0	0.001 ug/L
Fluoxetine (Prozac)	359.4	0.001 ug/L
Iopromide	733.9	0.05 ug/L
Lasalocid	345.8	0.001 ug/L
Lincomycin	791.1	--
Meprobamate	345.8	0.001 ug/L
Monensin	692.9	0.001 ug/L
Narasin	765.0	0.001 ug/L
Nicotine	162.2	0.005 ug/L

Table 2-12. Radioactivity			
Parameters	Method¹	Reportable Detection	Drinking Water MCL
Gross Alpha	7110C (Standard Methods)	3pCi/L	15 pCi/L
Gross Beta	900.0	4 pCi/L	EL
Radium 226 and 228 Combined	903.1/904.0	1 pCi/L	5 pCi/L
Strontium-90	905.0	2 pCi/L	8 pCi/L
Uranium	908.0	1 pCi/L	30 µg/L

1. EPA, unless otherwise noted.

2. EL-Exposure limited to annual dose of 4 millirem/year.

Table 2-13. Disinfectants/Disinfectant By-Products				
Parameters	Molecular Weight	Method¹	Reportable Detection	MCL
Total Trihalomethanes	--	524.2	0.5 µg/L	0.08 mg/L
Dichlorobromomethane	163.83	524.2	0.5 µg/L	--
Dibromochloromethane	208.29	524.2	0.5 µg/L	--
Bromoform	252.75	524.2	0.5 µg/L	--
Chloroform	119.38	524.2	0.5 µg/L	
Haloacetic Acids	--	552.2	1 µg/L	0.06 mg/L
Monochloroacetic acid	94.50	552.2	1 µg/L	--
Dichloroacetic acid	128.94	552.2	1 µg/L	--
Trichloroacetic acid	163.39	552.2	1 µg/L	--
Monobromoacetic acid	138.95	552.2	1 µg/L	--
Dibromoacetic acid	217.86	552.2	1 µg/L	--
Bromate	--	300.1B	0.5 µg/L	0.01 mg/L
Chlorite	--	300.1B	10 µg/L	1.0 mg/L
Free Chlorine	--	4500-CID (Standard Methods)	Lab	4.0 ²
Combined Chlorine	--	4500-CID (Standard Methods)	Lab	4.0 ²

1. EPA, unless otherwise noted.

2. Maximum Residual Disinfectant Limit.

3.0 GROUNDWATER QUALITY CHARACTERIZATION

3.1 REVIEW OF EXISTING GROUNDWATER WELLS IN THE AREA

The quality of the groundwater within the aquifer must be determined in order to establish the regulatory framework for the treatment and quality of the reclaimed water that must be used for recharge and to perform fluid compatibility analyses for the chemical interactions between the recharge water and the native groundwater. Rule 62-610.800(11) addresses characterization of the total dissolved solids (TDS) concentration in the groundwater receiving the recharge water. The groundwater must be characterized at the time of the initial permit application based upon best available information or, if insufficient information exists, based upon an exploratory well constructed prior to the submittal of the engineering report. The fluid compatibility analysis is required to insure that the recharge neither causes significant precipitation of dissolved minerals that will limit the rate of recharge at each well site nor causes significant dissolution of minerals in the aquifer matrix that could lead to the formation of significant voids or the release of contaminants. The groundwater quality information that is required for determination of fluid compatibility includes mostly the physical and inorganic constituents that are listed in Table 3-1. More extensive groundwater quality information will be required later in the program to establish background water quality within the aquifer for the purpose of determining compliance with groundwater quality regulations. However, this information will be collected from monitoring wells constructed specifically for this purpose as part of the permitting requirements for the program and to ensure maintenance of ground water quality after the recharge system is placed into operation.

Table 3-1. Basic Groundwater Quality Information Required for Fluid Compatibility Determination	
Parameter	Unit
pH	pH Units
Calcium	mg/L
Magnesium	mg/L
Potassium	mg/L
Sodium	mg/L
Iron	mg/L
Alkalinity	mg/L as CaCO ₃
Chloride	mg/L
Nitrate	mg/L
Sulfate	mg/L
Sulfide	mg/L
Conductivity	microsiemens per centimeter (µS/cm)
Total Dissolved Solids	mg/L

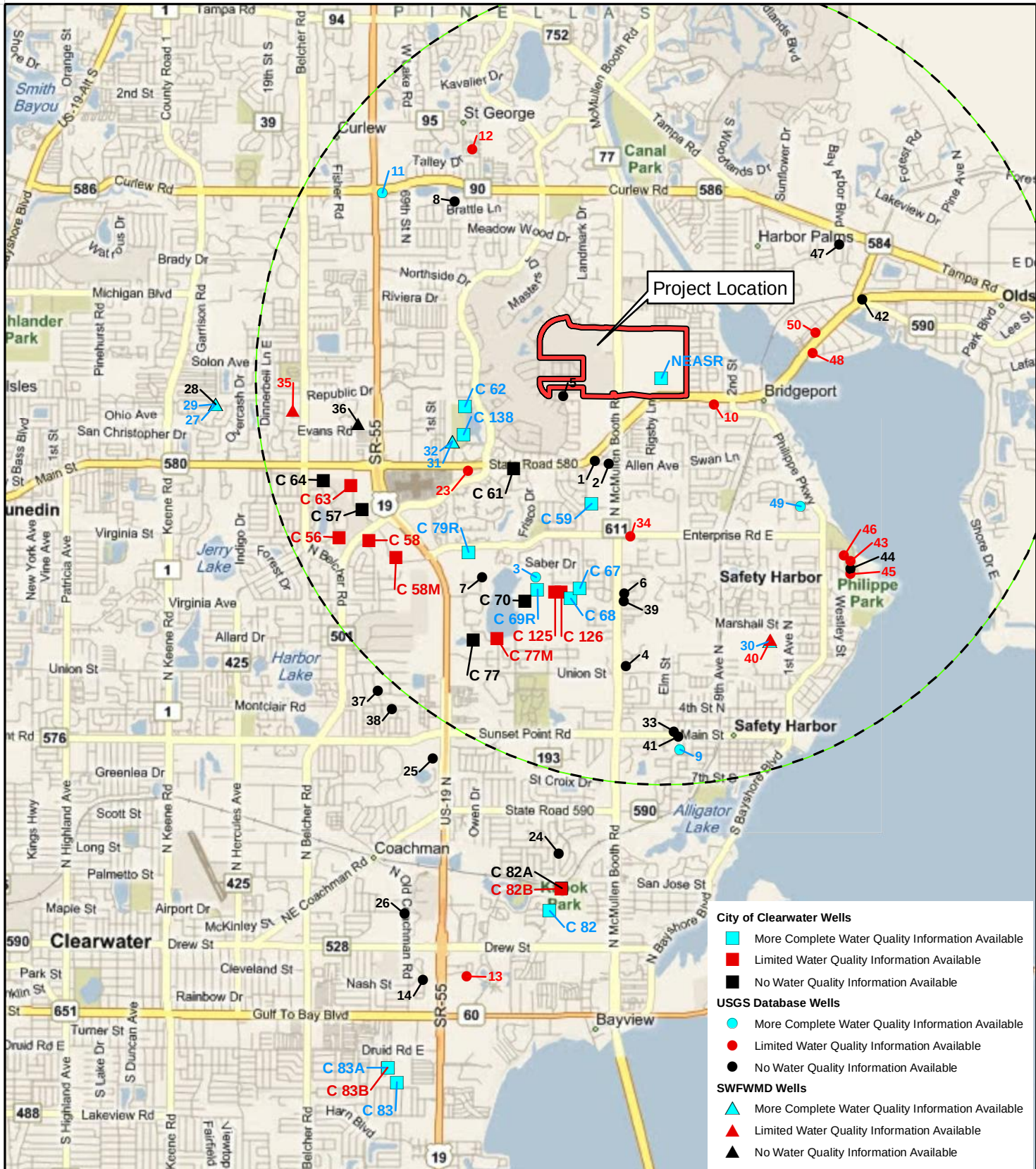
Information published about the existing wells in the vicinity of the proposed recharge area were reviewed from several sources including the U.S. Geological Survey National Water Information System database, the SWFWMD Regional Observation and Monitor-Well Program (ROMP) reports, the SWFWMD Water Management Information System, and water quality information and reports provided by the City of Clearwater in order to collect and compile existing ground water quality information. The review of the well information was focused upon wells that were constructed into the Floridan aquifer that penetrated Zone A and Zone B. Wells that were completed into the uppermost portion of the Tampa Formation, generally, less than 100 feet in depth below land surface and wells constructed into the surficial sands were generally not included in the well data base that was developed. Groundwater at this depth was very fresh throughout the study area and wells of this depth did not provide useful information about the quality immediately above, in the zone or below the proposed recharge zone. Additionally, they did not provide information about the depth at which the total dissolved solids concentration would be expected to exceed 500 mg/L, the quality at which the more stringent treatment requirements of Rule 62-600.540(3), F.A.C. do not apply or 3,000 mg/L, the quality at which the more stringent treatment requirements of Rule 62-610.563(3), F.A.C. do not apply.

The SWFWMD ROMP data base was reviewed for Pinellas County to identify wells that were in the vicinity of the proposed recharge area. Three wells were identified to be in the immediate vicinity of the proposed recharge area, (TR 14-1, TR-14-2, TR 14-3), one well was identified to the north of the proposed recharge area closer to Tarpon Springs (TR 15-3) and two wells were identified south of the proposed recharge area (TR 13-1X and TR 13-2X) in Largo. The reports for each of the wells which included lithologic and water quality information were downloaded and it was determined that each of these wells had been constructed into or below lower Zone A. At most of the ROMP well locations, construction was completed by constructing dual zone monitor wells from which water level and quality information could be obtained from different depths and formations. The USGS National Water Information System database was queried to locate all of the wells in their database within the vicinity of the proposed recharge area. Generally, all of the wells within a 2 to 3 mile radius of the proposed recharge area were reviewed to determine if they were constructed to a sufficient depth to provide groundwater quality information for upper Zone A, lower Zone A or Zone B. All of the Floridan aquifer wells of sufficient depth in the USGS database were identified and the records for all of the wells that had historic water quality data were retrieved. The well data base was completed with water quality information obtained from the City's water production and monitoring wells. The SWFWMD Water Management Information System database was also queried to retrieve water quality information for any of the Floridan wells identified within the vicinity of the proposed recharge area, included in the database.

All of the wells that were identified to have been constructed into the Floridan aquifer with depths greater than 100 feet below land surface are shown on Figure 3-1. The greatest number of wells occurs to the south of the proposed recharge area, many of them being wells constructed by the City of Clearwater. There are significantly fewer wells meeting the selection criteria to the north of the proposed recharge area. The wells shown on the figure have been color-coded to indicate the availability of water quality information. The wells were divided into three categories: wells with no water quality information available or provided, wells with water quality data which typically was limited to specific conductance, TDS, chlorides and/or sulfate; and wells with more extensive water quality information available. The available water quality information for specific conductance, TDS and chlorides is tabulated for each of the wells for which data was provided in Table 3-2.

The wells have been sorted by total depth, if available, to illustrate the variation of water quality with depth. Table 3-2 includes the most recent water quality data for the well and the year in which it was obtained, as well as the open hole interval of the well, if available. The water quality sampling performed by the City at several of their wells recently constructed contains measurements of both TDS and conductivity for each of the samples. Since much of the sampling in the USGS database provides information for conductivity only, the City data were used to obtain a correlation between TDS and conductivity. The paired TDS and conductivity data were graphed and a trend line constructed. The graph is shown in Figure 3-2. The trend line shows a high correlation between the data and therefore, the equation of the trend line was utilized to estimate the TDS of the groundwater from each well for which the conductivity had been measured, but not TDS. TDS values that were calculated from the specific conductance measurements have been marked with an asterisk to denote that they are not laboratory analysis results. Table 3-3 includes a compilation of selected water quality for several of the wells that was collected during drilling of the wells. As a means to further define the quality within the recharge zone, sampling of the ASR test well constructed at the NEWRF was performed in September 2010. The results of this sampling are summarized in Table 3-4 along with the most recent data for other wells in the survey area for which more complete water quality analysis data were available.

The well information was used to construct several cross sections that ran through or adjacent to the proposed recharge area which are shown on Figures 3-3, 3-4, 3-5 and 3-6. Figure 3-3 shows the location of the cross sections created using the information collected for the existing wells. Three cross sections were created as follows: one running north-south along the eastern edge of the proposed recharge area (Figure 3-4), one running east-west across the proposed recharge area (Figure 3-5), and a third running northwest-southeast south of the proposed recharge area (Figure 3-6). The well information was reported relative to depth below land surface; however, there was significant land surface elevation variation across the cross sections from +5 to +95 feet, MSL. Therefore, the information for each well was adjusted for land surface elevation and each well is shown on the cross sections at its elevation relative to mean sea level. Water quality information for both chlorides and TDS is shown for each well for which data was available.



Source: Well data obtained from the City of Clearwater, FL and USGS Nat'l Water Info System

- Project Location
- 3 Mile Radius

LEGEND



CITY OF CLEARWATER
GROUNDWATER REPLENISHMENT FEASIBILITY STUDY
WELL LOCATION MAP

FIGURE 3-1

Table 3-2. Summary of Well Depth and Quality Information for Wells Included in Survey

WELL LABEL	STATION NAME	USGS NUMBER	WELL DEPTH Feet, msl	Open Hole Interval Feet, msl	Zone	Most Recent Sample Year	Chloride mg/L	Cond. µS/cm	TDS mg/L
23	FOREST SER DEEP WELL NEAR DUNEDIN FL	280107082433801	-10	--	UA	1987	12	531	330*
1	13328S16E28 NEAR OLDSMAR FL	280112082424201	-37	--	UA	NS	--	--	--
2	28S16E28134 NEAR OLDSMAR FL	280111082423601	-46	--	UA	NS	--	--	--
50	802-241-44428516e22412 NEAR OLDSMAR FL	280201082410701	-54	--	UA	1965	1540	4400	2890*
46	CLE-DUN NO. 422428516E34 NEAR SAFETY HARBOR FL	280035082405401	-60	--	UA	1978	40	585	360*
12	CLE-DUN DEEP WELL 19 NEAR CURLEW FL	280311082433701	-61	--	UA	1976	13	320	190*
43	PHILLIPE PARK 800240134 NEAR SAFETY HARBOR FL	280033082405101	-64	--	UA	1966	76	680	430*
C-77M	CLEARWATER MONITOR WELL 77M		-64	26 to -64	UA	N/A	129	--	513
5	44428S16E20 NEAR MECCA FL	280137082425601	-65	--	UA	NS	--	--	--
C-58M	CLEARWATER MONITOR WELL 58		-71	26 to -71	UA	N/A	32	--	315
49	GRAHAM WELL PINE HRS-26 FL	280054082411301	-75	--	UA	1988	23	578	360*
C-125	CLEARATER MONITOR WELL 68M SHALLOW		-77	-17 TO 76.5	UA	N/A	38	780	334
3	28S16E3223228S16E32 NEAR SAFETY HARBOR FL	280026082430801	-81	--	UA	1975	22	286	170*
32	ROMP TR14-3 TAMPA WELL NEAR DUNEDIN FL	280118082434502	-81	-30 to -81	UA	1997	75	506	333
39	800242413A14328S16E33 NEAR SAFETY HARBOR FL	280018082422901	-84	--	UA	NS	--	--	--
10	CLE-DUN DEEP WELL 05 NEAR OLDSMAR FL	280133082415102	-85	--	UA	1979	130	800	510*
44	PHILLIPE PARK 242 NEAR SAFETY HARBOR FL	280030082405101	-87	--	UA	NS	--	--	--
47	28516E15442 NEAR OLDSMAR FL	280236082405602	-90	--	UA	N/A	--	--	--
C-138	CLEARWATER PRODUCTION WELL 3-1		-96	-21 to -96	UA	N/A	19	468.3	250
C-59	CLEARWATER PRODUCTION WELL 3-2		-99	-47 to -99	UA	N/A	210	912.7	550
7	80024332214128S16E32 NEAR MECCA FL	280027082433101	-115	--	UA	NS	--	--	--
34	STALLS DEEP WELL NEAR SAFETY HARBOR FL	280042082422701	-115	--	UA	1983	27.0	560	350*
C-68	CLEARWATER PRODUCTION WELL 68	280018082425301	-117	-25 to -117	UA	N/A	60	488	380
C-56	CLEARWATER PRODUCTION WELL 56	280041082443401	-124	-13 to -124	UA	N/A	326	--	330
28	ROMP TR 14-2 TAMPA ANNULAR WELL	280132082452801	-145	-14 to -145	UA, SC1	NS	--	--	--
C-63	CLEARWATER PRODUCTION WELL 63	280101082442901	-148	-2 to -148	UA	N/A	267	--	--
40	ROMP TR14-1 TAMPA WELL NEAR SAFETY HARBOR FL	280002082412602	-154	-54 to -154	UA	1999	19.0	360	210*

Table 3-2. Summary of Well Depth and Quality Information for Wells Included in Survey

C-62	CLEARWATER PRODUCTION WELL 3-5		-158	-18 to -158	UA, SC1	N/A	55	483.7	270
C-79R	CLEARWATER PRODUCTION WELL 79R		-162	-97 to -162	UA, SC1	N/A	25	528	310
29	ROMP TR 14-2 TAMPA WELL NEAR DUNEDIN FL	280132082452802	-163	-158 to -163	SC1	2010	726	2910	1550
C-69R	CLEARWATER PRODUCTION WELL 69R		-163	-27 to -163	UA, SC1	N/A	230	1049	450
4	28S16E33343 NEAR SAFETY HARBOR FL	275953082422801	-178	--	UA	NS	--	--	--
C-82	CLEARWATER PRODUCTION WELL 82 (KAPOK)		-179	-46 to -179	UA	2009	29	534.3	280
C-82A	CLEARWATER MONITOR WELL 82A		-181	-53.7 to -181	UA	NS	--	--	--
37	SYL ABBEY DEEP WELL 2	275943082441601	-184	--	SC1	NS	--	--	--
38	SYLVAN ABBEY DEEP WELL	275936082441001	-185	--	SC1	NS	--	--	--
36	SWFWMD 6" TEST WELL 2 AT DUNEDIN FL	280125082442601	-187	--	SC1	NS	--	--	--
C-126	CLEARWATER MONITOR WELL 68M DEEP		-188	-168 to -188	SC1	N/A	421	1610	1101
C-77	CLEARWATER PRODUCTION WELL 77		-194	-25 to -194	A	NS	--	--	--
C-58	CLEARWATER PRODUCTION WELL 58	280040082442101	-199	-14 to -199	UA	N/A	224	--	--
6	80024241314328S16E33NR SAFETY HARBOR FL	280021082422901	-213	--	SC1	NS	--	--	--
C-70	CLEARWATER PRODUCTION WELL 70	280017082431301	-219	--	LA	NS	--	--	--
NEASR	CLEARWATER EXPLORATORY RW ASR WELL		-220	-151 to -220	LA	2010	327.5		698
14	CLE-DUN DEEP WELL 31 NEAR CLEARWATER FL	275753082435301	-228	--	UA	NS	--	--	--
31	ROMP TR14-3 SUWANNEE WELL	280118082434501	-230	-204 to -224	LA	2010	388	1560	946
C-57	CLEARWATER PRODUCTION WELL 57	280052082442401	-231	--	LA	NS	--	--	--
8	80224322331128S16E17 NEAR MECCA FL	280252082434401	-234	--	LA	NS	--	--	--
35	SWFWMD 6 IN TEST WELL 1 AT DUNEDIN FL	280129082445501	-234	--	LA	1987	240	1090	697*
C-64	CLEARWATER PRODUCTION WELL 64	280103082444101	-235	--	LA	NS	--	--	--
33	SAFETY HARBOR MONITOR WELL	275928082420701	-235	--	LA	NS	--	--	--
C-67	CLEARWATER WELL 67 AT CLEARWATER FL	280022082424901	-237	-32 to -237	UA	2010	30.2	600	371.0
9	CITY OF SAFETY HARBOR WELL FL	275920082420501	-239	--	SC1, LA	1949	43	472	290*
48	OLDSMAR DOT WELL 16-13 NEAR OLDSMAR FL	280153082410801	-258	--	LA	1987	2100	6730	4430*
26	PINELLAS WELL 665 NEAR CLEARWATER FL	275815082440401	-265	-47 to -265	A	NS	--	--	--
41	SAFETY HARBOR 759-242-422 NEAR 13TH AVE MAIN ST FL	275926082420501	-293	--	LA	NS	--	--	--
24	MISSION HILLS NEAR SAFETY HARBOR FL	275842082430301	-328	10 to -328	UA	NS	--	--	--
11	CLE-DUN DEEP WELL 17 NEAR DUNEDIN FL	280254082441602	-339	--	B	1997	480	--	1250

Table 3-2. Summary of Well Depth and Quality Information for Wells Included in Survey

30	ROMP TR14-1 SUWANNEE WELL	280002082412601	-340	-288 to -324	B	1992	12.0	313	180*
42	80224033213128516E23 NEAR OLDSMAR FL	280215082404601	-392	--	B	NS	--	--	--
27	ROMP TR 14-2 OCAL WELL NEAR DUNEDIN FL	280132082452801	-406	-386 to -406	B	1997	1208	4220	2428
C-82B	CLEARWATER MONITOR WELL 82B		-451	-380.6 to -450.6B	B	2008	19600	51145	37160
13	CLE-DUN DEEP WELL 27 NEAR CLEARWATER FL	275753082433701	-500	-475 to -500	B	1990	1400	3670	2410*
25	PINELLAS 667 FL	275917082435201	-778	--	B	NS	--	--	--
45	PHILLIPE PARK WELL NEAR SAFETY HARBOR FL	280028082405101	--	--	--	1988	680	2910	1900*
C-83	CLEARWATER PRODUCTION WELL 83 (McMULLEN)		--	--	--	2009	160	791.7	452.5
C-61	CLEARWATER PRODUCTION WELL 3-4		--	--	--	NS	--	--	--
C-83A	CLEARWATER WELL LOWER A 83LA		--	--	LA	2009	158	774.0	405
C-83B	CLEARWATER WELL ZONE B 83B		--	--	B	2009	16800	47790	31650

* Value derived from conductivity measurement, UA = Upper Zone A, LA = Lower Zone A, B = Zone B, SC1 = Semi-confining Unit 1,

A = Zone A, NS = No water quality information available, N/A = Sample Collection Date Not Available

Figure 3-2
Correlation Between Conductivity and TDS, Chlorides, and Sulfate
Concentrations in Groundwater with Conductivity Less Than 3,000 $\mu\text{S}/\text{cm}$

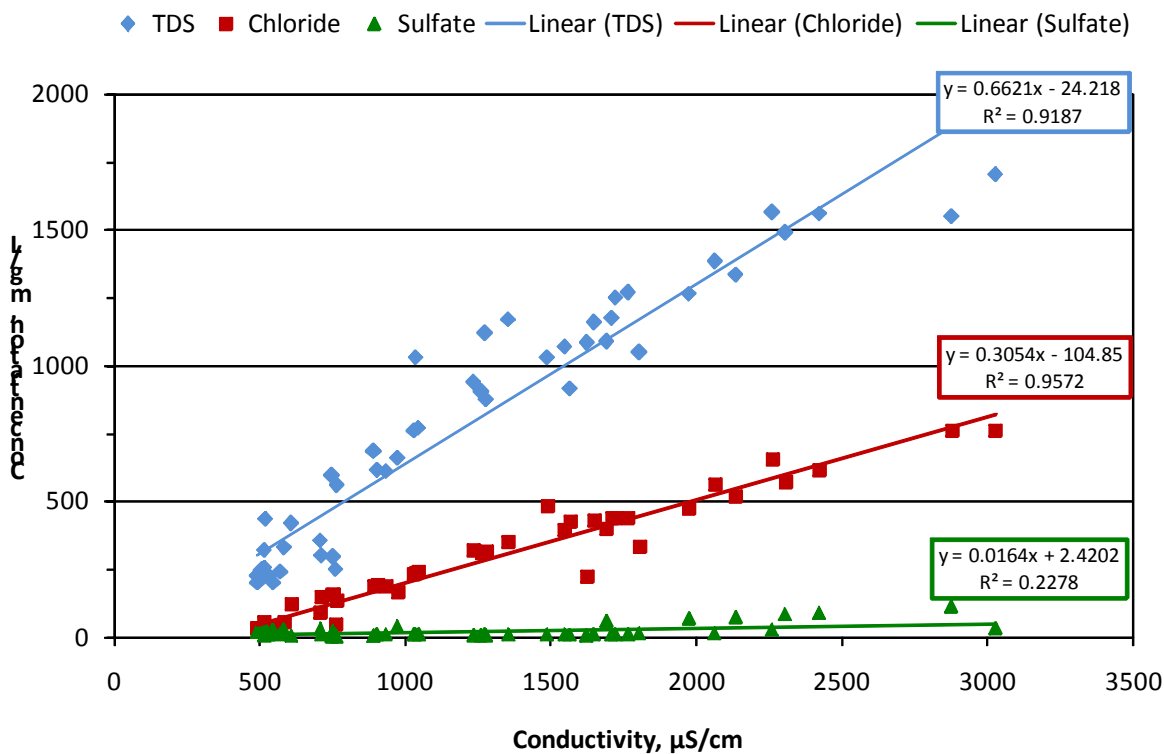


Table 3-3. Historical Water Quality Data for Wells Collected During Drilling

Well name or number	Latitude and Longitude	Elevation (feet asl)	Total depth (feet)	Depth Below Sea Level	Depth of Sample (feet bls)	Conductivity (uMHOS)	TDS (mg/L)	Chlorides (mg/L)
ROMP 14-3	280118/824345	97	319	222	145	179	--	13
					320	260	--	13
					349	460	--	22
					359	1200	--	255
MCMULLEN (83)	275717/824408	40	700	660	80	517	320	55
					100	610	420	123
					120	2065	1385	565
					140	1724	1250	438
					160	1710	1175	441
					200	1650	1160	433
					220	1549	1070	398
					240	1236	940	322
					260	1279	875	315
					320	935	610	188
					340	1031	760	234
					360	1047	770	242
					380	905	615	191
					400	1037	1030	236
					420	1274	1120	311
					440	2262	1565	658
					460	3029	1705	760
					480	19940	12415	6740
					500	8778	5450	2480
					520	8855	6685	2940
					560	9572	5515	2990
					580	10840	5775	3370
					600	11510	7060	3710
					620	18390	13290	7260

Table 3-3. Historical Water Quality Data for Wells Collected During Drilling

Well name or number	Latitude and Longitude	Elevation (feet asl)	Total depth (feet)	Depth Below Sea Level	Depth of Sample (feet bls)	Conductivity (uMHOS)	TDS (mg/L)	Chlorides (mg/L)
MCMULLEN (83) (Continued)					640	51290	34820	31900
					660	51090	35640	31100
					680	52930	36880	20400
KAPOK (82)	275825/824258	18	700	691	161	491	225	33
					185	493	200	34
					200	500	205	34
					225	508	250	35
					265	507	220	35
					285	505	225	34
					305	503	225	34
					345	502	225	34
					365	504	245	34
					385	517	255	35
					405	585	330	57
					425	709	355	90
					445	974	660	168
					465	1693	1090	401
					485	1976	1265	477
					505	2137	1335	519
					525	2306	1490	573
					545	2424	1560	615
					565	2878	1550	760
					585	5335	2930	1560
					605	12700	7905	3930
					625	17310	10635	5660
					645	16680	10445	5520
					665	16410	10450	5700
					685	17880	10890	6080

Table 3-3. Historical Water Quality Data for Wells Collected During Drilling

Well name or number	Latitude and Longitude	Elevation (feet asl)	Total depth (feet)	Depth Below Sea Level	Depth of Sample (feet bls)	Conductivity (uMHOS)	TDS (mg/L)	Chlorides (mg/L)
RWASR	280144/824213	58	550	492	148	259	110	37
					180	316	130	47
					211	575	280	69
					273	1400	700	340
					305	1398	610	210
					336	1700	790	370
					368	1600	810	380
					400	1800	850	400
					430	1700	790	390
					450	1800	860	400
					495	5200	2600	1400
					522	26000	14000	7800
					550	9100	4700	2600
ROMP 14-2- Near Dunedin FL	280132/824528	55	461	406		5908	3898	1737
					74	750	--	99.5
					84	710	--	102.0
					94	700	--	100.0
					104	1000	--	195.0
					114	820	--	160.0
					124	500	--	66.5
					134	580	--	83.5
					144	600	--	83.0
					154	700	--	100.0
					164	700	--	99.0
					174	750	--	121.5
					184	2650	--	710.0
					194	2825	--	757.0
					204	3275	--	870.0

Table 3-3. Historical Water Quality Data for Wells Collected During Drilling

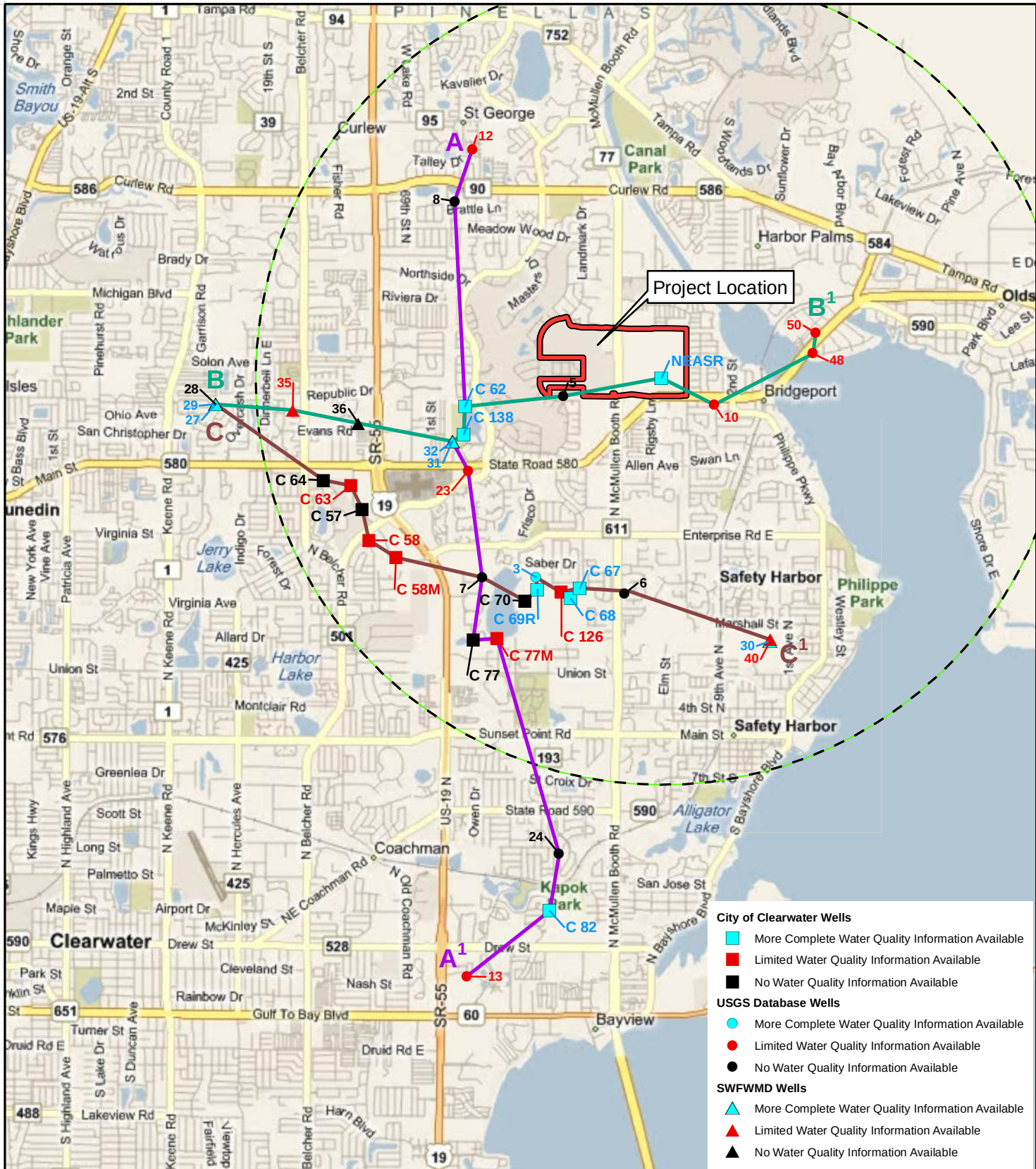
Well name or number	Latitude and Longitude	Elevation (feet asl)	Total depth (feet)	Depth Below Sea Level	Depth of Sample (feet bls)	Conductivity (uMHOS)	TDS (mg/L)	Chlorides (mg/L)
ROMP 14-2 (Continued)					214	2500	--	617.0
					224	4480	--	1960.0
					229	9500	--	2860.0
					234	11,200	--	3550.0
					254	10,600	--	3400.0
					274	12,000	--	3800.0
					294	12,500	--	3750.0
					314	6250	--	1620.0
					334	4700	--	1400.0
					354	5500	--	1630.0
					374	5500	--	1720.0
					394	5500	--	1380.0
					414	6100	--	1840.0
					434	13,500	--	4225.0
					454	20,025	--	6700.0
					474	23,000	--	8825.0
					494	28,000	--	10,750.0
					514	29,250	--	9850.0
					534	32,250	--	10,750.0
					554	48,800	--	14,600.0
					574	38,000	--	13,500.0

Table 3-4. Water Quality Data for Selected Wells

		Well Number:	32	40	29	C 82	C 83LA	C 83	NEASR	31	C 67	11	27
		Well ID	14-3 TMPA	14-1 TMPA	14-2 TMPA					14-3 SWNN		CLE-DUN 17	14-2 OCAL
		Depth:	-81	-154	-163	-179			-220	-224	-237	-339	-406
		Zone:	UA	UA/SC1	SC1	UA	LA		LA	LA	UA-LA	B	B
		Sample Date:	03/21/97	07/22/96	08/25/99	03/09/10	07/09/10	06/09/10	9/23/2010	07/18/96	03/07/10	4/3/1997	04/03/97
Parameter	Units	DWS**											
Alkalinity	mg/L as CaCO ₃			145	160	190	143	147.5	162.5	127	262	199	142 (1992)
Color	CPU	15		--	30	9	5	5.0					--
Eh (hydrogen electrode)	mV	--		-50.4	-72.4					-154			
Hardness, Total	mg/L as CaCO ₃	--	179	--	694 (1999)	218	210	242.5				458	651
Organic Carbon, Dissolved	mg/L	--		1	5.4 (1996)	2.0	1.2	1.2		3.5			--
Organic Carbon, Total	mg/L	--		1.3	5.8	2.3	1.2	1.3		4.1			4.58 (1992)
Oxygen, Dissolved	mg/L	--		0.2	0.1	7.48	2.8	0.2		0.09			--
pH	pH units	--	7.6	7.43	7.38	7.37	7.45	7.5		7.48	7.47	7.87	7.7
Phosphorus, Total	mg/L	--		0.11 (Diss)	0.024 (Diss)	0.14	0.1	0.0		0.05			--
Silica, Dissolved	mg/L	--	7.6	11	23.2 (Diss)	18.9	17	2.5		17	23.7	22.3881	11.6
Solids, Total Dissolved	mg/L	500	333	--	2593 (1999)	280	405	452.5	698		371	1245	2428
Specific Conductance	µS/cm	--	506	355	4025	534.3	774.0	794.7		433	618 23.3 (2009)	1961	4220 25.47 (2005)
Temperature	°C	--		24	25.9	23.7	25.5	25.3		26.1		24.9	
Turbidity	NTU	--		16	6	6.4	0.4	0.6		3.7			--
UV 254 Absorbance	mg/L	--		--	--	0.096	0.042	0.0					--
Aluminum Total	µg/L	200		58	150 (1996)					45			--
Ammonia	mg/L	--		0.053	0.21	0.24	0.2	0.2		0.34			--
Arsenic Total	µg/L	10		12.1	4.0 (1996)				<1	2			--
Barium	µg/L	2		8.9	71.6 (1996)	15	16	21		18.8			--
Cadmium Total	µg/L	5								0.2			
Calcium	mg/L	--	60	67.2	167	70.7	72.4	77.6	78	56.8	94.1	142	155
Iron, Total	µg/L	300	45 (Diss)	1780	108 (Diss)	1400	23	86	<20	202	188 (Diss)	271 (Diss)	53 (Diss)
Magnesium	mg/L	--	7	2.5	62.2	9.7	7.1	11.1	17	6.42	15.6	25	64.0
Manganese	µg/L	50		15	28 (1996)	28	1.5	3.3		6			--
Potassium	mg/L	--	0.9	0.4	12.4	0.13	0.8	2.1	4.1	0.89	0.97	2.4	14.0
Sodium	mg/L	160	24	6.62	627	9.2	56	51.0	168	18.6	14	191	612
Strontium	µg/L	--	300	528	2270	150	250	300		572	250	500	2900
Bromide	mg/L	--	0.2	--	4.52 (1998)	0.09	0.5	0.2			.05 (1998)	1.9	4.7
Chloride	mg/L	250	75	15	1100	29	158	160	327.5	57	30.2	475	1208

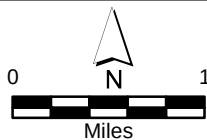
Table 3-4. Water Quality Data for Selected Wells

Fluoride	mg/L	4		0.24	0.22	0.16	0.2	0.3		0.25			--
Nitrate	mg/L	10		0.014*	0.11*	0.44	0.02	0.01	<0.01	0.01			--
Nitrite	mg/L	1		--	--	0.01	0.01	0.01		0.01			--
Orthophosphate	mg/L	--		0.09	0.024	0.01	0.08	0.01		0.049			--
Total Sulfide	mg/L	--		0.05	0.67	0.18	0.2	0.1		1			--
Sulfate	mg/L	250	1	2.5	190	20	0.8	1.7	15.3	3.4	13.9	5.4	140.0
* Includes NO ₂ + NO ₃ **DWS--Maximum Contaminant Level for Constituents included in the Primary and Secondary Drinking Water Standards (year)--Parameter data reported for another time period than overall water quality data													
(Diss) = measured concentration of dissolved constituent													



Source: Well data obtained from the City of Clearwater, FL and USGS Nat'l Water Info System

- LEGEND**
- Project Location
 - 3 Mile Radius
 - A to A1
 - B to B1
 - C to C1



CITY OF CLEARWATER
GROUNDWATER REPLENISHMENT FEASIBILITY STUDY
HYDROGEOLOGIC CROSS SECTION
LOCATION PLAN

FIGURE 3-3

Figure 3-4
Geologic Section A-A'

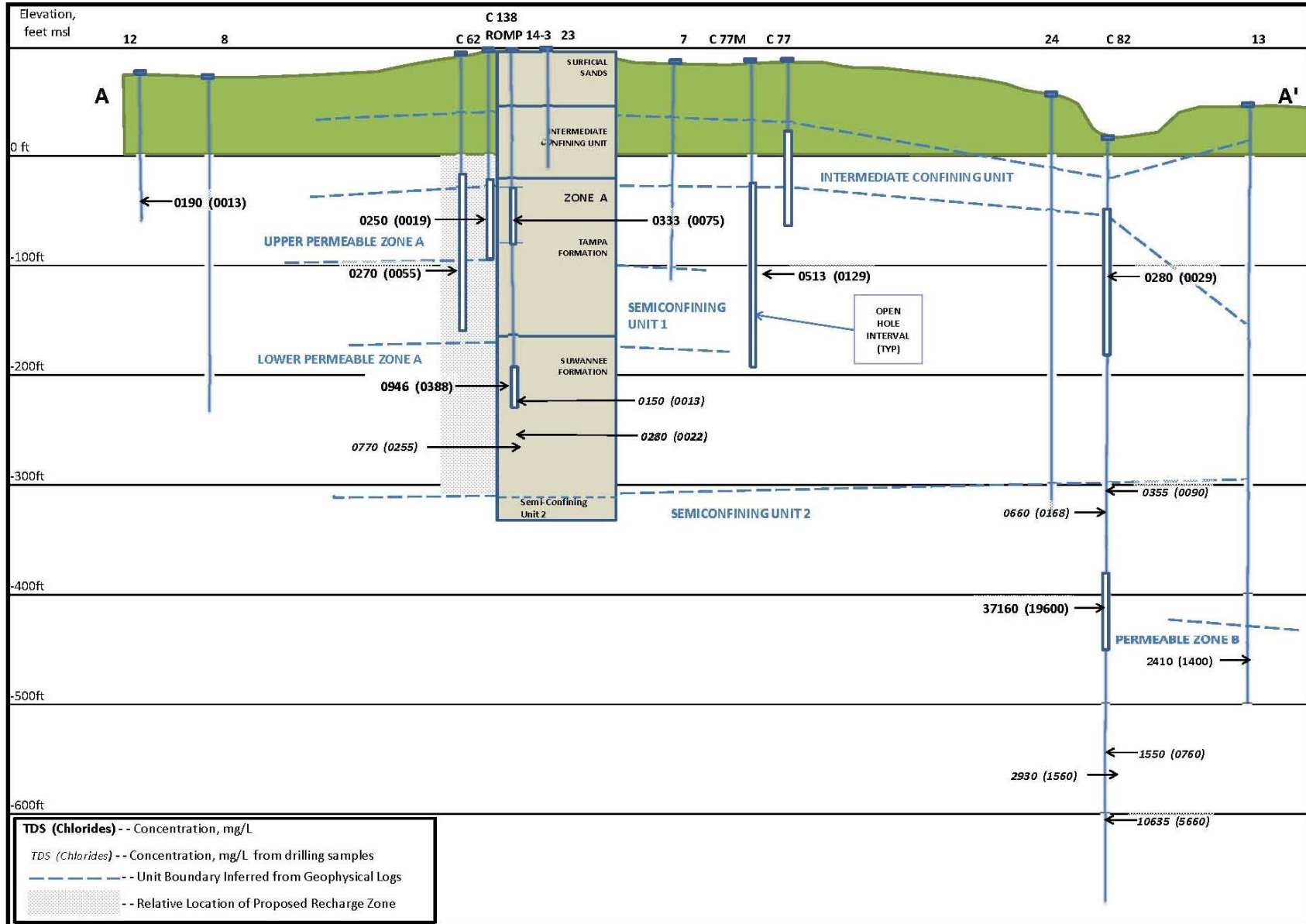
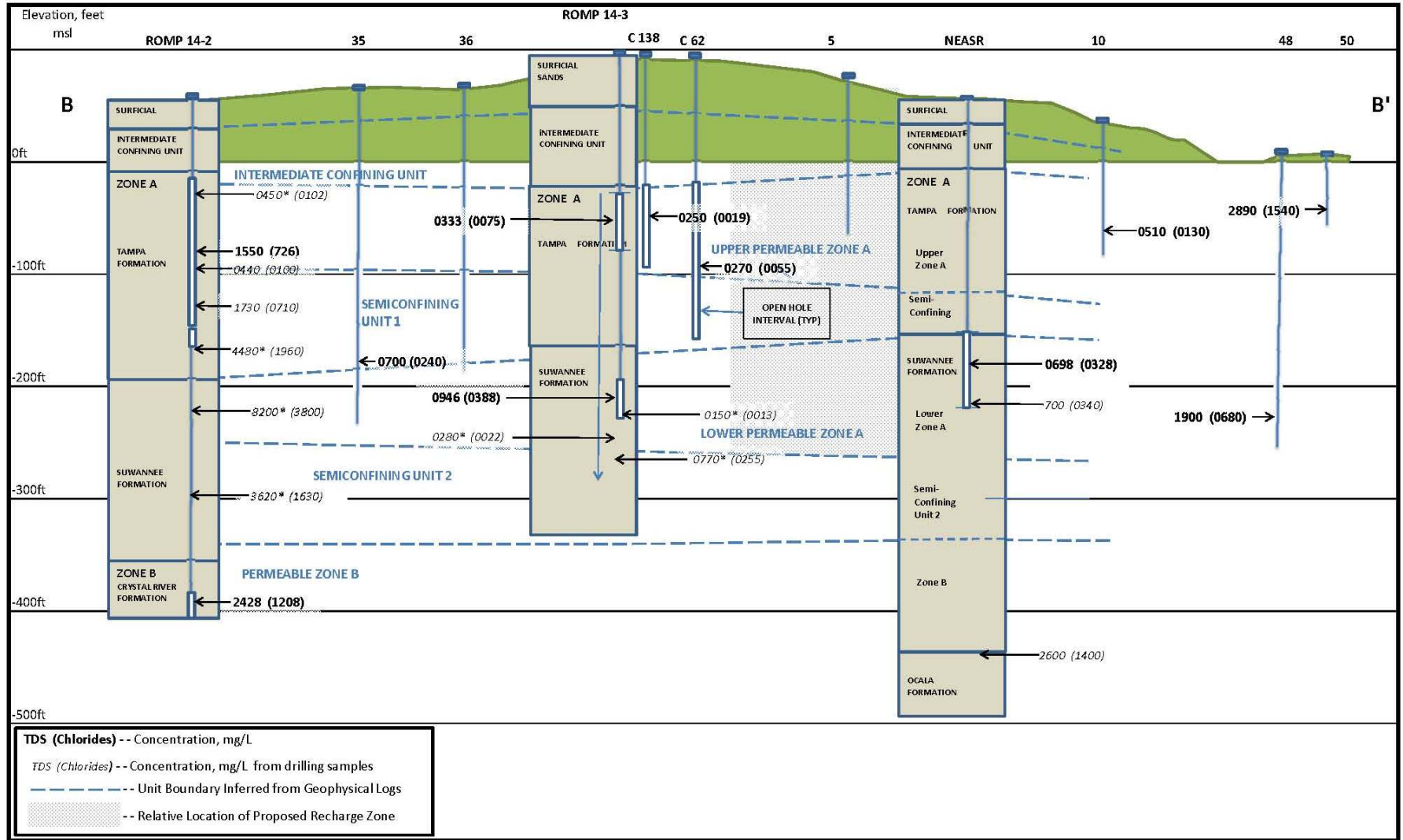
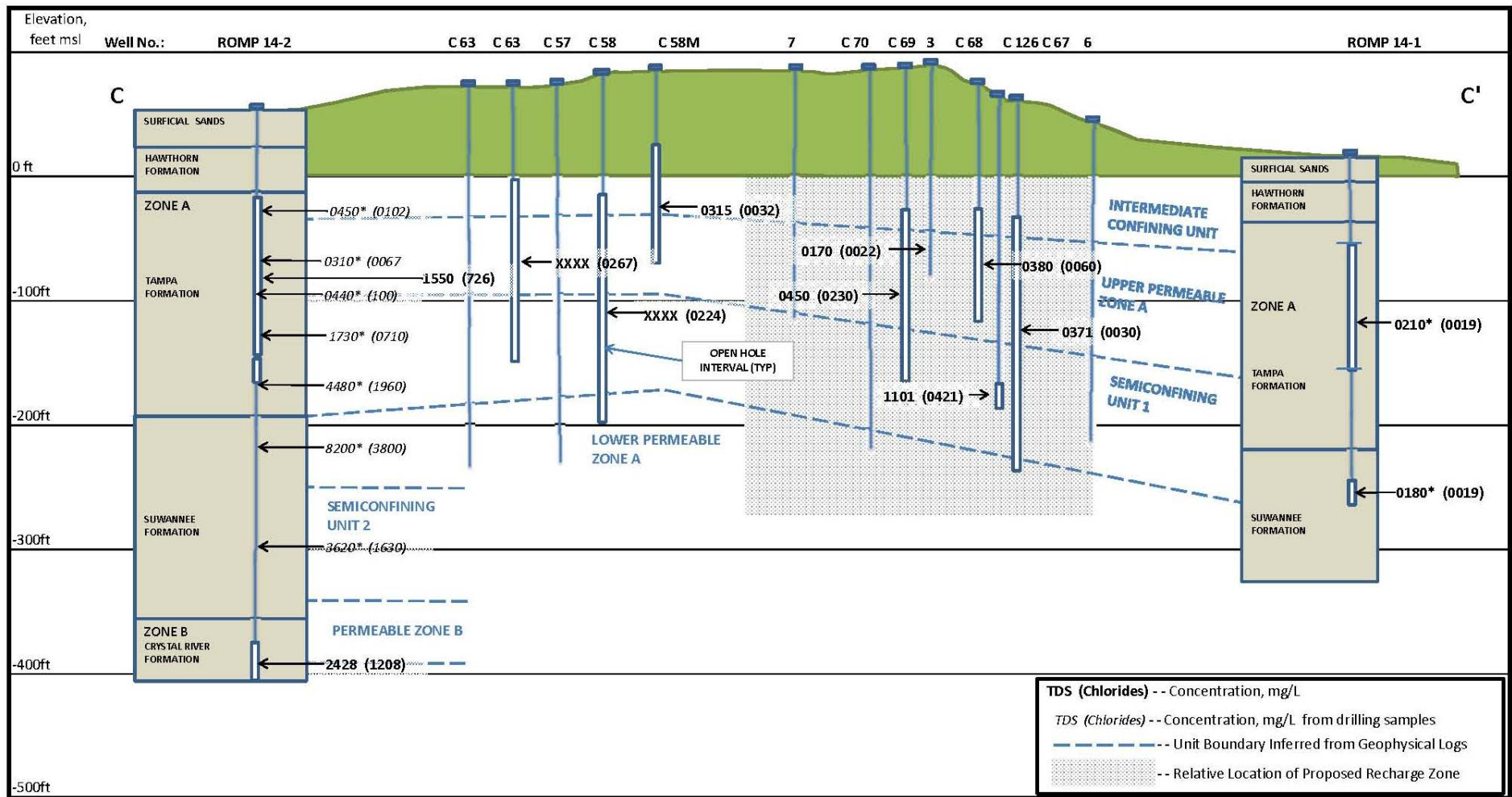


Figure 3-5
Geologic Section B-B'



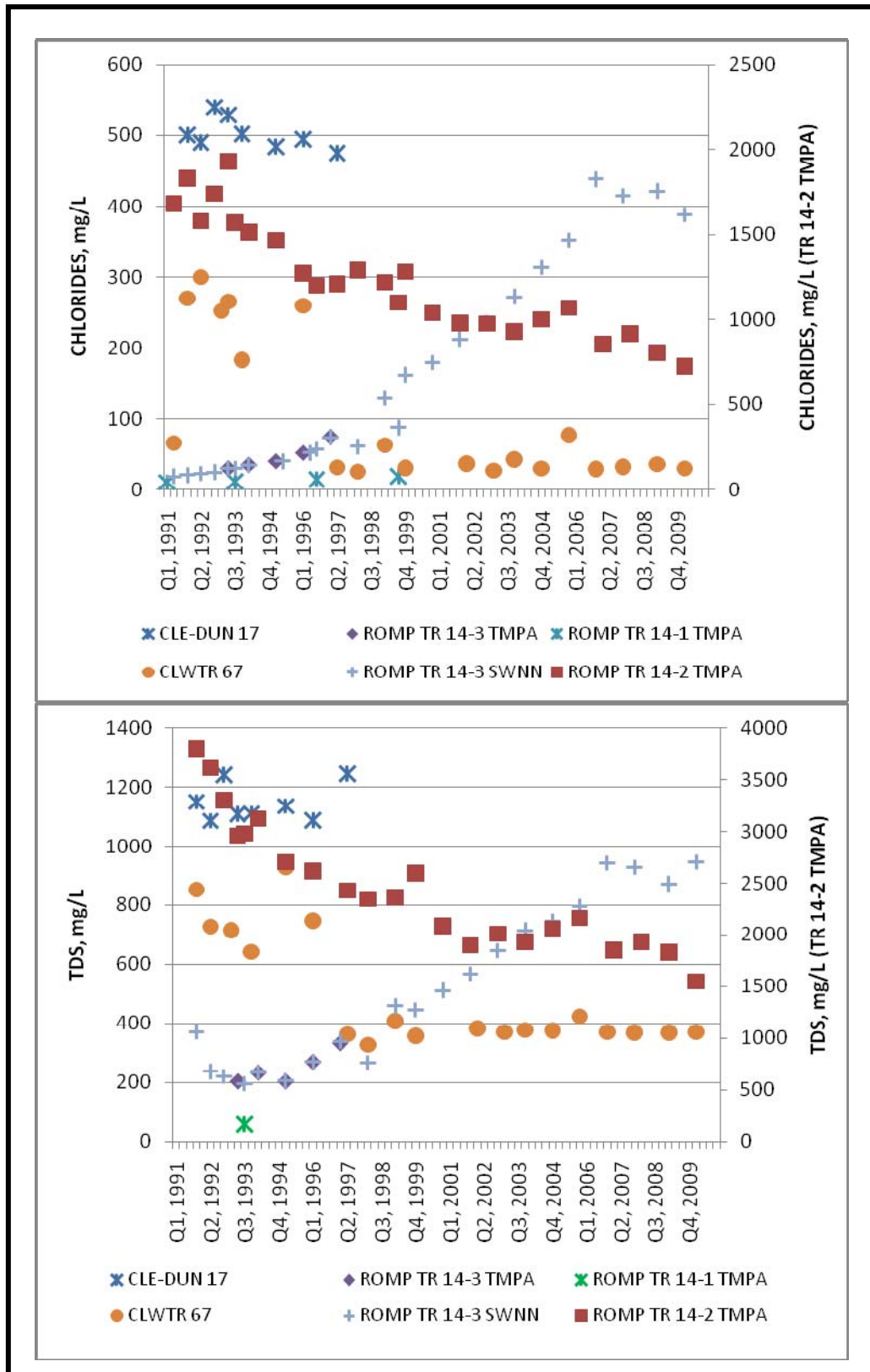
**Figure 3-6
Geologic Section C-C'**



The water quality data have been placed on the cross section at the elevation from which it was collected or the mid-point of the open hole interval of the well sampled. The most recent data available was utilized from the data for all wells that has been summarized in Table 3-2. Information for several of the wells was collected during drilling of the wells and selected water quality data have been placed on the cross sections obtained during the drilling process and the data are compiled in Table 3-3. This information is noted in italics on the cross sections to differentiate it from the other water quality sampling data. The drilling water quality data were selected to show the first value where TDS exceeded 500 mg/L and thereafter where significant changes in TDS occurred over a short interval. Exact information was not available for the samples collected as drilling commenced to determine how the samples were collected (i.e., drill stem, pumped, packer interval, etc.). Therefore, it is not know whether this information is strictly representative of the depth at which it was collected from or a larger interval of open hole. If groundwater from the wells above the reported sample depth were included in the samples collected during drilling, it is safe to assume that the values shown represent minimum concentrations for those depths due to mixing with fresher water from above. Geologic information for the wells, where available in the published information, has also been placed on the cross sections. This information was obtained primarily from the SWFWMD ROMP well reports and the inferred depths of the semi-confining units separating upper and lower Zone A and Zone B have been taken from two reports (Knochenmus and Swenson, 1995, p. 9 and Broska and Barnette, 1999, p. 5) in which natural gamma logs were used to delineate these zones.

The conclusions that can be drawn from the TDS and chloride data are limited by the fact that the data are not contemporaneous (spanning over a period of 61 years). This is illustrated by the data from several of the wells in which there is sufficient data to show more recent changes in water quality over time. Figure 3-7 shows historical sampling data from several of the wells included in the survey which illustrate the changes in water quality that have occurred in some of the wells in the area. Chloride and TDS data were available for several of the wells from measurements taken over the last twenty years. Unfortunately, data was not available over the entire period for all of the wells. The three wells, Clearwater 67, ROMP TR 14-2 Tampa and ROMP TR 14-3 Suwannee, for which data spanning the entire period were collected, show distinct but opposite trends over the sampling period. ROMP Well TR 14-3 Suwannee located approximately one mile west of the proposed recharge area showed almost a five fold increase in TDS and a 20 fold increase in chloride concentration. In contrast, well Clearwater 67 located approximately 1.5 miles south of the proposed recharge area and ROMP well TR 14-2 Tampa located two miles west of the proposed recharge area both showed close to a threefold reduction in TDS over the same time period. Therefore, some caution should be exercised in the interpretation of the available data when older historic water quality data is being compared to data that was collected much more recently. However, in reviewing the overall data and information that was available some general observations about the groundwater in the area have been formed which are summarized in the following paragraphs.

Figure 3-7
Historical Water Quality Trends in Select Wells



Upper Zone A occurs in the top of the Tampa formation limestone in the project area and generally is found at 10 to 100 feet below mean sea level. The water in upper Zone A is fresh throughout the project area with chlorides generally less than 100 mg/L and total dissolved solids less than 400 mg/L (wells 23, 46, 12, 58M, 49) with the exception of the areas outside of the proposed recharge area as you move east toward Oldsmar as shown in Figure 3-5.

A large number of the wells have open hole intervals spanning a large depth range and the open hole intervals were not documented for a number of wells. The information available, along with the recent sampling of the City's exploratory ASR well, indicates that at a depth of 150 to 200 feet below mean sea level, which corresponds to the bottom of semi-confining Unit 1 or top of lower Zone A, the chlorides can be expected to be greater than 150 mg/L and the TDS will be greater than 500 mg/L (wells 31, C 126, 29, 35). The exception to this is the water quality information reviewed occurs in Safety Harbor to the south of the proposed recharge area as evidenced by the water quality in the samples obtained from approximately 250 feet below sea level from the Suwannee formation in ROMP well TR 14-1. This well is located approximately 2.5 miles south southeast of the proposed recharge area and is not representative of groundwater quality in the proposed recharge zone. Reviewing the water quality in cross section B-B which crosses through the proposed recharge area, the water quality information indicates that higher TDS water is found at about 100 feet below mean sea level as indicated by the water quality from ROMP well TR 14-2 to the west and well 10 to the east. The TDS increases above 3,000 mg/L at a depth of 400 to 500 feet below mean sea level in Zone B (wells C 82B, C 83B, 13) although the number of observations is limited.

Water quality data was available for several wells that included a much more extensive and complete set of parameters for which analysis results were reported. These data have been summarized in Table 3-4. The water quality data comes from the most recent data set that has the most complete water quality information. Therefore, more recent sampling and analysis may have been performed for some of the parameters at each of these wells, but was not reported in the table due to the more limited number of parameters sampled. The data in the table have been arranged in the order of increasing depth from which the samples were obtained. The four samples included in the table taken from upper permeable Zone A and the semi-confining unit 1 shows that the water quality met each of the parameters of the primary and secondary drinking water standards that were measured except for arsenic and iron in ROMP well TR 14-1 in the Tampa formation and color, TDS, sodium and chloride in ROMP well TR 14-2 in the Tampa formation. With the exception of ROMP well TR 14-2, the water in the upper portion of the Floridan aquifer was very low in salinity, mineralized primarily with calcium and to a lesser extent magnesium both associated with carbonates, very low in concentration of sulfates and slightly alkaline in pH in the range of 7.4-7.6. The four samples that were identified to contain at least some portion of the sample from lower permeable Zone A show that the water quality met each of the parameters of the primary and secondary drinking water standards that were measured except for TDS,

sodium and chloride in the ASR test well at the Northeast Wastewater Treatment Plant. The water in lower permeable Zone A was low in salinity, mineralized primarily with calcium and to a lesser extent magnesium both associated with carbonates, very low in concentration of sulfates and slightly alkaline in pH in the range of 7.4-7.5. The four samples that were obtained from Zone B show that the water met each of the parameters of the primary drinking water standards that were measured and reported in the table except for TDS, sodium and chloride which reflects the increase in salinity that occurs at greater depth. The water in Zone B was higher in salinity, mineralized primarily with sodium associated with chlorides and calcium and to a lesser extent magnesium both associated with carbonates, the concentration of sulfate ranged from very low in well 11 and much higher in ROMP well TR 14-2 in the Ocala formation and had a more alkaline pH in the range of 7.7-7.8.

The oxidation reduction potential of the groundwaters can be generally described as reducing based upon the negative E_h reported for several of the wells shown in the tables, the generally higher concentration of ammonia relative to the concentration of the oxidized forms of nitrogen and the comments by the samplers that a number of the samples had a H_2S odor. Dissolved oxygen concentrations reported were generally less than 0.2 mg/L; however, significantly higher values were reported for wells C 82 and C 83LA. The higher values are most likely a result of the manner in which the samples were taken or the method by which the dissolved oxygen was measured and are not considered to indicate that oxidizing conditions exist within the aquifers from which the samples were obtained. Arsenic concentrations measured in water from the Suwannee limestone, wells NEASR and 14-3 SWNN, were 2 µg/L or less.

Additional data for the City production wells were obtained and reviewed for several key water-quality parameters. Those parameters are chloride, TDS and arsenic concentrations. The City production wells primarily obtain groundwater from lower Zone A of the upper Floridan aquifer. Figure 3-8 shows the values of those three parameters at each production well from samples obtained in 2010 with the majority sampled in December. Chloride concentrations range from 19 mg/L to 342 mg/L and average about 125 mg/L in the 29 wells sampled. The distribution of chloride concentrations does not follow any specific geographic pattern and in the immediate vicinity of the proposed recharge area the chlorides were higher to the south (wells 61/3-4 and 59/3-2) and much lower to the west (wells 62/3-5 and 58/3-1). TDS concentrations range from 250 mg/L to 905 mg/L and average about 580 mg/L. Generally, TDS concentrations above 550 mg/L are associated with higher chloride concentrations, >140 mg/L and TDS concentrations above 750 are associated with higher chloride concentrations, >250 mg/L. This data indicates that the water in upper Zone A is somewhat brackish. Similar to the chloride concentration data, the TDS data do not follow any specific geographic pattern and are higher in the wells immediately south of the recharge area and lower in the wells immediately to the west. Arsenic concentrations range from 1.0 µg/L to 96 µg/L. When averaged across all of the production wells, the average arsenic concentration is 18.3 µg/L. It should be noted that of the 29 production wells sampled,

FIGURE NO.: 3-8

18 of them exceeded the arsenic drinking water MCL of 10 µg/L. Once again the distribution of the arsenic concentration data did not follow a specific geographic pattern and higher concentrations were found in the wells immediately south of the recharge area and lower concentrations, less than the MCL, were found in the two wells immediately west of the recharge area.

3.2 GROUNDWATER SAMPLING

The water quality collected and compiled from the historical well data base does provide insight into the expected water quality of the groundwater in the vicinity of the proposed recharge area. However, the data were not all collected in the same time period and the groundwater samples from most of the wells have not been analyzed for the complete list of parameters contained in Table 3-1. Many of the wells sampled measured conductivity rather than TDS and although a good correlation was established between the two, laboratory analysis for TDS is preferred. Finally, some of the water quality was obtained from drill stem samples taken during well construction and may not accurately represent the quality of the ground water at the depth to which drilling had progressed. Therefore, additional sampling of the wells and analysis of the groundwater quality is recommended.

Further characterization of the groundwater in the proposed recharge area can be obtained by either sampling of existing wells, the construction of exploratory and monitoring wells within the project area or some combination of both. The approach taken will primarily depend upon the timing of the submission the permit application and any subsequent well construction and geochemical modeling that is performed. The recommendations made below for additional groundwater sampling assume that the sampling will occur prior to any additional well construction as part of this program. The recommendations contained herein will therefore be modified as the overall program is further developed and phased.

The purpose of the groundwater sampling program would be to obtain a set of current, contemporaneous samples for analysis that would provide a water quality characterization of the quality of the groundwater in upper Zone A and lower Zone A in the immediate vicinity of the proposed recharge area. It is proposed that each of the wells be sampled for the parameters listed in Table 3-1 and the following additional parameters: oxidation reduction potential (field), dissolved oxygen (field), conductivity (field), total organic carbon, heterotrophic plate current, arsenic (III and V), iron (II and III), ammonia, nitrate plus nitrite, and silica. To characterize the groundwater quality in upper Zone A, samples could be collected from wells 2, 5, 10, 32, C 62 and C 138. To characterize the groundwater quality in semi-confining unit 1 and lower Zone A, samples could be collected from wells 31, NEASR, 8 and C 70. The location of the wells is shown in Figure 3-1. Wells C 62, C138, NEASR and C 70 are owned by the City of Clearwater. The remainder of the wells are either owned by SWFWMD or private wells. Since several of the wells are not owned by the City, permission would have to be obtained from the owners to obtain the samples for analysis. Existing well construction information suggests that the open hole portion of several of these wells

span a large depth and therefore it may be advantageous to consider the installation of a packer in some of the wells to facilitate sampling of the lower portion of the open hole or to isolate the portion of the well constructed through upper Zone A from lower Zone A. The total cost for one round of sampling on these ten wells would be approximately \$10,000.

4.0 HYDROGEOLOGIC EVALUATION

4.1 INTRODUCTION

This feasibility study is concentrated on direct beneficial aquifer replenishment of at least 3 MGD of reclaimed water through the use of injection (recharge) wells. The recharge wells are proposed to be constructed on and near the City's NEWRF. Based on available aquifer characteristics and groundwater quality data, the projected injection zone for the recharge wells at this time is lower Zone A. Upper Zone A generally has a similar aquifer transmissivity as lower Zone A, but the total dissolved solids (TDS) concentration is <500 mg/L, which has more stringent treatment requirements. Zone B has a much lower transmissivity, which is not as efficient for recharge, and would require more wells operating at higher pressures to achieve the desired recharge volume. More importantly the occurrence of saltwater in Zone B makes the zone unsuitable for direct recharge, as the buoyancy effect of injected freshwater will force the saltwater to migrate upward ahead of the injected water into the overlying producing zones.

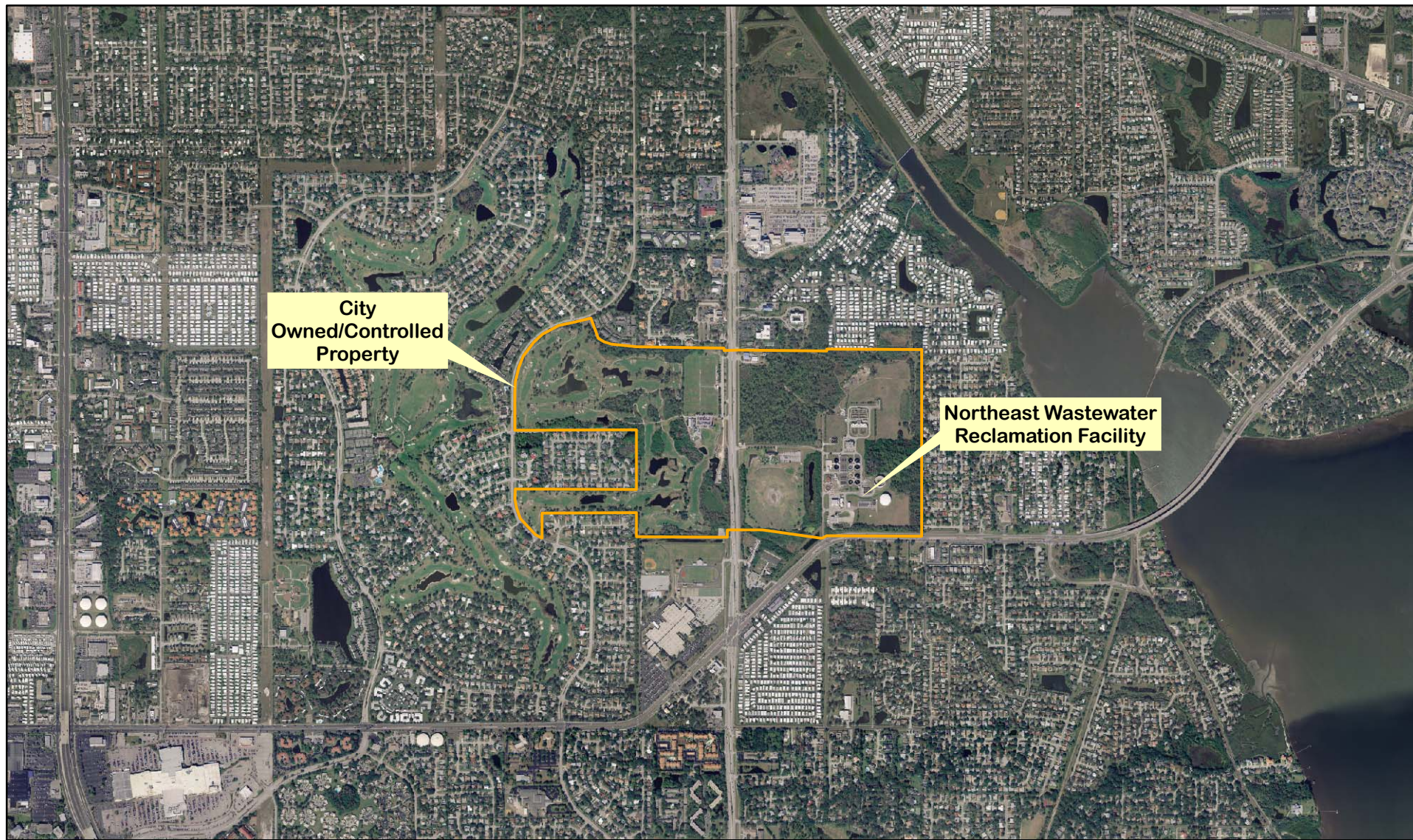
The available hydrogeologic information that is available allows us to perform a sound evaluation for the feasibility of groundwater replenishment. This section of the feasibility report will describe a number of hydrogeologic aspects evaluated including hydrogeologic conditions, groundwater flow modeling, travel-time modeling, geochemical analysis, concentrate management, permitting needs, preliminary design and recommendations related to future hydrogeologic activities.

4.2 GROUNDWATER MODELING

A key hydrogeologic aspect of this feasibility study was the use of groundwater modeling as a tool to assist in evaluating recharge potential with highly treated waste water. The project area consists of properties owned or controlled by the City of Clearwater in the area of the NEWRF as shown on Figure 4-1. The purpose of the groundwater modeling analysis was to: 1) evaluate the hydraulic benefit to recharging the aquifer relative to the drawdown from the City's water supply well field; and 2) evaluate the travel-time zones for recharge water from the recharge wells. The evaluation of the hydraulic benefit was performed using a calibrated MODFLOW groundwater flow model. The travel-time evaluation was required by the FDEP, and was performed using a MODPATH particle-tracking model.

4.2.1 Area Hydrogeology

Area hydrogeology was defined using information from various U.S. Geological Survey (USGS) reports, information obtained from the City's well fields and the report City of Clearwater Reclaimed Water ASR Exploratory Well Program (PBS&J, 2006). The ASR exploratory well was constructed on the City's NEWRF property, which is the proposed



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Feet

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**CITY OF CLEARWATER
GROUNDWATER REPLENISHMENT FEASIBILITY STUDY**

PROJECT AREA

PREPARED BY:



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DATE:	Apr. 2011
FIGURE NO.:	4-1

location for the reclaimed water treatment and recharge facility. Two aquifers are present in Pinellas County: the surficial aquifer and the Upper Floridan aquifer. Figure 4-2 shows an area hydrogeologic section. The surficial aquifer is an unconfined aquifer that occurs in the surficial unconsolidated sand layer. Immediately beneath the surficial aquifer is a clayey intermediate confining unit. Below the confining unit is the Upper Floridan aquifer that consists of a number of distinct limestone sections.

Hickey (1982) subdivided the Upper Floridan aquifer in Pinellas County into four permeable zones separated by semi-confining units. The zones were alphabetically labeled with increasing depth from A to D. The producing zones occur where open fractures and solution cavities (secondary porosity) are present in the rock. The producing zones are separated by semi-confining layers composed of lower permeability limestone and dolomite. Cores taken from the carbonate semi-confining units indicate that closed fractures predominate and, therefore, primary porosity rather than secondary porosity controls permeability in the semi-confining units (Hickey, 1982). The semi-confining units do not yield large quantities of water and are considered non-producing zones in Pinellas County.

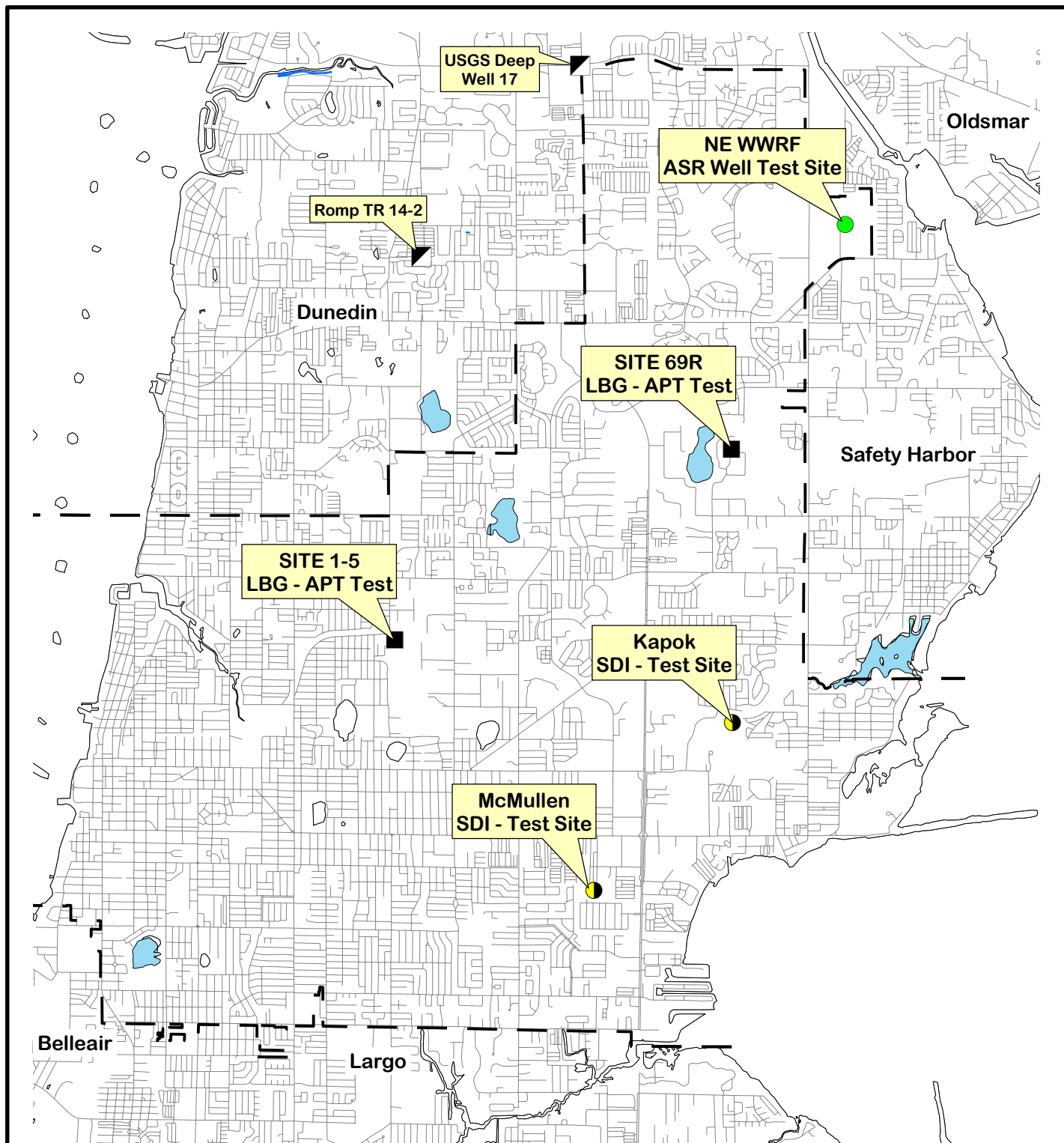
Zone A comprises the Tampa Member and the uppermost part of the Suwannee Limestone and is the shallowest and freshest of the producing zones. Zone A is typically separated into upper Zone A and lower Zone A. Upper Zone A is comprised of the Tampa Member and is the primary source for water supply in the north Pinellas County area. Upper Zone A was identified in the ASR exploratory well located at the City's NEWRF at depths ranging from 63 to 172 feet below land surface (bls). The primary producing zones typically occur near the top of the limestone in each zone. Lower Zone A occurs in the upper part of the Suwannee Limestone, and was identified in the ASR exploratory well at a depth of 210 to 330 feet bls. The lower portion of the Tampa Member from 172 to 210 feet bls consists of a lower permeability limestone that provides minor semi-confinement between upper and lower Zone A. Lower Zone A is the target zone for the recharge water for this groundwater replenishment project.

Geraghty and Miller, Inc. (1976), Robertson and Mallory (1977), Black, Crow and Eidness, Inc. (1979), Hickey (1982), and M.P. Brown and Associates (1986), and SDI (1993) reported values of transmissivity for Zone A that ranged from 10,000 to 43,000 square feet per day (ft^2/day) and values of storativity that ranged from 4×10^{-5} to 8×10^{-4} . The references for these test results do not differentiate whether the tests were in upper or lower Zone A or both. Site-specific test data from the ASR exploratory well yielded transmissivity values from 20,300 to 27,000 ft^2/day for lower Zone A. Upper Zone A was not tested in this well. Recent aquifer tests performed by LBG resulted in transmissivity values ranging from 6,400 to 19,700 ft^2/day , and storativity values ranging from 5×10^{-5} to 1×10^{-4} . Recent tests performed at the McMullen Tennis Complex in eastern Clearwater by SDI yielded transmissivity values of 11,300 ft^2/day in upper Zone A and 9,500 ft^2/day in lower Zone A. Figure 4-3 shows the locations of some of these test sites.

Depth Below Land Surface

Lithology	Geologic Unit	Hydrogeologic Unit		Aquifer Properties	Water Quality
Sand	Undifferentiated	Surficial Aquifer		N.A.	N.A.
Clay	Hawthorn Group	Intermediate Confining Unit		Leakance = $1 \times 10^{-3} \text{ day}^{-1}$	N.A.
Limestone	Tampa Member	Upper Floridan Aquifer	Upper Zone A	Transmissivity 10,000 to 25,000 ft ² /day	TDS = < 500 mg/l
			Semi-Confining Layer	N.A.	N.A.
	Suwannee Limestone		Lower Zone A	Transmissivity = 5,000 - 25,000 ft ² /day	TDS = 800 to 900 mg/l
			Semi-Confining Layer	Leakance = $3 \times 10^{-3} \text{ day}^{-1}$	N.A.
Limestone and Dolomitic Limestone			Zone B	Transmissivity = 3,000 - 5,000 ft ² /day	TDS = 18,000 mg/l
	Ocala Limestone		Semi-Confining Layer	Leakance = $7 \times 10^{-3} \text{ day}^{-1}$	N.A.
Dolomite	Avon Park Formation		Zone C	Transmissivity = 50,000 - 1,000,000 ft ² /day	TDS = > 20,000 mg/l

DATE	REVISED	☒ ASG ☐ GIS ☐ CORI	CITY OF CLEARWATER GROUNDWATER REPLENISHMENT FEASIBILITY STUDY	PREPARED BY: LEGGETTE, BRASHEARS & GRAHAM, INC. Professional Ground-Water and Environmental Engineering Services Cypress Point Office Park 10014 North Dale Mabry Highway - Suite 205 Tampa, FL 33618 (813) 968-5882	DRAWN: TDH
					CHECKED: JMT
			DATE: Apr. 2011		
FILE NAME: Figure4-2			AREA HYDROGEOLOGIC SECTION	FIGURE: 4-2	



**CITY OF CLEARWATER
GROUNDWATER REPLENISHMENT
FEASIBILITY STUDY**

LOCATION OF AQUIFER TEST SITES AND
MONITORING WELLS

PREPARED BY:

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FILE NAME: FIGURE4-3.MXD

FIGURE NO.: 4-3

Lower Zone A is underlain by a lower permeability section of the Suwannee Limestone that forms a semi-confining layer between lower Zone A and Zone B. The hydrologic properties of the semi-confining unit underlying Zone A reported by Seaburn and Robertson, Inc. (1983), and M.P. Brown and Associates (1996) are 0.4 ft/day for horizontal hydraulic conductivity, 0.4 ft/day for vertical hydraulic conductivity, and 2.9×10^{-3} to 7×10^{-3} day⁻¹ for leakance. Hickey (1982) reported vertical hydraulic conductivities ranging from 1.3×10^{-3} to 2 ft/day and a leakance of 2.9×10^{-3} day⁻¹.

Permeable Zone B is composed of dolomite, dolomitic limestone, and limestone and includes the lower part of the Suwannee Limestone and the upper part of the Ocala Limestone. The top and bottom of the producing zone are defined by Hickey (1982) by the presence of dolomite and dolomitic limestone and by relatively high electrical resistivity. The thickness of Zone B ranges from 50 to 75 feet. The top of Zone B was identified at a depth of approximately 396 feet bls in the ASR exploratory well. Broska and Barnett, 1999, report a transmissivity of approximately 5,000 ft²/day for Zone B. Test data from the ASR exploratory well yielded values from 3,500 to 3,900 ft²/day.

Permeable Zone B is underlain by a lower permeability section of the Ocala Limestone that forms a semi-confining layer between Zone B and Zone C. The Ocala Limestone extends to a depth of approximately 600 feet bls, and is underlain by the Avon Park Formation. Permeable Zone C occurs in the upper portion of the Avon Park Formation. An aquifer test performed at the City of Oldsmar's injection well yielded a transmissivity value of 3.7×10^5 ft²/day. Aquifer tests performed in Zone C in the northern and southern portions of Pinellas County indicate that transmissivity ranges from approximately 5×10^4 ft²/day in the northern part of the county, to 1×10^6 ft²/day in the southern portion of the county.

Water quality in the Upper Floridan aquifer ranges from freshwater (total dissolved solids (TDS)<500 mg/L) in upper Zone A to saltwater (TDS>18,000 mg/L in Zones B and C). Lower Zone A, which is of primary interest for this recharge project, generally contains brackish groundwater. Data from the exploratory ASR well at the City's NEWRF indicates that the TDS concentration in lower Zone A is approximately 800 to 900 mg/L. FDEP has indicated that a zone targeted for recharge of a TDS greater than 500 mg/L would only require a one year pilot test rather than two years of full scale testing if the target/zone was less than 500 mg/l.

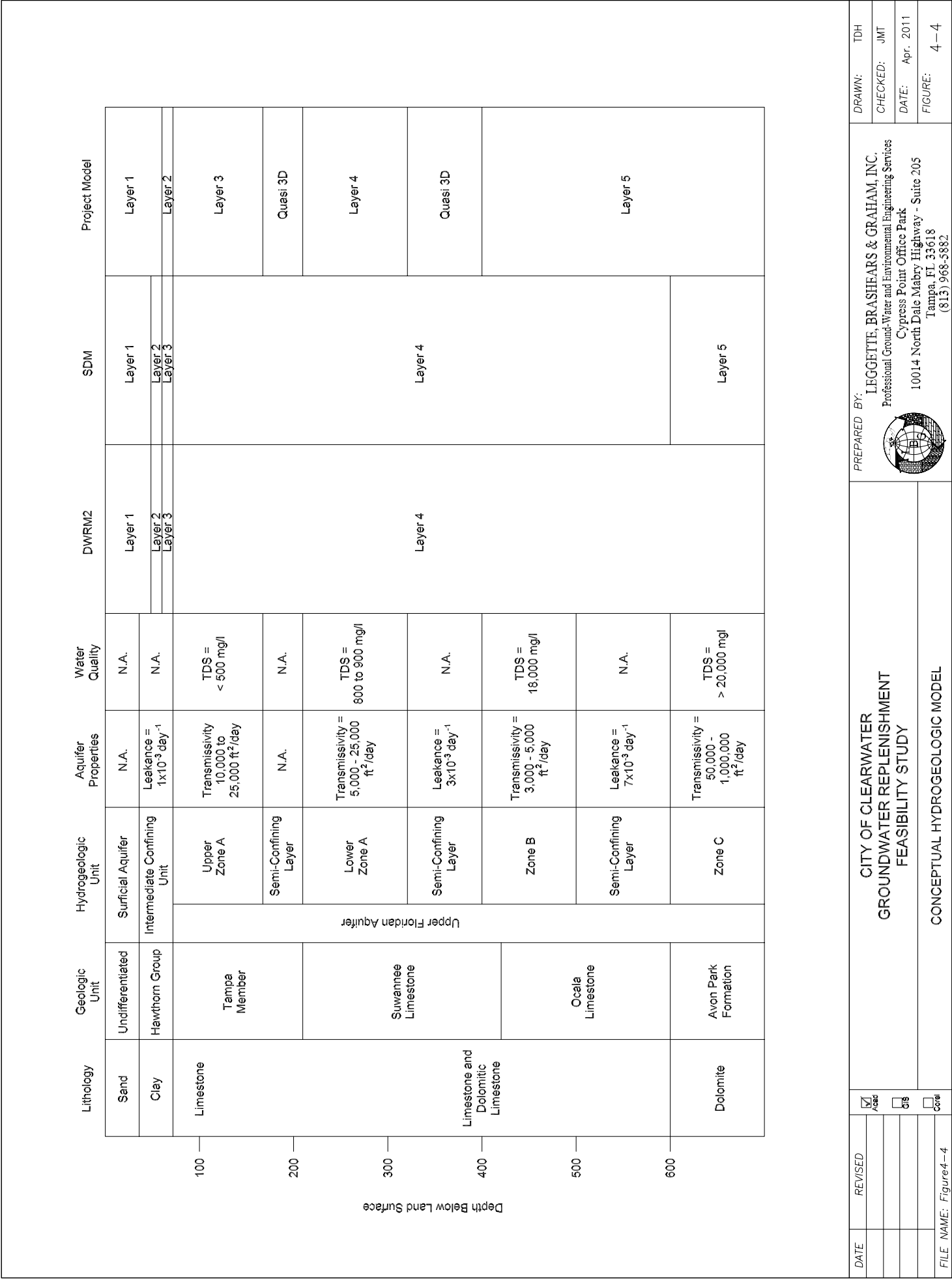
The recharge wells will inject into lower Zone A, where TDS concentration is approximately 800 to 900 mg/l. The transition zone to 10,000 mg/l is at the top of Zone B, which is separated from lower Zone A by a semi-confining layer. The injected water will mix with the formation water in lower Zone A because the densities of the two waters are too similar to induce a buoyancy factor in lower Zone A. The semi-confining layer between lower Zone A and Zone B will minimize downward vertical migration of the recharge water to Zone B. Therefore, the recharge water will primarily mix with formation water and migrate laterally in lower Zone A, and migrate upward under hydraulic head gradient to upper Zone A.

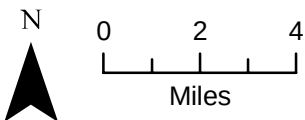
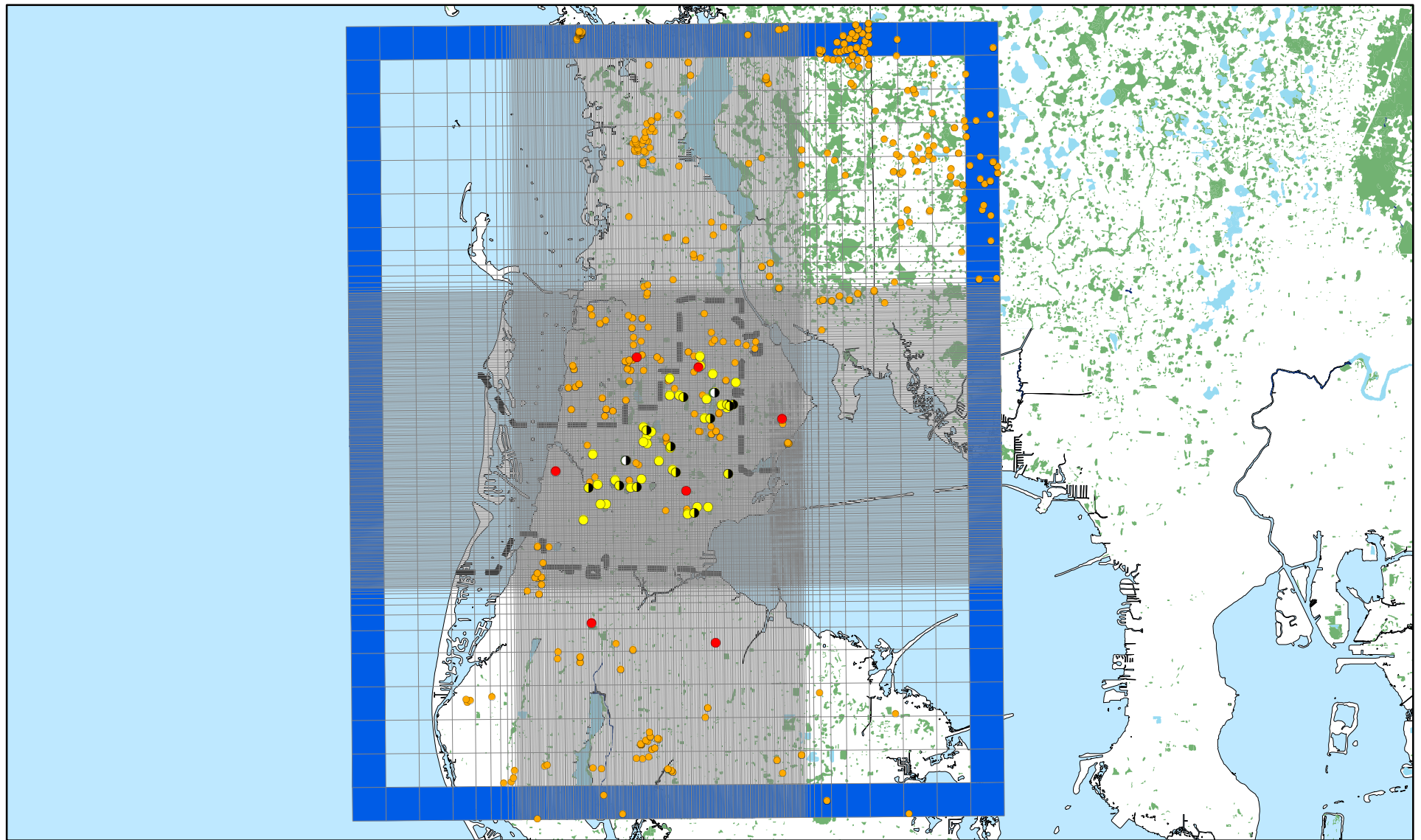
4.2.2 Groundwater Flow Model Set-Up

All but two of the City's existing public supply wells obtain water from upper Zone A. Two wells are open to both upper and lower Zone A. The recharge wells for this project are proposed to utilize lower Zone A for groundwater replenishment. No wells in the area are open to Zones B or C due to the occurrence of highly brackish or salty water. Therefore, the conceptual model (Figure 4-4) for this project was to develop a quasi-3D model with individual model layers for the surficial aquifer, upper Zone A, lower Zone A, and a layer for underlying Zones B and C.

Existing Southwest Florida Water Management District (SWFWMD) regional groundwater flow models were reviewed to assess whether focused telescopic mesh refinement (FTMR) models could be used as a base model for this analysis. The benefit of using SWFWMD models is that they are calibrated and they include all permitted withdrawals. Three models were reviewed: the District-Wide Regulatory Model (DWRM2), the Northern Tampa Bay Model (NTB), and the Southern District Model (SDM). Each of these models can be utilized with the FTMR process to create a sub-model out of the calibrated regional model. The DWRM2 was deemed unsuitable for this use because the entire UFA is represented with one model layer, and the aquifer properties and layer elevations needed to fit the conceptual model for the area were not suitable for the necessary re-layering of the model grid. Figure 4-4 shows the DWRM2 model set-up. The NTB was not suitable because the southern boundary of the model is immediately south of the City's well field. This model set-up is also shown on Figure 4-4. Review of the SDM indicated that the UFA is divided into two layers. Layer 4 represents Zones A and B, and layer 5 represents Zone C. Layers 2 and 3 represent the Intermediate Aquifer System where it exists to the south of Pinellas County, but in Pinellas County are relatively thin units that represent the zone at the interface between the surficial aquifer and the Upper Floridan aquifer. Layer 1 represents the surficial aquifer. Figure 4-4 also shows the model set-up for the SDM. Review of the layer elevations and aquifer characteristics of the SDM indicated that the model grid could be revised to re-layer the grid while maintaining the overall aquifer properties, boundary conditions, and permitted well withdrawal rates of model. Therefore, a FTMR model was created from the SDM for use as a base model and modified in order to fit the conceptual model described above in Figure 4-4. The model grid and boundary conditions for the new project model are shown on Figure 4-5.

The first step in modifying the FTMR model was to modify the grid layers to fit the conceptual hydrogeologic model as shown in Figure 4-4. Layers 1 and 2 were unchanged and represent the surficial aquifer and the interface between the intermediate confining unit and the UFA, respectively. The water table in layer 1 of the SDM is represented as a constant head boundary. The use of a constant head boundary for the layer 1 means that the model cannot be used to evaluate drawdown impacts to the surficial aquifer and surface water features. However, the purpose of this model was to evaluate head changes in the Upper Floridan aquifer and the





Legend

- Model Grid ● Model Wells ● Monitoring Well ● UFAS Monitoring Well — Service Area Lakes
- Model Boundary ● Calibration Well Locations ● SAS Monitoring Well ● Active Production Well ■ Wetlands ■ Rivers

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CITY OF CLEARWATER GROUNDWATER REPLENISHMENT FEASIBILITY STUDY

FTMR MODEL GRID

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DATE:	Apr. 2011
FIGURE NO.:	4-5

corresponding particle-tracking of recharge water injected into the Upper Floridan aquifer. Evaluation of impacts to the surficial aquifer will be part of the impact analysis modeling in future Water Use Permit activities. Layer 3 was converted to represent upper Zone A. Layer 4 was converted to represent lower Zone A, and Layer 5 was converted to represent Zones B and C.

Layer top and bottom elevations, and aquifer characteristics from the original FTMR model were used as the basis for the revised elevations and aquifer characteristics in the new model to maintain the original calibrated values. A summary of the new layer elevations and aquifer characteristics is provided in Table 4-1.

Table 4-1 Model Set Up				
Layer	Top Elevation	Bottom Elevation	Transmissivity	Leakance
1	Original SDM	Original SDM	Original SDM	Original SDM adjusted during calibration
2	Layer 1 bottom	Original SDM Layer 3 bottom	Original SDM	Original SDM
3	Original SDM Layer 3 bottom	New Layer 4 top + 35 feet	60% original SDM Layer 4 transmissivity	0.01 d-1
4	New Layer 4 bottom + 80 feet	New Layer 5 top + 60 feet	40% original SDM Layer 4 transmissivity	0.001 d-1
5	Original SDM Layer 4 bottom + 200 feet	Original SDM Layer 5 bottom	Original SDM	N.A.

Top elevations were not set or used for layers 2 – 5 in the original FTMR model, but since the model was being converted to quasi-3D for the future MODPATH simulations, top elevations were set for these layers. New top and bottom elevations were based on existing layer elevations to maintain the overall contoured surface configuration of the layers in the original model. The semi-confining layers separating the producing zones in a quasi-3D model are represented using leakance values of the overlying layer, with the semi-confining layer thickness defined as the difference between the bottom elevation of the overlying layer and top elevation of the underlying layer.

The division of transmissivity values from layer 4 of the original FTMR model to layers 3 and 4 of the new model shown in Table 4-1 was based on aquifer test results described in section 4.1. Leakance between layers 3 and 4 was set at 0.01 d^{-1} to represent the high degree of connection between upper and lower Zone A. Leakance between layers 4 and 5 was set at the same value ($1 \times 10^{-3} \text{ d}^{-1}$) as the original FTMR model.

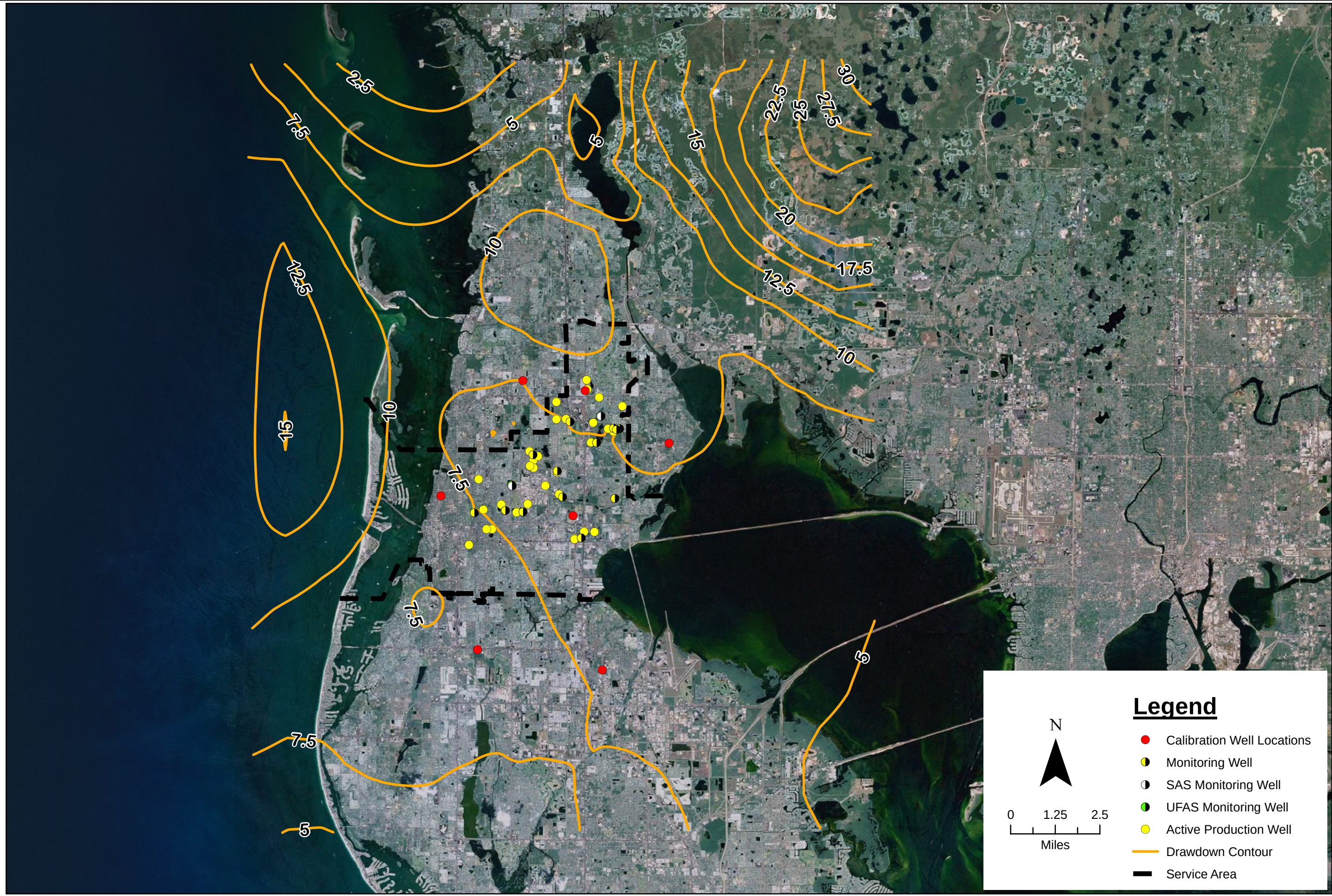
Permitted wells in the original FTMR model were set in layer 4, with some wells in the northern portion of the model in layers 4 and 5. With the re-layering of the model, the wells also had to be reassigned to the appropriate model layers. Wells with a total depth of less than 200 feet were set in layer 3. Wells with casing depths less than 200 feet and total depths greater than 200 feet were set in both layers 3 and 4. Wells with casing depths greater than 200 feet were set in layer 4. Where total well depths were greater than 350 feet wells were also open to layer 5.

A FTMR model is comprised of three stress periods. Stress period 1 is steady-state with no pumping to simulate pre-development conditions. Stress period 2 is steady-state with permitted wells set at 2006 reported pumping rates. Stress period 3 is transient with the duration and pumping rates set by the user. The new groundwater flow model will be used for particle tracking with MODPATH, which does not function with a combination steady-state/transient stress period configuration. Therefore, the steady-state stress periods were converted to 10-year transient stress periods. Storativity was set at 1×10^{-4} in layers 3, 4, and 5.

4.2.3 Model Calibration

Throughout the process of modifying the grid, the model was run and the potentiometric surface contours were compared with those from the original FTMR to confirm that the modifications did not affect the model results. The final modified grid model with three transient stress periods was used as the new base model for calibration to known heads in seven wells located around the Clearwater area. The calibration well locations are shown in Figure 4-6. Average potentiometric surface levels for 2009 were set for the calibration targets. Pumping rates for the City wells were set at 2009 reported rates in both stress periods 2 and 3. The potentiometric surface at the end of stress period 3 is shown on Figure 4-6. Calibration statistics for the base model run are shown in Table 4-2.

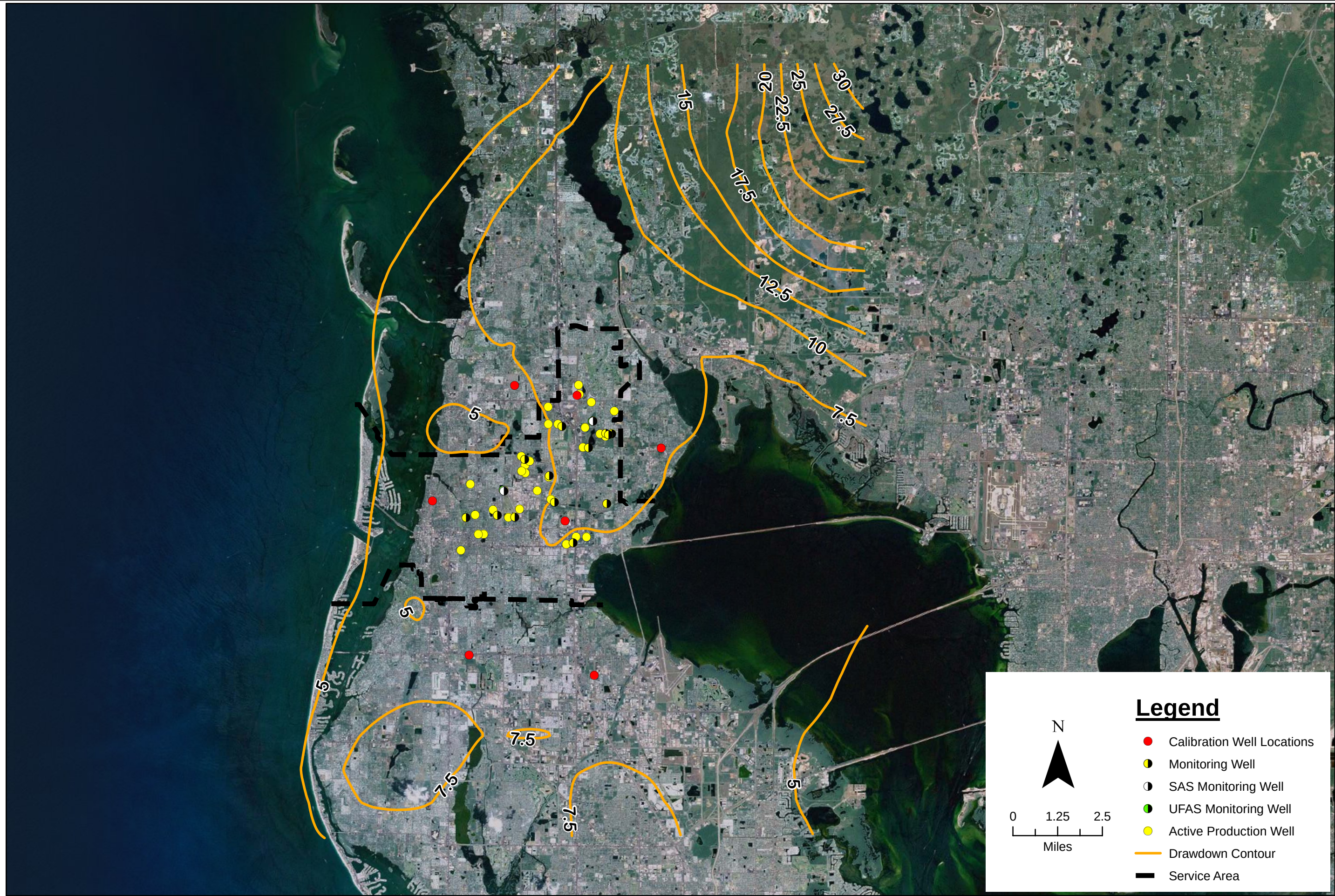
Table 4-2 Base Model Calibration Statistics					
Name	Time	Layer	Observed	Computed	Residual
Romp_13-2	7665	3	6.5	7.36	-0.86
Romp_13-1	7665	3	7	7.95	-0.95
Romp_14-1	7665	3	8.5	7.72	0.78
Romp_14-2	7665	3	5.5	7.67	-2.17
Romp_14-3	7665	3	7.8	8.84	-1.04
Pinellas_665	7665	3	9.5	6.93	2.57
Garden_Street	7665	3	5.7	8.10	-2.40
Residual Mean	-0.5829				
Abs. Res. Mean	1.539				
Res. Std. Dev.	1.604				
Sum of Squares	20.392				
RMS Error	1.707				
Min. Residual	-2.399				
Max. Residual	2.567				
Number of Observations	7				
Range in Observations	4				
Scaled Std. Dev.	0.401				
Scaled Abs. Mean	0.385				
Scaled RMS	0.427				



☐ Acad ☒ GIS ☐ Corel		FILE NAME: <i>FIGURE4-6.MXD</i>	
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CITY OF CLEARWATER GROUNDWATER REPLENISHMENT FEASIBILITY STUDY BASE MODEL POTENTIOMETRIC SURFACE CONTOURS			
PREPARED BY:  LEGGETT, BRASHEARS & GRAHAM, INC. Professional Groundwater and Environmental Engineering Services Cypress Point Office Park 10014 North Mabry Highway, Suite 205 Tampa, Florida 33618 (813) 968-5882			
DRAWN BY: TDH		CHECKED BY: JMT	
DATE: Apr. 2011		FIGURE NO.: 4-6	

As shown on Figure 4-6, the primary problem with the modeled potentiometric surface contours is the potentiometric surface high in the Gulf of Mexico, which causes the potentiometric surface to be higher in the western portion of Pinellas County than what actually occurs. This is due to the head values assigned to the western constant head boundary of the model, which range from 5 to 12 feet above mean sea level (msl). The western constant head boundary was reset to 2 feet msl, which reduced the residual at the Garden Street Well (western-most calibration well) from 2.4 feet higher than observed to 0.36 feet lower than observed. Sensitivity runs indicated that leakance of layer 1 had the most significant impact on overall head levels in layers 3 and 4. Changes in transmissivity values in layers 3 and 4 within a reasonable range in values based on existing data referenced in section 4.2 had relatively little effect on head elevations. Model calibration consisted of manual changes to layer 1 leakance values and layer 3 and 4 transmissivity values. Excessively high heads in the northern part of the county were reduced to observed levels by setting the maximum layer 1 leakance value to $1 \times 10^{-4} \text{ d}^{-1}$. Heads in the eastern portion of the City's well field were increased by increasing leakance by one order of magnitude, to a range of $1.6 \times 10^{-5} \text{ d}^{-1}$ to $1 \times 10^{-4} \text{ d}^{-1}$ in the eastern portion of the City. The final calibration adjustment consisted of setting the maximum transmissivity value in layers 3 and 4 to 39,800 ft^2/day over the entire model domain. The final calibrated potentiometric surface is shown on Figure 4-7, and the final calibration statistics are shown in Table 4-3.

Table 4-3 Final Calibration Statistics					
Name	Time	Layer	Observed	Computed	Residual
Romp_13-2	7665	3	6.5	7.16	-0.66
Romp_13-1	7665	3	7	7.06	-0.06
Romp_14-1	7665	3	8.5	7.84	0.66
Romp_14-2	7665	3	5.5	6.51	-1.01
Romp_14-3	7665	3	7.8	8.50	-0.70
Pinellas_665	7665	3	9.5	7.87	1.63
Garden_Street	7665	3	5.7	5.69	0.01
Residual Mean	-0.01694				
Abs. Res. Mean	0.675				
Res. Std. Dev.	0.847				
Sum of Squares	5.028				
RMS Error	0.847				
Min. Residual	-1.006				
Max. Residual	1.630				
Number of Observations	7				
Range in Observations	4.0				
Scaled Std. Dev.	0.212				
Scaled Abs. Mean	0.169				
Scaled RMS	0.212				



☐ Acid ☒ GIS ☐ Corel		CITY OF CLEARWATER GROUNDWATER REPLENISHMENT FEASIBILITY STUDY		PREPARED BY:		 LEGGETTE, BRASHEARS & GRAHAM, INC. Professional Groundwater and Environmental Engineering Services Cypress Point Office Park 10014 North Dale Mabry Highway, Suite 205 Tampa, Florida 33618 (813) 968-5882	DRAWN BY: TDH	
		FINAL CALIBRATION POTENTIOMETRIC SURFACE CONTOURS		CHECKED BY: JMT			DATE: Apr. 2011	
							FIGURE NO.: 4-7	
FILE NAME: FIGURE4-7.MXD								

4.2.4 Predictive Groundwater Flow Simulation

One of the City's objectives for implementing a groundwater recharge project is to offset new drawdown from future increases in withdrawals from their well fields through groundwater replenishment. In order to evaluate the benefit of groundwater replenishment on water levels while increasing the withdrawal quantity from the well field, the calibrated model was run in the same manner as an impact analysis model. The model was run with 2009 pumping rates (3.9 mgd) assigned to the City's supply wells in stress period 2 to simulate current conditions. The well field withdrawals were increased to 8.0 mgd with no recharge in stress period 3 to simulate the amount of drawdown produced by increasing the well field withdrawal by 4.1 mgd. The model was then run with the same 8.0 mgd withdrawal in stress period 3, but also with 3.0 mgd of recharge via five recharge wells located along a corridor from the NEWRF to about one mile to the west of the NEWRF. Figure 4-8 shows the preliminary locations of the recharge wells. Actual well locations will be determined in a subsequent phase of the project. As described in section 4.2, the City's supply wells withdraw groundwater from layer 3 (upper Zone A) and the recharge wells inject into layer 4 (lower Zone A) (see Figure 4-9). Stress Period 3 was run for a period of one year. Other permitted wells within the model domain are included at their 2006 average annual withdrawal quantities in stress periods 2 and 3. Stress period 3 of the predictive simulations was increased to a period of two years to accommodate subsequent particle tracking modeling.

The drawdown contours shown on Figure 4-10 indicate that the increase in withdrawal from 3.9 mgd to 8.0 mgd results in up to 1.8 feet of drawdown in the area of Well Field 3, and up to 4.5 feet of drawdown in Well Field 1. The 0.5-foot drawdown contour extends to a distance of approximately 5 miles to the north of the City boundary in the Dunedin area, and approximately one mile to the south of the City boundary in the Belleair area.

The model was then run to evaluate the amount of potentiometric surface increase that will occur from recharge of 3 mgd. The contours shown on Figure 4-11 represent the potentiometric surface increase due to the proposed 3 mgd. Maximum head increase at the recharge wells is approximately 3.5 feet in lower Zone A and 2.2 feet in Upper Zone A. At a distance of approximately 3,000 feet from the recharge wells head increases in lower and upper Zone A is nearly equivalent. Head increases in Well Field 3 range from 0.6 to 1.0 feet. Head increases in Well Fields 1 and 2 range from 0.2 to 0.5 feet.

The drawdown contours on Figure 4-12 show the net drawdown from the 4.1 mgd increase in the City wellfield together with the 3.0 mgd recharge. The net effect is to reduce maximum drawdown to 1.0 foot in Well Field 3, and 4 feet in Well Field 1. The 0.5-foot drawdown contour for this simulation is reduced to less than two miles to the north of the City boundary in the Dunedin area. The area around the recharge wells has over 1.2 feet of increase in water level as a result of the recharge.



0 300 600
Feet

DATE	REVISED

FILE NAME: FIGURE 4-8.MXD



CITY OF CLEARWATER GROUNDWATER REPLENISHMENT FEASIBILITY STUDY

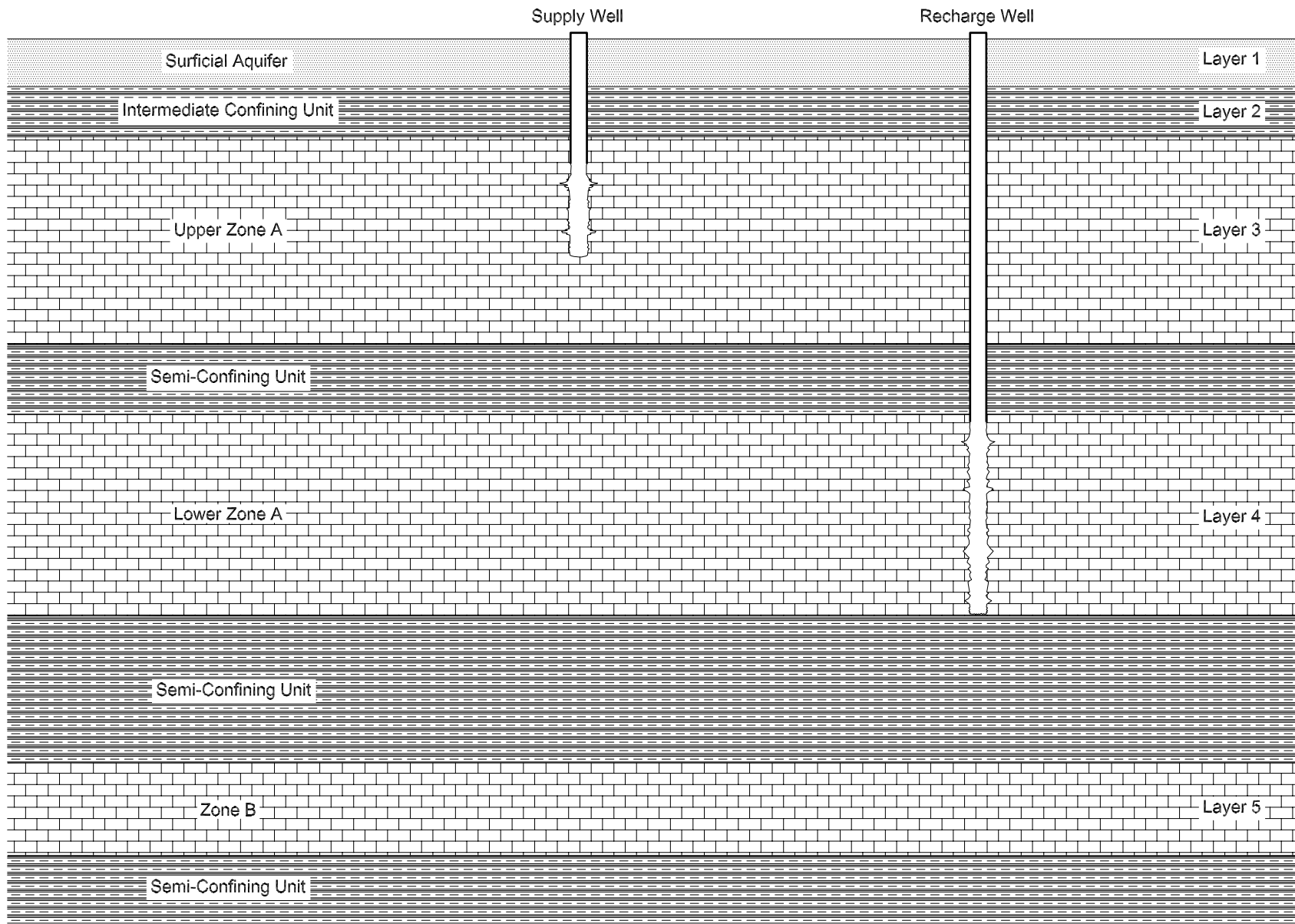
PRELIMINARY RECHARGE WELL LOCATIONS

PREPARED BY:



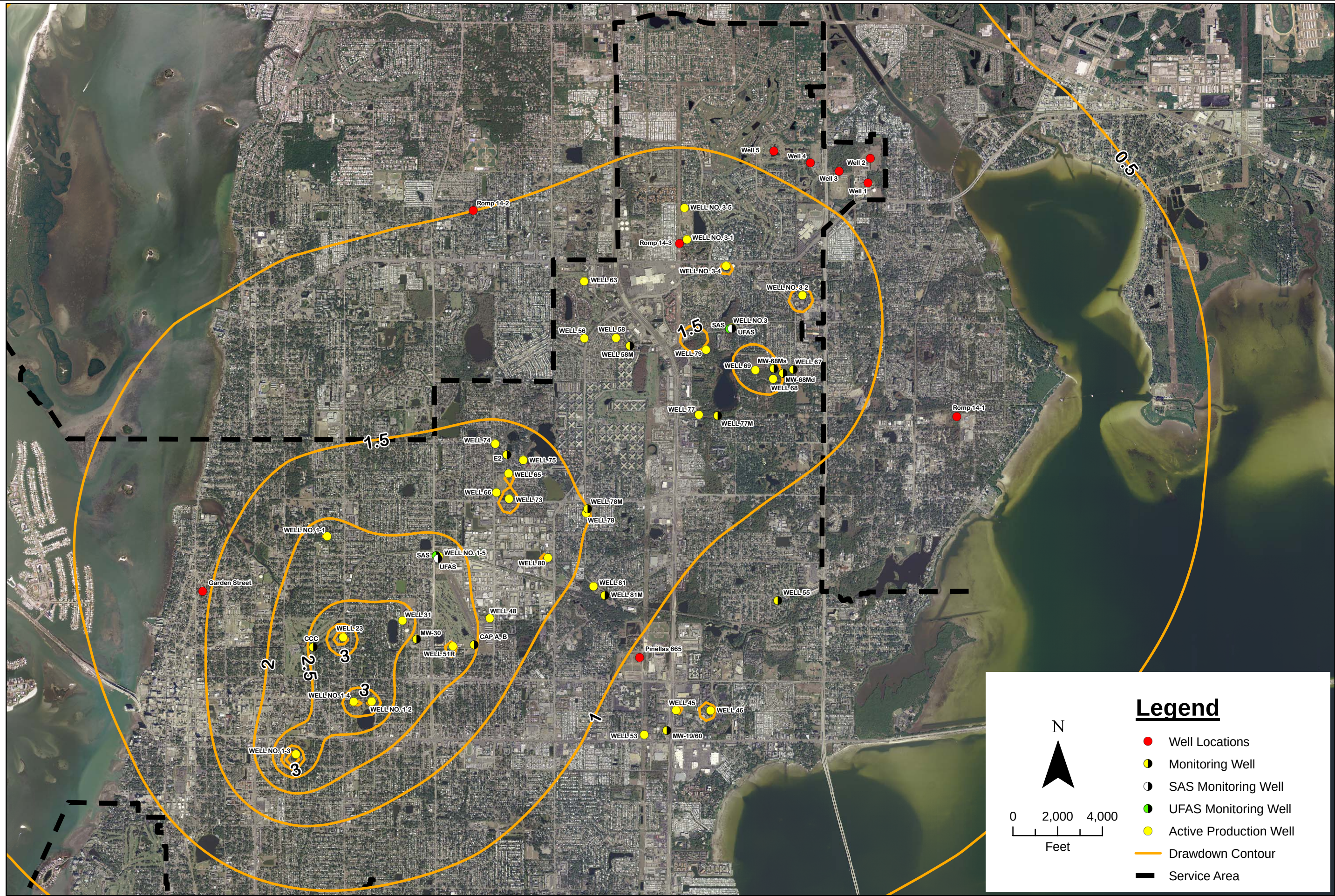
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FIGURE NO.:	4-8



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		☐ GIS			CHECKED: DAW
		☐ Corel			DATE: Apr. 2011
FILE NAME: Figure4-9					FIGURE: 4-9



DRAWN BY:	TDH
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DATE:	Dec. 2010
FIGURE NO.:	4-10

PREPARED BY:

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Cypress Point Office Park

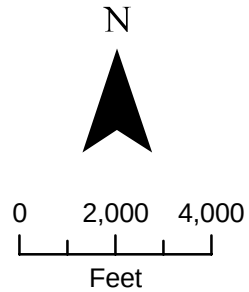
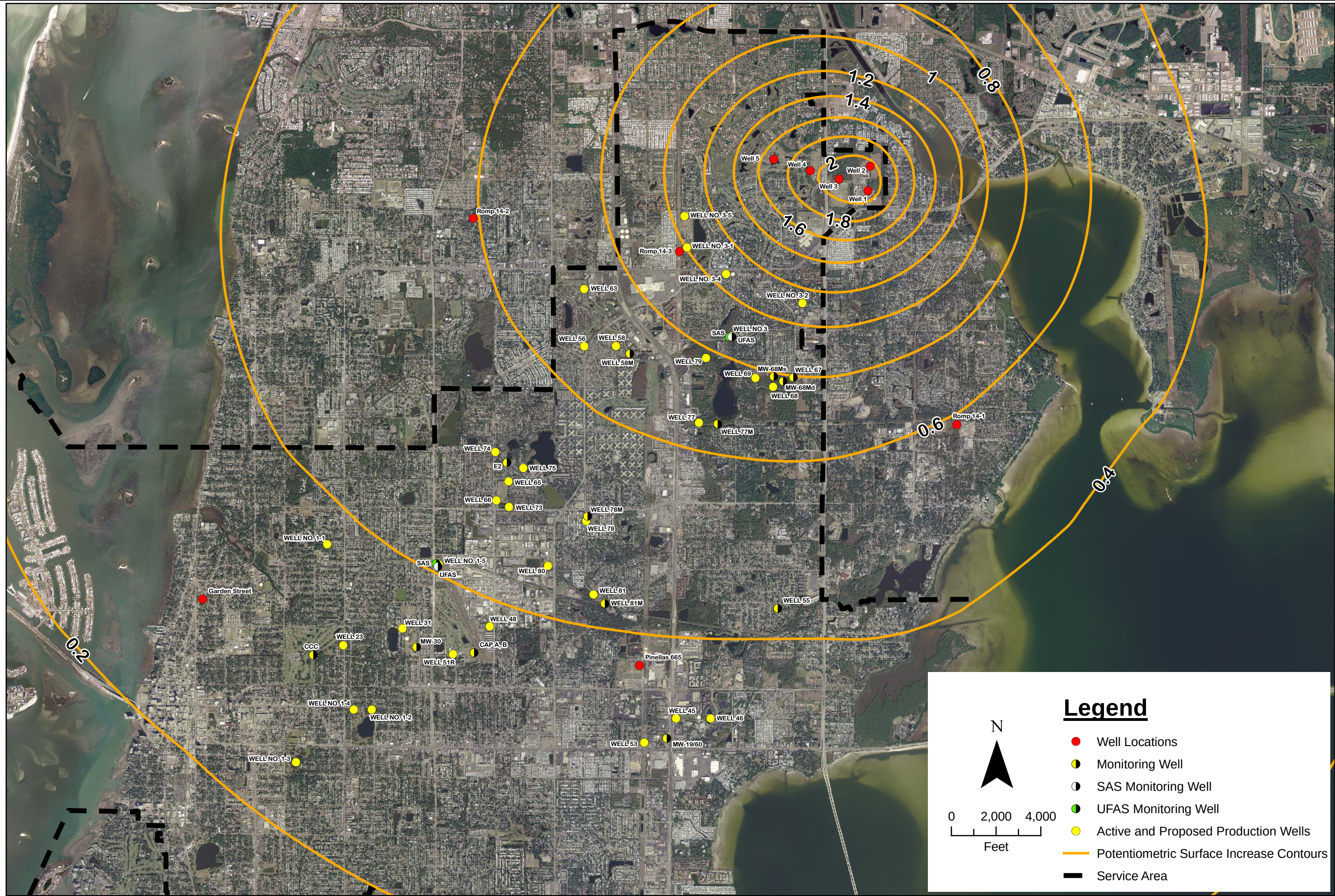
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CITY OF CLEARWATER
GROUNDWATER REPLENISHMENT FEASIBILITY STUDY
CHANGE IN DRAWDOWN WITH 8.0 mgd
WITHDRAWAL AND NO RECHARGE

DATE	REVISED	FILE NAME: FIGURE4-10.MXD

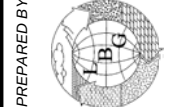


Legend

- Well Locations
- Monitoring Well
- SAS Monitoring Well
- UFAS Monitoring Well
- Active and Proposed Production Wells
- Potentiometric Surface Increase Contours
- Service Area

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FIGURE NO.:	4-11

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CITY OF CLEARWATER
GROUNDWATER REPLENISHMENT FEASIBILITY STUDY
INCREASE IN UPPER ZONE A POTENTIOMETRIC
SURFACE DUE TO RECHARGE

DATE	REVISED	FILE NAME: FIGURE4-11.MXD

The City of Oldsmar is currently constructing a brackish groundwater well field approximately 2.5 miles northeast of the City of Clearwater's NEWRF. The Oldsmar well field is permitted to withdraw 2.7 mgd from upper and lower Zone A, and will be in operation prior to the start of operation of the proposed groundwater replenishment project. Based on this information, the groundwater flow model was run to include the Oldsmar well field at its full permitted capacity in stress period 3 to evaluate the combined effect of the City's well fields, Oldsmar's well field, and the proposed recharge wells. As shown on Figure 4-13, the cone of depression from the Oldsmar well field reduces the affect of the recharge-related mounding on the City's well fields. Comparison of Figure 4-12 and Figure 4-13 shows that drawdown in the area of Well Field 3 increases by up to approximately 0.4 feet, but drawdown in the area of Well Field 1 increases by only about 0.1 feet. The increase in water level in the area around the recharge wells is reduced by about 0.5 feet. Overall, the proposed groundwater replenishment creates offsets to not only new drawdown due to increasing the withdrawal from the City's well fields, but also the drawdown from Oldsmar's new well field. Comparison of Figure 4-10 (drawdown from the City's increased withdrawal and no replenishment) and Figure 4-12 (drawdown from the City's increased withdrawal and Oldsmar's well field with recharge) shows that the area extent of the 0.5-foot drawdown contour is reduced by a few miles, and the maximum drawdown outside of the City limits is less than one foot.

4.2.5 MODPATH Travel Time Modeling

The MODFLOW model that included the City's increase in well field withdrawals (8.0 mgd), the Oldsmar well field withdrawals (2.7 mgd), and the proposed recharge wells (3.0 mgd) in stress period 3 was used as the base model set-up for a MODPATH simulation to evaluate the flow paths of particles of water from the recharge wells. MODPATH utilizes the grid structure, aquifer characteristics, and cell to cell flow terms from the MODFLOW model to move particles through the three dimensional flow system. In addition to the input parameters used in the MODFLOW model, aquifer porosity, the number and initial location of particles, and the particle tracking time are required for the MODPATH simulation.

Review of available aquifer data and existing solute transport models for the area indicate that porosity values for the Upper Floridan aquifer range from 0.2 to 0.3. As requested by the FDEP staff, a conservative value of 0.2 was used in this MODPATH model. Particle circles consisting of 10 particles each were emplaced around each recharge well. The particle circles had release points at the top, center, and bottom of layer 4. Multiple release points were used to evaluate flow paths across the entire thickness of the lower Zone A recharge zone.

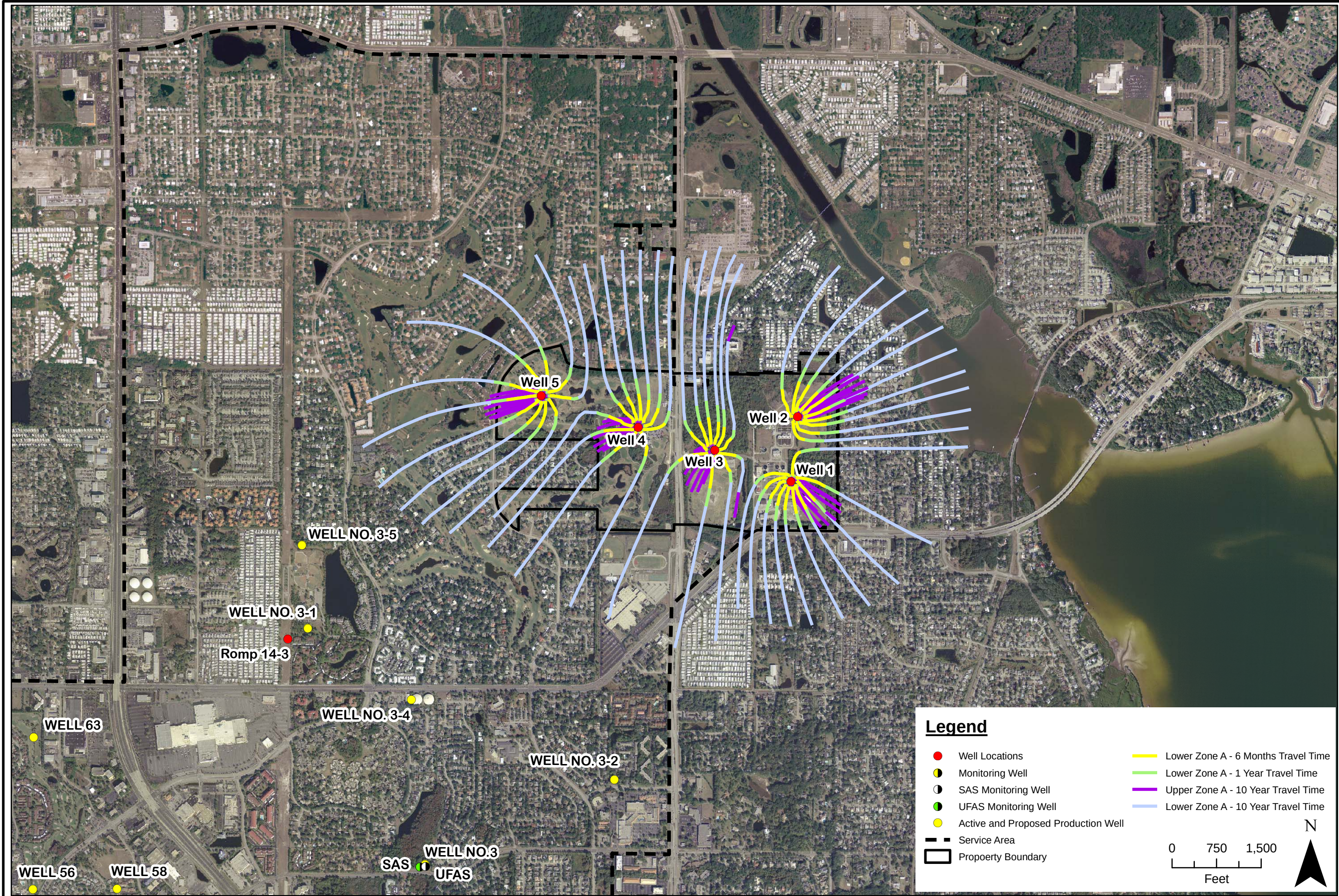
Stress period 3 was run for a period of 10 years. The particles were released coincident with the start of the recharge wells at the start of stress period 3, and were tracked for the two year stress period. The particle tracking evaluation criteria for this project was adopted from previous work at the Orange County California ground water recharge

project, which stipulated a minimum six month travel time from the recharge wells to any potable supply wells. The results shown on Figure 4-14 indicate that the particle traces within layer 4 (lower Zone A) migrate radially from the area of the recharge wells to a maximum distance of approximately 600 feet from the wells within the first six months. At six months, all of the particle traces remain within the City-controlled property boundary. These particles are the set released in the center of layer 4. A cross section view (Figure 4-15) shows that the particles released at the top of layer 4 migrate upward through the semi-confining layer into layer 3, then approximately 20 feet radially from the wells in layer 3 (upper Zone A). The cross section view also shows the particles released at the bottom of layer 4 migrate downward into the semi-confining layer but do not reach layer 5 (zone B) within the six-month travel time.

The purpose of particle-tracking model was to determine the potential time that it may take a water particle to reach the nearest public supply or potable domestic wells from the recharge wells. The model results indicate that no public supply or potable domestic wells will be reached by injected water within the six-month travel time. Figure 4-14 also shows the particle traces for the one-year and 10-year travel times in lower and upper Zone A. The one-year travel time particle traces in lower Zone A extend to just beyond the City property boundary in the northeast and northwest corners of the site. The particle traces in upper Zone A are contained within the property boundary. No public supply or potable domestic wells will be reached by injected within the one-year travel time. The 10-year travel time particles traces extend to a distance of up to approximately one-quarter mile around the site in lower Zone A, and approximately 500 feet from the northeast corner of the site in upper Zone A. As shown on Figure 4-16 there are no public supply wells within a one-quarter mile radius of the site. The only permitted wells within one-quarter mile of the project site are irrigation wells at Countryside Country Club and Countryside High School. These wells are now only used for back-up irrigation since the City provides reclaimed water to those two facilities. There are only three permitted domestic wells in the section inclusive of the subdivision and the east and northeast corner of the site. Depending on the exact location of these wells, there is a potential that these wells in upper Zone A could be within the 10-year travel time particle traces.

4.3 AREA WELL INVENTORY

A well inventory was conducted to better understand the locations of other permitted wells and private domestic wells in the project area. For this inventory a two-mile radius from the center of the project area was used for identifying other wells. The SWFWMD data base was queried for this well inventory. Figure 4-16 is a map showing the locations of other permitted wells in the two-mile area. Table 4-4 lists the permitted wells. This inventory shows that there are 10 water use permits in the project area. The closest permitted wells are golf course irrigation wells for the Countryside Country Club. The closest golf course well is located approximately 2,000 feet from the nearest proposed recharge well location (Figure 4-16). The nearest public supply well to the proposed recharge wells is a City of Clearwater well that is approximately 4,000 feet to the southwest as shown on Figure 4-16.

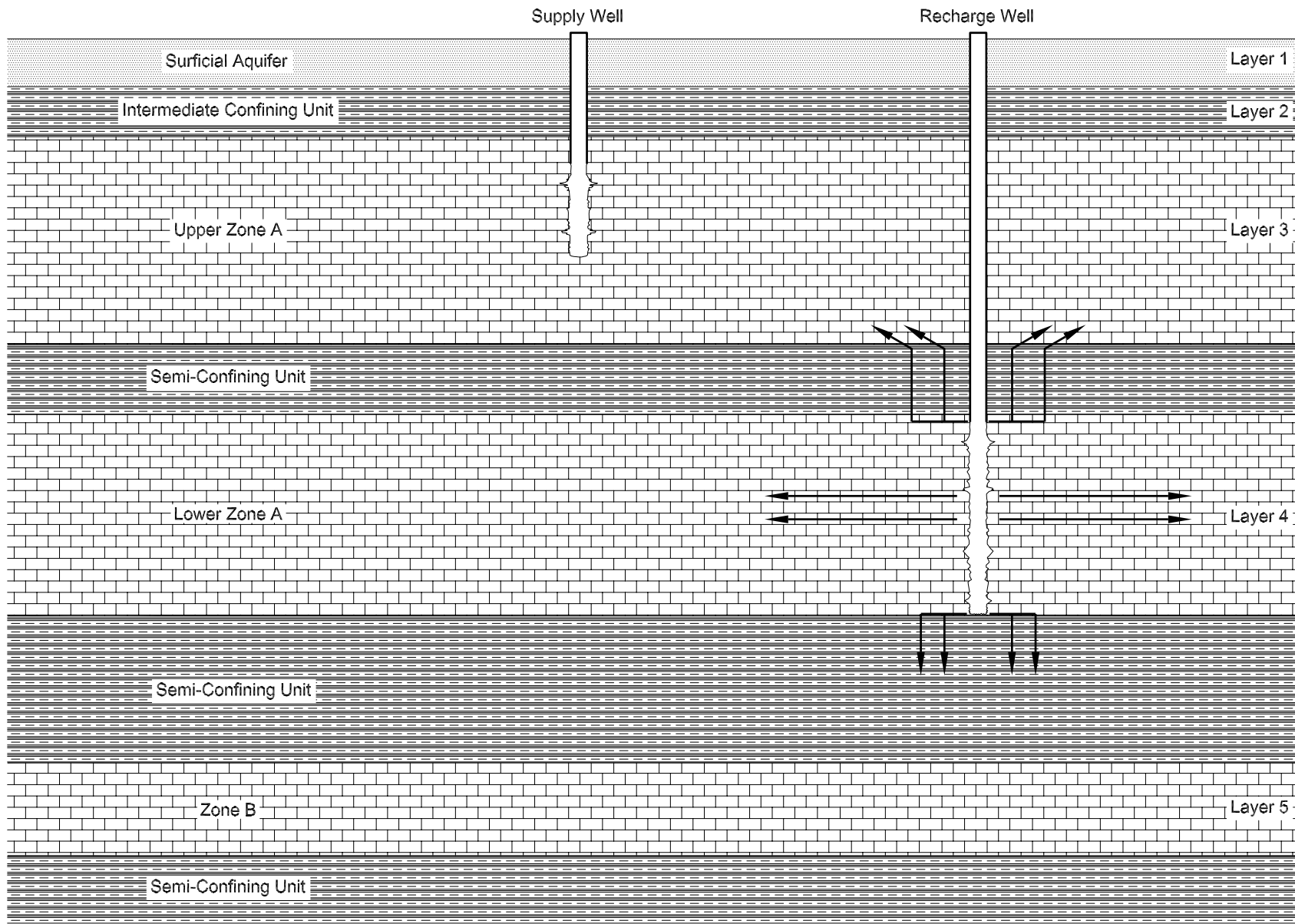


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LEGGETTE, BRASHEARS & GRAHAM, INC.

CITY OF CLEARWATER
GROUNDWATER REPLENISHMENT FEASIBILITY STUDY
PARTICLE-TRACKING MODEL RESULTS

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FIGURE NO.:	4-14

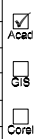


Legend

← Approximate Modeled Particle Tracks

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DATE	REVISED
FILE NAME: Figure4-15	



CITY OF CLEARWATER GROUNDWATER REPLENISHMENT FEASIBILITY STUDY

CONCEPTUAL CROSS-SECTION SHOWING APPROXIMATE PARTICLE TRACKS

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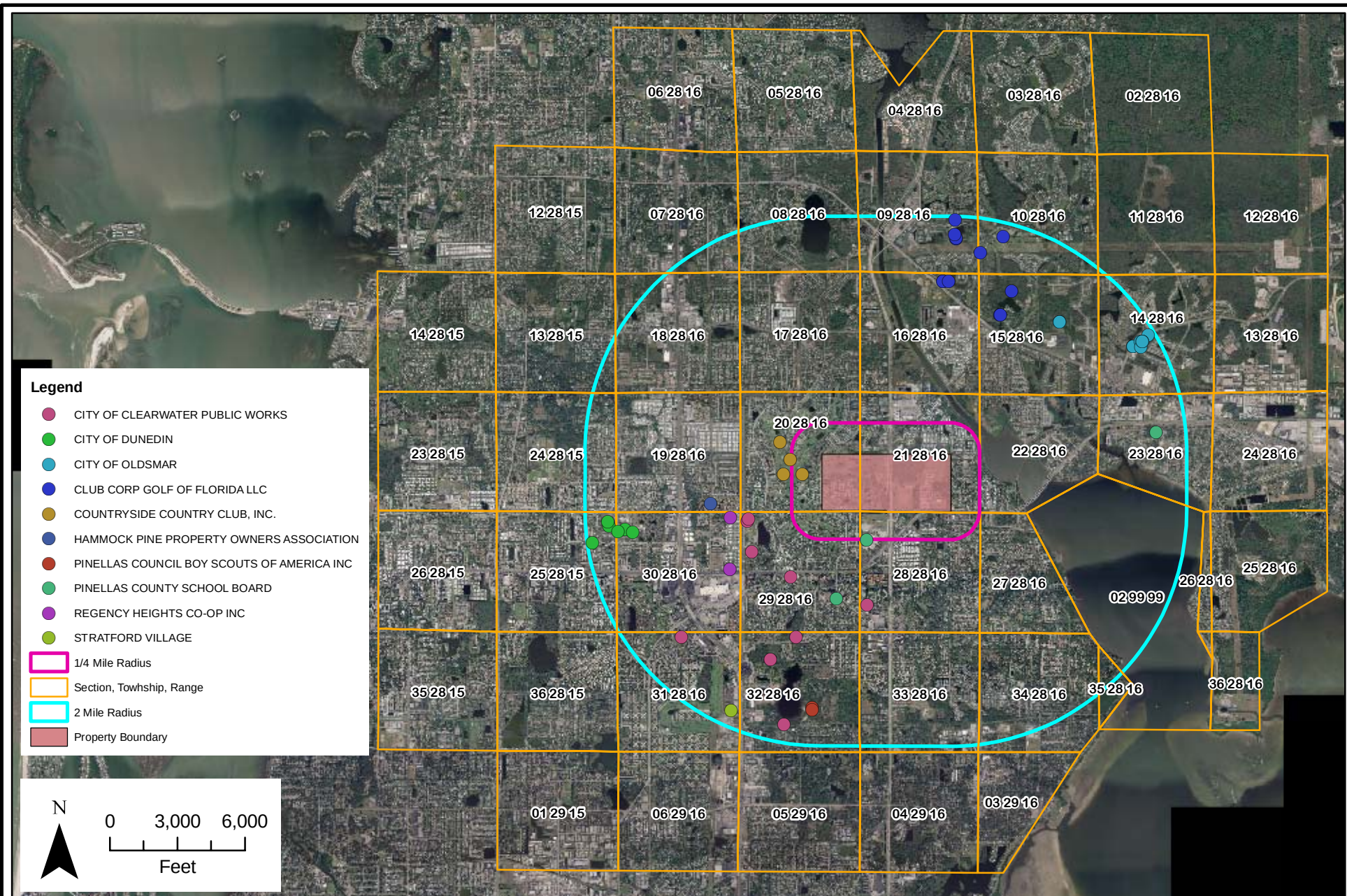
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FIGURE: 4-15



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CITY OF CLEARWATER GROUNDWATER REPLENISHMENT FEASIBILITY STUDY

WATER USE PERMITS WITHIN A 2 MILE RADIUS

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FIGURE NO.:	4-16

Table 4-4 Other Water Use Permits Within 2 Miles

CITY OF CLEARWATER GROUNDWATER REPLENISHMENT FEASIBILITY STUDY

Owner Name	Water Use Permit No.	Water Use DID User Name	Casing Depth (ft)	Well Diameter (in)	Water Use Total Depth (ft)	Permitted withdrawal average (gpd)	Permitted withdrawal max (gpd)	Permitted peak month withdraw rate	Withdrawal peak (gpd)	Water Use Application status description	Water Use Permit predominant use description	Latitude	Longitude
CITY OF CLEARWATER PUBLIC WORKS	2981	79R	60	12	250	154,000	0	0	184,800	Approved	PUBLIC SUPPLY	28 0 31.14	82 43 31.54
CITY OF CLEARWATER PUBLIC WORKS	2981	R3-4	60	12	250	154,000	0	0	184,800	Approved	PUBLIC SUPPLY	28 1 7.94	82 43 21.78
CITY OF CLEARWATER PUBLIC WORKS	2981	CRMW-1	60	6	250	0	0	0	0	Approved	PUBLIC SUPPLY	28 1 32.67	82 43 43.39
CITY OF CLEARWATER PUBLIC WORKS	2981	R3-1	60	12	250	154,000	0	0	184,800	Approved	PUBLIC SUPPLY	28 1 18.88	82 43 41.09
CITY OF CLEARWATER PUBLIC WORKS	2981	R3-5	60	12	250	154,000	0	0	184,800	Approved	PUBLIC SUPPLY	28 1 33.7	82 43 42.87
CITY OF CLEARWATER PUBLIC WORKS	2981	R3-3	60	12	250	154,000	0	0	184,800	Approved	PUBLIC SUPPLY	28 0 41.13	82 43 18.76
CITY OF CLEARWATER PUBLIC WORKS	2981	R3-2	60	12	250	154,000	0	0	184,800	Approved	PUBLIC SUPPLY	28 0 55.54	82 42 43.54
CITY OF CLEARWATER PUBLIC WORKS	2981	58M	60	6	150	0	0	0	0	Approved	PUBLIC SUPPLY	28 0 41.02	82 44 15.86
CITY OF CLEARWATER PUBLIC WORKS	2981	77M	60	6	150	0	0	0	0	Approved	PUBLIC SUPPLY	28 0 2.5	82 43 24.6
CITY OF DUNEDIN	2980	18M	85	10	300	0	0	0	0	Approved		28 1 22.7	82 45 0.41
CITY OF DUNEDIN	2980	34M	85	6	380	0	0	0	0	Approved	PUBLIC SUPPLY	28 1 30.24	82 44 52.28
CITY OF DUNEDIN	2980	89	76	12	262	82,400	0	0	103,000	Approved	PUBLIC SUPPLY	28 1 31.9	82 44 52.8
CITY OF DUNEDIN	2980	96	80	12	200	205,000	0	0	256,300	Approved	PUBLIC SUPPLY	28 1 28.69	82 44 44.29
CITY OF DUNEDIN	2980	26	82	12	245	0	0	0	0	Approved		28 1 27.28	82 44 40.41
CITY OF DUNEDIN	2980	91	90	12	255	107,400	0	0	125,000	Approved	PUBLIC SUPPLY	28 1 27.7	82 44 47.8
CITY OF OLDSMAR	11218	S-1	10	4	15	0	0	0	0	Approved	PUBLIC SUPPLY	28 2 51.07	82 40 28.33
CITY OF OLDSMAR	11218	LSMW1	341	6	373	0	0	0	0	Approved	PUBLIC SUPPLY	28 2 50.94	82 40 31.85
CITY OF OLDSMAR	11218	USMW1	182	6	250	0	0	0	0	Approved	PUBLIC SUPPLY	28 2 50.97	82 40 31.87
CITY OF OLDSMAR	11218	TPPW1	75	12	130	225,000	0	0	358,337	Approved	PUBLIC SUPPLY	28 2 51.06	82 40 28.33
CITY OF OLDSMAR	11218	TMW1	94	6	128	0	0	0	0	Approved	PUBLIC SUPPLY	28 2 50.96	82 40 31.86
CITY OF OLDSMAR	11218	1	75	6	453	0	0	0	0	Approved	PUBLIC SUPPLY	28 2 56.05	82 40 24.34
CITY OF OLDSMAR	11218	W-15	0	0	0	0	0	0	0	Approved	PUBLIC SUPPLY	28 2 53.21	82 40 27.06
CITY OF OLDSMAR	11218	W-8P	0	0	0	0	0	0	0	Approved	PUBLIC SUPPLY	28 3 1.72	82 41 8.51
CITY OF OLDSMAR	11218	W-11P	0	0	0	0	0	0	0	Approved	PUBLIC SUPPLY	28 2 53.4	82 40 28.07
CITY OF OLDSMAR	11218	USTPW1	171	12	250	225,000	0	0	358,333	Approved	PUBLIC SUPPLY	28 2 50.8	82 40 27.77
CITY OF OLDSMAR	11218	W-8	0	0	0	0	0	0	0	Approved	PUBLIC SUPPLY	28 3 1.71	82 41 8.53
CITY OF OLDSMAR	11218	W-11	0	0	0	0	0	0	0	Approved	PUBLIC SUPPLY	28 2 53.3	82 40 27.06
CITY OF OLDSMAR	11218	W-15P	0	0	0	0	0	0	0	Approved	PUBLIC SUPPLY	28 2 53.22	82 40 27.06
CLUB CORP GOLF OF FLORIDA LLC	7437	G-2	40	6	368	59,000	0	0	187,000	Approved	RECREATION/AESTHETIC	28 3 32.07	82 41 48.22
CLUB CORP GOLF OF FLORIDA LLC	7437	G-3	54	6	325	54,000	0	0	197,000	Approved	RECREATION/AESTHETIC	28 3 46.52	82 42 0.65
CLUB CORP GOLF OF FLORIDA LLC	7437	S-1	0	24	0	120,000	0	0	590,000	Approved	RECREATION/AESTHETIC	28 3 19.23	82 42 6.45
CLUB CORP GOLF OF FLORIDA LLC	7437	S-2	0	24	0	239,000	0	0	761,000	Approved	RECREATION/AESTHETIC	28 3 4.73	82 41 38.32
CLUB CORP GOLF OF FLORIDA LLC	7437	S-4	0	24	0	179,000	0	0	584,000	Approved	RECREATION/AESTHETIC	28 3 38.3	82 42 0.01
CLUB CORP GOLF OF FLORIDA LLC	7437	STF-1	0	0	0	0	0	0	0	Approved	RECREATION/AESTHETIC	28 3 19.29	82 42 6.63
CLUB CORP GOLF OF FLORIDA LLC	7437	STF-2	0	0	0	0	0	0	0	Approved	RECREATION/AESTHETIC	28 3 4.78	82 41 37.92
CLUB CORP GOLF OF FLORIDA LLC	7437	STF-4	0	0	0	0	0	0	0	Approved	RECREATION/AESTHETIC	28 3 38.61	82 41 59.99
CLUB CORP GOLF OF FLORIDA LLC	7437	CYPRESS	60	4	160	0	0	0	0	Approved	RECREATION/AESTHETIC	28 3 40.31	82 42 0.76
CLUB CORP GOLF OF FLORIDA LLC	7437	CART BARN	60	4	200	0	0	0	0	Approved	RECREATION/AESTHETIC	28 3 39.06	82 41 36.96
CLUB CORP GOLF OF FLORIDA LLC	7437	G-1	24	6	350	95,000	0	0	270,000	Approved	RECREATION/AESTHETIC	28 3 15.2	82 41 32.37
CLUB CORP GOLF OF FLORIDA LLC	7437	SHILOH	100	4	200	0	0	0	0	Approved	RECREATION/AESTHETIC	28 3 19.17	82 42 3.8
COUNTRYSIDE COUNTRY CLUB, INC.	288	2	115	6	340	25,000	0	0	293,000	Approved	RECREATION/AESTHETIC	28 1 59.9	82 43 22.3
COUNTRYSIDE COUNTRY CLUB, INC.	288	3	135	6	340	25,000	0	0	292,000	Approved	RECREATION/AESTHETIC	28 2 7.7	82 43 27.5
COUNTRYSIDE COUNTRY CLUB, INC.	288	1	124	6	340	25,000	0	0	293,000	Approved	RECREATION/AESTHETIC	28 1 53.7	82 43 25.5
COUNTRYSIDE COUNTRY CLUB, INC.	288	4	0	12	0	435,000	0	0	878,000	Approved	RECREATION/AESTHETIC	28 1 53.6	82 43 16.1
HAMMOCK PINE PROPERTY OWNERS ASSOCIATION	6652	1	60	6	150	36,000	0	0	89,400	Approved	RECREATION/AESTHETIC	28 1 40.2	82 44 1.84
PINELLAS COUNCIL BOY SCOUTS OF AMERICA INC	3977	1	0	4	325	6,000	0	0	12,000	Approved	PUBLIC SUPPLY	28 0 10.2	82 43 10.54
PINELLAS COUNCIL BOY SCOUTS OF AMERICA INC	3977	2	136	6	300	1,000	0	0	2,000	Approved	PUBLIC SUPPLY	28 0 9.09	82 43 10.63
PINELLAS COUNTY SCHOOL BOARD	6076	1	119	6	202	10,700	0	0	26,800	Approved	RECREATION/AESTHETIC	28 0 58.6	82 42 58.86
PINELLAS COUNTY SCHOOL BOARD	10375	1	102	6	160	32,400	0	0	81,400	Approved	RECREATION/AESTHETIC	28 2 13.04	82 40 19.97
PINELLAS COUNTY SCHOOL BOARD	7980	1	0	8	285	57,700	0	0	149,000	Approved	RECREATION/AESTHETIC	28 1 24.63	82 42 43.8
REGENCY HEIGHTS CO-OP INC	10114	1	0	8	150	22,500	0	0	45,000	Approved	PUBLIC SUPPLY	28 1 11	82 43 52.08
REGENCY HEIGHTS CO-OP INC	10114	2	0	8	150	22,500	0	0	45,000	Approved	PUBLIC SUPPLY	28 1 34.03	82 43 52.04
STRATFORD VILLAGE	6974	1	0	6	250	8,000	0	0	0	Approved	AGRICULTURAL	28 0 8.52	82 43 50.94

Table 4-5 Domestic Wells in The Vicinity of Clearwater Wells

CITY OF CLEARWATER GROUNDWATER REPLENISHMENT FEASIBILITY STUDY

Permit #	Owner	Well Location Street	Well Use	County	Diameter	Static Water Level	Casing Depth	Total Depth	Application Received Date	Well Completion Date	Section	Township	Range
319603	W A PINCKLE	NO ADDRESS	DOMESTIC	PINELLAS	4	35	55	135	1970-01-01	1979-07-01	1	29	15
319604	W A PINCKLE	NO ADDRESS	DOMESTIC	PINELLAS	4	35	63	145	1970-01-01	1979-07-01	1	29	15
320809	J B SELLERS	NO ADDRESS	DOMESTIC	PINELLAS	4	42	53	116	1970-01-01	1979-07-01	1	29	15
342613	G HUNT INC	NO ADDRESS	DOMESTIC	PINELLAS	4		125	213	1970-01-01	1979-07-01	1	29	15
336985	MEDLOCK M R	NO ADDRESS	DOMESTIC	PINELLAS	4	62	90	172	1970-01-01	1979-07-01	2	28	16
768594	VORCE MICHAEL	14032 SE 125TH LN	DOMESTIC	MARION	4	12	87	170	2007-11-19	2007-12-06	2	99	99
775813	STONE CHRISTINE L TR	9 SE CHINICA DR	DOMESTIC	MARION	4	18	86	103	2008-06-19	2008-07-08	2	99	99
778238	MARSHALL /ARMSTRONG 3571	21395 NW 39TH COURT	DOMESTIC	MARION	4	42	50	80	2008-09-15	2008-09-30	2	99	99
782298	CORDELL CECIL	10945 SE TIMUCUAN RD	DOMESTIC	MARION	4	15	129	135	2009-02-26	2009-03-16	2	99	99
783974	THURSTON GARY A & LEE ANN	10900 SE TIMUCUAN RD	DOMESTIC	MARION	4	18	128	132	2009-04-28	2009-05-05	2	99	99
800701	UNDERWOOD L D III & MARILYN	50 SE CHINICA DR	DOMESTIC	MARION	4	15	64	70	2009-11-02	2009-11-06	2	99	99
803888	WILLIAMS NOLA J	33 SE OCALE WAY	DOMESTIC	MARION					2010-04-02		2	99	99
356224	MILGRAM, SYE	1630 CEYLEW RD	DOMESTIC	PINELLAS	4		84	101	1978-10-18	1978-10-11	3	28	16
308120	D JORDAN	NO ADDRESS	DOMESTIC	PINELLAS	3	10	92	92	1970-01-01	1979-07-01	3	29	16
369847	BURGLEORDT, HARRY	1680 EYSLEY AVE	DOMESTIC	PINELLAS	2		75	75	1981-10-26	1981-10-29	3	29	16
472131	HIBBELN, DAN	10 DEERPATH DR	DOMESTIC	PINELLAS					1988-11-28		4	28	16
530257	KEN MARKS JR	1975 FISH HATCHERY COURT	DOMESTIC	PINELLAS	4	14	62	90	1992-09-25	1992-10-08	4	28	16
596946	MARTIN MCVICKER	880 14TH AVE S	DOMESTIC	PINELLAS	4	28	90	145	1997-09-09	1997-09-22	4	28	16
306340	NO NAME - DO NOT MODIFY	NO ADDRESS	DOMESTIC	PINELLAS	4	30	51	128	1970-01-01	1979-07-01	4	29	16
308850	NO NAME - DO NOT MODIFY	NO ADDRESS	DOMESTIC	PINELLAS	4	45	105	180	1970-01-01	1979-07-01	4	29	16
311955	C LOHMEYER	NO ADDRESS	DOMESTIC	PINELLAS	3		200	225	1970-01-01	1979-07-01	4	29	16
321253	J GOLDEN	NO ADDRESS	DOMESTIC	PINELLAS	3	8	27	60	1970-01-01	1979-07-01	4	29	16
328216	R HILKER	NO ADDRESS	DOMESTIC	PINELLAS	3	28	80	166	1970-01-01	1979-07-01	4	29	16
328233	R THOMAS	NO ADDRESS	DOMESTIC	PINELLAS	4		54	88	1970-01-01	1979-07-01	4	29	16
354045	JONES, JESS L.	2295 MCMULLEN BOOTH RD	DOMESTIC	PINELLAS					1980-05-15		4	29	16
552768	RICHARD BLUDER	5 OAK AVENUE NORTH	DOMESTIC	PINELLAS	4	28	54	95	1994-05-20	1994-06-11	4	29	16
588663	WAYNE BARNHISEL	1963 OAK RIDGE CT	DOMESTIC	PINELLAS	4	34	100	140	1997-02-25	1997-02-27	4	29	16
596082	TONY SIMON	1200 FERN TERRACE DR	DOMESTIC	PINELLAS	4	25	84	135	1997-08-13	1997-10-21	4	29	16
745898	JANET FREBOLD MATTHEWS	1220 7TH. ST. S., SAFETY HARBOR	DOMESTIC	PINELLAS	4	35	54	90	2006-08-14	2006-08-23	4	29	16
306713	B JAMES	C.R. 90 (P.O.BOX 547)	DOMESTIC	PINELLAS	3	42	63	130	1970-01-01	1979-07-01	5	28	16
312921	REX FISHER	BOX 650 F (5120 TOWN&COUNTRY BLV	DOMESTIC	PINELLAS	3	8	9999	117	1970-01-01	1979-07-01	5	28	16
335692	F.L. SHINNER TRUST	RT # 1 (C.R. 90)	DOMESTIC	PINELLAS	4	55	37	100	1970-01-01	1979-07-01	5	28	16
339794	CARLTON RHODES	2909 MAC ALPIN DRIVE SOUTH	DOMESTIC	PINELLAS	4		52	75	1970-01-01	1979-07-01	5	28	16
366543	POLASKI, CLARINE	3379 CO RD 70	DOMESTIC	PINELLAS	4	52	95	140	1981-06-17	1981-06-19	5	28	16
752892	BRENT SOWELL	2939 ABBEY LAKE RD., CLEARWATER	DOMESTIC	PINELLAS	4	43	83	160	2006-12-19	2007-01-01	5	28	16
308502	J N ROE	NO ADDRESS	DOMESTIC	PINELLAS	3	11	176	238	1970-01-01	1979-07-01	5	29	16
325375	M SAYNT	NO ADDRESS	DOMESTIC	PINELLAS	4		75	110	1970-01-01	1979-07-01	5	29	16
336904	ELECTROLINE	NO ADDRESS	DOMESTIC	PINELLAS	3		105	105	1970-01-01	1979-07-01	5	29	16
397326	JOHNSON, RICHARD	400 S CR 195	DOMESTIC	PINELLAS	5	28	90	135	1984-10-15	1985-05-25	5	29	16
619653	KATHY DAVIDSON	2915 ABBEY LAKE DRIVE	DOMESTIC	PINELLAS	4	33.6	100	160	1999-05-05	1999-06-15	5	29	16
628766	PETER BARGBON	2981 ABBY LAKE RD	DOMESTIC	PINELLAS	4	38	63	75	1999-12-06	1999-12-08	5	29	16
684780	CHARLES BROWN C/O PALM HARBOR VILLAGE	2965 UNION ST	DOMESTIC	PINELLAS	4	46	94	150	2003-05-14	2003-07-11	5	29	16
323258	STANTONS, BILL	RFD 1 BOX 661	DOMESTIC	PINELLAS	4	65	75	102	1974-04-10	1979-07-01	6	28	16
332269	STEADHAM, J	2309 NEBRASKA AVE.	DOMESTIC	PINELLAS	4	53	85	140	1976-08-30	1979-07-01	6	28	16
335196	SCOTT, LEO	2311 NEBRASKA AVE.	DOMESTIC	PINELLAS	4	53	90	140	1977-08-25	1979-07-01	6	28	16
339349	BERTALAN, JOHN J.	1120 FAMEMOORE TRACE	DOMESTIC	PINELLAS	4	60	100	160	1978-10-03	1979-07-01	6	28	16
320102	Z B GROSS J	NO ADDRESS	DOMESTIC	PINELLAS	4		84	173	1970-01-01	1979-07-01	6	29	16
324500	EVANS, WILLIAM	R.R.1 BOX 567 C.R.94	DOMESTIC	PINELLAS	3	56	100	105	1974-08-02	1979-07-01	7	28	16
367316	CRUMBLEY, JAMES	COUNTY RD 94	DOMESTIC	PINELLAS	4	57	105	160	1981-07-13	1981-12-16	7	28	16
378781	MCEACHERN	2760 SUTTON	DOMESTIC	PINELLAS	4	65	120	139	1982-12-27	1986-02-18	7	28	16
393558	CRAFT, DON	PO BOX 155	DOMESTIC	PINELLAS	4	50	63	100	1984-07-02	1984-07-10	7	28	16
535673	ROBERTA CRIST	4446 WINDING WAY	DOMESTIC	PINELLAS	4	71	96	185	1993-03-10	1993-03-17	7	28	16
306294	NO NAME - DO NOT MODIFY	NO ADDRESS	DOMESTIC	PINELLAS	5	30	41	75	1970-01-01	1979-07-01	8	28	16
533947	MICHAEL DEEGAN	2624 KAVALLIER DR	DOMESTIC	PINELLAS					1993-01-21		8	28	16
705113	BILL ZISA	2936 LAKE VALENCIA E	DOMESTIC	PINELLAS	4	28	63	80	2004-08-02	2004-08-10	8	28	16

Table 4-5 Domestic Wells in The Vicinity of Clearwater Wells

CITY OF CLEARWATER GROUNDWATER REPLENISHMENT FEASIBILITY STUDY

Permit #	Owner	Well Location Street	Well Use	County	Diameter	Static Water Level	Casing Depth	Total Depth	Application Received Date	Well Completion Date	Section	Township	Range
333877	EQUITY INVESTMENTS CORP	11300 N CENTRAL AVE	DOMESTIC	PINELLAS	3		53	108	1970-01-01	1979-07-01	10	28	16
314165	R MAJOR	NO ADDRESS	DOMESTIC	PINELLAS	3	37	44	100	1970-01-01	1979-07-01	12	28	15
315773	J VINSON	NO ADDRESS	DOMESTIC	PINELLAS	4	62	84	180	1970-01-01	1979-07-01	12	28	15
318886	W C ROSS	NO ADDRESS	DOMESTIC	PINELLAS	4	45	70	80	1970-01-01	1979-07-01	12	28	15
319644	EDWARDS RAN	NO ADDRESS	DOMESTIC	PINELLAS	4	36	63	80	1970-01-01	1979-07-01	12	28	15
319942	J C JERKINS	NO ADDRESS	DOMESTIC	PINELLAS	4	52	93	102	1970-01-01	1979-07-01	12	28	15
320452	C SRSICH	NO ADDRESS	DOMESTIC	PINELLAS	4	57	110	121	1970-01-01	1979-07-01	12	28	15
328748	C SAHLIN	NO ADDRESS	DOMESTIC	PINELLAS	4	38	74	100	1970-01-01	1979-07-01	12	28	15
329935	D BILGORE &	NO ADDRESS	DOMESTIC	PINELLAS	3	53	83	88	1970-01-01	1979-07-01	12	28	15
334750	PRESLEY, H H	NO ADDRESS	DOMESTIC	PINELLAS	4	30	55	110	1970-01-01	1979-07-01	12	28	15
337594	C JONES	NO ADDRESS	DOMESTIC	PINELLAS	4	18	43	81	1970-01-01	1979-07-01	12	28	15
347123	CARLTON JONES, MD	795 BALDWIN ROAD	DOMESTIC	PINELLAS					1979-08-21		12	28	15
347291	CARLTON JONES, MD	795 BALDWIN ROAD	DOMESTIC	PINELLAS					1979-08-28		12	28	15
351260	BOLES, R. C.	1926 FLA AVE	DOMESTIC	PINELLAS					1980-02-11		12	28	15
367005	SERCHEL, RICHARD	1721 GEORGIA AVE	DOMESTIC	PINELLAS	4	25		132	1981-07-02	1981-07-02	12	28	15
374106	JONES, DR. CARLTON	815 BALDWIN RD	DOMESTIC	PINELLAS	4	21	50	120	1982-04-29	1982-05-05	12	28	15
386907	BURCHAM, DAVE	LOT 4-B LANEY RD	DOMESTIC	PINELLAS	4	27	63	125	1983-11-02	1983-12-06	12	28	15
414457	WILSON, ROBERT W	2108 PALMETTO STREET	DOMESTIC	PINELLAS	4	61	74	145	1986-04-14	1986-04-26	12	28	15
445212	COPLEY, RICHARD	1660 LANEY DRIVE	DOMESTIC	PINELLAS	4	30	67	145	1988-02-18	1988-02-24	12	28	15
529214	GREG STEELE	5 STILES LA	DOMESTIC	PINELLAS	4	22	55	150	1992-09-01	1992-10-05	12	28	15
534612	DONNA CLIFFORD	751 BALDWIN RD	DOMESTIC	PINELLAS	4	23	83	180	1993-02-09	1993-02-18	12	28	15
544041	DAN NAPLES	20 BOGIE LANE	DOMESTIC	PINELLAS	4	18	63	113	1993-10-14	1993-11-15	12	28	15
545250	STEVE MCKENZIE	1670 LANEY ROAD	DOMESTIC	PINELLAS	4	23	56	141	1993-11-16	1993-12-03	12	28	15
569893	VINCENT GENOVESE	162 ARBOR DRIVE WEST	DOMESTIC	PINELLAS	4	26	66	140	1995-07-14	1995-07-16	12	28	15
598727	CARLTON JONES	815 HERMOSA DR	DOMESTIC	PINELLAS	4	26	60	115	1997-10-23	1997-11-05	12	28	15
608161	GEORGE LAI	655 BALDWIN RD	DOMESTIC	PINELLAS	4	35	68	100	1998-07-16	1998-07-20	12	28	15
310281	FLORIDA POWER CORP	NO ADDRESS	DOMESTIC	PINELLAS	4	1	104	140	1970-01-01	1979-07-01	12	28	16
315213	B WEINFURTE	NO ADDRESS	DOMESTIC	PINELLAS	4	23	63	110	1970-01-01	1979-07-01	12	28	16
306051	GROUPMAN, NORMAN	GENERAL DELIVERY	DOMESTIC	PINELLAS	4	15	31	100	1970-06-18	1970-07-13	13	28	15
306601	A L FRANK	NO ADDRESS	DOMESTIC	PINELLAS	3	55	63	100	1970-01-01	1979-07-01	13	28	15
309105	NO NAME - DO NOT MODIFY	NO ADDRESS	DOMESTIC	PINELLAS	4	33	33	100	1970-01-01	1979-07-01	13	28	15
309377	JACK C MUETTIG	NO ADDRESS	DOMESTIC	PINELLAS	4	33	60	95	1970-01-01	1979-07-01	13	28	15
313656	D NIKOLAUS	NO ADDRESS	DOMESTIC	PINELLAS	4	25	54	95	1970-01-01	1979-07-01	13	28	15
315114	G R DOUGLAS	NO ADDRESS	DOMESTIC	PINELLAS	4	13	32	70	1970-01-01	1979-07-01	13	28	15
320450	J O CLARK	NO ADDRESS	DOMESTIC	PINELLAS	4	15	148	175	1970-01-01	1979-07-01	13	28	15
321287	T LEFEBVRE	NO ADDRESS	DOMESTIC	PINELLAS	4	30	31	80	1970-01-01	1979-07-01	13	28	15
329182	R M VARNER	NO ADDRESS	DOMESTIC	PINELLAS	4	32	55	80	1970-01-01	1979-07-01	13	28	15
333183	TODD S	NO ADDRESS	DOMESTIC	PINELLAS	4	16	30	157	1970-01-01	1979-07-01	13	28	15
335639	VANHORN HMS	NO ADDRESS	DOMESTIC	PINELLAS	4	16	32	132	1970-01-01	1979-07-01	13	28	15
348992	JOE GANES	1726 CURLEW RD	DOMESTIC	PINELLAS					1979-11-07		13	28	15
362770	FRANK W. POLASKI	RT 1, BOX 224	DOMESTIC	PINELLAS	4	40	65	100	1981-03-09	1981-03-30	13	28	15
373312	CHARLES JONES	911 MANNING RD	DOMESTIC	PINELLAS	3	36	38	60	1982-03-30	1982-04-23	13	28	15
379138	BUTTS, DAN P.	1075 MANNING RD	DOMESTIC	PINELLAS	4	25	82	140	1983-01-14	1983-01-15	13	28	15
412058	ROCKLEY, GRAM MR	1680 CURLEW RD	DOMESTIC	PINELLAS	4	23	32	120	1986-01-31	1986-02-06	13	28	15
414795	KRALL, STANLEY	1610 CURLEW ROAD	DOMESTIC	PINELLAS	4	26	72	120	1986-04-23	1986-08-10	13	28	15
427278	VCHRIN, PAUL	LOT 16 QUAIL & CARDINAL RD	DOMESTIC	PINELLAS	4	12	76	151	1987-01-26	1987-07-16	13	28	15
434301	DOUGLAS JONES	1622 HERMOSA DR	DOMESTIC	PINELLAS	4	26	57	150	1987-06-26	1987-07-20	13	28	15
434967	ROCKLEY, GRAM MR	1680 CURLEW RD	DOMESTIC	PINELLAS	4		102	140	1987-07-13	1987-07-14	13	28	15
441795	MORRIS, CLAUDE	1650 WINDING CREEK ROAD	DOMESTIC	PINELLAS	4	23	84	160	1987-12-10	1987-12-18	13	28	15
442952	LEWIS, DON	1624 HERMOSA AVE.	DOMESTIC	PINELLAS	4	25	64	150	1988-01-07	1988-01-14	13	28	15
478112	ROCKLEY GRAHAM	3447 US 19 NORTH	DOMESTIC	PINELLAS	4	21	63	100	1989-04-04	1989-04-10	13	28	15
505740	MARK WEINRICH	6210 6TH AVE S	DOMESTIC	PINELLAS	4	13	63	110	1990-10-19	1990-11-16	13	28	15
509002	CARDOZO, WOODY DR.	1324 WINDING GREEK RD.	DOMESTIC	PINELLAS					1991-01-07		13	28	15
524001	ERMENT BRADLEY	869 MORNING ROAD	DOMESTIC	PINELLAS	2	36	46	56	1992-04-22	1992-04-26	13	28	15
526260	ERMENT BRADLEY	869 MORNING ROAD	DOMESTIC	PINELLAS	4	25	46	75	1992-06-22	1992-06-23	13	28	15

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Permit #	Owner	Well Location Street	Well Use	County	Diameter	Static Water Level	Casing Depth	Total Depth	Application Received Date	Well Completion Date	Section	Township	Range
537490	DONALD NIKOLAUS	1501 WINDING CREEK	DOMESTIC	PINELLAS	4	9	63	120	1993-04-27	1993-05-14	13	28	15
544588	CARLTON JONES, MD	795 BALDWIN ROAD	DOMESTIC	PINELLAS	4	36	68	135	1993-10-28	1993-12-23	13	28	15
584658	MARK OSSIAN	1660 QUAIL DR	DOMESTIC	PINELLAS	4	22	63	135	1996-10-21	1996-11-27	13	28	15
636592	CHARLES JONES	911 MANNING RD	DOMESTIC	PINELLAS	4	36	40	70	2000-05-23	2000-05-29	13	28	15
681943	JOHN PORRELLO	940 SPANISH OAKS BLVD.	DOMESTIC	PINELLAS	4	23	80	120	2003-03-11	2003-04-01	13	28	15
689444	BRIAN REESER	1605 CURLEW RD	DOMESTIC	PINELLAS	4	15	63	120	2003-09-05	2003-09-25	13	28	15
305003	KEIL, HENRY	2038 NIGELS DR	DOMESTIC	PINELLAS	3	35	42	110	1970-02-09	1970-02-19	13	28	16
328232	R BEHAR	NO ADDRESS	DOMESTIC	PINELLAS	4	22	44	120	1970-01-01	1979-07-01	13	28	16
339535	JENKINS, R E	NO ADDRESS	DOMESTIC	PINELLAS	4	57	64	120	1970-01-01	1979-07-01	13	28	16
351060	JOHN KOZEK	3150 LAS OLAS DR	DOMESTIC	PINELLAS	4	37	73	116	1980-02-01	1980-02-21	13	28	16
662720	JOSEPH BRADLEY	1580 HERMOSA DR	DOMESTIC	PINELLAS	5		100	160	2001-12-20	2002-03-14	13	28	16
305612	DAVIS, DOUGLAS	559 CHICAGO AVE	DOMESTIC	PINELLAS	4	19	39	104	1970-04-30	1970-05-11	14	28	15
315300	ISHAM	NO ADDRESS	DOMESTIC	PINELLAS	4	8	72	94	1970-01-01	1979-07-01	14	28	15
317730	R MCDONALD	NO ADDRESS	DOMESTIC	PINELLAS	6	40	63	95	1970-01-01	1979-07-01	14	28	15
318434	A JOHNSON	NO ADDRESS	DOMESTIC	PINELLAS	4	13	51	70	1970-01-01	1979-07-01	14	28	15
319031	S M MILLER	NO ADDRESS	DOMESTIC	PINELLAS	4		33	94	1970-01-01	1979-07-01	14	28	15
319540	B BARNES	NO ADDRESS	DOMESTIC	PINELLAS	4		31	86	1970-01-01	1979-07-01	14	28	15
320605	C FEDDELER	NO ADDRESS	DOMESTIC	PINELLAS	4	8	52	90	1970-01-01	1979-07-01	14	28	15
320998	C T SMITH	NO ADDRESS	DOMESTIC	PINELLAS	4		32	94	1970-01-01	1979-07-01	14	28	15
326315	F BAKER JR	NO ADDRESS	DOMESTIC	PINELLAS	4	16	72	89	1970-01-01	1979-07-01	14	28	15
334943	F BAKER JR	NO ADDRESS	DOMESTIC	PINELLAS	4	17	33	75	1970-01-01	1979-07-01	14	28	15
335463	LONGLAND E	10BOGIE DRIVE	DOMESTIC	PINELLAS	4	13	46	90	1970-01-01	1979-07-01	14	28	15
337667	SITTER, W	NO ADDRESS	DOMESTIC	PINELLAS	4	6	63	100	1970-01-01	1979-07-01	14	28	15
338046	ROTHSCHILD	NO ADDRESS	DOMESTIC	PINELLAS	4	15	84	130	1970-01-01	1979-07-01	14	28	15
341558	GRICE, J G	NO ADDRESS	DOMESTIC	PINELLAS					1970-01-01		14	28	15
341955	GEAR, B	NO ADDRESS	DOMESTIC	PINELLAS					1970-01-01		14	28	15
355186	FUHS, MR. & MRS. ED	8 BIRDIE LN	DOMESTIC	PINELLAS	4	19	60	100	1980-06-23	1980-07-07	14	28	15
356574	MATSON, HENRY	825 TOPAY LN	DOMESTIC	PINELLAS					1980-07-28		14	28	15
378676	WOLSTEIN, DAVID G.	17 BIRDIE LANE	DOMESTIC	PINELLAS	4	14	80	140	1982-12-20	1982-12-23	14	28	15
384868	SUCIV, S. N.	19 BIRDIE LANE	DOMESTIC	PINELLAS	4	7	49	100	1983-08-22	1983-09-12	14	28	15
406657	WELLS, RAY	LOT 4 BOGIE LANE	DOMESTIC	PINELLAS	4	12	41	120	1985-07-23	1985-08-21	14	28	15
410304	JOHNSON, HOWARD W	12 EAGLE LANE	DOMESTIC	PINELLAS	4	13	63	125	1985-11-22	1985-11-28	14	28	15
414180	FAMILANT, ELLIOT J	12 BIRDIE LANE	DOMESTIC	PINELLAS	4	18	28	116	1986-04-04	1986-04-08	14	28	15
436394	MCIVER, DON	11 BIRDIE LANE	DOMESTIC	PINELLAS	4	14	55	110	1987-08-12	1987-08-16	14	28	15
524397	JOSEPH GOULD	6 BIRDIE LANE	DOMESTIC	PINELLAS	4	25	48	80	1992-05-04	1992-06-02	14	28	15
527097	FRANCE ARGALL	5 BIRDIE LANE	DOMESTIC	PINELLAS	4	20	25	70	1992-07-08	1992-07-09	14	28	15
537006	DANIEL NAPLES	2957 LARUEL COURT	DOMESTIC	PINELLAS	4		70	140	1993-04-14	1993-04-26	14	28	15
537921	ELEANOR TERRANOVA	3 BIRDIE	DOMESTIC	PINELLAS	4	15	53	85	1993-05-07	1993-09-11	14	28	15
539540	JIM HAMPSEY	30 EAGLE LANE	DOMESTIC	PINELLAS	4	11	58	95	1993-06-16	1993-06-23	14	28	15
541849	DAN NAPLES	1370 HEATHER RIDGE BLVD #202	DOMESTIC	PINELLAS	4	18	56	100	1993-08-13	1993-08-17	14	28	15
557279	KEN HAMMER	3334 CARDINAL DRIVE	DOMESTIC	PINELLAS					1994-09-02		14	28	15
308251	RUBY LAMBER	NO ADDRESS	DOMESTIC	PINELLAS	3	16	71	95	1970-01-01	1979-07-01	14	28	16
311145	W B TAYLOR	NO ADDRESS	DOMESTIC	PINELLAS	4	22	35	100	1970-01-01	1979-07-01	14	28	16
331927	V H HOMES	NO ADDRESS	DOMESTIC	PINELLAS	4	19	75	120	1970-01-01	1979-07-01	14	28	16
439348	B & M CONSTRUCTION	3980 US HWY 19	DOMESTIC	PINELLAS	4		42	75	1987-10-15	1987-10-16	15	28	16
390926	ZIEMBA, STANLEY	1928 HUDSON COURT	DOMESTIC	PINELLAS	4	9	42	100	1984-04-16	1984-04-30	16	28	16
407469	RUTENBERG CORPORATION	5456 SPRING HILL DRIVE	DOMESTIC	PINELLAS	4	8	89	186	1985-08-19	1985-10-15	16	28	16
304931	HOBBY, J R	PINE ST	DOMESTIC	PINELLAS	4	50	60	140	1970-01-29	1970-04-13	18	28	16
305989	ROSS, DR M E	5188 ROLAND PL	DOMESTIC	PINELLAS	3	10	52	100	1970-06-12	1970-06-18	18	28	16
308441	NO NAME - DO NOT MODIFY	NO ADDRESS	DOMESTIC	PINELLAS	4	61	57	103	1970-01-01	1979-07-01	18	28	16
308800	NO NAME - DO NOT MODIFY	NO ADDRESS	DOMESTIC	PINELLAS	4	58	50	123	1970-01-01	1979-07-01	18	28	16
310307	E HUTTO	NO ADDRESS	DOMESTIC	PINELLAS	4	62	157	225	1970-01-01	1979-07-01	18	28	16
311998	E L WALKER	NO ADDRESS	DOMESTIC	PINELLAS	3	60	53	82	1970-01-01	1979-07-01	18	28	16
312893	OTTO C TILL	NO ADDRESS	DOMESTIC	PINELLAS	4	54	105	155	1970-01-01	1979-07-01	18	28	16

Table 4-5 Domestic Wells in The Vicinity of Clearwater Wells

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Permit #	Owner	Well Location Street	Well Use	County	Diameter	Static Water Level	Casing Depth	Total Depth	Application Received Date	Well Completion Date	Section	Township	Range
315816	C HARRINGTO	NO ADDRESS	DOMESTIC	PINELLAS	3	27	53	63	1970-01-01	1979-07-01	18	28	16
317227	H VAUGHN	NO ADDRESS	DOMESTIC	PINELLAS	4	61	73	100	1970-01-01	1979-07-01	18	28	16
317288	W DILLARD	NO ADDRESS	DOMESTIC	PINELLAS	4		58	117	1970-01-01	1979-07-01	18	28	16
320405	D L RHODES	NO ADDRESS	DOMESTIC	PINELLAS					1970-01-01		18	28	16
322278	W FRIERSON	NO ADDRESS	DOMESTIC	PINELLAS	4	58	74	125	1970-01-01	1979-07-01	18	28	16
334699	ROOSEVELT, G	NO ADDRESS	DOMESTIC	PINELLAS	4	54	84	127	1970-01-01	1979-07-01	18	28	16
350169	RICHARD DAVIS	12945 SEMINOLE BLVD	DOMESTIC	PINELLAS	4	53	81	110	1979-12-31	1980-01-04	18	28	16
356612	MARION, MRS.	16 EAGLE LANE	DOMESTIC	PINELLAS	4	10	89	95	1980-07-30	1980-10-10	18	28	16
410969	COYLE, PAMELA	6890 CO RD 95	DOMESTIC	PINELLAS	4	48	84	160	1985-12-18	1986-01-08	18	28	16
528561	NOEL MCCORMICK	1920 SHEFFIELD CT.	DOMESTIC	PINELLAS	4		85	140	1992-08-10	1992-09-17	18	28	16
530484	MARGARET D ENDRES	3411 C.R. 70	DOMESTIC	PINELLAS	4		90	140	1992-10-02	1992-10-06	18	28	16
310364	B MC LAIN	NO ADDRESS	DOMESTIC	PINELLAS	4	56	80	128	1970-01-01	1979-07-01	19	28	16
319541	F GASPELIN	NO ADDRESS	DOMESTIC	PINELLAS	3		89	106	1970-01-01	1979-07-01	19	28	16
322032	J LOCKE	NO ADDRESS	DOMESTIC	PINELLAS	4	47	60	150	1970-01-01	1979-07-01	19	28	16
327276	HERB PEEL	NO ADDRESS	DOMESTIC	PINELLAS	4	46	85	140	1970-01-01	1979-07-01	19	28	16
337943	VOUGHT, E J	NO ADDRESS	DOMESTIC	PINELLAS	4	53	56	93	1970-01-01	1979-07-01	19	28	16
345937	BUTTS, WILLIS	NO ADDRESS	DOMESTIC	PINELLAS	4	62	76	166	1979-07-06	1979-07-20	19	28	16
357328	SMITH, BARLOWE	17 PINWOOD AVE	DOMESTIC	PINELLAS	4	48	84	150	1980-08-21	1980-09-02	19	28	16
312158	DAVIS, C	NO ADDRESS	DOMESTIC	PINELLAS	4		120	150	1970-01-01	1979-07-01	20	28	16
390547	STELZER, RICHARD W	2265 MCMULLEN BOOTH ROAD	DOMESTIC	PINELLAS	4	45	69	120	1984-04-02	1984-04-23	20	28	16
352973	BOLHM, RODGER V.	RT 1 BOX 105	DOMESTIC	PINELLAS	4		40	103	1980-04-10	1980-05-01	21	28	16
363451	EUFEMA, CHARLES	COUNTY ROAD 193 BOX 376	DOMESTIC	PINELLAS	4	30	67	85	1981-03-31	1981-04-02	21	28	16
377853	GEIGER, R.	3281 LANDMARK BLVD	DOMESTIC	PINELLAS	4	35	56	143	1982-11-05	1982-11-19	21	28	16
313328	GLEN THOMPS	NO ADDRESS	DOMESTIC	PINELLAS					1970-01-01		23	28	15
319772	E OWENS	NO ADDRESS	DOMESTIC	PINELLAS	4		85	94	1970-01-01	1979-07-01	23	28	15
321366	T PARNELL	NO ADDRESS	DOMESTIC	PINELLAS	4	14	38	70	1970-01-01	1979-07-01	23	28	15
324278	S COMPTON	NO ADDRESS	DOMESTIC	PINELLAS	4	17	43	82	1970-01-01	1979-07-01	23	28	15
326102	H KEMINSKI	NO ADDRESS	DOMESTIC	PINELLAS	4		76	128	1970-01-01	1979-07-01	23	28	15
582803	REVERAND NICK PANICO	1924 DUNLOE CR	DOMESTIC	PINELLAS	4		64	110	1996-08-22	1996-09-24	23	28	15
705498	SEA BREEZE CONST. SER	3230 Brady Dr. Dunedin Fl.	DOMESTIC	PINELLAS	4	32	58	145	2004-08-09	2004-08-18	23	28	15
331184	Y RIDDLE	NO ADDRESS	DOMESTIC	PINELLAS	3	5	30	50	1970-01-01	1979-07-01	23	28	16
331430	P EVANS	NO ADDRESS	DOMESTIC	PINELLAS	3	5	32	50	1970-01-01	1979-07-01	23	28	16
388489	ROUSH, LOUISE H	1510 INDIANA	DOMESTIC	PINELLAS	2	37	42	80	1984-01-16	1983-09-15	23	28	16
528741	SCOTT MORRIS	3805 SHORE BLVD	DOMESTIC	PINELLAS	2	4	42	52	1992-08-17	1992-08-20	23	28	16
309287	B DUNLAP	NO ADDRESS	DOMESTIC	PINELLAS	5	48	75	115	1970-01-01	1979-07-01	24	28	15
309298	NO NAME - DO NOT MODIFY	NO ADDRESS	DOMESTIC	PINELLAS	4	37	64	120	1970-01-01	1979-07-01	24	28	15
309994	NO NAME - DO NOT MODIFY	NO ADDRESS	DOMESTIC	PINELLAS	4		144	170	1970-01-01	1979-07-01	24	28	15
310968	J SEIFERT	NO ADDRESS	DOMESTIC	PINELLAS	3	57	63	85	1970-01-01	1979-07-01	24	28	15
312240	J D WALLER	NO ADDRESS	DOMESTIC	PINELLAS	4	51	62	113	1970-01-01	1979-07-01	24	28	15
312726	B B MCNEELY	NO ADDRESS	DOMESTIC	PINELLAS	3	22	75	155	1970-01-01	1979-07-01	24	28	15
313655	R ISHAM	NO ADDRESS	DOMESTIC	PINELLAS	4	25	95	120	1970-01-01	1979-07-01	24	28	15
319959	J NORTON	NO ADDRESS	DOMESTIC	PINELLAS	4	34	58	125	1970-01-01	1979-07-01	24	28	15
322315	W S SHARPE	NO ADDRESS	DOMESTIC	PINELLAS	4	47	63	160	1970-01-01	1979-07-01	24	28	15
325940	EARL JONES	NO ADDRESS	DOMESTIC	PINELLAS	4	43	107	143	1970-01-01	1979-07-01	24	28	15
335770	NIGHTENGALE	NO ADDRESS	DOMESTIC	PINELLAS	4	26	38	80	1970-01-01	1979-07-01	24	28	15
335944	W H CLARK	NO ADDRESS	DOMESTIC	PINELLAS	4	26	44	120	1970-01-01	1979-07-01	24	28	15
336113	BRANNEN J P	NO ADDRESS	DOMESTIC	PINELLAS	3		37	60	1970-01-01	1979-07-01	24	28	15
339132	NIGEIS, L	NO ADDRESS	DOMESTIC	PINELLAS	4	18	64	87	1970-01-01	1979-07-01	24	28	15
342792	RICHARD GINGRASS	OFF COUNTRY RD	DOMESTIC	PINELLAS	4	50	70	100	1970-01-01	1979-04-11	24	28	15
356429	BECKER, ROBERT	2840 N SUMMERDALE	DOMESTIC	PINELLAS	4	63	122	260	1980-07-22	1980-07-24	24	28	15
391292	ROWAN, PETER	3171 SHARPE LN	DOMESTIC	PINELLAS	4	42	63	145	1984-04-26	1984-04-30	24	28	15
392612	SCOGGINS, BEVERLY	2001 BRADY ROAD	DOMESTIC	PINELLAS	4	36	67	136	1984-06-05	1984-06-10	24	28	15
393732	GARRISON, OPAL	3233 GARRISON ROAD	DOMESTIC	PINELLAS	4	52	63	135	1984-07-09	1984-08-02	24	28	15
394576	MCCARTY, HAROLD	3155 GARRISON ROAD	DOMESTIC	PINELLAS	4	38	114	165	1984-08-03	1985-03-18	24	28	15
409402	DEHAGEN, DON	1886 SHARPE LA	DOMESTIC	PINELLAS	4	56	80	185	1985-10-25	1985-11-18	24	28	15

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Permit #	Owner	Well Location Street	Well Use	County	Diameter	Static Water Level	Casing Depth	Total Depth	Application Received Date	Well Completion Date	Section	Township	Range
411032	MEADOWS, RICHARD	1700 COUNTY ROAD	DOMESTIC	PINELLAS	4	40	63	120	1985-12-20	1985-12-26	24	28	15
414921	PICK KWIK FOOD STORES	PO BOX 6288	DOMESTIC	PINELLAS	2	5	1	11	1986-04-25	1986-05-08	24	28	15
430456	WAGNER, MARVIN	3189 GARRISON ROAD	DOMESTIC	PINELLAS	4	54	84	180	1987-04-06	1987-04-12	24	28	15
474762	G.C.R BUILDERS INC	1860 SHARP LANE	DOMESTIC	PINELLAS	4	51	63	145	1989-01-24	1989-01-27	24	28	15
504241	PAT ANNEL	8193 GARRISON RD	DOMESTIC	PINELLAS					1990-09-17		24	28	15
522744	ALLAN ROSENBAUM INC.	1570 MICHIGAN BLVD.	DOMESTIC	PINELLAS	4	52	84	185	1992-03-16	1992-04-09	24	28	15
550372	STEVEN W NEWPORT	1860 SHARPE LANE	DOMESTIC	PINELLAS	4	48	84	185	1994-04-04	1994-04-20	24	28	15
566765	BOWITA ROBIN TOW	3187 GARRISON RD	DOMESTIC	PINELLAS	4	44	84	175	1995-05-01	1995-05-06	24	28	15
582085	WAYNE NIGHTINGALE	2025 BRADY DRIVE	DOMESTIC	PINELLAS	4	21	62	120	1996-07-30	1996-08-20	24	28	15
668516	JOYCE GRAY	3244 CR 1	DOMESTIC	PINELLAS	4	58	65	100	2002-05-01	2002-06-10	24	28	15
740215	LOU WELK	3235 COUNTY RD 1	DOMESTIC	PINELLAS	4	58	105	210	2006-05-10	2006-06-02	24	28	15
311101	H SIMMONS	1930 SADDLEHILL ROAD	DOMESTIC	PINELLAS	4	42	66	130	1970-01-01	1979-07-01	24	28	16
326339	JASON RIDISILL	2251 PADDOCK CIRCLE	DOMESTIC	PINELLAS	4	42	63	158	1970-01-01	1979-07-01	24	28	16
328023	RUTENBERG/VAN HORN CORP.	COUNTY RD.1 & CURLEW RD.	DOMESTIC	PINELLAS	4	25	50	100	1970-01-01	1979-07-01	24	28	16
328024	VAN HORN CO	NO ADDRESS	DOMESTIC	PINELLAS	4	23	32	100	1970-01-01	1979-07-01	24	28	16
386173	CLEMES, RICHARD	2300 BARCELONA DR	DOMESTIC	PINELLAS	4	36	94	136	1983-10-14	1983-10-19	24	28	16
323115	REYNOLDS ME	NO ADDRESS	DOMESTIC	PINELLAS	6	63	80	146	1970-01-01	1979-07-01	25	28	15
331431	W HEITHAUS	NO ADDRESS	DOMESTIC	PINELLAS	4	42	60	82	1970-01-01	1979-07-01	25	28	15
339733	J D WARD JR	NO ADDRESS	DOMESTIC	PINELLAS	4	41	63	140	1970-01-01	1979-07-01	25	28	15
357035	BRYANT, ROY	3806 BEECHWOOD BLVD	DOMESTIC	PINELLAS	4	45	83	200	1978-10-19	1978-11-02	25	28	15
502182	OWENS, HAROLD	1519 INDIANA ST	DOMESTIC	PINELLAS	4	38	60	125	1990-07-26	1990-08-20	25	28	15
311103	R DUFFY	NO ADDRESS	DOMESTIC	PINELLAS	4	27	46	120	1970-01-01	1979-07-01	25	28	16
417672	SOFARELLI, PETER	3501 FAIRVIEW STREET	DOMESTIC	PINELLAS	4	25	63	155	1986-07-01	1986-10-21	25	28	16
322101	E DICKSON	NO ADDRESS	DOMESTIC	PINELLAS	4	24	42	79	1970-01-01	1979-07-01	26	28	15
324377	J H HARRIS	NO ADDRESS	DOMESTIC	PINELLAS	3	46	61	88	1970-01-01	1979-07-01	26	28	15
349383	RICHARD A. PEA	650 OLD COACHMAN RD	DOMESTIC	PINELLAS	3	38	43	78	1979-11-26	1979-12-10	26	28	15
408567	MCKUNNE, CURTIS	1680 UNION STREET	DOMESTIC	PINELLAS	4	24	46	100	1985-09-27	1985-10-01	26	28	15
433673	ROUSH, LOUISE H	1510 INDIANA	DOMESTIC	PINELLAS	4	38	47	120	1987-06-17	1987-06-25	26	28	15
436751	HOWELL, JERRY	855 LAKE HAVEN DR	DOMESTIC	PINELLAS	4			140	1987-08-19	1987-08-20	26	28	15
523337	JAMES NOFFZ	90 HIGHLAND AVENUE	DOMESTIC	PINELLAS	4	23	82	180	1992-04-01	1992-04-06	26	28	15
579497	LORENA H WEATHERS	1322 GEORGIA AVE	DOMESTIC	PINELLAS	4	36	138	203	1996-05-15	1996-07-10	26	28	15
316759	S HUMPHRIES	NO ADDRESS	DOMESTIC	PINELLAS	4	30	62	100	1970-01-01	1979-07-01	27	28	16
316948	J FISHER	NO ADDRESS	DOMESTIC	PINELLAS	3	27	54	73	1970-01-01	1979-07-01	27	28	16
327676	J FORSLUND	NO ADDRESS	DOMESTIC	PINELLAS	4	33	220	230	1970-01-01	1979-07-01	27	28	16
335235	RUTENBURG H	NO ADDRESS	DOMESTIC	PINELLAS	4	24	80	180	1970-01-01	1979-07-01	27	28	16
335360	GRASS B	NO ADDRESS	DOMESTIC	PINELLAS	4	31	63	120	1970-01-01	1979-07-01	27	28	16
335796	DAVIS, C	NO ADDRESS	DOMESTIC	PINELLAS	4	24	63	66	1970-01-01	1979-07-01	27	28	16
337021	TINSLEY L	NO ADDRESS	DOMESTIC	PINELLAS	4	13	72	90	1970-01-01	1979-07-01	27	28	16
337691	C LOHMEYER	NO ADDRESS	DOMESTIC	PINELLAS	4	26	83	130	1970-01-01	1979-07-01	27	28	16
338129	FIESS, R	NO ADDRESS	DOMESTIC	PINELLAS	4	26	75	130	1970-01-01	1979-07-01	27	28	16
340719	NAEDEL, MARK	3696 CR 102	DOMESTIC	PINELLAS					1979-01-03		27	28	16
341184	BLACKBURN, W	NO ADDRESS	DOMESTIC	PINELLAS	2		40	60	1970-01-01	1979-07-01	27	28	16
346912	MR. ZIEB	ROUTE 2, BOX 590	DOMESTIC	PINELLAS					1979-08-13		27	28	16
358728	CLAYTON DAVIS	3445 SR 580	DOMESTIC	PINELLAS	4	30	42	62	1980-10-10	1981-02-03	27	28	16
381097	MERLIN SR., MICHAEL J.	102 COUNTY RD	DOMESTIC	PINELLAS	4	23	54	100	1983-04-11	1983-06-15	27	28	16
384153	LAWRENCE, SALLY	3678 CO RD 102	DOMESTIC	PINELLAS	4	23	42	100	1983-07-22	1983-07-27	27	28	16
384865	FISHER, DAVID G.	2421 NAVAREZ	DOMESTIC	PINELLAS	4	28	63	100	1983-08-22	1983-08-24	27	28	16
389334	FARRAR, HARLAND	3536 CO RD 102	DOMESTIC	PINELLAS	4	40	84	116	1984-02-20	1984-02-22	27	28	16
389799	DAMPIER, FRED C	3455 BUTLER ST	DOMESTIC	PINELLAS	4	12	100	132	1984-03-07	1984-03-20	27	28	16
414794	PATTON, MAX	3600 CO RD 102	DOMESTIC	PINELLAS	4	34	71	120	1986-04-23	1986-04-29	27	28	16
434904	STINSON, EDWARD	3301 MEANDER LANE	DOMESTIC	PINELLAS	4	12	100	140	1987-07-10	1987-07-17	27	28	16
435694	DILLEY, RUSSELL	2870 PHILIP PARK WAY	DOMESTIC	PINELLAS	4	12	41	80	1987-07-28	1987-07-30	27	28	16
491055	DOMAGTDIU, MANUEL	5 MAR BAY LN.	DOMESTIC	PINELLAS	4	4	42	62	1989-12-27	1990-01-01	27	28	16
560465	WATERFORD HOMES & DESIGN	2255 PHILLIPPE PKWY, SAFETY HAR	DOMESTIC	PINELLAS	4	12	42	55	1994-11-21	1994-12-01	27	28	16
582806	CLAYTON & PAULINE DAVIS	3445 ST RD 580	DOMESTIC	PINELLAS	4	22	50	60	1996-08-22	1997-01-22	27	28	16

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309402	D A SALLS	NO ADDRESS	DOMESTIC	PINELLAS	4	32	72	160	1970-01-01	1979-07-01	28	28	16
310994	H R NOREAK	NO ADDRESS	DOMESTIC	PINELLAS	3	4	45	65	1970-01-01	1979-07-01	28	28	16
320760	CA HEIDMAN	NO ADDRESS	DOMESTIC	PINELLAS	3	50	73	75	1970-01-01	1979-07-01	28	28	16
327050	F DENBY	NO ADDRESS	DOMESTIC	PINELLAS	4	42	50	118	1970-01-01	1979-07-01	28	28	16
329482	CONG CONST	NO ADDRESS	DOMESTIC	PINELLAS	4	25	50	105	1970-01-01	1979-07-01	28	28	16
332743	G A NELSON	NO ADDRESS	DOMESTIC	PINELLAS	4	33	65	100	1970-01-01	1979-07-01	28	28	16
336112	MONTE LA	NO ADDRESS	DOMESTIC	PINELLAS	4		51	130	1970-01-01	1979-07-01	28	28	16
338384	ZINSSER, L D	NO ADDRESS	DOMESTIC	PINELLAS	4	24	63	90	1970-01-01	1979-07-01	28	28	16
342127	SNOW, M	NO ADDRESS	DOMESTIC	PINELLAS	4	13	30	35	1970-01-01	1979-07-01	28	28	16
354891	ESPIRITU SANTO RECTORY	CR# 102 PHILIPPE PKWY	DOMESTIC	PINELLAS	4	31	40	110	1980-06-11	1980-10-31	28	28	16
354892	ESPIRITU SANTO RECTORY	CR# 102 PHILIPPE PKWY	DOMESTIC	PINELLAS	4	31	48	110	1980-06-11	1980-10-31	28	28	16
374313	KOUBA, KEN	3287 MALLARD DR	DOMESTIC	PINELLAS	4	45	63	120	1982-05-10	1982-05-12	28	28	16
397119	HARGETT, DAVID JAMES	3290 CR 102	DOMESTIC	PINELLAS	4	50	84	170	1984-10-05	1984-10-18	28	28	16
406471	WETHINGTON, DON	3246 CO RD 102	DOMESTIC	PINELLAS	4	30	70	160	1985-07-16	1985-08-17	28	28	16
407002	JANOCHA, JAMES	3626-CR 102	DOMESTIC	PINELLAS					1985-08-02		28	28	16
435399	EATON, GEORGE	21 SEEDLING DR	DOMESTIC	PINELLAS	4	22	98	160	1987-07-22	1987-07-27	28	28	16
523408	NOHL CREST HOMES	4023 TAMPA RD STE 2800	DOMESTIC	PINELLAS	4	32	110	180	1992-04-03	1992-04-13	28	28	16
567484	JOE CRONIN	3005 HARGETT DR	DOMESTIC	PINELLAS	4	32	90	120	1995-05-16	1995-05-19	28	28	16
629330	RICK COLE	3228 ENTERPRISE ROAD EAST	DOMESTIC	PINELLAS	5	35	82	160	1999-12-20	1999-12-23	28	28	16
314750	J FLETCHER	NO ADDRESS	DOMESTIC	PINELLAS	3	5	42	80	1970-01-01	1979-07-01	29	28	16
325263	W H MURRAY	NO ADDRESS	DOMESTIC	PINELLAS	4		105	150	1970-01-01	1979-07-01	29	28	16
334418	GREENSTREET	NO ADDRESS	DOMESTIC	PINELLAS	4	35	63	120	1970-01-01	1979-07-01	29	28	16
341587	WILCOX, D E	NO ADDRESS	DOMESTIC	PINELLAS					1970-01-01		29	28	16
366494	OSBORNE, MR.	34 SUMMIT LANE	DOMESTIC	PINELLAS	4	34	63	75	1981-06-16	1981-06-16	29	28	16
383223	HOLDINGS INC., VICTORIA	2480 LANDMARK DR	DOMESTIC	PINELLAS	4	62	135	180	1983-06-17	1983-07-21	29	28	16
328456	J THOMPSON	NO ADDRESS	DOMESTIC	PINELLAS	3	15	31	50	1970-01-01	1979-07-01	30	28	16
341559	SLENKAMP, G	NO ADDRESS	DOMESTIC	PINELLAS					1970-01-01		30	28	16
391271	LAMB, MICHAEL	2871 N SUMMERDALE DR	DOMESTIC	PINELLAS	4	77	105	165	1984-04-25	1984-04-27	30	28	16
646549	CORNERSTONE TREE FARM	3046 DOMINION COURT	DOMESTIC	PINELLAS	4	42	89	180	2001-01-05	2001-01-08	31	28	16
311929	L IRION	NO ADDRESS	DOMESTIC	PINELLAS	4		108	230	1970-01-01	1979-07-01	32	28	16
316061	D WILLIAMSO	NO ADDRESS	DOMESTIC	PINELLAS	3	29	64	81	1970-01-01	1979-07-01	32	28	16
319201	J ANDERSON	NO ADDRESS	DOMESTIC	PINELLAS	4	82	105	143	1970-01-01	1979-07-01	32	28	16
321330	D H INION	NO ADDRESS	DOMESTIC	PINELLAS	4		126	158	1970-01-01	1979-07-01	32	28	16
323964	RUDY ASBELL	NO ADDRESS	DOMESTIC	PINELLAS	4	51	82	125	1970-01-01	1979-07-01	32	28	16
334566	CATER K INC	NO ADDRESS	DOMESTIC	PINELLAS	4	80	148	220	1970-01-01	1979-07-01	32	28	16
355836	MCCONIHAY, STEVE	PO BOX 5328	DOMESTIC	PINELLAS					1978-08-28		32	28	16
381944	ROTH, CHARLES	6446 EAST NEFF CT	DOMESTIC	PINELLAS	4	68	180	192	1983-05-10	1983-05-17	32	28	16
595206	WILLIAM TREGILLUS	3040 JONES LANE	DOMESTIC	PINELLAS	4	32	63	90	1997-07-21	1997-08-10	32	28	16
312894	W DRAEGER J	NO ADDRESS	DOMESTIC	PINELLAS	4	35	42	60	1970-01-01	1979-07-01	33	28	16
313835	R W STELZER	NO ADDRESS	DOMESTIC	PINELLAS	4	43	91	140	1970-01-01	1979-07-01	33	28	16
324054	W THOMPSON	NO ADDRESS	DOMESTIC	PINELLAS	3	10	49	80	1970-01-01	1979-07-01	33	28	16
326103	B WILLIS	NO ADDRESS	DOMESTIC	PINELLAS	3		32	42	1970-01-01	1979-07-01	33	28	16
326588	J W MORTON	NO ADDRESS	DOMESTIC	PINELLAS	4	28	41	102	1970-01-01	1979-07-01	33	28	16
326934	W THOMPSON	NO ADDRESS	DOMESTIC	PINELLAS	3	10	128	157	1970-01-01	1979-07-01	33	28	16
333978	RICKETT D	NO ADDRESS	DOMESTIC	PINELLAS	4	28	42	100	1970-01-01	1979-07-01	33	28	16
339571	RYAN CONSTRUCTION	PO BOX 1119	DOMESTIC	PINELLAS	4	5	177	190	1970-01-01	1979-07-01	33	28	16
339572	RYAN	2223 WESTCHESTER DR	DOMESTIC	PINELLAS	4	5	163	211	1970-01-01	1979-07-01	33	28	16
405714	HARRIS, JIM	1751 CHIEFWICK DRIVE	DOMESTIC	PINELLAS	4		70	120	1985-06-20	1985-06-23	33	28	16
513914	MASUI LANG	2205 MCMULLEN BOOTH RD	DOMESTIC	PINELLAS	4	33	125	200	1991-05-28	1991-06-04	33	28	16
626432	LEE HUFFMAN	6762 MILLSTONE DR	DOMESTIC	PINELLAS	4	10	70	140	1999-10-05	1999-12-07	33	28	16
311954	D PRICHARD	NO ADDRESS	DOMESTIC	PINELLAS	3	12	63	110	1970-01-01	1979-07-01	34	28	16
321322	FRANK HENDL	NO ADDRESS	DOMESTIC	PINELLAS	4	5	57	140	1970-01-01	1979-07-01	34	28	16
321323	E HENDLEY	NO ADDRESS	DOMESTIC	PINELLAS	4	5	58	140	1970-01-01	1979-07-01	34	28	16
321324	H N HENDLEY	NO ADDRESS	DOMESTIC	PINELLAS	4	5	42	140	1970-01-01	1979-07-01	34	28	16
329127	W ETHERIDGE	NO ADDRESS	DOMESTIC	PINELLAS	4	5	32	45	1970-01-01	1979-07-01	34	28	16

Table 4-5 Domestic Wells in The Vicinity of Clearwater Wells

CITY OF CLEARWATER GROUNDWATER REPLENISHMENT FEASIBILITY STUDY

Permit #	Owner	Well Location Street	Well Use	County	Diameter	Static Water Level	Casing Depth	Total Depth	Application Received Date	Well Completion Date	Section	Township	Range
335706	G GUSTAFSON	NO ADDRESS	DOMESTIC	PINELLAS	3	9	48	111	1970-01-01	1979-07-01	34	28	16
337495	MCMURRAY,S	NO ADDRESS	DOMESTIC	PINELLAS	4		105	138	1970-01-01	1979-07-01	34	28	16
345393	HENDLEY, FRANK	2185 BOW LANE	DOMESTIC	PINELLAS	3	10	54	141	1970-01-01	1979-10-31	34	28	16
345394	HENDLEY, FRANK	2185 BOW LANE	DOMESTIC	PINELLAS	3	12	51	151	1970-01-01	1979-10-31	34	28	16
396730	FINCH, KERMITT	3545 C R 102	DOMESTIC	PINELLAS	4	35	54	120	1984-09-20	1984-10-10	34	28	16
523304	LAURICE JENNINGS	2245 BOW LANE	DOMESTIC	PINELLAS					1992-03-31		34	28	16
333580	TOOKE J	NO ADDRESS	DOMESTIC	PINELLAS	4	32	50	80	1970-01-01	1979-07-01	35	28	15
356354	MILGROM, SY	124 CEDARWOOD	DOMESTIC	PINELLAS	4	21	74	130	1980-07-18	1980-08-31	35	28	15
582912	ALVAREZ HOMES	825 BUTTON WOOD LANE	DOMESTIC	PINELLAS	4		63	162	1996-08-26	1996-09-18	35	28	15
335798	SPEED D	NO ADDRESS	DOMESTIC	PINELLAS	4	7	42	50	1970-01-01	1979-07-01	35	28	16
338690	SOFARELLI,P	NO ADDRESS	DOMESTIC	PINELLAS	4	38	63	101	1970-01-01	1979-07-01	35	28	16
667149	CATENAC GULFWYND INC	1024 LYNDBURST DR	DOMESTIC	PINELLAS	4	36	80	135	2002-04-05	2002-04-17	35	28	16
305484	DOUGLAS, STANLEY R	GENERAL DELIVERY	DOMESTIC	PINELLAS	4	38	53	120	1970-04-14	1970-04-30	36	28	15
334220	SMITH,G	NO ADDRESS	DOMESTIC	PINELLAS	3	16	32	65	1970-01-01	1979-07-01	36	28	15
389679	MCKUNNE, CURTIS	1680 UNION STREET	DOMESTIC	PINELLAS	4	32	56	100	1984-03-02	1984-03-08	36	28	15
398667	WHITEHEAD, CHARLES	2103 CUNNIHAM	DOMESTIC	PINELLAS	4	52	58	125	1984-12-03	1985-01-20	36	28	15
498850	KENT, D.E.	1949 FISH HATCHERY CT	DOMESTIC	PINELLAS	2		42	58	1990-05-18	1990-05-21	36	28	15
311555	D MCCRANEY	NO ADDRESS	DOMESTIC	PINELLAS	4	28	52	110	1970-01-01	1979-07-01	36	28	16

Figure 4-17 shows the locations of private domestic wells located within a two-mile radius of the project area. Table 4-5 lists these wells. The map shows the number of domestic wells by section. The wells are shown by section because the SWFWMD data base does not provide the actual location of each well. Figure 4-17 shows that there are 5 domestic wells located in the two sections that occupy the proposed recharge wells. There are an additional 25 domestic wells in two sections adjacent to the south of the proposed recharge wells.

Based on this well inventory, there are no potable supply wells in lower Zone A within the six-month particle track zones of layer 4, and no potable supply wells in upper zone A within the six-month travel time zone of layer 3.

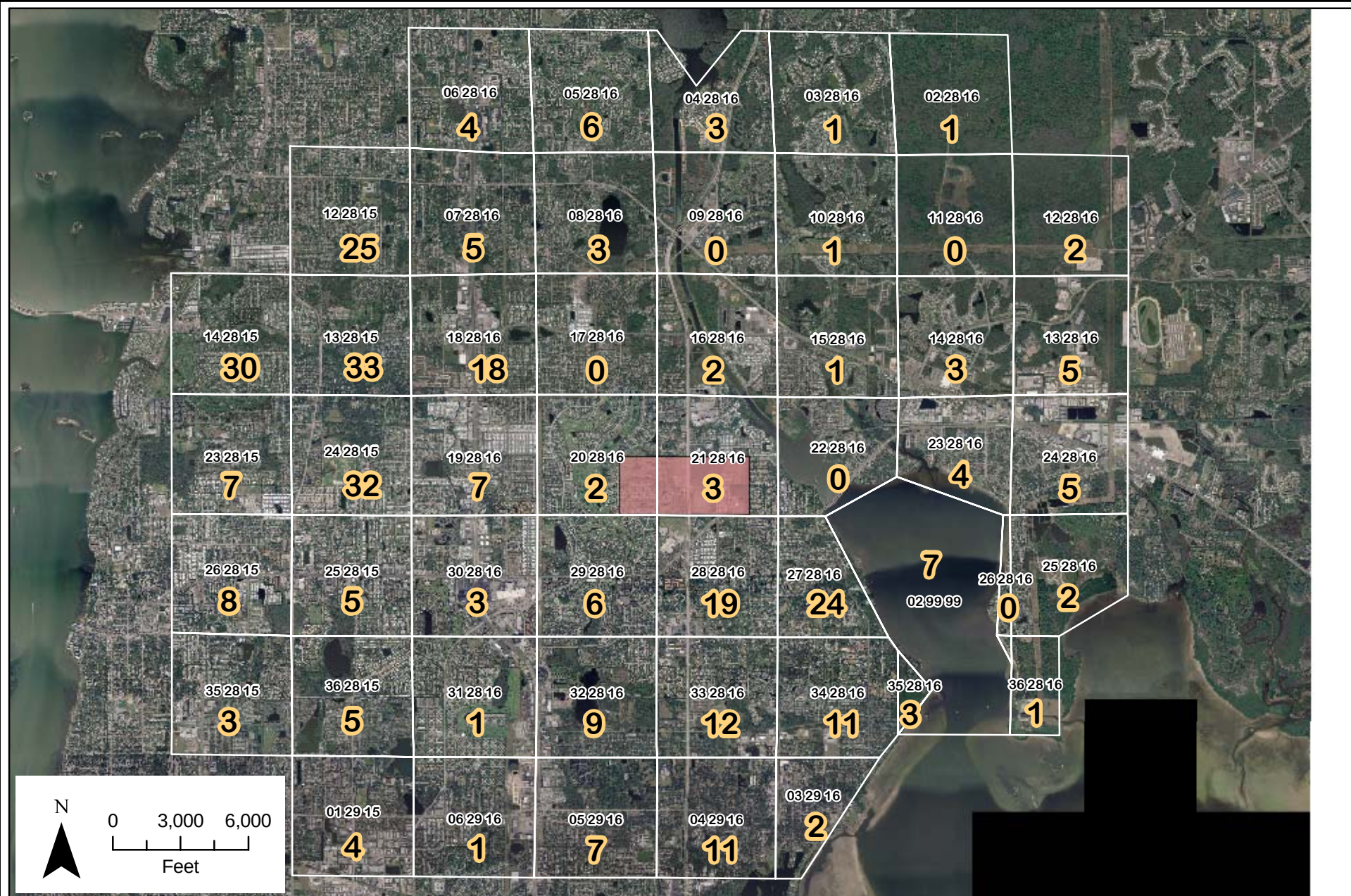
4.4 GEOCHEMICAL ANALYSIS

This section of the report presents the results of an exploratory geochemical investigation of groundwater in the vicinity of the project area (Figure 4-18) located in northeast Clearwater by LBG with assistance from Southwest Groundwater Consulting. The investigation included an assessment of potential recharge waters and blend waters. The objectives of the geochemical investigation were the following:

1. Describe and characterize the major-ion composition of recharge waters, potential blend waters, and groundwater.
2. Describe and characterize reduction-oxidation (redox) states.
3. Determine whether treatment with sodium bisulfide (NaHS) is an effective means of creating sufficiently reducing conditions in different recharge waters and combinations of recharge and blend waters to minimize the potential for the dissolution of arsenic-bearing sulfides.
4. Model the results of mixing different recharge waters with potential blend waters and groundwater.
5. Develop recommendations for additional work (if any) needed to address unanswered questions related to this investigation.

4.4.1 The Problem of Arsenic in Floridan Groundwater

The potential for the mobilization of arsenic at ASR sites in Florida is a matter of great concern to regulators and to water management districts. Since there are no operational recharge well systems in Florida, studies performed on ASR well systems provide data that are beneficial in assessing the potential for the mobilization of arsenic for this project. ASR Systems (ASRS) conducted a survey of arsenic in 52 ASR wells and 41 monitor wells (ASRS, 2007) from 12 ASR sites for the Southwest Florida Water Management District (SWFWMD). Table 4-6 lists the well fields, along with the number of ASR wells and monitor wells at each site.



DATE	REVISED

☐ Acad
☒ GIS
☐ Corel

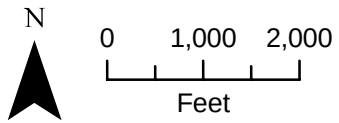
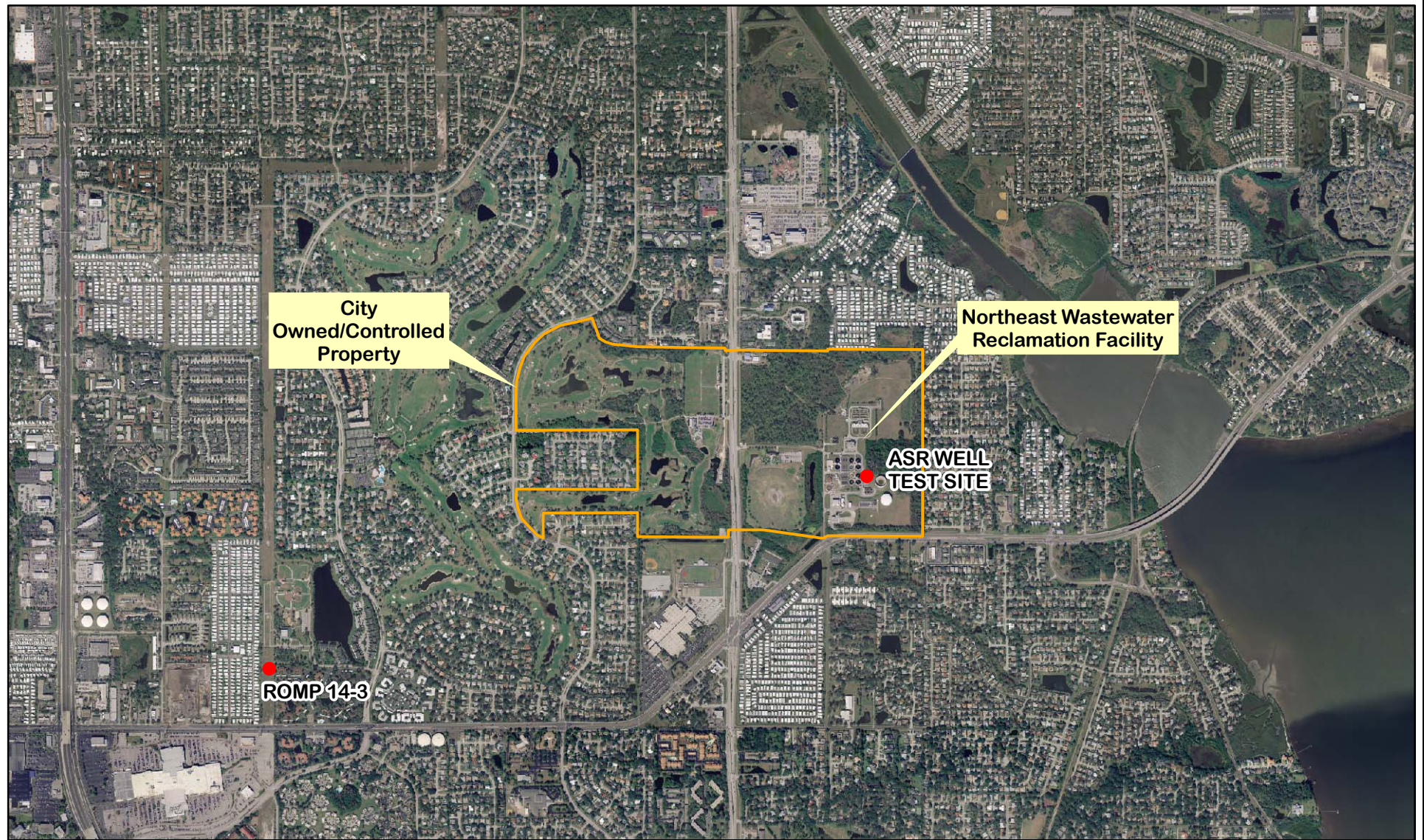
FILE NAME: FIGURE4-17.MXD

CITY OF CLEARWATER
 GROUNDWATER REPLENISHMENT FEASIBILITY STUDY

 DOMESTIC WELL INVENTORY

PREPARED BY:
LEGGETTE, BRASHEARS & GRAHAM, INC.
 Professional Ground-Water and Environmental Engineering Services
 Cypress Point Office Park
 10014 North Dale Mabry Highway, Suite 205
 Tampa, Florida 33618
 (813) 968-5882

DRAWN BY: TDH
 CHECKED BY: DAW
 DATE: Apr. 2011
 FIGURE NO.: 4-17



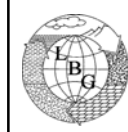
DATE	REVISED
FILE NAME: FIGURE4-18.MXD	

☐ Acad
☒ GIS
☐ Corel

CITY OF CLEARWATER
 GROUNDWATER REPLENISHMENT FEASIBILITY STUDY

 PROJECT AREA

PREPARED BY:



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 (813) 968-5882

DRAWN BY:	TDH
CHECKED BY:	DAW
DATE:	Apr. 2011
FIGURE NO.:	4-18

Table 4-6 ASR Well Fields in SW Florida Evaluated by ASRS (2007)			
Well Field		Number of ASR Wells	Number of Storage Zone Monitor Wells
1	City of Bradenton	1	1
2	City of Tampa	8	5
3	PRMRWSA Old Well Field	9	20
4	PRMRWSA New Well Field	12	
5	Manatee County	6	2
6	Englewood Water District	1	1
7	City of Punta Gorda	4	3
8	City of Northport	1	1
9	Lee County Olga Facility	1	2
10	Lee County North Reservoir	1	1
11	Collier County Marco Lakes	3	2
12	Collier County Corkscrew Well Field	5	3
Total		52	41

ASRS (2007) noted the following with regard to the occurrence of arsenic in the wells:

- ASR wells:** Most wells showed low initial As (arsenic) concentrations during recovery, increasing steadily during recovery, reaching a peak concentration and then declining until the end of recovery. For a few ASR wells the peak occurred at the beginning of recovery and then declined. For other wells the concentration continued to climb until the end of recovery.
- Monitor wells:** Distances from the ASR wells to the monitor wells ranged from 90 to 450 feet and most were at about 150 feet. In almost every case the arsenic concentration reported at the monitor well during recharge and storage was below 10 micrograms per liter ($\mu\text{g/l}$), usually showing no change even though it was clear from other water-quality data that the stored water extended past the monitor well. Where elevated arsenic concentrations occurred at the monitor well they tended to occur during recovery, particularly toward the end of extended recovery when the more brackish water in the buffer zone was pulled in past the monitor well.
 Monitor wells at distances greater than 200 feet from the ASR well showed no elevation of arsenic concentrations. Where elevated arsenic concentrations occurred in the monitor wells, they attenuated rapidly with successive operating cycles, typically reaching acceptable levels in approximately three cycles with approximately equal volumes stored in each cycle.

Examples of arsenic concentrations in recovered water at some Florida ASR sites are listed below:

1. Arthur and others (2001) documented the occurrence of high levels of naturally occurring arsenic during cycle tests at two ASR sites (Rome Avenue, Hillsborough County, and Punta Gorda, Charlotte County) in the SWFWMD. The concentrations of arsenic at the sites were as much as 10 times the EPA drinking water standard (10 µg/L).
2. Mirecki and others (2005) noted the occurrence of arsenic concentrations as much as 40 µg/L during cycle tests at several Lee County ASR systems.
3. At the Bradenton (Manatee County) ASR site, arsenic increased from background levels (<2.8 µg/L) during the first phase of recovery cycles to peak concentrations of 15 to 23 µg/L during the second half of cycle testing (ASRS, 2007).

4.4.2 Sources of Arsenic

Arthur and others (2001 and 2002) proposed three sources of naturally occurring arsenic in Suwannee Limestone groundwater:

1. Arsenious sulfide minerals (e.g., pyrite – FeS₂) disseminated within the aquifer matrix.
2. Arsenic sorbed to iron and manganese oxyhydroxide coatings on limestone grains.
3. Arsenic in organic material in the limestone matrix.

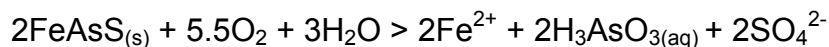
Price and Pichler (2002, and poster found at the following address: dep.state.fl.us/geology/geologictopics/asr4/posters/Price.pdf) studied cores from 22 southwest Florida wells to gain a better understanding of the distribution of arsenic and the mineralogy within the Suwannee Limestone. They concluded that visual and microscopic inspection of the cores revealed that all of the above-suggested sources of arsenic are present in trace amounts. They also found the following:

1. Framboidal pyrite, the most abundant sulfide, was unevenly distributed, occurring most often with secondary calcite in moldic porosity zones.
2. The concentration of arsenic in framboidal pyrite is greater than 1,000 parts per million (ppm), but the concentration varies from crystal to crystal.
3. Other trace minerals contain arsenic in much lower concentrations, compared to framboidal pyrite.
4. Nodular phosphate, quartz, clay, and organics were also present in trace amounts, but iron hydroxides were rarely found.

Price and Pichler concluded that framboidal pyrite is a primary source of arsenic. According to Price and Pichler, the treatment of recharge water with ozone (O₃) prior to injection causes the water to become highly oxidized relative to the low-oxygen conditions of Suwannee Limestone groundwater. The change in redox conditions within

the aquifer leads to the release of high concentrations of arsenic through the dissolution of framboidal pyrite.

An example of the oxidation of an arsenious iron sulfide (arsenopyrite, FeAsS) is:



In the above equation, the reaction of oxygen with arsenopyrite drives the oxidation of Arsenic as As(III) [arsenite] to As(V) [arsenate]. Under reducing conditions, As(III), arsenic exists as part of a stable solid (arsenopyrite). After oxidation, arsenate [As(V)] occurs in aqueous form and arsenic is available for transport by advective and dispersive processes.

4.4.3 Mobilizing Processes and Triggering Factors

ASR Systems (2007) summarized processes that lead to the mobilization of arsenic and factors that trigger mobilization as shown in the following Table 4-7:

Table 4-7 Arsenic Mobilization and Triggering Factors	
Mobilizing Processes	Triggering Factors
Oxidation of pyrite (FeS ₂) and Arsenopyrite (FeAsS)	High redox potential; high temperature; microbial activity
Dissolution of arsenic-sulfides	Changes in pH; increased presence of carbonates
Desorption due to reduction of iron hydroxides	Decreased redox potential; microbial activity
Desorption due to changes in mineral surface chemistry	Increased pH
Competitive adsorption	Competition by PO ₄ ³⁻ , HCO ₃ ⁻ , H ₄ SiO ₄ , DOC, SO ₄ ²⁻

4.4.4 Water Groups

Waters considered in this study were divided into three groups: recharge waters (RW), blend waters (BW), and groundwater (GW). There were five RW samples (RW-1 through RW-5), two blend waters (BW-1 and BW-2), and one source of groundwater (GW). Among the recharge waters, only RW-4 and RW-5 were considered in the final part of this investigation. Each group is described in the following sections of this report.

4.4.4.1 Recharge Water

Tetra Tech submitted five analyses of potential recharge waters (Table A-1 in Appendix A). The five recharge waters were differentiated as follows:

1. RW-1: Aeration and no chemical stabilization.
2. RW-2: Aeration and pH adjustment with NaOH.
3. RW-3: Aeration and pH adjustment with Ca(OH)₂.
4. RW-4: No aeration and pH adjustment with Ca(OH)₂.
5. RW-5: No aeration and pH adjustment with CO₂ and Ca(OH)₂.

4.4.4.2 Groundwater

Four groundwater samples were collected by LBG on September 23, 2010 from the ASR test well located at the NEWRF in Clearwater, Florida (Figure 4-17). The depth of the well is 275 feet bls. The well has a 12-inch diameter casing to a depth of 208 feet bls, and the static water level was 52.2 feet bls. A 1-horsepower submersible pump was lowered to a depth of 136 feet bls, and water was discharged through a 5/8-inch diameter garden hose 100 feet to the south of the well.

The well was purged at a discharge rate of 180 gallons per minute (gpm) for three hours before the pumping rate was reduced to 20 gpm. A Y-valve was then used to divert water to a flow cell, where the flow rate was reduced to 1 gpm. The well water at the flow cell was monitored with a Oakton # 109779 pH/Conductivity meter for pH, temperature, conductivity, dissolved oxygen, turbidity and ORP at 5 minute intervals for 1 hour prior to sample collection for laboratory analyses. Ferrous iron (mg/l) levels were also recorded at 1-minute interval with a (HACH DR 890 colorimeter).

A 0.45 micron in line filter was used to collect water samples for laboratory analysis after one hour (NEASR-1). This procedure was followed for a second hour prior to sample collection of the second sample (NEASR-2). A duplicate water sample was collected at this time (NEASR-4). The same sample procedure was followed for a third hour for the final water sample (NEASR-3). All samples were placed on ice and taken to Southern Analytical Laboratories of Oldsmar, FL.

Field notes and groundwater sampling logs (Form FD 9000-24) are found in Appendix A. The results of the laboratory analyses are listed in Table A-1 in Appendix A.

4.4.4.3 Blend Water

The water produced by the proposed purification system to treat the reclaimed water will include the use of reverse osmosis which will effectively remove most of the inorganic constituents from the reclaimed water. Chemicals will be added to adjust the alkalinity, pH and calcium concentration in the recharge water, but the water will still be deficient in many inorganic constituents such as sulfate, iron, potassium, sodium, chloride, etc. Therefore, the concept of replacing some of these constituents by blending of the purified reclaimed water with natural

groundwater that is more highly mineralized to replace some of the inorganic constituents removed by the purification process was modeled to determine its effect.

Water quality for the groundwater to be used for blending was obtained from historical data available from two wells in the vicinity that were higher in total dissolved solids and could serve as potential sources to supply water for blending with the purified reclaimed water. Information about the construction of the first well was obtained from the U.S. Geological Survey National Water Information System data base. The well is named CLE-DUN Deep Well 17 near Dunedin FL and has USGS number 280254082441602 and is shown as USGS Deep Well 17 on Figure 4-3. The well is constructed to a depth of 339 feet below mean sea level which is into the lower portion of the Suwannee formation and is located approximated 1 mile to the northwest of the project area at the intersection of U.S. Highway 19 and Curlew Road. The water-quality data for this well was obtained from the SWFWMD Water Management Information System (WMIS) from analysis of a sample that was collected on April 3, 1997.

The second well was the SWFWMD ROMP well TR 14-2 that was constructed into the Ocala formation with an open hole interval between 386 and 406 feet below mean sea level which is in lower permeable Zone B. The well is located approximately two miles due west of the proposed recharge area in Dunedin north of State Road 580 and east of County Road 1 and is shown as well number ROMP TR 14-2 on Figure 4-3. The water quality for this well was obtained from the SWFWMD WMIS from analysis of a sample that was collected on April 3, 1997. The samples were not analyzed for nitrates, fluoride and dissolved oxygen and therefore, reasonable values were assumed for the concentration of these constituents based upon data from other wells sampled at similar depth for which information was available. The compositions of the blend waters are found in Table A-1 in Appendix A.

4.4.5 Modeling Methods

All geochemical modeling for this study was performed with Geochemist's Workbench[®] (GWB) and PHREEQC. Developed at the Department of Geology of the University of Illinois at Urbana-Champaign, GWB is a set of software tools for manipulating chemical reactions, calculating stability diagrams and the equilibrium states of natural waters, tracing reaction processes, modeling reactive transport, plotting the results of calculations, and storing the related data (Bethke and Yeakel, 2010). The GWB Essentials Package, Release 8.0, consists of six programs (Bethke and Yeakel, 2010):

- **GSS** stores analyte and sample data in a spreadsheet specially developed to work with the GWB set of software tools.
- **Rxn** automatically balances chemical reactions, calculates equilibrium constants and equations, and solves for the temperatures at which reactions are in equilibrium.

- **Act2** calculates and plots stability diagrams on activity and fugacity axes. It can also project the traces of reaction paths calculated using the React program (GWB Standard, Release 8.0).
- **Tact** calculates and plots temperature-activity and temperature-fugacity diagrams and projects the trace of reaction paths.
- **SpecE8** calculates species distributions in aqueous solutions and computes mineral saturations and gas fugacities. SpecE8 can account for sorption of species onto mineral surfaces according to a variety of methods, including surface complexation and ion exchange.
- **Gtplot** graphs SpecE8 results and GSS datasets as xy plots, ternary, Piper, Durov, and Stiff diagrams.

PHREEQC is designed to perform a wide variety of aqueous geochemical calculations. The program has capabilities for (1) speciation and saturation-index calculations, (2) reaction-path and advective-transport calculations involving specified irreversible reactions, mixing of solutions, mineral and gas equilibria surface-complexation reactions, and (3) inverse modeling, which finds sets of mineral and gas mole transfers that account for composition differences between waters, within specified compositional uncertainties (Parkhurst, 1995; and Parkhurst and Appelo, 1999).

Durov and Schoeller (Schoeller, 1935; Hem, 1985; Bethke and Yaekel, 2010) geochemical diagrams were constructed with the plotting options in Gtplot of GWB. The software packages were used to calculate electrical charge balances, key saturation indices, indices of reduction-oxidation potential (Eh and pe), and compositions of different blends of water. Durov diagrams and Schoeller diagrams are used in this report to illustrate geochemical composition and the results of mixing different waters.

All laboratory reports for samples of groundwater are in Appendix A, and the concentrations of major and minor dissolved solids and field measurements (pH, ORP [oxidation-reduction potential], dissolved oxygen, electrical conductivity) of all waters are listed in Table A-1 (Appendix A). Table A-2 (Appendix A) is a summary of basic geochemical properties of the five recharge waters (RW-1 – RW-5), the last groundwater sample (NEASR-3), and the two blend waters (BW-1 and BW-2).

4.4.6 Geochemical Classification Waters

Durov and Schoeller diagrams (Figure 1, Appendix A) are graphical representations of geochemical composition. The diagrams are described in the following paragraphs:

A Durov diagram (Figure 1 in Appendix A, left) is based on the percentage of major-ions in units of milliequivalents per liter (meq/L) or milliequivalents per kilogram (meq/kg). The cation and anion values are plotted on two separate trilinear fields and the data points are projected on to a square grid at the base of each triangle. Each point within the square field is projected into the TDS field to the right and into the pH field below the square. This format conveys information

about the overall composition of a sample or of many samples, along with information about TDS and pH. The addition of the TDS and pH fields allows for more effective comparison of samples and geochemical differentiation than is possible with a Piper (Piper, 1944) diagram.

A Schoeller diagram (Figure 1 in Appendix A, right) is a semi-logarithmic plot that represents the different ions are listed along the horizontal axis. The major anions (SO_4 , HCO_3 , and Cl) are usually listed along the left half of the horizontal axis, and the major cations (Mg , Ca , and $\text{Na}+\text{K}$) are on the right half of the axis. Lines connecting the meq values for the anions and cations create “fingerprint” patterns that demonstrate different hydro chemical types on one figure.

Durov and Schoeller diagrams divide recharge waters, blend waters, and groundwater into three geochemical groups:

Durov diagram (Figure 1, Appendix A): The RW wells are clustered at TDS concentrations less than 100 mg/L. The geochemical signatures of these waters range from $\text{Ca}:\text{HCO}_3$ (RW-3, RW-4 and RW-5) to $\text{Na}:\text{Cl}$ (RW-1). Intermediate to the above classifications is one sample with a $\text{Na}:\text{HCO}_3$ signature (RW-2).

The composition of groundwater (GW) is $\text{Na}:\text{Cl}$, and the TDS is 800 mg/L. The two blend waters (BW-1 and BW-2) are also $\text{Na}:\text{Cl}$, but the TDS concentrations of these waters range from 1245 mg/L (BW-1) to 2,428 mg/L (BW-2).

Schoeller Diagram (Figure 1, Appendix A): The RW samples plot in the lower half of the figure. The fingerprint patterns of these samples show peaks for Ca and HCO_3 (RW-3, RW-4 and RW-5), one with peaks for Na and HCO_3 (RW-2), and one with peaks for Na and Cl (RW-1). The fingerprint patterns of the GW and BW samples are in the upper half of the diagram. The fingerprints all show peaks for Na and Cl (GW, BW-1 and BW-2).

The difference in geochemical signatures between the RW samples and the GW sample raises at least one point of concern. Injecting water with a geochemical composition different from that of local groundwater could lead to adverse rock-water reactions (dissolution of the aquifer matrix or other minerals). In order to minimize the potential for adverse reactions, Tetra Tech recommended blending the recharge water with another water of composition similar to that of local groundwater. That option is examined in a later section of this report.

4.4.7 Arsenic

Analyses of arsenic in the four samples of groundwater submitted to Southern Analytical Labs by LBG were all less than the method detection limit of 0.001 mg/L (1.0 $\mu\text{g/L}$), based on the analytical method SM 3113 B (Table A-1, Appendix A). Tetra Tech did not report arsenic as a detectable constituent in any of the five potential recharge waters or in the two samples of blend water.

One of two inferences can be drawn from the low concentrations of arsenic reported for the groundwater analyses:

1. Arsenic is not available; that is, all of the sources of arsenic described above are not present in the vicinity of the water well; or
2. Arsenic is present in a stable form such as arsenopyrite (FeAsS). If this is the case, redox conditions are probably sufficiently reducing to prevent the mobilization of arsenic by oxidative dissolution of arsenious sulfide minerals.

It will be necessary to resolve the matter of arsenic availability in groundwater. This will be more directly addressed by the acquisition of cores and/or cuttings from new wells, as core/cuttings data will yield the information needed to conduct a thorough assessment of the aquifer matrix, the occurrence of potential sources of arsenic, mobilization mechanisms, and factors that might trigger mobilization. The well from which groundwater samples were collected by LBG should continue to be sampled. Specific recommendations regarding the collection of additional water samples are addressed at the end of this section of the report.

4.4.8 Reduction-Oxidation (Redox) States

Because the occurrence of arsenic in groundwater systems can be traced to factors that affect reduction-oxidation (redox) states, a primary focus of the groundwater sampling program was to collect data that would support a preliminary assessment of groundwater redox conditions. This required consistent and reliable data on pH, ferric iron and total iron, dissolved oxygen, pH, and oxidation-reduction potential (ORP).

The field measurements of ferrous iron (Fe^{2+}) were larger than Southern Analytical Laboratories reported concentrations of total iron (Fe_T) (Table A-1, Appendix A). The maximum concentration detected by the HACH[®] DR 890 colorimeter was 0.09 mg/L. The laboratory did not detect Fe_T at concentrations greater than 0.02 mg/L, the limit of detection for the method (EPA 200.7). The discrepancy between Fe^{2+} and Fe_T negated the use of the $\text{Fe}^{3+}/\text{Fe}^{2+}$ pair as a means of calculating the groundwater redox state.

Tetra Tech did not report iron as a dissolved constituent of the five potential recharge waters; and ferrous iron concentrations reported for the blend waters were 0.271 mg/L (BW-1) and 0.053 (BW-2). Total iron was not reported.

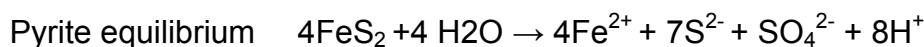
Dissolved oxygen (DO) measurements in groundwater ranged from a minimum of 0.30 mg/L to a maximum of 1.32 mg/L. These DO measurements appear relatively high for local groundwater. Tetra Tech estimated DO concentrations in the five recharge waters of less than 0.1 mg/L. For all subsequent modeling, a concentration of 0.001 mg/L was assumed. Tetra Tech also assumed that DO for each of the blend waters was 0.1 mg/L.

The measurement of groundwater ORP was -307.1 millivolts (mV), a direct indicator of reducing conditions. This was consistent with ambient ORP measurements cited by ASRS (2007) for ASR sites in Florida. SWG adjusted OPR to pe by adding +199 mV (adjustment for electrode and Ag/AgCl reference solution) to the ORP measurement and then multiplying by 16.9 (Pankow, 1991). The measurement of pe is an indication of the reducing or oxidizing potential of an aqueous solution. If pe is negative, the solution is reducing. If pe is positive, the solution is oxidizing. All pe estimates for potential recharge waters and blend waters were based on the assumed DO measurements given by Tetra Tech. Calculations of pe were made using the "Spec8" option of GWB. Even at the low DO estimates assumed for the recharge and blend waters, pe values were strongly positive (Table A-2, Appendix A).

The DO measurements recorded during sample collection yield pe estimates greater than +11 (values greater than zero indicate potentially oxidizing conditions). This would be equivalent to ORP measurements of +450 mV or greater. The sharply higher pe values for the lowest DO measurement indicate that the system is highly sensitive to oxygen. Hence, it will be necessary to maintain reducing conditions (negative pe) in the vicinity of the wellbore.

4.4.9 Titrations with NaHS

One of the objectives of the geochemical study was to evaluate the effectiveness of titrating recharge waters and/or mixtures of recharge waters and blend waters with a reducing agent such as sodium bisulfide (NaHS). ENTRIX (undated and unpublished memorandum on the use of NaHS as an alternative methodology to control the leaching of arsenic during aquifer storage and recovery operations), for example, has proposed a process designed to remove oxidants and to drive the reaction below toward the left (precipitation of pyrite):



The following reactions are key factors either in generating or maintaining reducing conditions:

- | | |
|---|---|
| 1. Sulfide oxidation half-cell reaction | $\text{HS}^- + 4\text{H}_2\text{O} \rightarrow \text{SO}_4^{2-} + 9\text{H}^+ + 8\text{e}^-$ |
| 2. Pyrite reduction half-cell reaction | $\text{FeS}_2 + 2\text{H}^+ + 2\text{e}^- \rightarrow \text{Fe}^{2+} + 2\text{HS}^-$ |
| 3. Reduction of oxygen by sulfide | $2\text{O}_2 + \text{HS}^- \rightarrow \text{SO}_4^{2-} + \text{H}^+$ |
| 4. Reduction of chlorine by sulfide | $4\text{ClO}^- + \text{HS}^- \rightarrow \text{SO}_4^{2-} + 4\text{Cl}^- + \text{H}^+$ |
| 5. Reduction of nitrate by sulfide | $\text{NO}_3^- + \text{H}_2\text{O} + \text{HS}^- \rightarrow \text{SO}_4^{2-} + \text{NH}_3$ |

Reactions 1 and 2 above are the primary half-cell reactions: 1) the reaction of sulfide with water to form sulfate and reduce pH and 2) the dissolution of pyrite in a low-pH environment. In reactions 3 through 5, sulfide (HS^-) acts as a reducing agent for oxygen and two oxyanions.

In the above-mentioned memorandum, ENTRIX notes the following (ENTRIX-a):

“The addition of NaHS to potable water prior to injection has been accepted by the FDEP. The NaHS chemical formula used in the pretreatment process has received NSF certification for use in public drinking water systems.”

Records were also located of NSF-60 certifications of the use of NaHS in “subsurface aquifers used as drinking water sources” in Louisiana:

nsf.org/Certified/PwsChemicals/Listings.asp?ChemicalName=Sodium+Hydrosulfide&

A test was set up following ENTRIX’s proposed method by using PHREEQC to calculate the effects on pe of titrating mixtures of selected recharge waters and blend waters and unblended recharge waters with NaHS. As an additional step in the modeling procedure, the pe calculated for a 50:50 mixture of water titrated with NaHS and local groundwater was looked at. After discussing the matter with Tetra Tech, RW-4 and RW-5 were focused on exclusively as the preferred recharge waters.

In addition to seeking an evaluation of the effectiveness of treatment with NaHS, Tetra Tech requested an estimate of the smallest mass of NaHS needed to generate/maintain reducing conditions. Both matters were addressed by specifying titration with 1×10^{-4} to 6×10^{-4} moles of NaHS per kg of water in five reaction steps – that is, an increment of 1×10^{-4} moles per step. The process in PHREEQC requires use of the REACTION keyword, and cumulative moles of reactant to be added in successive steps of a reaction series.

4.4.10 Results of Simulations

Simulations were set up (one step per simulation), including titrations with NaHS of the following blends:

1. RW-4 and BW-1,
2. RW-5 and BW-1,
3. RW-4 and BW-2,
4. RW-5 and BW-2

Blends with BW-1 were in increments of 5 percent BW, from:

- 95 percent RW/5percent BW to 75 percent RW/25percent BW.

Blends with BW-2 were specified in increments of 5 percent BW, from:

- 95 percent RW/5percent BW to 85 percent RW/15 percent BW.

Tables A-3 through A-10 in Appendix A show the results of the titrations on RW:BW blends and 50:50 mixtures with groundwater on pH and pe. The percent distribution of RW to BW is listed in the first column and the initial pH or pe in the second. The

modeled pH and pe values for different moles of NaHS are listed in columns three through eight. Corresponding values at a 50:50 mix with groundwater are listed in parentheses. The modeled pH and pe values are shown up to the first positive pe between 1×10^{-4} and 1×10^{-6} moles NaHS.

The minimum mass of NaHS required to maintain reducing conditions in RW:BW mixtures is 3×10^{-4} moles/kg (~16.8 mg/L NaHS) at a 95:05 (19-to-1) ratio of any RW:BW blend. The mass of NaHS increases as the RW:BW ratio decreases. The maximum amount of NaHS is 5×10^{-4} mols/kg (~28.02 mg/L) at 80:20 (5-to-1) and 75:25 (4-to-1) ratios. This assumes that the pe values of recharge and blend waters are strongly positive (Table A-2, Appendix A). Lower pe values of RW and BW waters will lower the mass of NaHS needed to maintain reducing conditions in the aquifer. For unblended recharge waters (RW-4 and RW-5), the smallest mass of NaHS required to produce negative pe is 2×10^{-4} mol/kg (11.2 mg/L) (Tables A-11 and A-12, Appendix A).

In an undated and unpublished PowerPoint presentation (ENTIRX-b) developed for the St. John's Water Management District and the City of DeLand, ENTRIX notes that ORP responds immediately to the addition of sulfides, dropping to very negative values indicative of sulfides and reducing conditions. In the same presentation, ENTRIX reported that a dosage of 4 ppm NaHS was highly effective in limiting the concentration of arsenic to 0.8 ppb in a 5-MG (million-gallon) cycle test at the DeLand ASR site.

It will be necessary to collect more accurate data on the redox states of local groundwater, recharge waters and blend waters before proceeding with a more aggressive approach to quantitative geochemical modeling. Because this is an exploratory-level investigation, there are too many possible combinations of pH and pe, along with other unknowns, to justify a more extensive modeling program at this time.

4.4.11 Results of Blending on Major Ion Chemistry

The results of blending waters of different compositions are illustrated by Figures 1 through 12, Appendix A. Each figure consists of a Durov diagram (left) and a Schoeller diagram (right). The figures trace the cumulative effects of combining end member waters in percentages of 25, 50, and 75 percent. The comparisons are between GW and mixtures of RW-4, RW-5 and BW-1; and GW and RW-4, BW-5, and BW-2. The mixtures follow the simple binary mixing pattern described by Faure (1991). Calculations of mixtures of conservative solutes (e.g., Na, K, Ca, Cl, Mg, HCO_3) were made directly by GWB. The overall signature of the mixtures is that of a Na:Cl water. That is a function of the Na:Cl dominance of the two blend waters and local ground water, both of which are Na:Cl in composition.

4.4.12 Conclusions and Recommendations

Five recharge waters (RW-1 through RW-5) proposed by Tetra Tech were considered in this analysis. The composition of the recharge waters ranged from Na:Cl (RW-1) to Na: HCO_3 (RW-2) to Ca: HCO_3 (RW-3, RW-4, and RW-5). The final analysis focused

on RW-4 and RW-5. The TDS of all recharge waters were less than 100 mg/L, and the highest TDS concentrations were from RW-4 and RW-5. The composition of local groundwater is Na:Cl, and TDS is 800 mg/L. Two potential blend waters (BW-1 and BW-2) were also considered. Both are Na:Cl, and TDS ranges from 1245 mg/L (BW-1) to 2428 mg/L, BW-2.

Local groundwater is anoxic, as indicated by field ORP measurements as low as -307.1 mV. The pe calculated from the last ORP measurement is -1.83. The negative ORPs measured for local groundwater are within the range of ambient ORP measurements reported for ASR sites in Florida. The values of pe based on reported or assumed DO concentrations in recharge waters and blend waters are all positive at DO concentrations 0.10 mg/L or less. The much higher pe values indicate a high degree of sensitivity recharge and blend waters to very small concentrations of DO. Because of that apparent sensitivity, anoxic conditions (reducing conditions) should be maintained in the vicinity of the wellbore.

Mixtures of recharge waters and blend waters appear to be very sensitive to additions of a reducing agent such as sodium bisulfide (NaHS). Simulated dosages of NaHS produce negative pe values at concentrations as low as 3×10^{-4} mol/kg (16.8 mg/L). The concentration decreases to 2×10^{-4} mol/kg (11.2 mg/L) if unblended recharge waters are treated with NaHS. It is highly probable that the pe values calculated for recharge waters and blend waters are much higher than is the actual case. Smaller dosages of NaHS should produce and maintain negative ORP measurements if pe values are much lower than those shown in Table A-2, Appendix A. More accurate measurements of ORP will be required for recharge waters and blend waters.

With regard to pH, it will be important to ensure that water is neither highly alkaline nor acidic, as arsenic can be mobilized at high or low pH values. The optimal pH range should be between 7 and 8. If recharge water is treated with calcium hydroxide ($\text{Ca}(\text{OH})_2$), pH can be controlled by the addition of hydrochloric acid or sulfuric acid, or by injection of carbon dioxide (CO_2).

With respect to the DeLand project, ENTRIX notes that “results of field tests indicate that the injection of the sulfide compound will normally raise the pH of the source water slightly, to approximately 8 to 8.5. Consequently, it likely will be desirable to lower the pH back to the normal level of 7 by injecting an acid. Suitable acids include hydrochloric acid and dilute sulfuric acid. Another option to lower the pH is CO_2 injection, which works by creating carboxylic acid”.

Reaction simulations run for this study did not show a tendency for pH to increase significantly when recharge waters or mixtures of recharge waters and blend waters are treated with sodium bisulfide. The most favorable pH values appear to be from RW-5 or any mixture of RW-5 and BW-1 or BW-2, as all calculated pH values were less than 8. The pH of RW-4 is 8.38.

The effect of pH must be considered in conjunction with redox conditions. ORP should be negative, preferably -200 mV or lower. Anything much higher than -200 mV is likely to indicate oxidizing or potentially oxidizing conditions once adjustments are made to calculate Eh and/or pe.

The reaction simulations (PHREEQC) do not indicate sharp increases with respect to pH when recharge waters or mixtures of recharge and blend waters are treated with sodium bisulfide. As noted above, the optimal pH range appears to be between 7 and 8. The negligible drift of pH with additions of sodium bisulfide ranging from 2×10^{-4} to 6×10^{-4} mol/kg indicate that the recharge waters and recharge/blend water mixes are sufficiently buffered to prevent pH from responding quickly to additions of strong acids or bases. Although ENTRIX noted for the De Land project that pH should increase to between 8 and 8.5 with the addition of a compound such as sodium bisulfide, we cannot offer further comment without more information regarding the major-ion chemistry of the treated water proposed for use at the De Land ASR site.

It is recommended that there be more detailed monitoring of pH in recharge waters and proposed blend waters. It will be especially important to determine, through repeated bench-scale tests, how pH responds to dosing with sodium bisulfide, compared to the results calculated by PHREEQI. The simulated results, thus far, indicate little reason to be concerned about changes in pH that might promote mineral dissolution and mobilization of arsenic.

It is clear that a lower pe (that is lower ORP) for the project water(s) would require a lower dose of sodium bisulfide. The problem at this time, however, is that the likely range of ORP for proposed recharge waters and blend waters is not known and a number of assumptions are necessary for this analysis. Based on the very high pe values calculated from the assumed DO concentrations, a range of 9.4×10^{-6} mols of total sulfide, or about 1.6 mg/L NaHS have been calculated, which is about 1/7 the minimum dose. This presupposes negative ORP values, probably in the range of -300 mV or lower, which would be equivalent to Eh of approx -0.100 V or a pe of approx -1.7; In other words, something akin to the measured ORP and calculated Eh/pe of local groundwater. Suffice it to say, the FDEP regulations will require that any recharge water not have an ORP that, when adjusted, will indicate oxidizing or potentially oxidizing conditions.

It will be very important to collect lithologic data (cores and cuttings) from future wells; as such data will support more detailed pictures of the aquifer matrix, potential sources of arsenic disseminated within the matrix, and along with the likely range of processes and trigger mechanisms that could lead to the mobilization of arsenic.

It is also recommended continued sampling in the area, especially from wells with documented arsenic concentration greater than the 10 µg/L MCL mandated by the USEPA.

It will be necessary to collect more accurate data on the redox states of local groundwater, recharge waters and blend waters before proceeding with a more aggressive approach to quantitative geochemical modeling.

Based on this geochemical analysis from available data and the proposed treatment processes for the water to be recharged, there is minimal probability for the mobilization of arsenic in the groundwater system. Site specific data collection and testing is necessary to develop the necessary data to further verify that the aquifer can be recharged with purified water and not cause unacceptable mobilization.

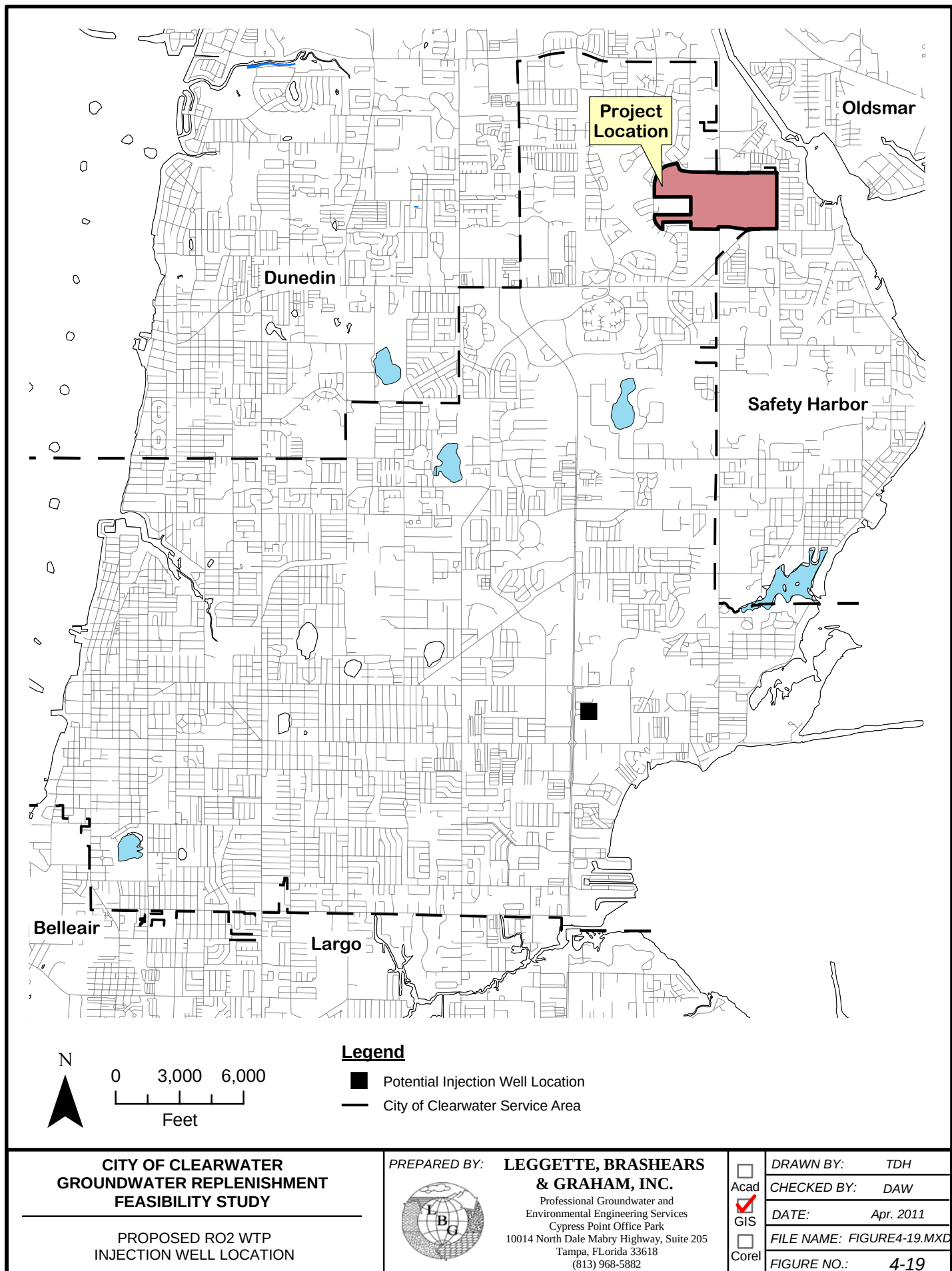
4.5 INJECTION OF CONCENTRATE

Additional treatment, including reverse osmosis (RO) treatment of the reclaimed water at the City's NEWRF prior to aquifer recharge is proposed to meet the water quality requirements for direct recharge. As a result of the additional treatment, there will be some amount of reject water or concentrate generated that will need to be disposed of properly. One of the concentrate disposal options for reject water from this additional treatment is deep well injection. The expected concentrate or reject quantity is approximately 530,000 gallons per day (gpd). Typically, the injection well systems in Pinellas County have utilized Zone C in the Avon Park Formation as the injection zone. The City of Oldsmar has recently obtained a permit to construct an injection well for disposal of RO concentrate from a brackish groundwater treatment plant utilizing Zone C as the injection zone.

The City is currently evaluating construction of a Class I injection well for disposal of concentrate from the existing RO Water Treatment Plant No. 1 and the planned RO Water Treatment Plant No. 2. This injection well will potentially be located at the site of planned RO Plant No. 2, or the East WWRF (Figure 4-19). If deep well injection is selected as the option for disposal of concentrate from the NEWRF RO treatment process, the injection well planned for the City's two RO Water Treatment Plants could be utilized for disposal of this relatively small amount of reject water. Mixing the concentrate from the NEWRF with the concentrate from the brackish groundwater RO Water Treatment Plant Nos. 1 and 2 will be beneficial because the low salinity of concentrate from the NEWRF will tend to migrate upward under buoyancy drive if injected alone, whereas mixing it with concentrate from RO 2 will alleviate the upward migration issue. Also, by sending the concentrate from the NEWRF to the injection well associated with the RO Water Treatment Plants, the City will avoid a complex and lengthy permitting process for a dedicated concentrate disposal injection well for this groundwater replenishment project.

4.6 PERMITTING

Permitting is a key activity for this groundwater replenishment project. Two state regulatory agencies will be involved with issuing permits; the Florida Department of professional Regulation (FDEP) and the Southwest Florida Water management District



(SWFWMD). A report prepared for the SWFWMD in March 2009 by MWH titled *"Feasibility of Using Reclaimed Water for Aquifer Recharge"* identified several FDEP regulations that will need to be addressed for a reclaimed water aquifer recharge project, including the following that apply to this project:

- 62-40 FAC – Water Resource Implementation Rule
- 62-520 FAC – Groundwater Classes, Standards, and Exemptions
- 62-521 FAC – Wellhead Protection Rule
- 62-522 FAC – Groundwater Permitting and Monitoring Requirements
- 62-528 FAC – Underground Injection Control
- 62-532 FAC – Water Well Permitting and Construction Requirements
- 62-550 FAC – Drinking Water Standard, Monitoring, and Reporting
- 62-555 FAC – Permitting, Construction, Operation and Maintenance of a Public Water System
- 62-610 FAC – Reuse of Reclaimed Water and Land Application
- 62-620 FAC – Wastewater Facility and Activities Permitting

The primary regulatory issues that will need to be addressed for this project are water quality of the treated reclaimed water and water quality of the receiving groundwater aquifer. The water to be used for direct recharge must meet all Florida Primary and Secondary drinking water standards. The FDEP has indicated that if the groundwater quality of the receiving aquifer is greater than 500 mg/L in total dissolved solids (TDS) then only a one year pilot test would be required. As discussed earlier in Section 4.2, lower Zone A is the target aquifer for the recharge water. Data from the exploratory ASR well at the City's NEWRF indicates that the TDS concentration in lower Zone A is approximately 800 to 900 mg/L. Based on this water-quality data, lower Zone A in the targeted aquifer replenishment project area is favorable for meeting FDEP requirements. During the testing phase of this project, additional site specific groundwater-quality data will be collected to further ensure that FDEP requirements are met. Assuming that treatment is provided at the NEWRF to meet the recharge water-quality requirements, the primary regulatory activities will be permitting of the recharge wells, the concentrate injection well (if used), and Water Use Permitting through the SWFWMD.

The recharge wells will be permitted as Class V, Group 2 injection wells. These wells inject water into a potable aquifer for the purpose of recharge, salinity barriers, or connection of aquifers. The initial well will be permitted as an exploratory well. The construction requirements for a Class V well are flexible, depending on the use of the well and the quality of the injected water. Since these wells will be injecting drinking water quality water, the wells can be constructed similarly to a public supply water well. Included with the construction of the exploratory test well will be a number of core samples and dedicated observation wells for monitoring groundwater levels and groundwater quality. The core samples are needed to show geochemical data and details of the limestone rock matrix. These core samples will be collected at various locations in the project area. Several dedicated observation wells will be constructed with the exploratory test well (Figure 4-20 and 4-21). There will be two observation wells

designed to collect data for lower Zone A and two observation wells for collecting data in upper Zone A. A testing program will be prepared defining all of the components of the exploratory testing. After the exploratory testing phase is completed, a subsequent testing phase will consist of a recharge cycle in the test exploratory test well for a period of six months. The recharge rate is expected to be at a minimum of 300 gpm. During this 6-month recharge period, water quality will be monitored in the test recharge well and the monitoring wells.

If an injection well is utilized for disposal of the concentrate as a result of RO treatment at the NEWRF, it will be permitted as a Class I injection well, and constructed with tubing and packer construction. This process would require the construction of an exploratory/test well to collect the required data related to the injection zone and overlying confining unit. Since some site-specific hydrogeologic data is available, and the proposed injection quantity will not require a large diameter well, it may be possible to construct the exploratory/test well to meet the construction requirements for an operational well, and ultimately permit and use the well as the operational injection well. However, as discussed in Section 4.5, it would be advantageous to send the concentrate to the planned concentrate disposal well associated with the City's RO Water Treatment Plant Nos. 1 and 2.

4.7 PRELIMINARY DESIGN

The conceptual well layout shown on Figure 4-8 is based on the estimate that five wells will be needed to recharge the proposed 3.0 MGD. It is anticipated that each well will recharge up to 600,000 gallons per day (gpd) at an injection rate of approximately 415 gallons per minute (gpm). Actual recharge rates will be determined from field testing in subsequent phases of this project. The recharge wells will likely be 12-inches in diameter, and cased to the top of lower Zone A at approximately 210 feet bls. An 18-inch diameter surface casing will be used to case off the surficial sand to facilitate effective well construction. Total well depth will be approximately 330 feet bls as shown on the well construction diagram (Figure 4-20). Based on nearby information, the depth to the static water level at the preliminary well locations ranges from approximately 35 to 75 feet bls. Discharge directly into the top of well has the potential to create turbulence that would aerate the injection stream, and increase the potential for mobilization of metals such as arsenic in the aquifer. Therefore, the wells should be constructed with an injection tube that extends below the static water level.

One of the primary design considerations for the recharge well system is the estimated operational injection pressure. Injection pressure is a function of aquifer transmissivity, well efficiency, depth to static water level, and injection rate. Transmissivity, pumping rate, and to a certain extent well efficiency are accounted for in the well specific capacity, which is measured in units of gallons per minute per foot (gpm/ft) of drawdown in a pumped well. A packer test performed in lower Zone A of the ASR exploratory well located at the City's NEWRF yielded a specific capacity value of 37 gpm/ft, while a final test performed after the well was back-plugged to 275 feet bls yielded a specific capacity of 3.3 gpm/ft. Based on these results, and specific capacity data from other

wells in the City's well field area, a value of 10 gpm/ft was used for estimation of injection pressure. Based on this value of specific capacity, and an injection rate of 420 gpm, the calculated increase in water level in the proposed injection (recharge) well is 42 feet. In a recharge well there are additional well losses that decrease the specific capacity from that of a pumped well. To account for the additional well loss in the pressure calculation, an efficiency factor of 50 percent was used, which results in a total water-level increase of 63 feet in the well. The water-level rise was added to the depth to the static water level at each well location to estimate the height of water above the top of the well, and then converted to a wellhead pressure. Based on the data and assumptions used, the estimated wellhead pressures ranged from 0 to 11 pounds per square inch (psi).

A monitoring well program will also be necessary to assist in the permitting process and managing the groundwater replenishment. The monitoring wells will be located near the property boundaries of the project area for ensuring that the recharge water does not create water-quality issues off site. Monitoring wells will be constructed for collecting data in lower Zone A and upper Zone A. Figure 4-20 shows the preliminary design of the monitoring wells while Figure 4-21 shows a very preliminary layout of locations. The exact number of monitoring wells will be determined after the exploratory testing phase of the project is completed. Both the recharge wells and the monitoring wells will be sampled and analyzed during the testing phase and operational phase for the following parameters on a monthly basis. Other parameters may be added as necessary.

Nonmetals

Bicarbonate Alkalinity as CaCO₃ @
Chloride
Nitrate #
Nitrite #
Sulfate #
Sulfide #

Metals

Arsenic (total)
Arsenic (V)
Arsenic (III)
Molybdenum
Calcium
Iron(total) #
Iron (II) #
Potassium
Magnesium
Sodium
Silica (SiO₂)

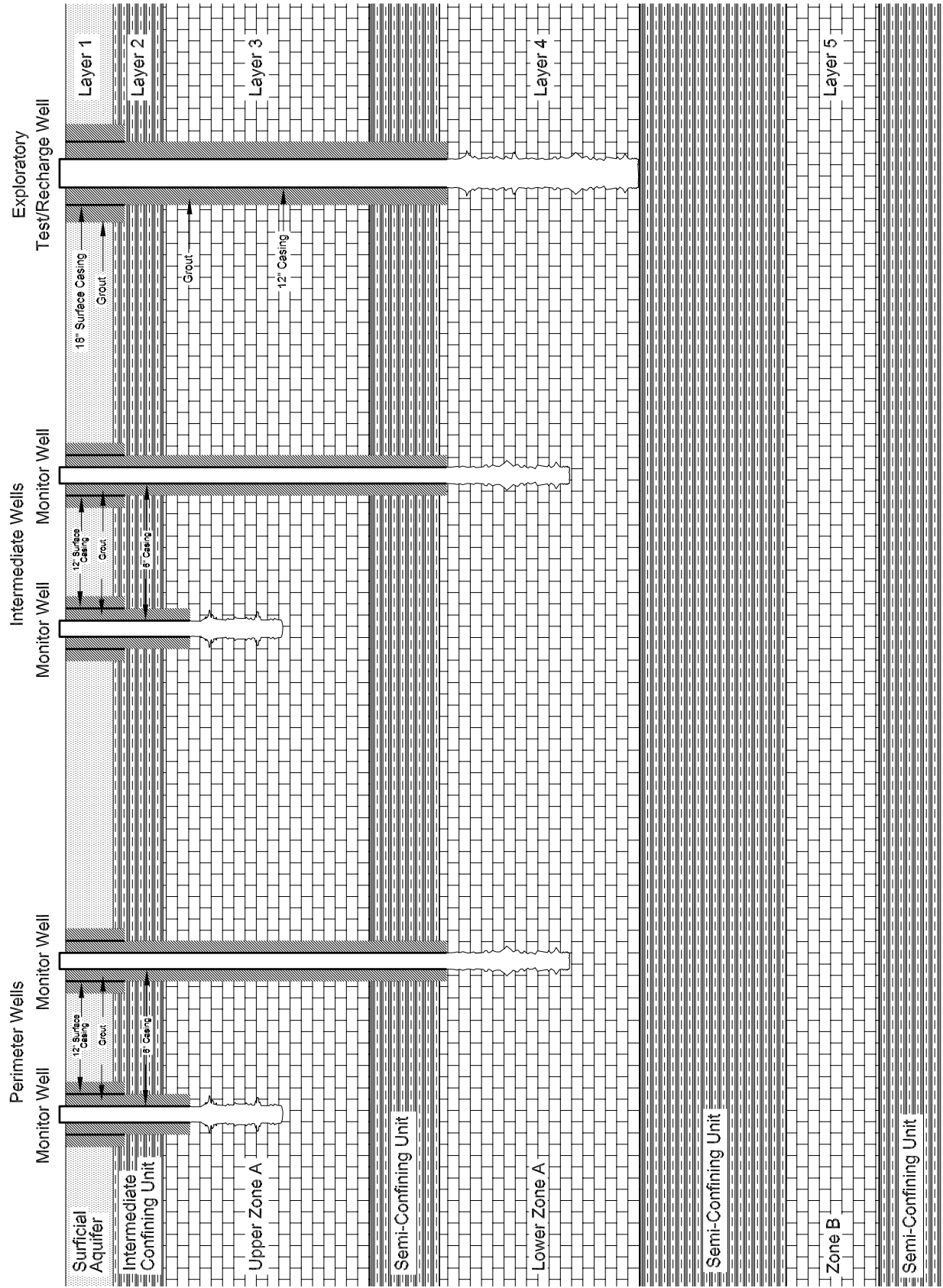
Onsite Measurements

Temperature
pH **
ORP
Specific Conductance **
Dissolved Oxygen

@Field and lab titration

#Laboratory analysis and field analysis with colorimeter

** Field and lab measurements



NOT TO SCALE

DATE	REVISED	☒ Asc	☐ GS	☐ Core
FILE NAME: Figure4-20				

CITY OF CLEARWATER
GROUNDWATER REPLENISHMENT
FEASIBILITY STUDY

PREPARED BY:

LEGGETTE, BRASHEARS & GRAHAM, INC.
Professional Ground-Water and Environmental Engineering Services
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10014 North Dale Mabry Highway - Suite 205
Tampa, FL 33618
(813) 968-5882



DRAWN: TDH

CHECKED: DAW

DATE: Apr. 2011

FIGURE: 4-20

WELL CONSTRUCTION DESIGN & RECHARGE TEST SET-UP



0 300 600
Feet

Legend



Zone A Monitoring Wells



Recharge Well

DATE	REVISED
FILE NAME: FIGURE 4-21.MXD	



CITY OF CLEARWATER GROUNDWATER REPLENISHMENT FEASIBILITY STUDY

PRELIMINARY WELL LOCATIONS

PREPARED BY:



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DRAWN BY:	TDH
CHECKED BY:	JMT
DATE:	Apr. 2010
FIGURE NO.:	4-21

4.8 CONCLUSIONS AND RECOMMENDATIONS

Based on our review of the available area hydrogeologic conditions, groundwater flow modeling, travel-time modeling, geochemical analysis, concentrate management, permitting needs, and preliminary design discussed in this Section of the report, it appears that direct recharge of reclaimed water with additional treatment provided to meet Florida Primary and Secondary Drinking Water Standards is feasible for the City. Based on available aquifer characteristics and groundwater quality data, the projected injection zone for the recharge wells at this time is lower Zone A. Data from the exploratory ASR well at the City's NEWRF indicates that the TDS concentration in lower Zone A is approximately 800 to 900 mg/L. FDEP has indicated that a zone targeted for recharge of a TDS greater than 500 mg/L would only require a one year of pilot test rather than two years of full scale testing if the target zone was less than 500 mg/L. The existing ASR test well, which is open to lower Zone A, will be incorporated into the subsequent testing phase described below as a monitoring well.

An FTMR model was created from the Southern District Model (SDM) for use as a base model for this project. The model was modified to fit the area hydrogeologic conditions and recalibrated. The recalibrated model matches area water levels either as good as or better than the original SDM for the area. A number of simulations were made with a recharge component along with groundwater withdrawals from the City's wells and other wells in the region that show beneficial results to area water levels as a result of groundwater replenishment. Modeling simulations were also made using MODPATH to evaluate the flow paths of particles of water from the recharge wells. Based on this modeling and a well inventory of the area, there are no potable supply wells in lower Zone A or upper Zone A within the six-month particle track zones.

Five recharge waters (RW-1 through RW-5) proposed by Tetra Tech were considered in the geochemical analysis. The composition of the recharge waters ranged from Na:Cl (RW-1) to Na:HCO₃ (RW-2) to Ca:HCO₃ (RW-3, RW-4, and RW-5). The final analysis focused on RW-4 and RW-5. The TDS of all recharge waters were less than 100 mg/L, and the highest TDS concentrations were from RW-4 and RW-5. The composition of local groundwater is Na:Cl, and TDS is 800 mg/L. Two potential blend waters (BW-1 and BW-2) were also considered. Both are Na:Cl, and TDS ranges from 1,245 mg/L (BW-1) to 2,428 mg/L, BW-2.

Local groundwater is anoxic, as indicated by field ORP measurements as low as -307.1 mV. The pe calculated from the last ORP measurement is -1.83. The negative ORPs measured for local groundwater are within the range of ambient ORP measurements reported for ASR sites in Florida. The values of pe based on reported or assumed DO concentrations in recharge waters and blend waters are all positive at DO concentrations 0.10 mg/L or less. The much higher pe values indicate a high degree of sensitivity recharge and blend waters to very small concentrations of DO. Because of that apparent sensitivity, anoxic conditions (reducing conditions) should be maintained in the vicinity of the wellbore.

Mixtures of recharge waters and blend waters appear to be very sensitive to additions of a reducing agent such as sodium bisulfide (NaHS). Simulated dosages of NaHS produce negative pe values at concentrations as low as 3×10^{-4} mol/kg (16.8 mg/L). The concentration decreases to 2×10^{-4} mol/kg (11.2 mg/L) if unblended recharge waters are treated with NaHS. It is highly probable that the pe values calculated for recharge waters and blend waters are much higher than is the actual case. Smaller dosages of NaHS should produce and maintain negative ORP measurements if pe values are much lower than those shown in Table A-2, Appendix A. More accurate measurements of ORP will be required for recharge waters and blend waters.

With regard to pH, it will be important to ensure that water is neither highly alkaline nor acidic, as arsenic can be mobilized at high or low pH values. The optimal pH range should be between 7 and 8. If recharge water is treated with calcium hydroxide ($\text{Ca}(\text{OH})_2$), pH can be controlled by the addition of hydrochloric acid or sulfuric acid, or by injection of carbon dioxide (CO_2). Reaction simulations run for this study did not show a tendency for pH to increase significantly when recharge waters or mixtures of recharge waters and blend waters are treated with sodium bisulfide. The most favorable pH values appear to be from RW-5 or any mixture of RW-5 and BW-1 or BW-2, as all calculated pH values were less than 8.

The effect of pH must be considered in conjunction with redox conditions. ORP should be negative, preferably -200 mV or lower. Anything much higher than -200 mV is likely to indicate oxidizing or potentially oxidizing conditions once adjustments are made to calculate Eh and/or pe.

It is recommended that there be more detailed monitoring of pH in recharge waters and proposed blend waters. It will be especially important to determine, through repeated bench-scale tests, how pH responds to dosing with sodium bisulfide, compared to the results calculated by PHREEQI. The simulated results, thus far, indicate little reason to be concerned about changes in pH that might promote mineral dissolution and mobilization of arsenic.

It will be very important to collect lithologic data (cores and cuttings) from future wells; as such data will support more detailed pictures of the aquifer matrix, potential sources of arsenic disseminated within the matrix, and along with the likely range of processes and trigger mechanisms that could lead to the mobilization of arsenic.

It is also recommended continued sampling in the area, especially from wells with documented arsenic concentration greater than the 10 $\mu\text{g/L}$ MCL mandated by the USEPA.

It will be necessary to collect more accurate data on the redox states of local groundwater, recharge waters and blend waters before proceeding with a more aggressive approach to quantitative geochemical modeling.

Based on this geochemical analysis from available data and the proposed treatment processes for the water to be recharged, there is minimal probability for the mobilization of arsenic in the groundwater system. Site specific data collection and testing is necessary to develop the necessary data to further verify that the aquifer can be recharged with purified water and not cause unacceptable metals mobilization.

The recharge wells will be permitted as Class V, Group 2 injection wells. The next phase of the feasibility assessment for this project should include construction and testing of a lower Zone A test well to collect the data needed to provide a more reliable evaluation of the number of recharge wells needed, the injection rates, and the injection pressures. Zone A monitoring wells and core sampling should also be constructed for this testing program. Data collected from this testing program will be used to perform a more detailed modeling analysis to evaluate the hydraulic and transport effects of the recharge water and to assist in final design and permitting. Preliminary design consists of five recharge wells into lower Zone A and a number of monitoring wells in both upper and lower Zone A. The recharge wells will likely be near the center line of City owned/controlled property and the monitoring wells will be near property boundaries.

The RO treatment component of the plant will require disposal of approximately 530,000 gpd of concentrate. If deep well injection is selected as the option for disposal of concentrate from the NEWRF RO treatment process, the injection well planned for the City's two RO Water Treatment Plants could be utilized for disposal of this relatively small amount of reject water.

5.0 PROPOSED GWR PURIFICATION PROCESS

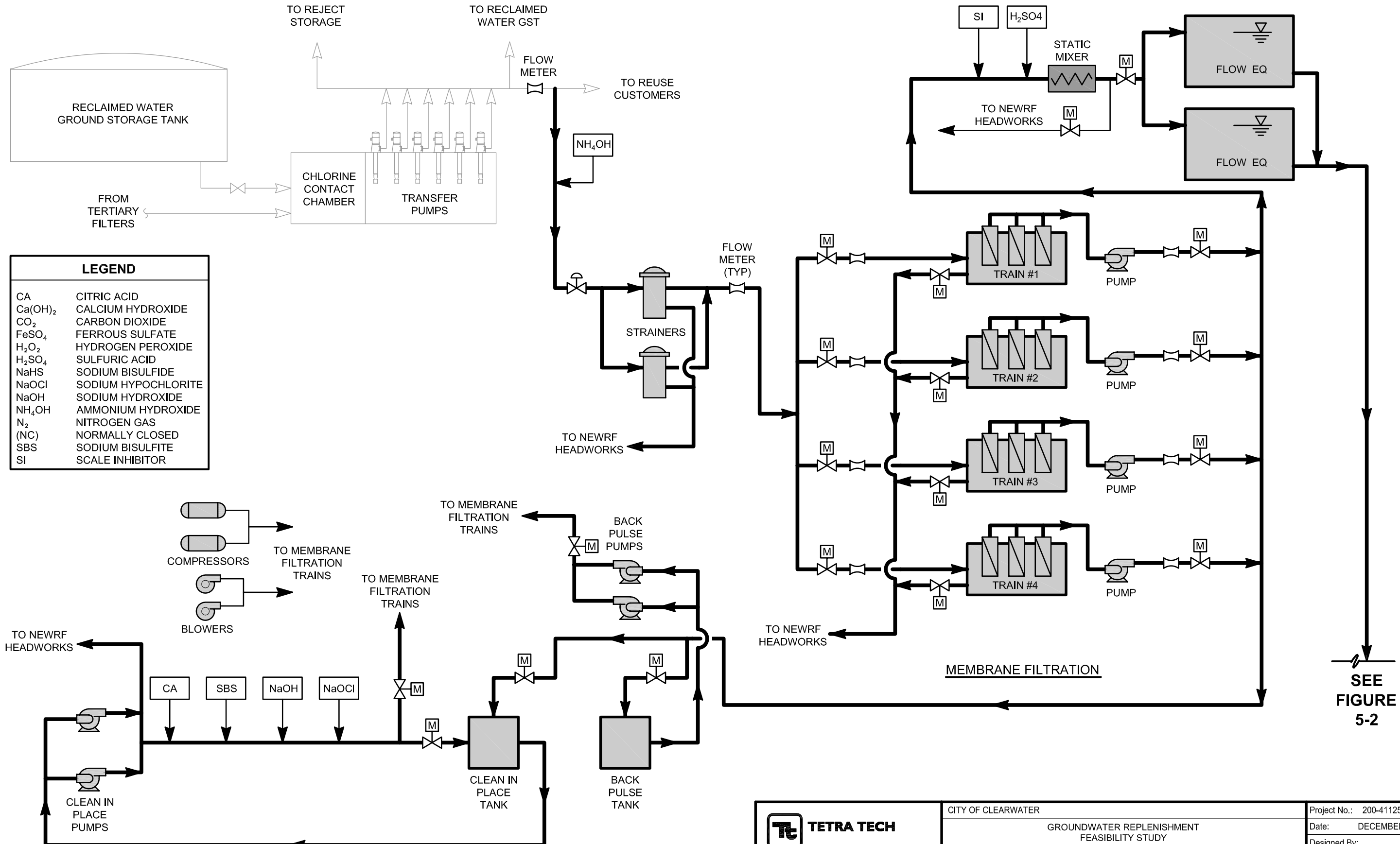
The proposed GWR purification process is intended to provide purified water that:

- meets drinking water standards;
- provides multiple barriers for contaminants;
- has been treated to reduce the risk due to acute or chronic toxicity (microconstituents);
- is stable;
- has been treated to reduce the potential for the mobilization of arsenic and other metals in the groundwater;
- and meets all other requirements for direct aquifer recharge as outlined in the FDEP regulations.

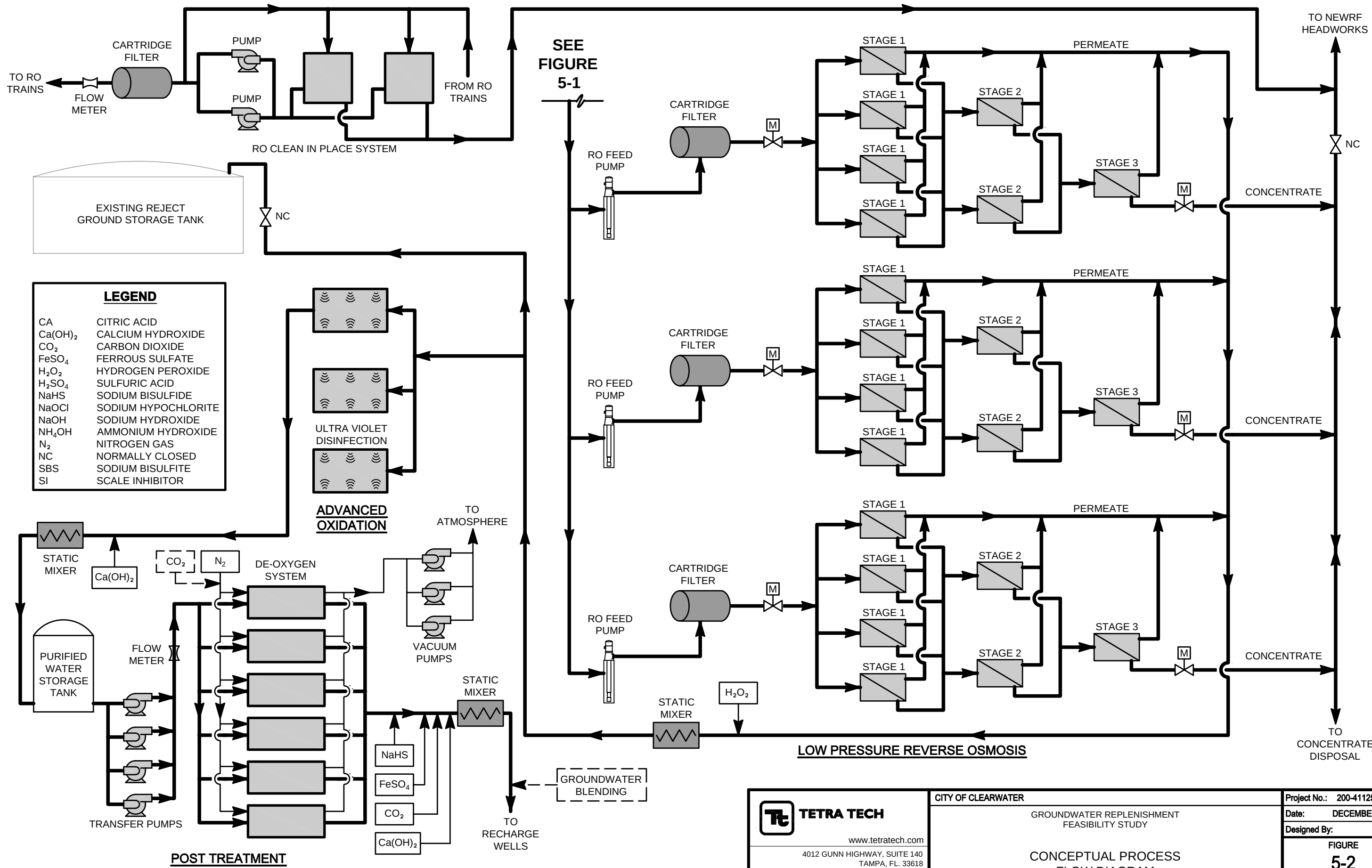
The major process components in the proposed process include chemical pretreatment (chloramines conversion), screening, membrane filtration, reverse osmosis (RO), advanced oxidation, post treatment stabilization, and oxygen removal. The process flows are based on a treated capacity of 3 MGD, and 85% recovery for the RO process, and a 95% recovery for the membrane filtration process. A conceptual process flow diagram for the proposed treatment facilities is shown in Figure 5-1 and 5-2. Post treatment following the purification process will be critical in producing a finished water that does not result in any negative effect on the aquifer, most importantly, control of mobilization of metals dissolution of the formation.

5.1 CHEMICAL PRETREATMENT

Commonly, membrane filtration requires the use of an oxidant to help prevent the accumulation of organic foulants on the membrane elements. This accumulation can reduce process efficiency by requiring higher feed pressures or causing a reduction in permeate production. Common oxidants used include chlorine or chloramines at concentrations that are compatible with the membrane filtration elements. For this analysis, it is assumed that a chloramine residual will be used to prevent the accumulation of organic foulants on the membranes while protecting the MF and RO membranes from possible damage caused by free chlorine. The effluent chlorine concentration at the City's NEWRF ranges from 2.0 mg/L to 3.6 mg/L based on historical data; however, the City adds sodium bisulfite to reduce the chlorine to approximately 1 mg/L in the reclaimed water. A chloramine residual of 1-2 mg/L is recommended to control biofouling on the membranes, therefore an adjustment to the sodium bisulfite feed will likely be required to increase the chlorine feed supplying the purification treatment process. The ammonium hydroxide dosages for this evaluation are based on a chlorine residual of 1-2 mg/L (average of 1.5 mg/L) of chlorine and a chlorine to ammonia (as nitrogen) ratio of 3.5-4.5. A summary of the general design parameters for the ammonia feed system is provided in Table 5-1.



1/3/2011 12:56:07 PM - P:\200-41125-10002 - CLEARWATER GWR FEASIBILITY\CAD\CONCEPTUAL\PILOT PDR\5-1 AND 5-2 PROCESS FLOW DIAGRAM.DWG - SANFORD, CHADWICK



 TETRA TECH www.tetrattech.com 4012 GUNN HIGHWAY, SUITE 140 TAMPA, FL. 33618 PHONE: 813.806.0202 FAX: 813.806.0405	CITY OF CLEARWATER	Project No.: 200-41125-10002
	GROUNDWATER REPLENISHMENT FEASIBILITY STUDY	Date: DECEMBER, 2010
	CONCEPTUAL PROCESS FLOW DIAGRAM	Designed By: JCB
		FIGURE 5-2

Table 5-1. Ammonia Chemical Feed Design Parameters	
Chemical	Ammonium Hydroxide (NH ₄ OH)
Solution Strength	19% (as NH ₃)
Specific Gravity	0.93
Dose – Range	0.25-0.7 mg/L (as NH ₃)
Dose – Average	0.46 mg/L (as NH ₃)
Average Use	14.1 lbs/day (as NH ₃) 74 lbs/day (Solution) 9.6 gallons/day (Solution) 287 gallons/30 days
Maximum Feed Rate	0.61 gph (Solution)
Storage	Totes or Drums
Metering Pumps	1 + 1 standby

5.2 MEMBRANE FILTRATION

Microfiltration (MF) and Ultrafiltration (UF) are low pressure membrane filtration processes that are utilized for removal of particulates, suspended solids, and organic material. For the purposes of this evaluation, MF will be the assumed membrane filtration system based on the recommendations in the previously mentioned SWFWMD report (MWH, 2009) and its use in the Orange County Water Districts Groundwater replenishment System process. MF can be utilized for physical pretreatment to remove suspended solids (including pathogens) and organic foulants. Significant advantages of membrane filtration technology include its ability to treat water to a consistently low turbidity and a relatively small footprint. Membrane filtration systems can operate as a pressure driven system or a vacuum driven system. In a pressure driven system, the feed water is pumped through the membrane module with the modules located inside a pressure vessel. In a vacuum driven system, the membrane modules sit in a tank and a vacuum is applied to the modules “pulling” the feed water through the membranes. The type of membrane filtration system can be selected and designed around space and power requirements, as well as other factors, including reliability. Selection of the type of membrane filtration system can be selected during preliminary design or alternate designs can be accommodated during final design with final selection decided after bidding. For the purposes of this evaluation, a vacuum driven system is assumed for sizing and costing. A summary of the general design parameters for the MF system is provided in Table 5-2.

Table 5-2. MF Process Design Parameters	
Pretreated Feed Water Capacity	3.72 MGD
Permeate Recovery Rate	95%
Permeate Capacity	3.53 MGD
Waste Flow (to NEWRF headworks)	0.19 MGD
Minimum Feed Water Temperature	20 Degrees C
Maximum Feed Water Temperature	30 Degrees C

5.2.1 Strainers

Strainers are often required prior to membrane filtration to protect the membrane elements from damage from abrasive materials such as sand or grit. These materials should be removed prior to membrane filtration in order to prevent clogging or damaging of the hollow fiber membranes. Strainers are commonly constructed of stainless steel wedgewire or plastic media with a nominal rating of 100-150 microns. Removing the accumulation of solids on the strainers can involve an air or water backwash. The backwash water used for cleaning can be recycled to the head of the NEWRF. A summary of the general design parameters for the strainers is provided in Table 5-3.

Table 5-3. Strainer Design Parameters	
Number of Units	1 + 1 Standby
Unit Type	Automatic Strainer
Nominal Rating	150 micron
Design Capacity per Unit	3.72 MGD
Backwash Flow Rate	50-200 gpm
Normal Pressure Drop	2-3 psi
Control	Automatic Timed Backwash

5.2.2 Membrane Trains

Microfiltration and ultrafiltration membranes that operate as vacuum driven systems incorporate open top tanks which contain multiple membrane elements arranged in cartridges in a parallel configuration. The feed water flows into the membrane tanks and passes through the membrane elements with the application of a vacuum to the permeate side of the membrane. This membrane process operates in outside-in flow where unfiltered water surrounds the outside of the hollow membrane fiber and the filtered water passes through to the inside. Similar to conventional media filters these systems typically operate in a dead end flow mode where water is filtered through the membranes for a predetermined time and then the system enters into a backwash (or backpulse) mode. A summary of the general design parameters for the MF membrane trains is provided in Table 5-4.

Table 5-4. MF Membrane Train Design Parameters	
Number of Trains	4
Average Permeate Capacity per Train	0.93 MGD
Peak Permeate Capacity per Train (one Train off-line)	1.24 MGD
Average Membrane Flux	25 gfd
Peak Membrane Flux (one Train off-line)	33.3 gfd
Membrane Area per Train	37,200 ft ²

5.2.3 Permeate Pumping

Permeate pumps are required to create the necessary vacuum on the hollow fiber membranes to induce the permeate flow and to provide the pressure required to fill the EQ tanks prior to the reverse osmosis process. The vacuum required on the membranes can be as high as 12 psi. Horizontal centrifugal pumps controlled by VFDs are commonly used for permeate pumps. The permeate pumps can be configured to operate for a single dedicated membrane train or can operate in parallel with multiple permeate pumps serving multiple membrane trains. Due to the relatively small size of the MF process, this evaluation assumes that the permeate pumps will be configured as a dedicated system with one (1) pump per membrane train and one (1) uninstalled spare pump for reliability. Estimated design parameters for the MF permeate pumping facilities are detailed in Table 5-5.

Table 5-5. MF Permeate Pump Design Parameters	
Number of Pumps	4 + 1 Spare
Pump Type	Horizontal Centrifugal End Suction
Drive Type	Variable Speed
Pump Design Flow	1.24 MGD
Pump Design TDH	20 psi
Motor Size	15 HP

5.2.4 Membrane Backpulse System

The suspended solids blocked by the hollow fiber membranes are periodically backwashed from the system by pumping permeate back through the membrane elements in the reverse direction using backpulse pumps in a process referred to as backpulsing. The water used for backpulsing can be recycled to the head of the NEWRF. The backpulse pumps typically initiate an automatic cleaning cycle for each skid every 20-60 minutes. The backpulse process typically includes an air scour across the membranes to help dislodge particles attached to the membrane surface. The backpulse pumps draw permeate from the backpulse tank and can include a sodium hypochlorite feed to provide a chemically enhanced backwash (CEB) cycle. Similar to a normal backpulse cycle, after a CEB cycle has commenced the backwash will be neutralized and discharged to the head of the NEWRF. A summary of the general design parameters for the MF backpulse system is provided in Table 5-6.

Table 5-6. MF Backpulse System Design Parameters	
Number of Back-pulse Pumps	1 + 1 Standby
Pump Type	Horizontal Centrifugal End Suction
Drive Type	Variable Speed (VFD)
Estimated Back-pulse Pump Flow Rate	1.24 MGD
Pump Design TDH	20 psi
Estimated Back-pulse Pump Motor Size	15 HP
Estimated Back-pulse Tank Capacity	3,000 gallons
Number of Air Blowers (sized by membrane manufacturer)	1 + 1 Standby

5.2.5 Membrane Cleaning System

Even with effective pretreatment, the MF membrane elements can experience gradual fouling over time. Fouling has a significant effect on membrane performance and can reduce process efficiency by requiring a higher vacuum (or feed pressure) or causing a reduction in permeate production. To combat fouling of the membranes, two types of cleaning are commonly performed for membrane filtration systems. The first type of cleaning is maintenance cleaning that occurs automatically on a daily or weekly basis. This maintenance cleaning typically involves the use of mild cleaning agents and/or sodium hypochlorite to reduce biofouling in the system. The second type of cleaning is a recovery cleaning, which is manually performed and is implemented to restore the condition of the membranes if fouling in the system significantly alters the normal operating pressure or permeate production. Recovery cleaning can include a low pH cleaning in addition to cleaning with sodium hypochlorite.

A membrane cleaning system is typically used to facilitate cleaning of the membrane modules in place such that the system performance is restored. The cleaning system commonly incorporates a chemical mixing tank for preparing cleaning solutions, pumps to transfer the cleaning solution to the membrane trains, associated piping and valves, and immersion heaters to heat the cleaning solutions when necessary. Common cleaning chemicals include citric acid and sodium hypochlorite. Sodium hydroxide and sodium bisulfite can be used to neutralize the cleaning solution after cleaning so that the cleaning solution can be returned to the head of the NEWRF. The tanks and pumps are commonly sized to provide the necessary flow rate to clean one train at a time. A summary of the general design parameters for the MF membrane cleaning system is provided in Table 5-7.

Table 5-7. MF Membrane Cleaning System Design Parameters	
Number of Mixing Tanks	1
Mixing Tank Size	2,000 Gallons
Number of Pumps	1 + 1 Standby
Pump Type	Horizontal Centrifugal
Drive Type	Variable Speed (VFD)
Pump Design Flow	500 gpm
Pump Design TDH	30 psi
Motor Size	15 HP

5.3 REVERSE OSMOSIS PROCESS

Based on the water quality goals stated previously, a reverse osmosis system utilizing low pressure RO membranes is the most appropriate level of treatment prior to the advanced oxidation process. RO membranes can provide greater than 95% removal of chlorides, sodium and TDS in addition to high removal of various microconstituents and naturally occurring organics that may be present in the feed water. A summary of the general design parameters for the RO system is provided in Table 5-8.

Table 5-8. RO Membrane Process Design Parameters	
Pretreated Feed Water Capacity	3.53 MGD
Permeate Recovery Rate	85%
Permeate Capacity	3.0 MGD
Concentrate Capacity	0.53 MGD
Minimum Raw Water Temperature	20 Degrees C
Maximum Raw Water Temperature	30 Degrees C

5.3.1 Chemical Pretreatment

As previously discussed in the MF pretreatment section, the feeding of ammonia (ammonium hydroxide) is proposed upstream of the MF process to convert free chlorine in the source water to chloramines (combined chlorine residual), which is an important feature to extending the useful life of the RO membrane elements and reducing the potential for biofouling.

Following the MF process chemical pretreatment is necessary prior to the reverse osmosis process to ensure that the dissolved solids remain soluble and sparingly soluble salts do not precipitate in the concentrate stream. Chemical additives such as acid and scale inhibitors (antiscalants) can help to prevent precipitation by influencing the water quality so that solubility limits of the dissolved ions are not exceeded. In order for chemical pretreatment to be effective, pretreatment chemical doses should be optimized based on the specific feed water quality and system recovery. In general, the

acid dose will depend on the pH and the alkalinity of the feed water, while the scale inhibitor dose will depend on the RO system recovery and the presence of sparingly soluble salts in the feed water. The pretreatment chemicals will be dosed into the MF permeate before entering the EQ tanks.

Based on the estimated feed water quality parameters, a feed water pH of approximately 6.9 would be needed to achieve a concentrate Langelier Saturation Index (LSI) of approximately +2.0, which is within the range of calcium carbonate scale control by a scale inhibitor. A scale inhibitor dose range of 3-5 mg/L provides a conservative estimate for sizing of these chemical feed systems. General design parameters for the RO chemical pretreatment chemical feed systems are provided in Table 5-9 (scale inhibitor) and Table 5-10 (sulfuric acid).

Table 5-9. Scale Inhibitor Chemical Feed Design Parameters	
Chemical	Scale Inhibitor
Solution Strength	100%
Specific Gravity	1.1 - 1.3
Dose – Range	3-5 mg/L
Dose – Average	4 mg/L
Average Use	118 lbs/day 11.8 gallons/day 353 gallons/30 days
Maximum Feed Rate	0.57 gph
Storage	Totes or Drums
Metering Pumps	1 + 1 standby

Table 5-10. Sulfuric Acid Chemical Feed Design Parameters	
Chemical	Sulfuric Acid (H ₂ SO ₄)
Solution Strength	93%
Specific Gravity	1.83
Dose – Range	0-80 mg/L
Dose – Average	35 mg/L
Average Use	1,030 lbs/day (H ₂ SO ₄) 1,108 lbs/day (Solution) 73 gallons/day (Solution) 2,180 gallons/30 days
Maximum Feed Rate	6.5 gph
Storage	3,500 gallon bulk storage tank 100 gallon day tank
Metering Pumps	1 + 1 standby

5.3.2 Equalization (EQ) Tank

The reverse osmosis trains are designed to operate at a fixed capacity, thus an EQ tank is necessary to even out fluctuations in flow from the MF system that occur on a regular basis due to back-pulse cycles. The preliminary design configuration would utilize two (2) 12,000 gallon tanks which would receive pretreated membrane filtration permeate, providing approximately 10 minutes of storage to balance flows between the MF and RO systems. The EQ tanks would be designed to allow disposal to the head of the NEWRF if the MF permeate is not of adequate quality to feed to the RO system.

5.3.3 Membrane Feed Pumps

The RO feed water from the EQ tanks will require pressurization to overcome the osmotic pressure and friction losses through the cartridge filters and membranes. The RO feed pumps raise the pressure following pretreatment up to the required feed head prior to the reverse osmosis membrane pressure vessels. The pressure required for the membrane system is dependent on the types of membranes used, the desired permeate recovery, and the salinity of the feed water. Typical pressures needed for reclaimed water applications (<1,500 TDS) can range from 150-250 psi. Vertical turbine pumps equipped with variable speed drives are the most common pumps used for RO membrane treatment. The RO feed pumps can be configured to operate for a single dedicated membrane train or can operate in parallel with multiple pumps to feed multiple membrane trains. Due to the relatively small size of the RO process and the benefit of more simplified controls, this preliminary analysis assumes that the RO feed pumps will be configured as dedicated units with one (1) pump per membrane train and one (1) common uninstalled spare pump for reliability. General design parameters for the RO feed pumping system based on membrane projections are provided in Table 5-11.

Table 5-11. RO Feed Pump Design Parameters	
Number of Pumps	3 + 1 Spare
Pump Type	Vertical Turbine
Drive Type	Variable Speed
Pump Design Flow	1.18 MGD
Pump Design TDH	200 psi
Motor Size	125 HP

5.3.4 Cartridge Filtration

Following the addition of pretreatment chemicals and RO feed pumps, the water is filtered using cartridge filters as a last level of protection to remove particulates which could damage and/or blind the membrane elements. These filters are provided as a precaution to remove any particles that could find their way into the feed water from the

EQ tanks or the RO process pretreatment chemicals. Disposable cartridge filters are typically used in this application and are manufactured with different nominal ratings and lengths. Cartridge filters are typically long tubes that have an estimated service life of 4-6 months, based on the feed water quality for the proposed application (downstream of membrane filtration). The filter elements (cartridges) are contained in pressure vessel housing units that can be oriented horizontally or vertically, allowing flow through many parallel cartridges at one time. Normal operation includes continuous flow through the housing until the pressure drop exceeds a predetermined limit and the cartridge filters need to be replaced with new filter cartridges. It is assumed in this analysis that the cartridge filters will be located downstream of the RO feed pumps and that the cartridge filter vessels will be rated for the anticipated RO feed pressure. For this reason it also assumed that each cartridge filter vessel will be dedicated to a single RO skid. General design parameters for the cartridge filtration units are provided in Table 5-12.

Table 5-12. Cartridge Filter Design Parameters	
Number of Units	3
Cartridge Filter Orientation	Horizontal
Cartridge Filter Type	String Wound Polypropylene
Cartridge Filter Rating	5 micron nominal
Hydraulic Loading Rate	4 gpm per 10" length
Filter Vessel Design Flow	1.18 MGD/ 820 gpm
Filter Vessel Design Pressure	250 psi

5.3.5 Membrane Trains

The primary treatment for the removal of dissolved solids and microconstituents is performed in the reverse osmosis process, which is typically composed of multiple trains. The RO process eliminates salts, viruses, pesticides and most organic compounds. Typically these membrane trains are configured in parallel and consist of a 2-stage or 3-stage process for each train where the concentrate generated in the first membrane stage is fed to a second bank of membranes (and then a third if applicable) to increase system recovery. Each membrane train is designed to operate at a fixed capacity and is comprised of spiral wound membrane elements that provide hundreds of square feet of membrane area per element. It is anticipated that each RO membrane train will utilize a combination of inter-stage booster pumping and permeate throttling to provide hydraulic balancing of flows between stages.

The membrane elements are housed in fiberglass pressure vessels that are arranged in parallel with common feed water, product water (permeate), and concentrate water piping. These sections or trees of pressure vessels are designed to allow isolation for maintenance and cleaning. Each vessel typically contains 6-7 spiral wound membrane elements. The most common diameter for elements and pressure vessels are 8-inch. General design parameters for the RO system based on membrane projections are provided in Table 5-13.

Table 5-13. RO Membrane Train Design Parameters	
Number of Trains	3
Number of Stages per Train	3
Design Permeate Flux	10 gfd
Permeate Capacity per Train	1.0 MGD
Concentrate Capacity per Train	0.18 MGD
Pressure Vessel Diameter	8 inches
Number of Pressure Vessels per Train	42
Stage 1	24
Stage 2	12
Stage 3	6
Membrane Elements per Pressure Vessel	6
Membrane Element Area	400 sf

5.3.6 RO Membrane Cleaning System

Even with effective pretreatment, the RO membrane elements can experience gradual fouling or scaling over time. Fouling and scaling of the membrane surface and of the feed spacer will increase the required feed pressure and have a significant effect on membrane performance and permeate production. A membrane cleaning system is typically used to facilitate cleaning of the spiral wound membrane elements in place such that the system performance is restored. The cleaning system commonly incorporates chemical mixing tanks for preparing cleaning solutions and neutralizing used solutions, pumps to recirculate cleaning solution through the membrane trains, immersion heaters to heat the cleaning solutions, a cartridge filter for the cleaning solution, instrumentation to monitor cleaning activities, and associated piping and valves.

Common cleaning chemicals for RO systems include citric acid, sodium hydroxide, and specially designed proprietary cleaning chemicals. Sodium hydroxide and sulfuric acid are commonly used to neutralize the cleaning solution after cleaning so the spent cleaning solution can be returned to the head of the NEWRF. The tanks and pumps are commonly sized to provide the necessary flow rate to clean a single tree or section of pressure vessels at a time, however due to a higher potential for biofouling when treating this supply source, a 2nd standby cleaning pump has been assumed that would allow cleaning of the entire 1st stage with both pumps and would provide redundancy. Cleaning of the RO membranes is less frequent than that required for the MF membranes and therefore, while a permanent cleaning system is typically installed, permanent chemical feed systems for RO membrane systems are not typically included. General design parameters for the RO membrane cleaning system are presented in Table 5-14.

Table 5-14. RO Membrane Cleaning System Design Parameters	
Number of Mixing Tanks	2
Mixing Tank Size	2,500 Gallons
Number of Cartridge Filter Vessels	1
Cartridge Filter Capacity	1,080 gpm
Number of Pumps	2
Pump Type	Horizontal Centrifugal
Drive Type	Variable Speed (VFD)
Pump Design Flow	540 gpm
Pump Design TDH	60 psi
Motor Size	25 HP

5.3.7 Concentrate Disposal Options

The disposal of concentrate will be a key component in the operation of the proposed facilities. The concentrate flow to be disposed of will be approximately 0.53 MGD. The RO process will remove a large portion of the microconstituents of concern, which will increase the concentration of these compounds in the RO concentrate. The RO concentrate will also have over 6 times the concentration of dissolved solids as the feed water. The concerns over microconstituents will make permitting the discharge of the concentrate more challenging than what is normally expected for the discharge of a RO concentrate from a drinking water facility. Recycling the RO concentrate to the head of the NEWRF will increase the concentration of microconstituents, which will impact the water quality to the purification treatment processes in the raw wastewater and reduce the likelihood of being a viable long term concentrate disposal option.

For the purposes of this evaluation, it is assumed that disposing of the concentrate through a deep injection well is the most feasible option. This option would likely be the easiest to permit, but also likely the costliest option. If a deep well were constructed just for the concentrate from the purification treatment process, it is anticipated that the well could be located on-site with adequate setbacks from the recharge wells and because interruptions in the treatment process will not affect the drinking water supply, it is assumed that only one deep well would be required. During the period when the deep well is down for testing or maintenance, the City may be able to obtain a waiver to discharge the concentrate back to the NEWRF headworks or would require temporary shutdown to the purification treatment process (increasing discharges to Tampa Bay during the down time). As discussed in Section 4, another option is to combine the concentrate with the concentrate from the RO Water Treatment Plant No. 1 and the proposed RO Water Treatment Plant No. 2 for disposal through the proposed injection well that will potentially be located at the site of the planned RO Water Treatment Plant No. 2. This would save on the cost of the injection well, but increase the concentrate pipeline costs. The feasibility of this would depend on the timing of the two projects. In order to provide a conservative cost opinion, it was assumed that a new deep injection well would be constructed at the NEWRF site.

Alternative disposal alternatives include:

- Discharge to the East WRF headworks: This option is more likely to be permitted than returning to the headworks of the NEWRF since the effluent from this facility will not be used to feed the groundwater recharge facilities. However the effluent from this facility is discharged into Tampa Bay and therefore the increasing microconstituents, while diluted due to blending with the effluent, may still pose permitting challenges. In addition, the proposed, more stringent Total Maximum Daily Loads (TMDLs) may make this option infeasible.
- Evaporation ponds: This option would also face permitting challenges due to the microconstituents in the concentrate and would require additional maintenance and large amounts of land that may not be available.

5.4 ADVANCED OXIDATION PROCESS

The advanced oxidation process is the final barrier in the treatment train. Advanced oxidation involves ultraviolet (UV) light and hydrogen peroxide combined with treatment, which is the most effective way to eliminate any remaining organic compounds in the water that may not have been removed in the upstream processes.

5.4.1 Hydrogen Peroxide

Hydrogen peroxide (H_2O_2) is a strong oxidant that is often used in wastewater collection and treatment systems for controlling sulfide and organic related odors. When combined with UV light, hydrogen peroxide is effective at breaking down complex organic compounds that are not completely removed through the RO process, including NDMA and other low molecular weight organic compounds, providing an additional level of treatment.

Hydrogen peroxide is a liquid chemical that typically is supplied in 35% or 50% solutions. Hydrogen peroxide feed systems typically consist of chemical storage tank(s), day tank(s), and metering pumps similar to other liquid chemicals at water and wastewater treatment facilities. General design parameters for the hydrogen peroxide system are based on the design criteria used at the OCWD GWR System and are provided in Table 5-15. Actual dosing criteria would be determined through pilot and demonstration testing.

Table 5-15. Hydrogen Peroxide Chemical Feed Design Parameters	
Chemical	Hydrogen Peroxide (H ₂ O ₂)
Solution Strength	50%
Specific Gravity	1.19
Dose – Range	3-15 mg/L
Dose – Average	10 mg/L (H ₂ O ₂)
Average Use	250 lbs/day (H ₂ O ₂) 500 lbs/day (Solution) 50 gallons/day (Solution)
Storage	3,000 gallon bulk storage 50 gallon day tank
Metering Pumps	1 + 1 standby

5.4.2 Ultraviolet (UV) Oxidation

The UV process works to breakdown organic compounds through two methods: photolysis and oxidation. The UV process is used to destroy certain trace organic compounds through direct photolysis. The hydrogen peroxide added upstream of the UV process is transformed into a hydroxyl radical through direct photolysis. The hydroxyl radical chemically combines with the trace organics that cannot be destroyed through direct photolysis and neutralizes them. The combination of hydrogen peroxide and UV is referred to as advanced oxidation.

The UV process used for advanced oxidation consists of low pressure, high output lamps. The process stream flows through a series of UV reactors operating in parallel that allow for easy modular expansion of the system. The UV reactor typically would include a stainless steel vessel with flanged inlet and outlet connections. General design parameters for the hydrogen peroxide system are based on the design criteria used at the OCWD GWR System and are provided in Table 5-16. This system is designed for a 1.2 log removal of NDMA and a 0.5 log removal of 1,4 Dioxane.

Table 5-16. UV Process Design Parameters	
Number of Reactors	3
Flow Per Reactor	1.0 MGD
Number of Bulbs per Reactor	72
Total Number of Bulbs	216
Energy Required per Bulb	0.25 kW
Estimated NDMA Removal	1-1.2 log (94%)
Estimated 1,4 Dioxane Removal	0.5-log (68%)

5.5 POST TREATMENT

The post treatment following the purification process will be critical in producing a stable product water that does not contribute to the mobilization of metals in the groundwater. The conceptual design of the post treatment processes was developed based upon the historical water quality data available on the reclaimed water, limited groundwater sampling for key water quality parameters, limited reclaimed water sampling for water quality parameters not available in the historical data, and the preliminary geochemical evaluation of the groundwater/purified water blend. Additional sampling of the reclaimed water and groundwater will be required to more fully characterize both as well as further investigations into the local formation of the injection zone in order to refine and optimize the post treatment processes in subsequent phases of the project.

The conceptual post treatment processes have been designed to provide a water that is essentially free of dissolved oxygen (DO), is stable relative to calcium carbonate precipitation and has a pH that closely matches the native groundwater. A pH of less than 8 was targeted due to both the native groundwater pH (7.7 – 7.8) and the pH/pe diagrams that show a lower pH results in arsenic in the insoluble form at higher pe values. Carbon dioxide and calcium hydroxide were proposed to increase the alkalinity and provide a water that is saturated with respect to calcium carbonate at a pH below 8. Saturating the water with respect to calcium carbonate is provided to prevent the dissolution of the aquifer formation.

Oxygen removal is provided to prevent the mobilization of arsenic and other metals. The geochemical modeling demonstrated that the presence of oxygen was the key reactant in oxidizing the metals in the aquifer formation. The use of sodium bisulfide is recommended as discussed in Section 4. The use of sodium bisulfide serves multiple purposes. Sodium bisulfide will reduce the oxidation-reduction potential of the water, which is demonstrated to favor the insoluble species of arsenic. Sodium bisulfide will also add sulfides to the water which will help to push the oxidation reaction of arsenic to arsenopyrite (FeAsS), which is the solid form. Finally sodium bisulfide will remove oxygen and chlorine from the water. The addition of iron into the purified water is also included in the post treatment to reduce the potential for iron dissolving in the groundwater upon injection, thereby releasing arsenic bound in the arsenopyrite.

5.5.1 Storage and Pumping

A storage tank for the purified water will be provided to provide a break in the process stream prior to the recharge pumps and to allow additional reaction time with any stabilization chemicals that are added prior to the DO removal process. The storage tank volume is based on providing 15-30 minutes of storage. For the purposes of this evaluation, a 50,000 gallon FRP storage tank is assumed due to the potentially aggressive nature of the process stream following the RO and advanced oxidation processes. The transfer (Recharge) pumps will transport water from the storage tank to the DO removal system and ultimately to the recharge wells. General design parameters for the recharge pumping system are summarized in Table 5-17.

Table 5-17. Recharge Pumping Design Parameters	
Number of Pumps	3+1 Standby
Pump Type	Vertical In-Line
Drive	Variable Speed
Pump Design Capacity	1.0 MGD
Pump Design TDH	100 psi
Motor Size	60 HP

5.5.2 Dissolved Oxygen Removal

Prior to injecting the purified water, it is desirable to remove the DO to match the nearly anaerobic conditions in the aquifer. Introducing water with a DO into the aquifer would likely promote the mobilization of metals into the groundwater. While removing all of the DO through one process is not feasible, it is possible to remove the DO to trace levels and a minimum 4-log (99.99%) removal is recommended for the purified water.

The primary technology for removing DO from water at extremely high efficiencies is by membrane contactors. To prevent particulate fouling the preferred location of membrane contactors is downstream of an RO membrane process. Membrane contactors incorporate hollow fiber membrane elements that are impermeable to water, but permeable to gases. A vacuum pump is used as a driving force to pull the gases through the membrane fibers. Nitrogen (N₂) gas is added to the membrane contactor vacuum supply to assist in removing the DO. Nitrogen gas can either be supplied or generated on-site with a nitrogen generator. For the purposes of this evaluation, it is assumed that nitrogen will be supplied to the site in the form of liquid nitrogen (stored in refrigerated storage tanks) for use in the membrane contactors. The membrane contactor system does not create a liquid concentrate stream, and the gases that are stripped are vented to the atmosphere. General design parameters of the membrane contactor system are shown in Table 5-18.

Table 5-18. Membrane Contactor System Design Parameters	
Number of Trains	6
Number of Membrane Vessels per Train	4
Design Flow per Train	0.5 MGD
Vessel Diameter/Length	14/28 inches
Estimated Pressure Drop	40-50 psi
Design Removal of DO	4 log (>99.99%)
Design Finished Water DO Concentration	< 0.001 mg/L
Design N ₂ Gaseous Feed	12 scfm
Nitrogen Use	618 lb/day
Nitrogen Storage	12 Tons
Number of Vacuum Pumps	2+1 Standby
Vacuum Pump Motor Size	20 HP

Along with DO removal, carbon dioxide will be removed through the membrane contactors. Since it is desirable to keep the carbon dioxide in the process stream to increase the alkalinity during stabilization, carbon dioxide can be added to the sweep gas with nitrogen to keep carbon dioxide in the purified water in solution. The benefits of this should be investigated during pilot testing. Carbon dioxide will be used during stabilization to increase the alkalinity; therefore, the addition of carbon dioxide to the sweep gas would only require a larger vaporizer and carbon dioxide gas regulator since there will already be storage for carbon dioxide on-site.

A second method of DO removal is through feeding of an oxygen scavenging chemical such as sodium bisulfide (NaHS), which also serves as a reducing agent to dechlorinate and reduce the ORP of the purified water. This process can be used in lieu of or in combination with membrane contactors to achieve high levels of DO removal.

5.5.3 Stabilization

Following the purification process, the water will be low in calcium, alkalinity, and pH, with a high amount of carbon dioxide. Calcium hydroxide is proposed as a means to increase the pH of the purified water while also adding calcium and alkalinity to the water. The calcium hydroxide will be added in quantities to increase the pH to approximately 7.7 to match the native groundwater. Based on preliminary water quality modeling, additional carbon dioxide will be added in conjunction with the calcium hydroxide to produce a stable water with respect to calcium carbonate precipitation potential at the desired pH. Calcium hydroxide could be added to the process upstream of the membrane contactors to reduce the corrosivity of the process water through the storage tank and recharge pumps while reducing the amount of carbon dioxide available to be removed through the membrane contactors. A second point of injection for the calcium hydroxide would be following the addition of carbon dioxide for final pH and alkalinity control prior to injection. The affect on adding calcium hydroxide prior to the membrane contactors (scaling and fouling potential) will be observed during pilot testing. Calcium hydroxide is available commercially in both powdered form and liquid slurry form. Due to the relatively small quantities to be added, it is proposed that a liquid slurry feed system be installed to provide a simpler feed system that is less maintenance intensive. General design parameters for the calcium hydroxide feed system are provided in Table 5-19 and general design parameters for the carbon dioxide feed system are provided in Table 5-20.

Table 5-19. Calcium Hydroxide Chemical Feed Design Parameters	
Chemical	Calcium Hydroxide (Ca(OH) ₂)
Solution Strength	35%
Specific Gravity	1.2
Dose – Range	50-100 mg/L
Dose – Average	62 mg/L
Average Use	1,551 lbs/day 4,432 lbs/day (Solution) 443 gallons/day (Solution) 13,286 gallons/30 days
Maximum Feed Rate	30 gph (Solution)
Storage	Two (2) 7,000 gallon bulk storage tank with mixers
Metering Pumps	2 + 2 standbys

Table 5-20. Carbon Dioxide Chemical Feed Design Parameters	
Chemical	Carbon Dioxide (CO ₂)
Dose - Range	0-85 mg/L
Dose – Average	65 mg/L
Average Use	1,626 lbs/day 68 lb/hr 48,780 lbs/30 days 24.4 tons/30 days
Maximum Feed Rate	2,127 lb/day 88.6 lb/hr
Storage	One (1) 26 ton storage tank
Feed Panels	1 + 1 standby

5.5.4 Additional Post Treatment

Following the oxygen removal, additional post treatment chemical addition includes sodium bisulfide and ferrous sulfate. The sodium bisulfide will act as a scavenger to remove any trace amounts of DO and chloramines in the water, reducing the oxidation reduction potential prior injection into the groundwater. Reducing the oxidation reduction potential will help keep the arsenic in its insoluble form in the groundwater formation. The addition of ferrous sulfate will add iron to the water to reduce the potential for iron pyrite to dissociate in the groundwater formation following injection of the purified water. The addition of ferrous sulfate will be limited to keep the iron concentration below the secondary MCL (0.3 mg/L). General design parameters for the sodium bisulfide feed system are provided in Table 5-21 and the General design parameters for the ferrous sulfate feed system are provided in Table 5-22.

Table 5-21. Sodium Bisulfide Chemical Feed Design Parameters	
Chemical	Sodium Bisulfide (NaHS)
Solution Strength	20%
Specific Gravity	1.152
Dose – Range	0 - 2 mg/L
Dose – Average	1 mg/L
Average Use	25.0 lbs/day 125 lbs/day (Solution) 13.0 gallons/day (Solution) 390 gallons/30 days
Maximum Feed Rate	1.1 gph (Solution)
Storage	Totes or Drums
Metering Pumps	1 + 1 standby

Table 5-22. Ferrous Sulfate Chemical Feed Design Parameters	
Chemical	Ferrous Sulfate ($\text{FeSO}_4 - 7\text{H}_2\text{O}$)
Solution Strength	25.5%
Specific Gravity	1.15 - 1.2
Dose – Range	0.1-0.3 mg/L (as Fe)
Dose – Average	0.2 mg/L (as Fe)
Average Use	5.0 lbs/day (as Fe) 97.6 lbs/day (Solution) 9.9 gallons/day (Solution) 297 gallons/30 days
Maximum Feed Rate	0.64 gph (Solution)
Storage	Totes or Drums
Metering Pumps	1 + 1 standby

The addition of a groundwater well from the Lower Zone A or Upper Zone B for the purposes of blending with the purified water prior to injection should also be considered. This would serve to remineralize the water to more closely mimic the native groundwater.

5.6 MODIFICATIONS TO EXISTING FACILITIES

5.6.1 Existing Site and Yard Piping

The NEWRF site is located in northeast Clearwater off of S.R. 580 at Rigsby Lane. The treatment facilities are spread out over a sprawling site which includes pretreatment facilities, the 4-Stage Bardenpho process, final clarifiers, effluent filters, chlorine contact and transfer pumps, reclaimed water storage, reject water holding tank, sludge thickening and digestion facilities, and ancillary facilities and buildings. There is a large

amount of yard piping on the treatment facilities site carrying the flow between treatment processes. The proposed purification treatment facilities for the GWR System are anticipated to be located on the north end of the site, while the transfer pumps that pump reclaimed water from the chlorine contact chamber to the reclaimed water system are located on the south end of the site. It is anticipated that approximately 1,800 linear feet of 16-inch reclaimed water pipe will be needed to supply the treated effluent to the proposed purification treatment facilities. The proposed pipeline will connect to the existing reclaimed water pipe downstream of the effluent flow meter, running north along the site service roads. In addition, it is anticipated that a new waste pumping station and approximately 1,500 linear feet of 16-inch piping will be required to transfer the combined flow from the MF backpulsing, strainer backwash, neutralized membrane cleaning solution, and the waste RO feed water back to the headworks of the NEWRF facility. The 16-inch waste line from the pump station is based on the need to size the pump station to pump all of the diverted flow back to the head of the plant in the event the RO feed water cannot be sent to the RO process.

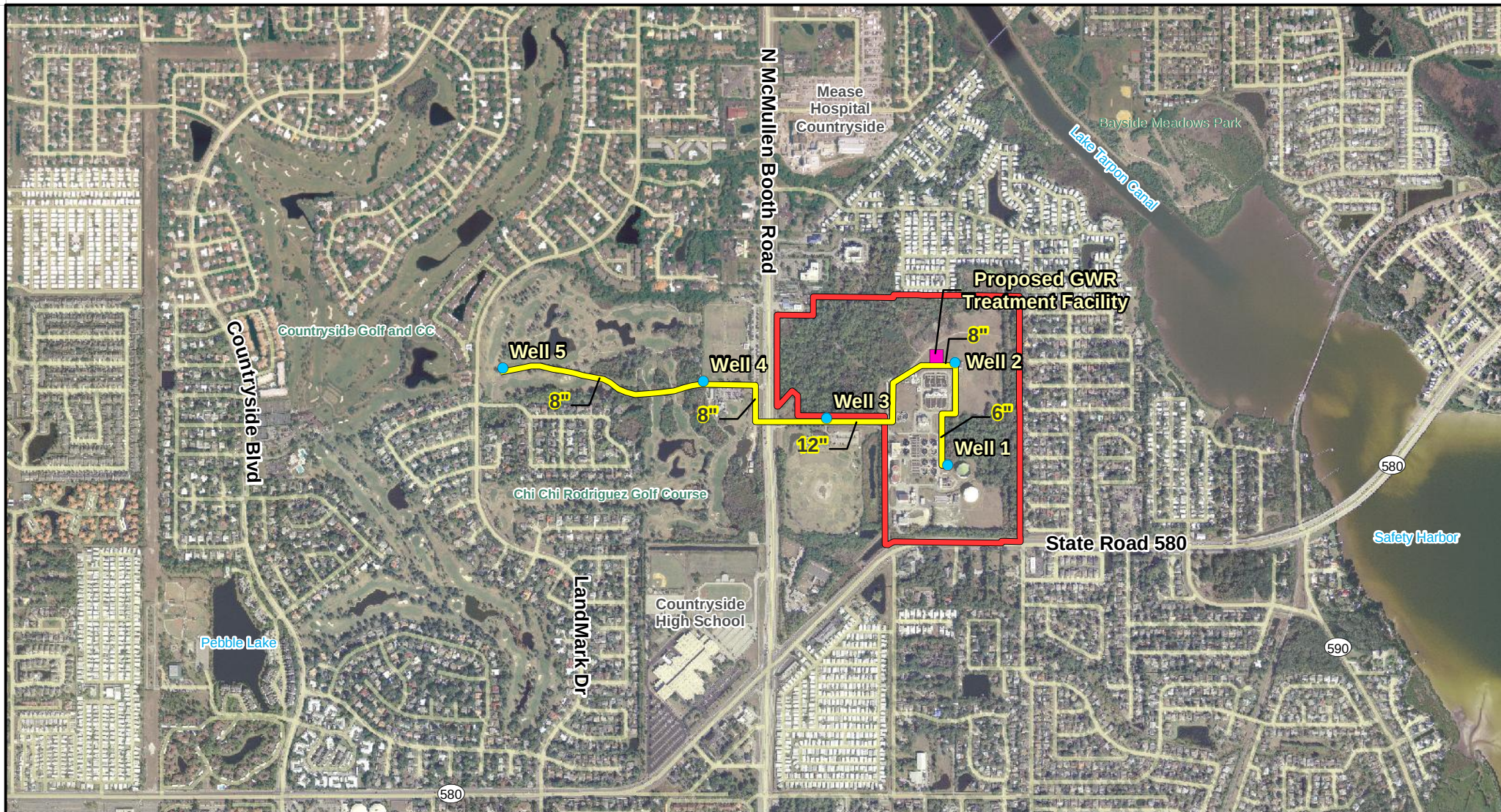
There are several buildings located on the existing treatment facility site, including a control building, multiple motor control center (MCC)/Control/Generator buildings, a disinfection building, a sludge dewatering building, a sludge processing building, a residuals building, and a blower building. It is anticipated that a new process building will be required for the MF, RO, and chemical facilities and another process building (or potentially a covered canopy area) will be required for the UV system and the DO removal system. It is anticipated that the clearwell, transfer pumps, carbon dioxide storage and waste pump station will be located outside near the process building. The new electrical and control facilities can be housed in or adjacent to the Oxidation Control Building on the northeast end of the site and the operation of the new treatment facilities will be tied into the existing operations.

A conceptual site plan is provided in Figure 5-3. The site plan shows the various components discussed and where they might be located at the existing site. The conceptual site plan also shows a 16-inch reclaimed water main supplying treated effluent to the purification treatment process and where it might tie into the existing reclaimed water main.

Figure 5-4 shows the proposed layout of the recharge wells and the proposed pipeline route. Two of the wells are shown on-site while the remaining wells are shown along the proposed pipeline route with two of these wells located on the nearby golf course. The pipe sizes shown are based on the 3 MGD of purified water with individual well capacities of 0.6 MGD. Flow to each well will be normalized using flow control valves. If the City anticipates that the purification treatment facilities could be expanded in the future, with additional recharge wells extending the proposed pipeline route downstream of Well No.5 along Landmark Drive, a 16-inch pipeline from the treatment facilities to Well No. 5 would allow for an additional 3 MGD of purified water to be delivered to future recharge wells.



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LEGEND

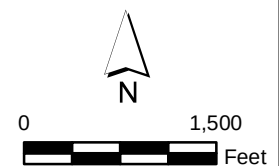
Source: WMD 2004 Aerial Imagery

CITY OF CLEARWATER GROUNDWATER REPLENISHMENT FEASIBILITY STUDY RECHARGE WELL LOCATION MAP

- NEWRF Site Boundary
- Proposed GWR Treatment Facility
- Recharge Wells
- Piping Route



FIGURE 5 - 4



5.6.2 Proposed Process Building

A conceptual building layout for the MF/RO process is provided in Figure 5-5. The layout shows the major MF and RO process equipment as well as room for chemical feed facilities and membrane cleaning systems. The conceptual layout shown is for a vacuum MF system. The actual layout for the MF system will vary depending on the type (vacuum or pressure driven) and manufacturer as MF equipment is not standardized among manufacturers.

5.6.3 Existing Electrical

The Oxidation Control Building is located on the northeast quadrant of the site near the proposed location for the groundwater replenishment purification treatment process. Power to the existing oxidation ditches is provided from the motor control center (MCC) in the Oxidation Control Building. A transformer outside of this building is utilized to step down from incoming utility power voltage to 480-volt, 3 phase power prior to the switchgear. An existing 600 kW auxiliary power generator is also located in the Oxidation Control Building with space for one (1) additional generator. The Oxidation Control Building has space set aside for future electrical equipment and is a likely location for future electrical service to the proposed purification treatment facilities.

5.6.4 Proposed Electrical

A new MCC, variable frequency drives (VFD's), an auxiliary power generator with switchgear, and SCADA I/O and control panels will be required to support the new groundwater replenishment purification treatment facilities. The additional generator and switchgear can be placed within the space available within the existing Oxidation Control Building in their respective locations marked "Future". To minimize motor lead lengths and other electrical wiring runs the MCC's, VFD's, and SCADA panels for the proposed process equipment would be located within a separate MCC/electrical room in the proposed process building. A new fuel storage tank can be located adjacent to the existing 6,000 gallon fuel tank to support the proposed auxiliary power generator. The new control panels shall interface with the plant-wide SCADA system to monitor and control required instrumentation and control signals. The existing transformer will need to be evaluated to determine if it can support the additional loads that are anticipated for the proposed treatment facilities. If the utility determines the transformer is capable then the existing conduits can be utilized to pull the necessary wires for the 2nd set of switchgear that would feed the process building. General design parameters of the electrical facilities are provided in Table 5-23.

Table 5-23. Electrical Facilities Design Parameters	
Primary Power	480 volt, 3 phase
Estimated Auxiliary Power Generator Size	900 kW
Diesel Fuel Storage Tank Size	3 days @ 80% load
Estimated MCC Bus Rating	1,600 Amp

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LEGEND

1

FERROUS SULFATE CHEMICAL STORAGE & FEED ROOM

2

SODIUM BISULFIDE CHEMICAL STORAGE & FEED ROOM

3

CALCIUM HYDROXIDE CHEMICAL FEED ROOM

4

CITRIC ACID CHEMICAL STORAGE & FEED ROOM

5

SODIUM BISULFATE CHEMICAL STORAGE & FEED ROOM

6

SODIUM HYDROXIDE CHEMICAL STORAGE & FEED ROOM

7

SODIUM HYPROCHLORITE CHEMICAL STORAGE & FEED ROOM

8

SCALE INHIBITOR CHEMICAL STORAGE & FEED ROOM

9

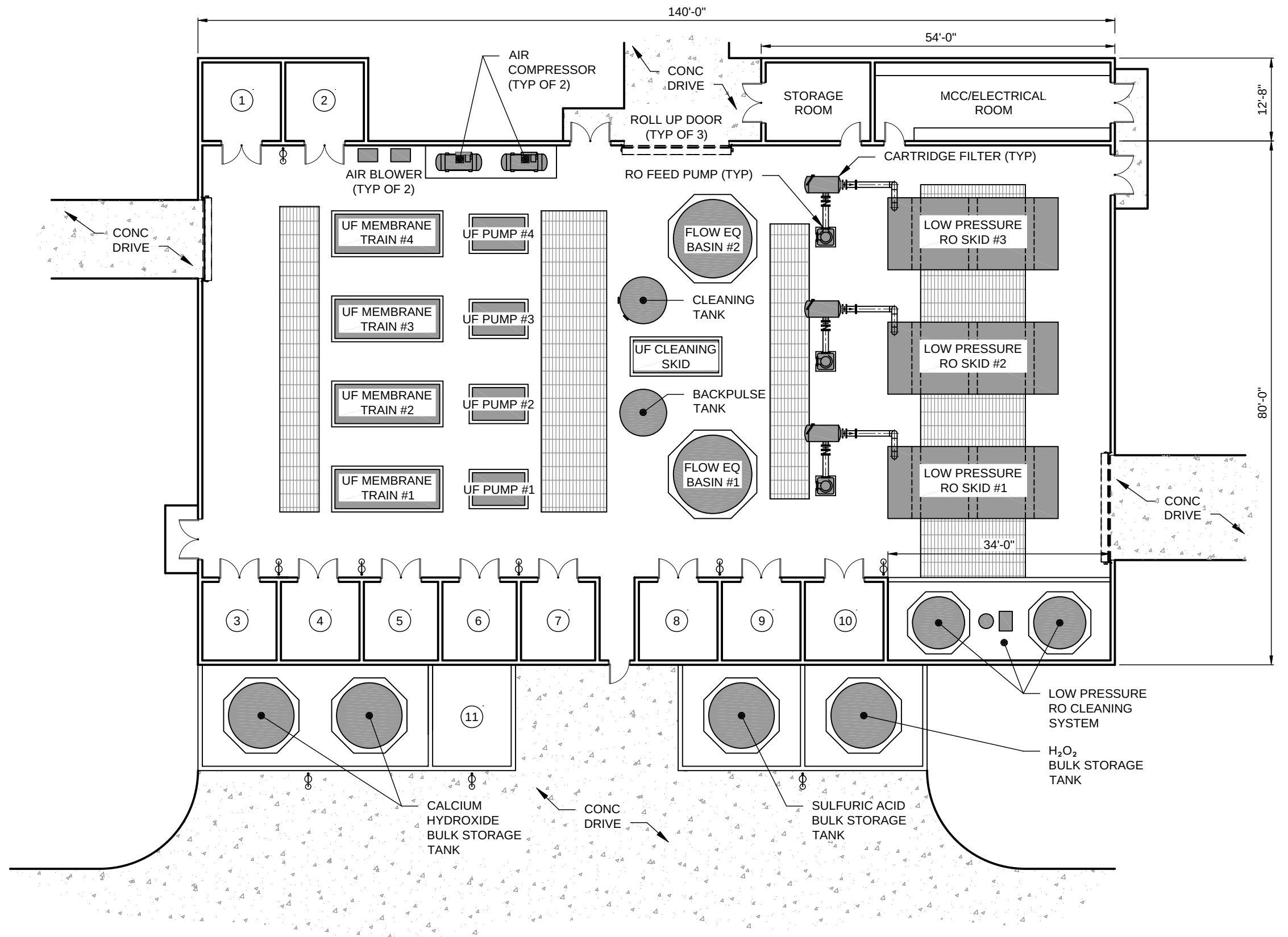
SULFURIC ACID CHEMICAL STORAGE & FEED ROOM

10

HYDROGEN PEROXIDE CHEMICAL STORAGE & FEED ROOM

11

AMMONIUM HYDROXIDE STORAGE & FEED AREA



PLAN
SCALE: NTS



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CITY OF CLEARWATER

GROUNDWATER REPLENISHMENT
FEASIBILITY STUDY

CONCEPTUAL
PROCESS BUILDING

Project No.: 200-41125-10002

Date: DECEMBER, 2010

Designed By: JCB

FIGURE

5-5

Copyright: Tetra Tech

5.6.5 Proposed Equipment List

A preliminary list of equipment based on the conceptual design discussed above is provided in Table 5-24. The equipment list is preliminary in nature and will be refined as the treatment processes are developed further, but are included to provide a basis for developing the cost opinions.

Table 5-24. Preliminary List of Equipment for GWR Facilities		
Equipment	Total Quantity¹	Capacity/Size (Each Unit)
Strainers	2	3.72 MGD
MF Process		
Membrane Trains	4	0.93 MGD (Avg. Permeate)
Blowers	2	TBD by MF Manufacturer
Compressors	2	TBD by MF Manufacturer
Permeate Pumps	5	1.24 MGD
Backpulse Pumps	2	1.24 MGD
CIP Tank	1	2,000 Gallons
Backpulse Tank	1	3,000 Gallons
Cleaning Pumps	2	0.72 MGD
RO Process		
EQ Tanks	2	12,000 Gallons
RO Feed Pumps	4	1.18 MGD
Cartridge Filters	3	1.18 MGD
Membrane Trains	3	1.0 MGD (Permeate)
Membrane Cleaning Pumps	2	540 GPM
Membrane Cleaning Tanks	2	2,500 Gallons
Membrane Cleaning Cartridge Filter	1	1.55 MGD
UV System Vessels	3	1.0 MGD
Purified Water Storage Tank	1	50,000 Gallons
Transfer (Recharge) Pumps	4	1.0 MGD
Membrane Contactors (DO Removal)		
Membrane Trains	6	0.5 MGD
Vacuum Pumps	3	20 HP
Recharge Wells	5	0.6 MGD
Chemical Metering Pumps		
Ammonium Hydroxide	2	< 1 HP
Citric Acid	2	< 1 HP
Sodium Bisulfite	2	< 1 HP
Sodium Hydroxide	2	< 1 HP
Sodium Hypochlorite	2	< 1 HP

Table 5-24. Preliminary List of Equipment for GWR Facilities		
Equipment	Total Quantity¹	Capacity/Size (Each Unit)
Scale Inhibitor	2	< 1 HP
Sulfuric Acid	2	< 1 HP
Hydrogen Peroxide	2	< 1 HP
Calcium Hydroxide	4	< 1 HP
Sodium Sulfide	2	< 1 HP
Ferrous Sulfate	2	< 1 HP
Chemical Storage²		
Sulfuric Acid Bulk Tank	1	3,500 Gallons
Sulfuric Acid Day Tank	1	100 Gallons
Hydrogen Peroxide Bulk Tank	1	3,000 Gallons
Hydrogen Peroxide Day Tank	1	50 Gallons
Calcium Hydroxide Bulk Tank (with mixer)	2	7,000 Gallons
Carbon Dioxide Storage Tank	1	26 Tons
Carbon Dioxide Feed Panels	2	90 lb/hr
Carbon Dioxide Makeup Water Pumps	2	90 gpm
Carbon Dioxide Vaporizer and Gas Regulator	1	20 lb/hr
Nitrogen Gas Regulator	2	12 scfm
Nitrogen Storage Tank	1	12 Tons

1. Includes any standbys or spares as discussed in the Sections above.

2. Chemical storage for membrane filtration cleaning chemicals to be in drums/totes.

6.0 PRELIMINARY COST OPINIONS

6.1 PRELIMINARY OPINION OF CAPITAL COST

The capital costs presented are conceptual in nature and based upon the estimates of design parameters discussed in Chapter 5. The design parameters were based on available literature, equipment manufacturer quotes, previous designs of similar processes, and a review of the historical water quality and water quality sampling that was done for this feasibility study. The preliminary cost opinion for the groundwater replenishment facilities presented in this feasibility study is provided in Table 6-1. The cost opinions represent the costs associated with design and construction of the GWR purification process, recharge wells and monitoring wells, pilot testing, and public participation program and may not be representative of the overall program costs due to the multi-phase approach to developing the GWR replenishment program.

6.2 PRELIMINARY OPINION OF OPERATING COSTS

The yearly operation and maintenance (O&M) costs presented are conceptual in nature and based upon the estimates of design parameters discussed above. Table 6-2 presents the preliminary opinion of O&M costs for the groundwater replenishment facilities discussed and are based on an average annual treated flow of 3 MGD, assuming that the treatment facilities operate continuously at or near capacity. Assumptions used in this analysis are a 5-year service life for the RO and Deoxygenation membranes, a 7-year service life for the MF membranes, a 6-month service life for the cartridge filters and a UV bulb service life of 12,000 hours. This analysis assumes full plant productivity (3 MGD of recharge water) with no significant downtime.

The conceptual cost opinion for the groundwater replenishment system is provided in Table 6-3, including capital, O&M and the present worth cost based on the capital and O&M cost opinions.

Table 6-1. Preliminary Capital Cost Opinion for GWR Facilities	
Process Building	\$1,600,000
UV and Membrane Contactor Building	\$300,000
Membrane Filtration System ¹	\$2,600,000
RO Pretreatment and High Pressure Pumping ²	\$630,000
RO Membrane and Cleaning System	\$1,900,000
Advanced Oxidation Process ³	\$1,100,000
Post-Treatment ⁴	\$810,000
Oxygen Removal System ⁵	\$1,100,000
Electrical, Instrumentation, and Standby Power (20%)	\$1,630,000
Site Work	\$400,000
Yard and Process Piping	\$600,000
Reclaimed Water Piping to GWR Treatment Facilities	\$190,000
Waste Pump Station and Piping	\$240,000
Transmission Piping to Recharge Wells ⁶	\$570,000
Recharge Wells and Monitoring Wells	\$1,040,000
Concentrate Disposal ⁷	\$4,000,000
Subtotal	\$18,710,000
Mobilization, Bonds, Permits, General Conditions (6%)	\$1,120,000
Contingency (20%)	\$3,740,000
Engineering, Permitting & Construction Admin. (15%)	\$2,810,000
Pilot Testing ⁸	\$1,200,000
Public Participation ⁹	\$1,000,000
Total	\$28,580,000

1. Includes strainers, membrane trains, clean-in-place system, backpulse tank and pumps, blowers, air compressors, and flow equalization tanks.
2. Includes sulfuric acid and scale inhibitor storage and feed systems, cartridge filters, and high pressure pumps
3. Includes UV reactors and hydrogen peroxide storage and feed system
4. Includes calcium hydroxide, sodium bisulfide, ferrous sulfate, and carbon dioxide feed systems, storage tank, and booster pumps
5. Includes nitrogen gas storage and feed system and membrane degasification system
6. The cost is based on pipe sizes for 3 MGD total flow for groundwater recharge. Should future expansion of the groundwater replenishment of up to an additional 3 MGD of purified water for recharge be expected, costs for this line item are estimated to be approximately \$660,000 more.
7. Assumes deep well injection disposal method with dual zone monitoring well, with the well located on the NEWRF site. The deep well injection cost is based on utilizing Zone C in the Avon Park Formation as the injection zone.
8. Pilot testing includes pilot design and construction and water sampling and assumes that the operation of the pilot will be performed by the City of Clearwater personnel.

Table 6-2. O&M Cost Opinion per Year for GWR Facilities	
Power ¹	\$430,000
Chemical Costs ²	\$320,000
Membrane & Cartridge Filter Replacement ³	\$220,000
UV Bulb Replacement	\$20,000
Maintenance & Supplies	\$150,000
Labor ⁴	\$400,000
WQ Monitoring	\$90,000
<i>Subtotal</i>	<i>\$1,630,000</i>
Contingency (20%)	\$330,000
Total	\$1,960,000

1. Based on \$0.10/kW-hr unit power cost.
2. Includes ammonium hydroxide, sulfuric acid, scale inhibitor, membrane filtration cleaning chemicals, hydrogen peroxide, calcium hydroxide, carbon dioxide, nitrogen, sodium bisulfide, and ferrous sulfate.
3. Includes MF, RO, and Deoxygenation Membranes
4. Based on the assumption that 28 additional operator man-hours will be required daily.
5. Includes preliminary estimate for regulatory WQ testing of GWR facility effluent and groundwater monitoring.

Table 6-3. Conceptual Cost Opinion Summary for GWR Facilities	
Capital Cost Opinion	\$28,580,000
O&M Cost Opinion	\$1,960,000/year
Capital Cost per Thousand Gallons ¹	\$2.28/kgal
O&M Cost per Thousand Gallons	\$1.79/kgal
Total Cost per Thousand Gallons ¹	\$4.07/kgal

1. Based on 20 years and 6%.

7.0 PILOT GWR PURIFICATION PILOT SYSTEM PRELIMINARY DESIGN

7.1 INTRODUCTION

The pilot GWR purification system preliminary design will outline the design criteria for pilot units of each of the proposed processes. The design criteria developed in this preliminary design will be the basis for the pilot system procurement documents to be developed in the next phase of the GWR Program. It is anticipated that the pilot GWR purification system will run for at least 12 months, and will meet the following objectives:

- Demonstrate the effectiveness of the selected treatment processes for Regulatory Compliance.
 - o Demonstrate ability to meet drinking water standards.
 - o Demonstrate ability to provide multiple barriers for viruses and pathogenic organisms.
 - o Collect and test samples for mutagenicity.
- Collect data relative to electrical power and chemical costs for verification of full scale treatment costs.
- Confirm the design criteria for the full-scale treatment processes.
- Evaluate effectiveness of differing post treatment process technologies and configurations.
 - o Evaluate membrane contactors for DO removal.
 - o Evaluate sodium bisulfide for residual DO scavenging and ORP adjustment.
 - o Evaluate benefits and drawbacks for calcium hydroxide feed upstream and downstream of membrane contactors.
 - o Evaluate optimal carbon dioxide feed points, including blending with nitrogen in the membrane contactor sweep gas.

The water supply for the pilot GWR purification system will be effluent from the NEWRF that supplies the City's reuse system. The process flows are based on a treated (finished water) capacity of approximately 12 gpm, an 85% recovery for the RO process, and a 95% recovery for the membrane filtration process.

7.2 WATER QUALITY

The feed water for the pilot GWR purification system will be the tertiary, disinfected effluent from the NEWRF. The reclaimed water was characterized in Chapter 2.0. A summary of the anticipated water quality based on the reclaimed water characterization is provided in Table 7-1. The water quality presented in Table 7-1 is the basis for the pilot system preliminary design.

7.3 PILOT SYSTEM PROCESS COMPONENTS

A process and instrumentation diagram (P&ID) for the proposed pilot GWR purification system is shown in Figures 7-1, 7-2 and 7-3. The design criteria for the various process components are discussed in the following subsections. The pilot system process includes the following components:

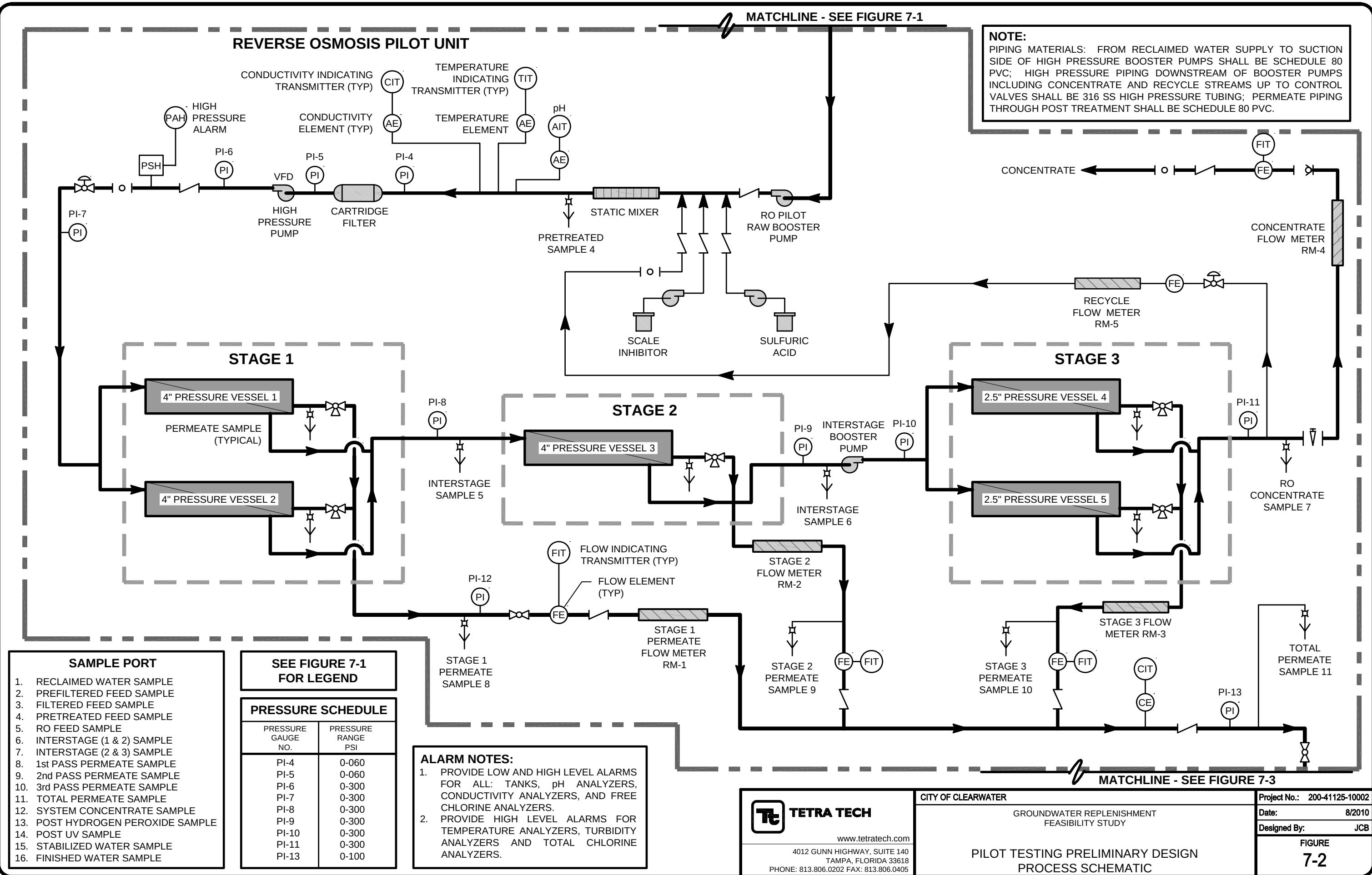
- Pretreatment
 - o Chemical
 - o Physical
- Membrane Filtration
- Reverse Osmosis (RO)
- Advanced Oxidation
- Post Treatment
 - o De-Oxygenation
 - o Dechlorination and ORP Adjustment
 - o Stabilization / Remineralization

Table 7-1 NEWRF Pilot System Feed Water Quality		
Parameter	Average (mg/L)	Range (mg/L)
pH (Unitless)	7.7	7.6 to 7.8
Temperature (°C)	28.3	26.4 to 29.7
Alkalinity (as HCO ₃ ⁻) ⁽²⁾	232	--
TDS	665	520 to 840
Calcium ⁽²⁾	110	--
Magnesium ⁽²⁾	15	--
Sodium	132	98 to 151
Potassium ⁽²⁾	11	--
Ammonia ⁽²⁾	<0.01 (BDL)	--
Sulfate	71	45 to 102
Chloride	219	190 to 277
Fluoride	0.46	0.43 to 0.48
Nitrate	2.2	0.2 to 3.4
Silica ⁽²⁾	23	--
Iron	0.034	0.026 to 0.048
Copper	0.0019	0.0013 to 0.0025
Zinc	0.015	0.012 to 0.018
Aluminum	-- ⁽¹⁾	BDL to 0.097
Arsenic	0.002	0.0011 to 0.0034
Color (CPU)	-- ⁽¹⁾	BDL to 10

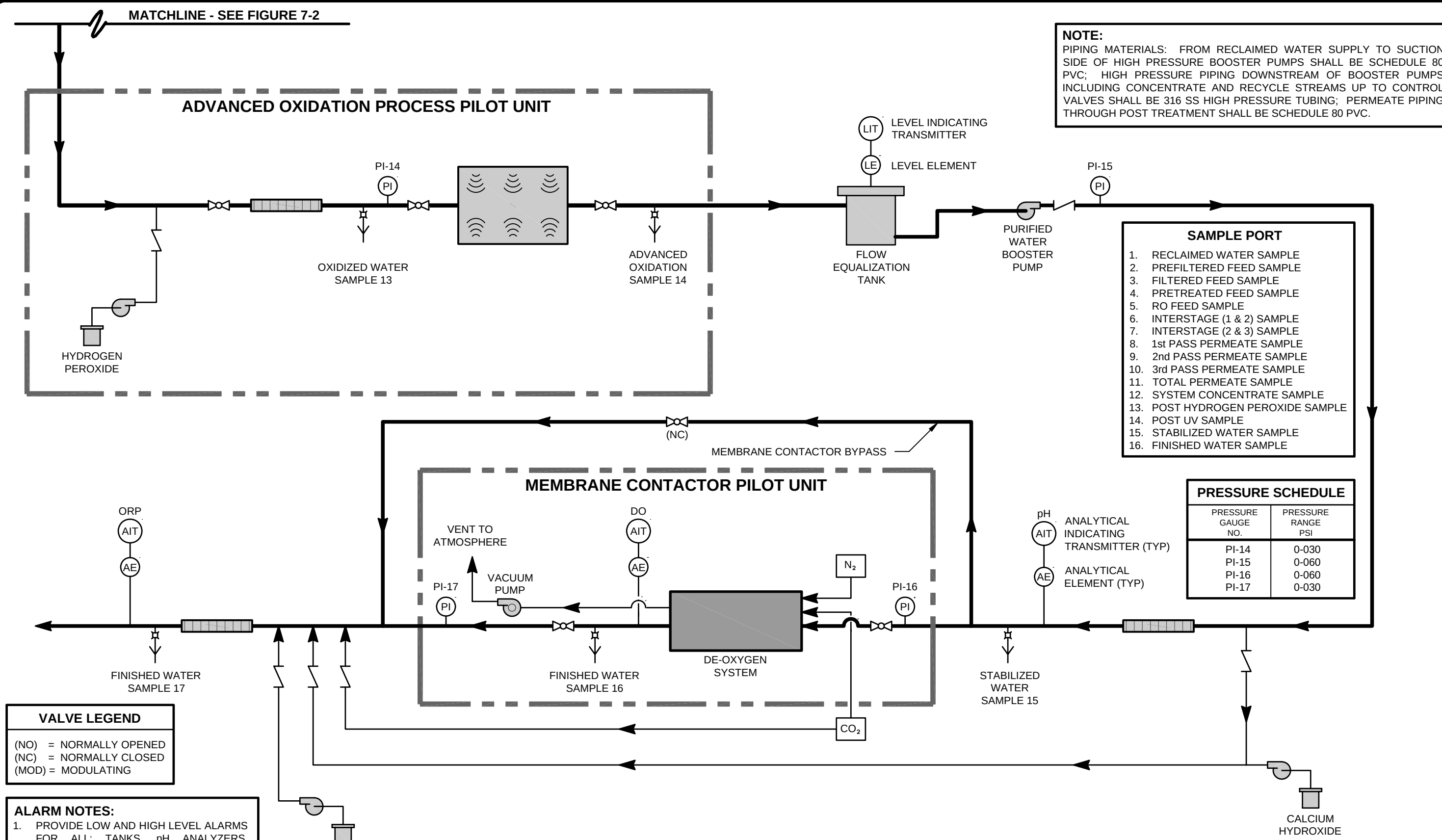
(1) Parameters measured below detection limits cannot be accurately averaged.

(2) Single sample collected.

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CITY OF CLEARWATER
GROUNDWATER REPLENISHMENT
FEASIBILITY STUDY

**PILOT TESTING PRELIMINARY DESIGN
PROCESS SCHEMATIC**

Project No.: 200-41125-10002
Date: 8/2010
Designed By: JCB

**FIGURE
7-3**

7.3.1 Pretreatment

Pretreatment processes are not typically furnished as part of the membrane filtration pilot system, however to control biofouling and protect the mechanical integrity of the hollow fiber membranes, both chemical and physical pretreatment are a necessary precaution. Equipment for the proposed pretreatment processes will be furnished and installed by the Contractor on the influent piping prior to the membrane filtration process.

7.3.1.1 Chemical Pretreatment

Chemical pretreatment will consist of the addition of ammonium hydroxide to combine with any free chlorine in the NEWRF effluent to form chloramines. Table 7-2 summarizes the design criteria for the ammonium hydroxide feed system. The ammonium hydroxide dosages are based on a chlorine residual of 0.8-2.0 mg/L of chlorine and a chlorine to ammonia (as nitrogen) ratio of 3.5-4.5. The effluent chlorine concentration at the City's NEWRF ranges from 2.0 mg/L to 3.6 mg/L based on historical data; however, the City adds sodium bisulfite to reduce the chlorine to approximately 1 mg/L in the reclaimed water.

Table 7-2 Membrane Filtration Pretreatment Ammonia Feed Design Criteria	
Chemical	Ammonium Hydroxide (NH ₄ OH)
Solution Strength	19% (as NH ₃)
Specific Gravity	0.93
Process Flow	32 gpm
Dose – Range	0.2 - 0.7 mg/L (as NH ₃)
Dose – Average	0.3 mg/L (as NH ₃)
Ammonia Feed - Range	0.4 - 1.4 lbs/day (solution) 0.002 – 0.008 gph (solution)
Ammonia Feed – Average	0.6 lbs/day (solution) 0.08 gallons/day (solution) 0.003 gph (solution)
Storage	Polyethylene Drum
Metering Pumps	
Quantity	1
Type	Peristaltic
Manufacturer	Watson-Marlow, or equal
Materials of Construction	316 stainless steel, PVC, polypropylene, PVDF, PTFE, EPDM

7.3.1.2 Physical Pretreatment

A strainer will be provided upstream of the membrane filtration process to protect the membrane elements from damage from abrasive materials such as sand or grit. These materials should be removed prior to membrane filtration in order to prevent clogging or puncturing of the hollow fiber membranes. The strainer will be in-line with a removable basket strainer for cleaning. A summary of the design criteria for the strainer is provided in Table 7-3.

Table 7-3 MF Pretreatment Strainer Design Criteria	
Number of Units	1
Unit Type	In-Line Basket Strainer
Nominal Rating	150 micron or 100 mesh
Design Capacity per Unit	32 gpm
Normal Pressure Drop	< 1 psi (clean strainer)
Materials of Construction	PVC Body with stainless steel mesh
Line Size	1-1/2" or 2"
Manufacturer	Hayward Flow Control Systems, or equal

7.3.2 Membrane Filtration Process

Membrane filtration pilot testing units are typically available in turn-key systems that include all equipment, piping, valves, tanks, and instrumentation and controls necessary for automated operation. A vacuum driven membrane filtration system is proposed for the pilot testing program. Vacuum driven systems incorporate open top tanks which contain multiple membrane elements arranged in cartridges in a parallel configuration. A summary of the general design criteria for the membrane filtration process is provided in Table 7-4.

Table 7-4 MF Membrane Train Design Criteria	
Number of Trains	1
Average Permeate Capacity	20 gpm
Permeate Recovery Rate	95%
Configuration	Vacuum driven, outside-in hollow fiber
Nominal pore size (maximum)	0.02 microns
Average Membrane Flux	25 gfd
Membrane Area	1,200 ft ²
Power Supply	480 V, 60 Hz, 3 Phase, 60 A
Major Process Components	Process Tank MF Permeate Pump Aeration Blower

	Backpulse Tank Air Compressor Cleaning System Instrumentation and Controls
Manufacturer	Siemens Memcor, GE Zenon, or equal
Pilot Unit Dimensions	7.5' x 4' x 7.5' (LxWxH)
Pilot Unit Footprint w/ Setbacks	14' x 10' (LxW)

The membranes will be submerged in the process tank. The process tank will be constructed of stainless steel and will be sized to handle fluctuations in the feed flow and contain the membrane modules. The MF permeate pump will create the necessary vacuum on the hollow fiber membranes to induce permeate flow and to provide the pressure required to fill the EQ tanks prior to the reverse osmosis process. The design criteria for the MF permeate pump is provided in Table 7-5.

Table 7-5 MF Permeate Pump Design Criteria	
Number of Pumps	1
Pump Type	Horizontal Centrifugal
Drive Type	Variable Speed
Pump Design Flow (minimum)	20 gpm
Pump Design TDH (minimum)	12 psi
Motor Size	2 Hp

Suspended solids are blocked by the hollow fiber membrane elements and are periodically backwashed from the system by reversing the permeate flow back through the membrane elements during backpulsing. The membrane filtration process will also allow for the use of aeration during backpulsing through the addition of air to the bottom of the membrane module. The air will be supplied by the aeration blower or compressed air system, which will also supply air during the chemical cleanings. The membrane manufacturer will be responsible for proper sizing of the aeration system. The membrane filtration process will be configured through the piping and valving such that the backpulse tanks will supply water to the MF permeate pump which will also serve as the pump for backpulse operations. The design criteria for the MF permeate pumps were provided in Table 7-5. The backpulse tank will be constructed of polyethylene with a minimum volume equal to the process tank.

The specific recommended cleaning chemicals can vary by the membrane manufacturer, however the two most common cleaning chemicals for membrane filtration to combat fouling and scaling include sodium hypochlorite and acid (citric acid is a common cleaning chemical for low pH cleanings). In general, the cleaning system will be capable of maintenance cleaning (at daily or weekly intervals) and recovery cleanings (dictated by membrane performance). The cleaning system will include the sodium hypochlorite and acid feed systems, a cleaning tank for mixing of the chemicals

and a cleaning pump to pump the cleaning solution to the process tank. During the pilot testing it is anticipated that spent cleaning solutions will be returned back to the NEWRF along with water from backpulse operations. To minimize upsets to the receiving wastewater treatment process, a return waste dilution tank will likely be necessary.

The membrane filtration system manufacturer will be responsible for providing a fully functioning membrane filtration process that will include the control system, instruments and automated valves required for the system to operate and monitor the process performance automatically. The minimum level of instrumentation required is shown in Figure 7-1 and includes flow meters, level elements for tanks, pressure and temperature indicators, and a turbidity analyzer. An air compressor will also be required to perform membrane integrity testing and operate any air-operated valves or equipment.

7.3.3 Reverse Osmosis Process

Following the Membrane Filtration Process, the primary treatment for the removal of dissolved solids and microconstituents will be performed in the reverse osmosis process. The RO process provides a high level of removal for salts, hardness, viruses, pesticides and most organic compounds. RO pilot testing units are typically available in portable, turn-key systems that include both chemical and physical pretreatment as well as supply, feed and interstage booster pumps.

7.3.3.1 Equalization Tank

Similar to the full scale process, the RO pilot unit is designed to operate at a fixed capacity, thus an EQ tank is necessary to even out fluctuations in flow from the membrane filtration pilot unit that occur on a regular basis due to back-pulse cycles and daily maintenance cleanings. The preliminary design configuration will include a 1,000 gallon polyethylene storage tank which would receive pretreated membrane filtration permeate, providing over 30 minutes of storage to balance flows between the membrane filtration and RO pilot units. The equalization tank will be located between the MF and RO pilot units, and installed directly on the concrete equipment pad that is constructed for the full system. To address potential excess capacity from the MF pilot unit, tank plumbing will include an overflow that returns flow to the NEWRF.

7.3.3.2 Reverse Osmosis Pretreatment

Following the membrane filtration process, the MF permeate water stored in the EQ tank will be boosted in pressure by a booster pump on the RO pilot unit, and then dosed with the RO pretreatment chemicals. The RO pilot unit will be equipped with the capability of adding acid and/or a scale inhibitor (antiscalant) to the RO process feed water at recommended chemical dosages based on the water quality projections for the RO feed water. The range of doses will provide enough flexibility to allow for optimization of the dosages during pilot operation.

Based on the estimated feed water quality parameters, an RO feed water pH of 6.5 would be needed to achieve a concentrate Langelier Saturation Index (LSI) of approximately +1.5. A scale inhibitor dose range of 1-5 mg/L provides a conservative range for sizing of these chemical feed systems. Design criteria for the RO chemical pretreatment chemical feed systems are provided in Table 7-6 and Table 7-7.

Table 7-6 Scale Inhibitor Design Criteria	
Chemical	Scale Inhibitor
Solution Strength	100%
Specific Gravity	1.1 - 1.3
Process Flow	15 gpm
Dose – Range	1-5 mg/L
Dose – Average	3 mg/L
Scale Inhibitor Feed - Range	0.18 – 0.9 lbs/day 0.018 – 0.09 gallons/day 0.001 – 0.004 gph
Scale Inhibitor Feed – Average	0.54 lbs/day 0.054 gallons/day 0.0023 gph
Storage	Polyethylene Drum
Metering Pumps Quantity Type Manufacturer	1 Peristaltic Watson-Marlow, or equal
Materials of Construction	PVC, polypropylene, PVDF, PTFE, EPDM

Table 7-7 Sulfuric Acid Design Criteria	
Chemical	Sulfuric Acid (H ₂ SO ₄)
Solution Strength	93%
Specific Gravity	1.83
Process Flow	15 gpm
Dose – Range	25-150 mg/L
Dose – Average	75 mg/L
Sulfuric Acid Feed – Range	9 - 60 lbs/day (solution) 0.6 - 4 gallons/day (solution) 0.02 – 0.16 gph (solution)

Sulfuric Acid Feed – Average	29 lbs/day (solution) 1.9 gallons/day (solution) 0.08 gph (solution)
Storage	Polyethylene Drum
Metering Pumps Quantity Type Manufacturer	1 Peristaltic Watson-Marlow, or equal
Materials of Construction	PVDF, PTFE, viton

Following the addition of pretreatment chemicals the water will be filtered using cartridge filters as a last level of protection to remove particulates which could damage and/or blind the membrane elements. Design criteria for the cartridge filtration units are provided in Table 7-8.

Table 7-8 Cartridge Filter Design Criteria	
Number of Units	1
Cartridge Filter Orientation	Vertical
Cartridge Filter Type	String Wound Polypropylene
Cartridge Filter Rating	5 micron
Hydraulic Loading Rate	4 gpm per 10" length
Filter Vessel Design Flow	20 gpm
Filter Vessel Design Pressure	100 psi
Materials of Construction	316 stainless steel housing

7.3.3.3 Reverse Osmosis Feed Pump

The RO high pressure feed pump will raise the pressure following pretreatment up to the pressure required in the reverse osmosis membrane pressure vessels. Membrane projections indicate a feed pressure of approximately 130 psi will be required, however experience with treating similar waters using RO has indicated that the actual feed pressure required by these systems is in the range of 175-200 psi after the first few months of operation. In order to provide enough feed pressure for the membranes and to account for head losses through the piping and cartridge filters, the proposed pump head is 225 psi. The design criteria for the RO feed pump is provided in Table 7-9.

Table 7-9 RO Feed Pump Design Criteria	
Number of Pumps	1
Pump Type	Vertical Multistage Centrifugal
Drive Type	Variable Speed
Pump Design Flow	15 gpm
Pump Design TDH	225 psi
Motor Size	5 HP
Materials of Construction	316 stainless steel
Manufacturer	Grundfos, or equal

7.3.3.4 Reverse Osmosis Treatment

The typical RO membrane configuration for this application consists of a 2 or 3-stage process where the concentrate from the first membrane stage is fed to a second and then a third bank of membranes to increase system recovery. The RO pilot unit will be designed to operate as a scaled down version of a full scale RO system, utilizing 4-inch and 2.5-inch membrane elements in lieu of the 8-inch elements used on a full scale system. The membrane elements are housed in fiberglass pressure vessels that are arranged in parallel with common feed water, product water (permeate), and concentrate water piping. The proposed RO pilot unit will utilize both 4-inch and 2.5-inch diameter pressure vessels and membrane elements in order to provide a 3-stage system while also minimizing flow requirements. Due to limitations in pressure vessel length in these sizes, two pressure vessels will be connected in series to allow pilot testing of 6-8 spiral wound membrane elements in series for the 1st and 2nd stages (4-inch diameter) and three pressure vessels will be connected in series to allow pilot testing of 6 spiral wound membrane elements in series for the 3rd stage (2.5-inch diameter).

The RO pilot unit will operate at a fixed capacity. Preliminary runs of membrane performance projections indicate that a 3-stage, 4:2:1 array with 6 membrane elements in series for each stage will provide the most reliable performance at the target recovery rate of 85%. For the proposed pilot unit, a 2:1:2 array using 4-inch diameter elements in the first and second stages and 2.5-inch diameter elements in the 3rd stage, will provide approximately the same ratio of membrane area as the 4:2:1 array modeled in the membrane projections. Due to the additional concentrate pressure drop that is added by the third stage, use of an interstage booster pump and/or permeate backpressure valve is warranted on the pilot unit to allow for balancing of permeate flux between the stages of the RO process. Each stage of pressure vessels will be configured to allow permeate sampling and isolation for maintenance and cleaning. Preliminary design parameters for the RO pilot unit are provided in Table 7-10.

Table 7-10 RO Membrane Pilot Unit Design Parameters	
Number of Stages	3
Permeate Recovery	85%
Design Permeate Flux	10.5 gfd
Permeate Capacity	12.5 gpm
Concentrate Capacity	2.2 gpm
Pressure Vessel Diameter	4 inches (1 st and 2 nd stages) 2.5 inches (3 rd stage)
Number of Pressure Vessels	12
Stage 1	4 (4-inch)
Stage 2	2 (4-inch)
Stage 3	6 (2.5-inch)
Membrane Elements per Pressure Vessel ¹	3 (4-inch) 2 (2.5-inch)
Membrane Element Area	78 sf (4 inch elements) 25 sf (2.5 inch elements)
Membrane Manufacturers	FilmTec, Hydranautics
Power Supply	460 V, 60 Hz, 3 Phase, 80 A
Major Process Components	RW Booster Pump Cartridge Filter Vessel Acid Feed System Antiscalant Feed System RO Feed Pump Interstage Booster Pump Pressure Vessels Motor Starters and Drives Instrumentation and Controls
Pilot Unit Dimensions	15' x 4' x 6' (LxWxH)
RO Pilot Unit Manufacturers	Harn RO, H2O Innovations, Aerex Industries

1. For flexibility, the recommended system will be configured to allow pilot testing of an alternate 2-stage system, with the 1st and 2nd stage pressure vessels configured with two (2) four-element vessels in series. This will allow pilot testing flexibility of 6-8 elements in series per stage.

Due to a higher potential for biofouling when treating this supply source and the length of the pilot testing program, the need for membrane cleaning of the RO system is anticipated during the pilot testing period. Cleaning of the RO membranes is less frequent than that required for the MF membranes, and can be reasonably predicted through use of membrane data normalization software. When cleaning does become necessary, the process must be taken offline and manually cleaned. Depending on the type of foulant encountered, RO membrane cleaning can often be more complex than membrane filtration system cleaning.

Due to the complexity and irregularity of cleaning it is doubtful that there will be a need for a permanently installed cleaning system. Many of reverse osmosis equipment manufacturers (ROEMs) who manufacture RO pilot units can provide membrane cleaning services through use of portable cleaning skids and experienced technicians for a fraction of the cost of purchasing and installing a membrane cleaning system. Therefore it is recommended that the RO pilot unit procurement documents include a requirement for membrane cleaning services within a specific response period for up to four (4) membrane cleaning events over the duration of the pilot testing period. A unit cost for additional cleaning events will also be required with the system bid items, along with a bid line item for membrane element replacement and membrane autopsy.

7.3.4 Advanced Oxidation Process

The final step in the purification process is the advanced oxidation process consisting of ultraviolet (UV) light and hydrogen peroxide in a combined treatment process. Hydrogen peroxide (H_2O_2) is a strong oxidant that is often used in wastewater collection and treatment systems for controlling sulfide and organic related odors. When combined with UV light, hydrogen peroxide is effective at breaking down complex organic compounds that are not completely removed through the RO process, including NDMA and other low molecular weight organic compounds.

The combined hydrogen peroxide/UV AOP pilot system will be designed to provide a 1.2 log removal of NDMA and a 0.5 log removal of 1,4 Dioxane, based on the design criteria used at the OCWD GWR System and other similar pilot testing projects in Florida. Preliminary sampling of the NEWRF reclaimed water for NDMA reported a concentration of 3.5 ng/L with a laboratory detection limit of 1.9 ng/L. Sampling for 1,4 Dioxane reported a concentration below laboratory detection limits of 1.0 ug/L. Currently there is no drinking water MCL for either of these constituents, however the California Department of Public Health has established a drinking water notification level of 10 ng/L for NDMA and 3 ug/L for 1,4 Dioxane. Based upon the design removal of the proposed pilot system, influent concentrations of approximately 150 ng/L and 9 ug/L for NDMA and 1,4 Dioxane, respectively, could be treated to below the California reporting limits. Since the preliminary sampling of the reclaimed water indicated concentrations of these constituents below the California reporting limits, regular quarterly spike testing is proposed during the 1 year operation period to demonstrate the treatment effectiveness of the purification pilot system.

Unlike the MF and RO pilot units, the proposed pilot equipment for the AOP process is typically furnished as separate components that require final installation and connection by the Contractor. The equipment components include a static mixer, a drum mounted hydrogen peroxide metering pump, a UV reactor vessel, and a control panel.

Hydrogen peroxide is a liquid chemical that will be supplied as 27% or 35% solution in drum containers. The hydrogen peroxide feed system will consist of chemical storage drums or totes, and a peristaltic metering pump. Due to chemical characteristics,

storage away from heat and sun exposure is required. General design parameters for the hydrogen peroxide system are provided in Table 7-11. The required chemical dose will be confirmed during pilot testing.

Table 7-11 Hydrogen Peroxide Chemical Feed Design Parameters	
Chemical	Hydrogen Peroxide (H ₂ O ₂)
Solution Strength	27%
Specific Gravity	1.10 @ 20°C
Process Flow	12.5 gpm
Dose – Range	10-15 mg/L
Dose – Average	12 mg/L (H ₂ O ₂)
Average Daily Demand	1.8 lbs/day (H ₂ O ₂) 6.7 lbs/day (Solution) 0.73 gallons/day (Solution)
Storage	55 gallon polyethylene drums
Metering Pumps	
Quantity	1
Type	Peristaltic
Manufacturer	Watson-Marlow, or equal
Materials of Construction	316 stainless steel, PVC, Viton

The UV process used for advanced oxidation consists of low pressure, high output lamps. The UV reactor typically would include a stainless steel vessel with flanged inlet and outlet connections. General design parameters for the UV system and are provided in Table 7-12.

Table 7-12 UV Process Design Parameters	
Manufacturer	Trojan Technologies
Pilot Unit Model	Trojan UVPhox Model B08
Number of Reactors	1
Process Flow	10-15 gpm
Lamp Type	Low Pressure, High Output
Number and Arrangement of Lamps	8, Parallel Flow
Reaction Chamber	Stainless Steel
Piping Connections	6-inch, 150 lb. ANSI flange
Electrical Requirements	1.9 kVA, 208-240V, 2-phase, 2-Wire + GND, 60 Hz
Targeted NDMA Removal	1.2-log (94%)
Targeted 1,4 Dioxane Removal	0.5-log (68%)
AOP Equipment Footprint	8' x 8' (LxW)

A photocatalytic process known as Photo-Cat, offered by Purifics ES Inc., is an alternate treatment technology in place of the hydrogen peroxide/UV AOP process described above. This process is certified to ANSI/NSF Standard 61, and utilizes titanium dioxide, UV, and ceramic membranes which recapture and recycle the titanium

dioxide catalyst. One advantage of this process is that it does not require chemical feed such as hydrogen peroxide, but instead utilizes DO that is already present in the RO permeate. Although this technology has been around for some time, it is relatively new to the municipal marketplace, which may incentivize the cost for lease of a pilot testing unit if it is approved for inclusion in the pilot testing program. The estimated capacity of a pilot unit for this technology is approximately 5 gpm.

7.3.5 Post Treatment

Additional treatment processes are proposed in the full scale system to produce a water of such quality that does not cause degradation of water quality in the aquifer as a result of recharge activities. Pilot testing requirements within Chapter 62-610 F.A.C. provides guidance with respect to testing primary treatment processes but do not directly address testing of additional treatment processes that may be necessary to provide fluid compatibility under a ground water recharge project. Therefore, for this project the proposed post treatment processes for pilot testing will include systems where operational data is deemed valuable for predicting performance and costs of the full scale system, which include:

- Dissolved Oxygen Removal
- Dechlorination / ORP Reduction
- Stabilization / Remineralization

Addition of carbon dioxide (CO₂) and calcium hydroxide to the recharge water will allow adjustment of the degree of calcium carbonate saturation. In the full scale treatment system these chemical additions will most likely be accomplished via conventional methods. This treatment can be simulated with reasonable accuracy through bench scale testing, however pilot scale testing is expected to be beneficial in determining the interactions between post treatment processes.

To achieve finished water quality that is compatible with the water quality and geology in the receiving aquifer, there may be other chemical adjustments that are necessary. For example, higher levels of sulfates and iron in the purified water may be deemed beneficial for achieving highly compatible finished water. The geochemical modeling and evaluation of these parameters is on-going and is expected to continue throughout the initial phases of the project, including the pilot testing phase. Although a solution is ultimately expected, the unavailability of results from these efforts deems impractical any effort to pilot test these chemical additions. Therefore, bench scale testing is considered a more practical method for evaluating the doses and interactions of these chemical additives.

7.3.5.1 Dissolved Oxygen Removal

The proposed pilot testing operations will include comparison of two processes for removal of dissolved oxygen (DO) from the purified water to match the nearly anaerobic conditions that exist in the aquifer.

The primary technology for removing dissolved oxygen from water at extremely high efficiencies is by membrane contactors. Membrane contactors incorporate hollow fiber membrane elements that are impermeable to water, but permeable to gases, where a vacuum pump is used as a driving force to pull the gases through the membrane fibers. For high DO removal efficiencies, nitrogen (N₂) gas is often added to the membrane contactor vacuum supply as a sweep gas to assist in removal.

Membrane contactor technology is currently being evaluated for DO removal performance for multiple aquifer storage and recovery (ASR) projects within Florida. Through these projects inorganic fouling, either from upstream chemical addition or from dissolved constituents in the source water, has been attributed to most of the membrane fouling that has been observed. Additional maintenance in the form of membrane cleaning is a direct result of membrane fouling, which is a significant consideration when evaluating the feasibility of these systems. To prevent particulate fouling, the preferred location of membrane contactors is directly downstream of an RO membrane process. For optimal conversion of carbon dioxide to bicarbonate in the purified water the initial pilot testing phase will consist of AOP treatment and calcium hydroxide addition just prior to the membrane contactor treatment.

Once the fouling potential is determined for the configuration described above, an alternate phase of pilot testing is recommended to evaluate the dosing of calcium hydroxide downstream of the membrane contactor system, which would likely reduce the potential for inorganic fouling. Under a conventional design using nitrogen sweep gas, this alternative would also result in removal of approximately 80% of dissolved carbon dioxide from the purified water, which would then need to be added back prior to the calcium addition. To reduce or prevent its removal the pilot unit is recommended to include a feature to allow the use of carbon dioxide as a sweep gas, which can be fed at varying feed rates along with nitrogen gas. Based on the ratio of N₂ to CO₂ in the sweep gas, it is anticipated that dissolved carbon dioxide concentrations can be either maintained or increased through the membrane contactor process, which may eliminate the need for supplemental carbon dioxide injection downstream. Therefore, for the pilot testing it is recommended to supply both nitrogen gas and carbon dioxide gas in reusable cylinders to evaluate these alternatives.

A second method of DO removal is through feeding of an oxygen scavenging chemical such as sodium bisulfide (NaHS), which also serves as a reducing

agent to dechlorinate and reduce the ORP of the purified water. This process can be used in lieu of or in combination with membrane contactors to achieve high levels of DO removal. The proposed pilot unit will evaluate use of sodium bisulfide in both configurations for removal of all DO as well as use of sodium bisulfide for DO removal polishing downstream of a membrane contactor system. Table 7-13 provides a general description for three (3) pilot testing alternatives for DO removal optimization. In addition to these alternatives, sub-alternatives may be evaluated to determine the optimal dosing of carbon dioxide to benefit the proposed downstream alkalinity adjustment and re-mineralization processes, as described above.

Table 7-13 Dissolved Oxygen Removal Pilot Testing Alternatives			
Testing Alternative	A	B	C
Membrane Contactor DO Removal	4-log	2-log	n/a
Effluent DO	<1 ppb	<100 ppb	n/a
Sweep Gas	N ₂ and/or CO ₂	N ₂ and/or CO ₂	n/a
Sodium Bisulfide DO Removal	Dechlorination	Polishing	Full
Estimated Dose	0.5 mg/L	2.5 mg/L	5 mg/L

The membrane contactor pilot unit will be capable of configuration for both 4-log (99.99%) and 2-log (99%) removal of DO to allow the potential testing regimes noted above. General design parameters of the membrane contactor system are shown in Table 7-14.

Table 7-14 Membrane Contactor System Design Parameters	
Number of Trains	1
Number of Membrane Vessels per Train	4 (1 per stage)
Design Flow per Train	5 gpm
Vessel Diameter/Length	2.5 inches
Estimated Pressure Drop	40-50 psi
Design Removal of DO	4 log (>99.99%)
Design N ₂ Gaseous Feed	0.5 scfm
Number of Vacuum Pumps	1
Vacuum Pump Motor Size	2 Hp
Design Finished Water DO Concentration	< 0.1 mg/L
Equipment Footprint	10' x 8' (LxW)

7.3.5.2 Dechlorination / ORP Reduction

As previously mentioned pilot testing of sodium bisulfide (NaHS) addition is anticipated as an alternative for DO removal. Dosing of sodium bisulfide will also serve as a reducing agent for dechlorination and reduction of the oxidation reduction potential (ORP) of the purified water, which are additional parameters of concern with respect to potential for metals mobilization. Fluid compatibility of

the purified water is improved by assimilating the ORP of the native water in the aquifer. General design parameters for the sodium bisulfide system are based on desktop chemical analysis and are provided in Table 7-15. Actual dosing criteria would be determined through pilot testing.

Table 7-15 Sodium Bisulfide Chemical Feed Design Parameters	
Chemical	Sodium Bisulfide (NaHS)
Solution Strength	5-10%
Specific Gravity	1.1
Process Flow	12.5 gpm
Dose – Range	0.5-5.0 mg/L
Dose – Average	2.5 mg/L (NaHS)
Average Daily Demand	0.38 lbs/day (NaHS) 3.8 lbs/day (Solution) 0.41 gallons/day (Solution)
Storage	55 gallon polyethylene drums
Metering Pumps	
Quantity	1
Type	Peristaltic
Manufacturer	Watson-Marlow, or equal
Materials of Construction	PVDF, PVC, EPDM

7.3.5.3 Stabilization / Remineralization

As previously mentioned pilot testing of carbon dioxide and calcium hydroxide addition is proposed to identify interactions between various chemical feed operations that may occur within the full scale system, and to evaluate alternate locations for placement of the chemical injectors within the series of post treatment processes. Since these chemical additions are well understood and widely used in full scale water treatment facilities, a conservative period of 6 months has been assumed for conducting this portion of the pilot testing.

Within this period, separate phases of the pilot testing will be apportioned to evaluate various locations and methods for feeding carbon dioxide and calcium hydroxide. These alternate configurations will primarily focus on optimizing the membrane contactor system reliability and minimizing the consumption of these chemicals.

Calcium hydroxide is commercially available as a fine slurry product, and therefore a small drum or tote-mounted mixer will be required to maintain a consistent solution. Chemical dosing will be flow paced using a metering pump. Carbon dioxide gas is commercially available in pressurized cylinders that are connected to pressure reducing valves and gas flow rate indicator/control devices. Due to the required feed equipment, the carbon dioxide system will likely require manual feed rate control and adjustment by the pilot system operator. General design parameters for the calcium hydroxide and carbon

dioxide feed systems are based on desktop chemical analysis and are provided in Table 7-16 and Table 7-17 respectively. Actual dosing criteria would be determined through pilot testing.

Table 7-16 Calcium Hydroxide Chemical Feed Design Parameters	
Chemical	Calcium Hydroxide (Ca(OH) ₂)
Solution Strength	35% (minimum)
Specific Gravity	1.20
Process Flow	12.5 gpm
Dose – Range	4-75 mg/L
Dose – Average	62 mg/L (Ca(OH) ₂)
Average Daily Demand	9.3 lbs/day (Ca(OH) ₂) 26.7 lbs/day (Solution) 2.7 gallons/day (Solution)
Storage	55 gallon polyethylene drums
Chemical Feed/Control	
Quantity	2
Type	Peristaltic
Manufacturer	Watson-Marlow, or equal
Materials of Construction	PVDF, PVC, EPDM

Table 7-17 Carbon Dioxide Chemical Feed Design Parameters	
Chemical	Carbon Dioxide (CO ₂)
Process Flow	12.5 gpm
Dose – Range	0-70 mg/L
Dose – Average	45 mg/L
Average Daily Demand	6.8 lbs/day
Storage	150 lb gas cylinders
Feed Rate Control	
Quantity	2
Type	Gas Feed Control Valve
Materials of Construction	316 stainless steel

7.4 ELECTRICAL AND INSTRUMENTATION BASIS OF DESIGN

Electrical power for the groundwater replenishment purification treatment process pilot units will be obtained from the NEWRF electrical system. Details of the power source will be specific to the location of the pilot system.

Due to the complexity of the proposed treatment processes, a manually operated system is considered impractical as it would require the full time attention of an operator. In order to operate the pilot system continuously with a minimal burden to the NEWRF operations staff, some level of automation will be required. In consideration of this necessity, considerable effort will be given to ensuring the controls and automation associated with the pilot system is adequate to protect the equipment and safety of the operators while also not being overly complicated.

The controls for the pilot system will be accessible directly on the control panels for each pilot unit. Connection of the purification pilot system SCADA and controls with the NEWRF SCADA system is not necessary or recommended, however the pilot system will be configured to allow remote monitoring of the pilot system operation through wireless data cards. In addition to these monitoring capabilities, alarm contacts will be provided on the pilot system to notify plant operators if an urgent condition occurs that requires their attention.

General design parameters of the electrical facilities are provided in Table 7-18.

Table 7-18 Pilot System Major Electrical Load Design Parameters	
MF Pilot Unit Electrical Feed	480 volt, 3 phase, 60 amps
RO Pilot Unit Electrical Feed	480 volt, 3 phase, 80 amps
AOP Pilot Unit Electrical Feed	208/240 volt, 2 phase, 15 amps
Membrane Contactor Pilot Unit Electrical Feed	480 volt, 3 phase, 30 amps

7.5 SITE AND YARD PIPING BASIS OF DESIGN

The pilot system will be located at the NEWRF site, which is located in northeast Clearwater off of S.R. 580 along Rigsby Lane. The main criteria in locating the pilot system at the NEWRF site are as follows:

1. Available Area (Footprint)
2. Proximity to supply water and discharge locations (minimum 35 gpm)
3. Proximity to electrical power feed for equipment (3 phase, 460 V power)
4. Ease of access for operators and the visiting public

Two (2) potential locations for the pilot system were identified based on these criteria are shown on Figure 7-4. The first location would be south of the chlorine contact basin, adjacent to the effluent flushing pump station. The power feed for this location would likely come from the MCC building that is east of the effluent clearwell. The feed water supply for this location will likely originate from an 8-inch effluent line that runs alongside the road between the effluent clearwell and the effluent water pumps. This option assumes that the pilot system effluent will be of good quality and can be returned to the head of the chlorine contact chamber. This location is also easily accessible by entering the south entrance gate.

The second location would be near the north entrance to the NEWRF, just west of the main control building. The power feed for this location would likely come from the MCC building near the oxidation ditches. The feed water supply for this location will likely originate from a 6-inch effluent line that proceeds west from the oxidation ditches. This option assumes that the pilot system effluent can be returned to the headworks of the WRF, at the influent structure or a nearby manhole. This location is also easily accessible by entering the north entrance gate.

7.6 PRELIMINARY OPINION OF PROBABLE COSTS

The conceptual cost opinion for the groundwater replenishment pilot system is provided in Table 7-19, based on a single contract procurement method with a prequalified general contractor, prequalified control system integrator, and pre-negotiated quotes for major process equipment leases.

Table 7-19 Purification Pilot System Preliminary Opinion of Probable Construction Costs¹	
Description	Costs
General Requirements	\$50,000
Mobilization & Demobilization	\$10,000
Site Preparation	\$12,000
Yard & Process Piping	\$30,000
Equipment Pad	\$16,000
Tent/Canopy	\$12,000
MF Pilot Unit (12 mo. Lease)	\$95,000
RO Pilot Unit (12 mo. Lease)	\$125,000
AOP Pilot Unit (12 mo. Lease)	\$50,000
Membrane Contactor Pilot Unit (12 mo. Lease)	\$60,000
Sodium Bisulfide Feed System	\$8,000
Calcium Hydroxide Feed System	\$12,000
Carbon Dioxide Feed System	\$12,000
Electrical	\$18,000
Control System Integration	\$60,000
Restoration	\$15,000
<i>Subtotal</i>	<i>\$585,000</i>
Contingency	\$117,000
Total	\$702,000

1. Conceptual costs for equipment lease or purchase and installation. Costs do not do not include pilot system operation and maintenance costs, including chemicals, electric power, membrane replacement, and membrane cleaning. Pilot program sampling, water quality analysis, and engineering services are also not included.

7.7 PROCUREMENT

Procurement documents for the pilot system will consist of contract documents associated with a typical municipal treatment facility that will fall under the responsibility of a General Contractor (Contractor) to deliver the completed work. Due to the specialized nature of this project, only Contractors possessing previous membrane treatment facility experience will be deemed as qualified to perform this work.

In terms of the packaged pilot units, wherever possible, multiple equipment manufacturers with comparable treatment processes will be specified to encourage competitive pricing. Each packaged process unit will include all equipment, piping,

valves, electrical starters, instrumentation and controls, and appurtenances necessary for full time operation of the treatment process.

Work that will be required in addition to the procurement of the pilot unit packages includes typical permitting and coordination activities as well as site preparation, construction of a concrete slab with a canopy or awning to protect the pilot system from the elements, construction of supply and return piping from the NEWRF facilities, connection of the pilot system to the electrical power supply facilities at the NEWRF, installation of interconnecting piping and process tanks, and system testing, check-out, troubleshooting and startup. Following the 1 year operation of the pilot system, the Contractor will be responsible for removal of the system, preparation of leased equipment for return shipping, and restoration of the site.

Each of the packaged pilot units would normally be configured to have separate controls for independent operation. In order to ensure overall compatibility of the treatment process and proper interaction between processes, the services of a control system integrator will be required. The system integrator will be responsible for furnishing and installing a primary control system to provide general process oversight, coordinate the startup and shutdown of the system, and include critical alarms that have an effect on upstream and downstream processes. Manufacturer specific differences in operational methodology will require coordination efforts to be provided based on the specific packaged equipment to be furnished. The integrator's scope will be specified to allow opportunity for cost savings through consolidation of controls, and will require the integrator to be the single source of responsibility for coordination, calibration, debugging, and start-up. Similar to the Contractor, the specialized nature of this project requires that only Control System Integrators who possess previous membrane treatment facility experience will be considered to perform this work.

8.0 EVALUATION OF EAST AND NORTHEAST WASTEWATER RECLAMATION FACILITIES AND GROUNDWATER REPLENISHMENT CONCEPT WITH RESPECT TO TOTAL MAXIMUM DAILY LOAD REGULATIONS

8.1 BACKGROUND

The City of Clearwater (City) owns and operates three (3) water reclamation facilities (WRFs) that provide central wastewater service to most areas within the City as well as some areas of unincorporated Pinellas County. The existing facilities include the East, Northeast, and Marshall Street WRFs. Treated effluent from all three facilities is reused as reclaimed water for irrigation. This reclaimed water is used within the City's service area and a portion of the Northeast WRF's reclaimed water is sold to Pinellas County through an interlocal agreement. Excess treated effluent produced by the East and Northeast WRFs is discharged to Old Tampa Bay through a common outfall located near the intersection of South McMullen Booth Road and Gulf to Bay Boulevard. Excess reclaimed water produced at the Marshall Street WRF is discharged to Stevenson Creek, which discharges to Clearwater Harbor.

As stated in previous sections of this document, the implementation of a groundwater replenishment program would involve providing additional treatment for a portion of the effluent produced at the Northeast WRF and subsequently injecting the highly-treated product into lower Zone A of the Floridan aquifer. This concept would minimize the amount of effluent discharged to Old Tampa Bay, which in turn, could help achieve compliance with total maximum daily load (TMDL) regulations. Since the Northeast and East WRFs share a common outfall, it is prudent to simultaneously consider both of these plants when evaluating compliance with the TMDL criteria and the feasibility of the groundwater replenishment concept. The excess reclaimed water discharge from the Marshall Street WRF is not being considered for groundwater replenishment at this time and therefore, is not evaluated in this report.

8.2 EXISTING FACILITIES

The East WRF has a permitted treatment capacity of 5.0 million gallons per day (MGD) on an average annual daily flow (AADF) basis. The existing plant includes screening, grit removal, a 5-stage biological nutrient removal (BNR) process, secondary clarification, filtration, disinfection via chlorination, dechlorination, and post aeration. Treated effluent from the Northeast WRF is introduced to the liquid treatment stream prior to the dechlorination and post aeration processes and these two unit operations provide the final stages of treatment for the combined flow prior to discharge. The East WRF includes a reclaimed water pump station that can deliver effluent to the City's reclaimed water distribution network; however, nearly all of the effluent is discharged to Old Tampa Bay. Residual solids from the biological treatment process are periodically removed from the system as waste active sludge (WAS), which is subsequently

thickened and hauled to the Northeast WRF for further processing and disposal. Figure 8-1 presents a process schematic for the East WRF.

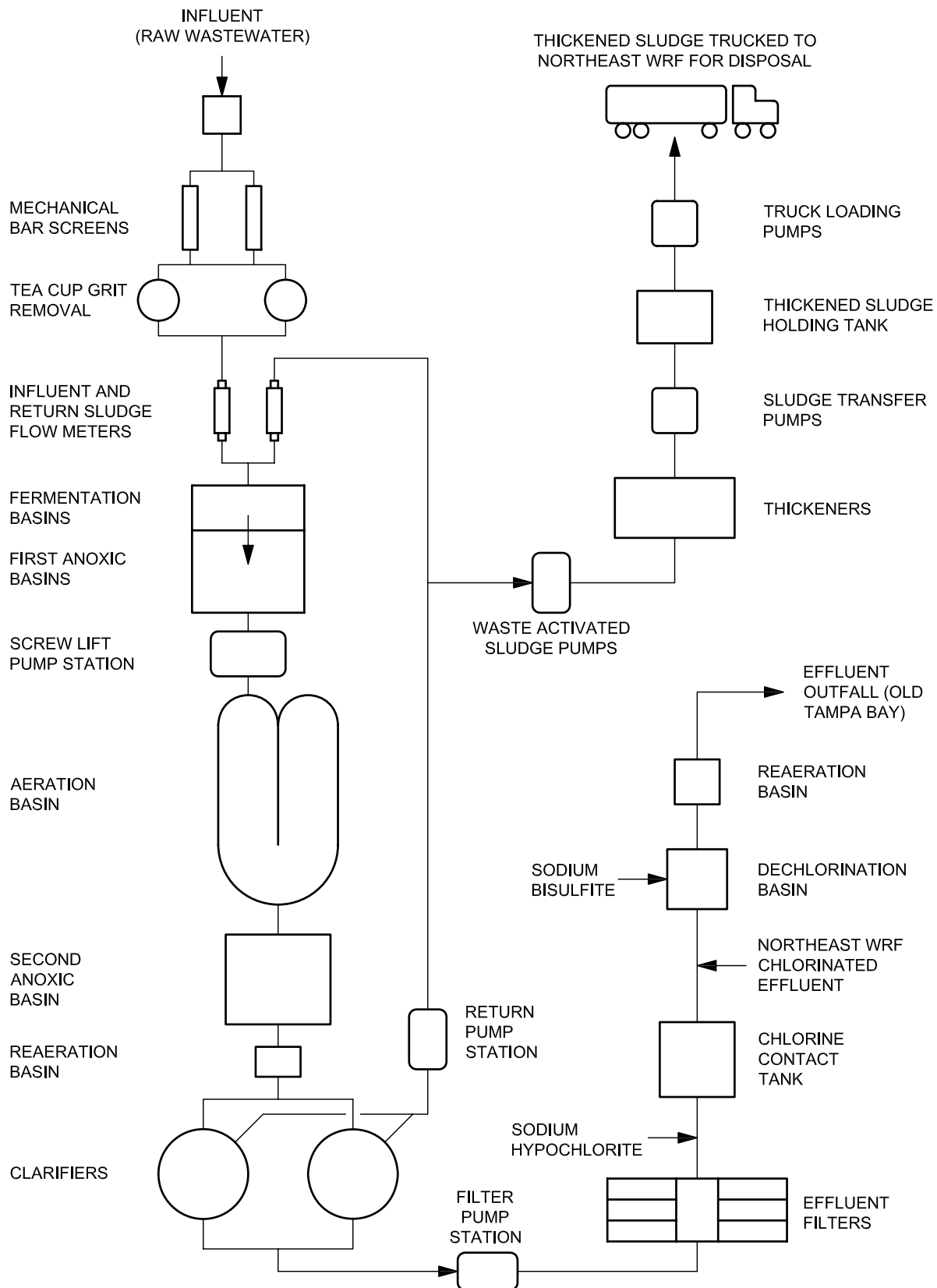
The Northeast WRF has a permitted treatment capacity of 13.50 million gallons per day (MGD) on an average annual daily flow (AADF) basis. The existing plant includes screening, grit removal, primary clarification, a 4-stage biological nutrient removal (BNR) process, secondary clarification, filtration, and disinfection via chlorination. Most of the treated effluent from the Northeast WRF is transferred to the East WRF for dechlorination and post-aeration prior to discharge. The plant includes significant reclaimed water storage and pumping facilities that can deliver effluent to the City's reclaimed water distribution network and to Pinellas County through an interconnection covered by an agreement between the two entities. Sludge from the primary settling process is thickened and combined with thickened WAS from the on-site biological treatment process and sludge from the East WRF. Anaerobic digestion is used to provide sludge stabilization prior to dewatering and disposal via land application. Figure 8-2 presents a process schematic for the Northeast WRF.

Currently, permits for the facilities issued by the Florida Department of Environmental Protection (FDEP) require high levels of removal for 5-day carbonaceous biochemical oxygen demand (CBOD₅), total suspended solids (TSS) and nitrogen, as well as dechlorination and post aeration. Further, the permits set forth limits for recoverable copper and a trihalomethane compound (dichlorobromomethane), and they establish requirements related to effluent toxicity. As previously stated a single outfall serves the East and Northeast WRFs, therefore, the effluent from for these two facilities is monitored at a single location and the limits are identical for surface water discharge. Table 8-1, presents a summary of the effluent limits applicable to the East and Northeast WRFs for discharge to Old Tampa Bay.

TABLE 8-1 EFFLUENT LIMITS FOR SURFACE WATER DISCHARGE				
Parameter	Annual Average	Monthly Average	Weekly Average	Single Sample
CBOD ₅	5.00 mg/L	6.25 mg/L	7.50 mg/L	10.00 mg/L
TSS	5.00 mg/L	6.25 mg/L	7.50 mg/L	10.00 mg/L
Total Nitrogen	3.00 mg/L	3.75 mg/L	4.50 mg/L	6.00 mg/L
pH	--	--	--	6.0 to 8.5
Total Coliform	--	ND ¹ in 75% of Samples	--	25/100 ml
Chlorine				0.01mg/L
Copper, Total Recoverable	--	--	--	3.7 µg/L
Dichlorobromomethane	43.0 µg/L	--	--	--
Dissolved Oxygen	--	--	--	≥ 4.0 mg/L

1 Non-Detectable

2/24/2011 11:00:36 AM - P:\200-41125-10002 - CLEARWATER GWR FEASIBILITY\CAD\SHEETFILES\FIGURE 1.DWG - NEUMEYER, SCOTT



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CITY OF CLEARWATER, FLORIDA

EAST WATER RECLAMATION FACILITY FLOW SCHEMATIC

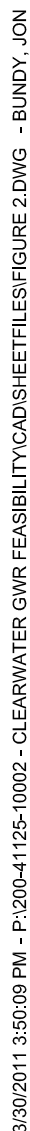
Project No.: 200-41125-10002

Date: 12/2010

Designed By:

Figure
8-1

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Currently, influent and effluent flows and reclaimed water demands are measured and recorded at both the East and Northeast WRFs. Also, the influent flow streams are sampled at each facility and laboratory analyses are conducted for CBOD₅, TSS, total kjeldahl nitrogen, total phosphorus and other parameters that are useful in the day to day operation of the facilities. Similarly, the effluent flow streams are sampled for various constituents in accordance with the requirements of the current permits; however, the sampling program is complicated by the fact that effluent for the Northeast WRF is pumped to the East WRF for dechlorination and post aeration prior to discharge to Old Tampa Bay. In order to simplify the compliance monitoring for surface water discharge, additional samples are collected from the combined flow stream prior to discharge and analyzed for parameters specifically related to the outfall rather than reclaimed water reuse. Table 8-2 presents a summary of the influent flows, wastewater characteristics, reclaimed water demands, and composite effluent quality for the two facilities for a period starting in January 2007 and ending in June 2010.

As shown in Table 8-2 the monthly flows range from 1.76 to 3.36 MGD for the East WRF and from 4.57 to 6.97 MGD for the Northeast WRF. The influent characteristics for both facilities are fairly typical for medium to large treatment plants serving mostly residential and commercial customers, although the influent CBOD₅ concentrations are slightly low in comparison to the TSS values. The effluent data shows consistent compliance with the permit requirements for surface water discharge and values that are typically observed at facilities employing a 4-stage BNR process.

8.3 TMDL REGULATIONS

Section 303(d) of the Federal Clean Water Act and the Florida Watershed Restoration Act require the development of TMDLs for all waters that are not meeting their “designated uses”. Such waters are defined as “impaired waters” under the current regulatory framework. Old Tampa Bay and other waters within the Tampa Bay estuary are considered to be impaired and various documents have been prepared to develop TMDLs for various areas. The TMDLs for Old Tampa Bay have not been finalized, however, the document entitled “Tampa Bay Nitrogen Management Consortium Draft Final TMDL Matrices” presents draft TMDL values for total nitrogen (TN) for various entities that discharge effluent to this particular water body. The current draft TMDLs for the East and Northeast WRFs equal 9.4 and 17.7 tons/year, respectively. Since the two facilities share a common outfall these values can be combined to establish a total allowable nitrogen load of 27.1 tons/year, or 148.5 lbs/day. Currently, there are no draft TMDL values for total phosphorus (TP) or other parameters, however, a draft overall allocation of 104.0 tons/year for Old Tampa Bay is proposed by the Tampa Bay Nitrogen Management Consortium.

TABLE 8-2 OPERATING DATA FOR EAST & NORTHEAST WATER RECLAMATION FACILITIES

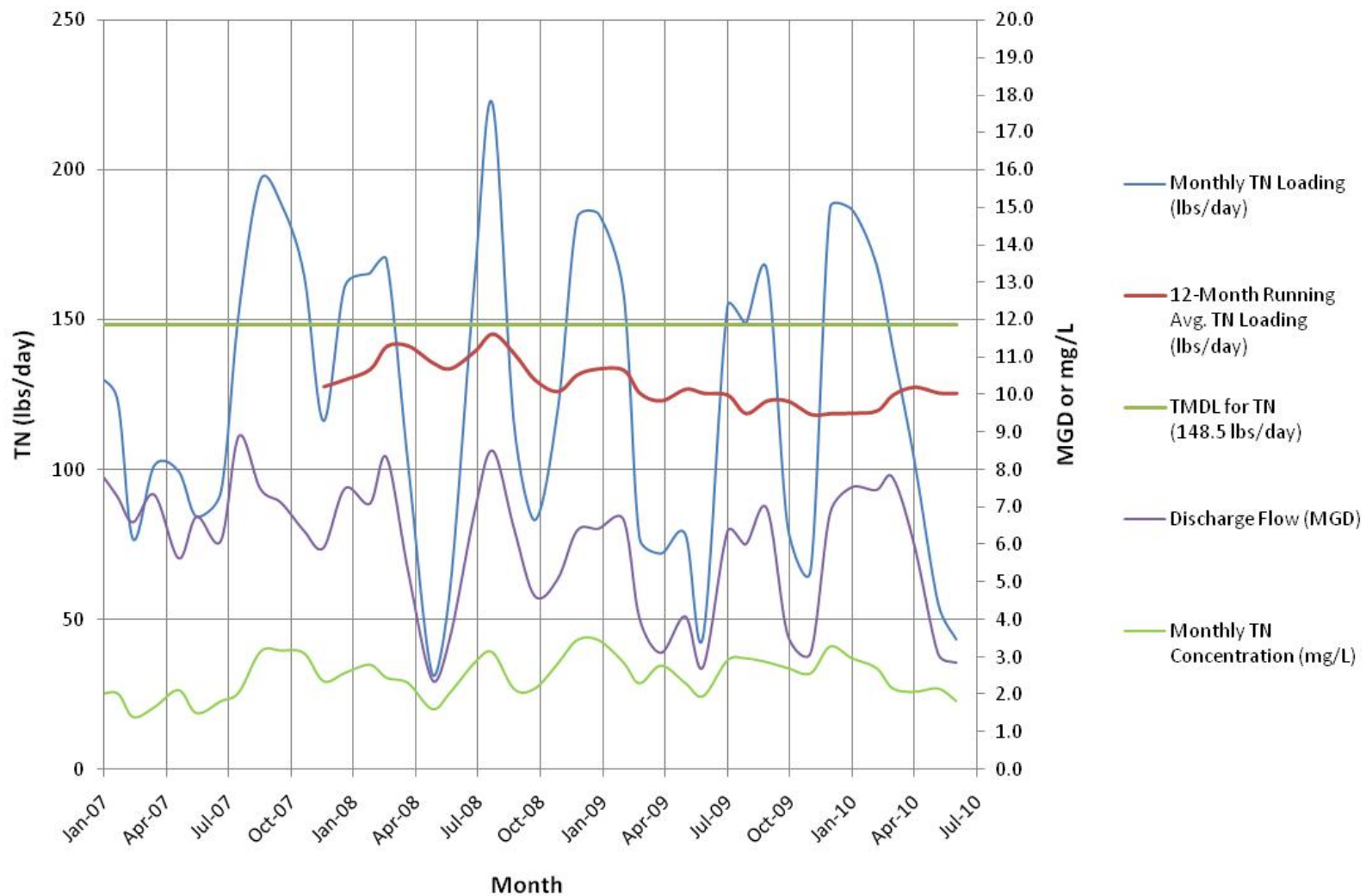
Month	East APCF Influent					Northeast APCF Influent					Combined Effluent Parameters									
	Flow (MGD)	CBOD5 (mg/L)	TSS (mg/L)	Ammonia (mg/L)	TP (mg/L)	Flow (MGD)	CBOD5 (mg/L)	TSS (mg/L)	Ammonia (mg/L)	TP (mg/L)	East Discharge (MGD)	Northeast Discharge (MGD)	Total Discharge (MGD)	East Reuse (MGD)	Northeast Reuse (MGD)	Total Reuse (MGD)	CBOD5 (mg/L)	TSS (mg/L)	TN (mg/L)	TP (mg/L)
Jan-07	2.34	204	221	32	5.5	5.41	231	256	28	5.6	3.03	5.19	8.22	0.00	0.97	0.97	2.11	1.15	1.93	0.25
Feb-07	2.58	187	225	29	5.1	5.20	206	240	28	5.5	2.72	4.57	7.29	0.00	0.41	0.41	2.00	0.62	2.04	0.17
Mar-07	2.96	199	223	26	4.9	4.94	244	284	30	5.9	3.10	3.49	6.59	0.00	0.68	0.68	2.00	0.55	1.40	0.34
Apr-07	3.02	200	233	43	5.8	5.07	243	301	27	5.3	3.25	4.07	7.32	0.00	1.30	1.30	2.05	0.61	1.66	0.65
May-07	2.70	196	258	34	6.5	4.91	215	285	29	5.5	2.43	3.20	5.63	0.00	1.90	1.90	2.15	0.66	2.12	0.81
Jun-07	2.70	180	214	31	5.1	5.61	194	271	25	5.4	2.58	4.16	6.74	0.00	1.88	1.88	2.00	0.69	1.50	0.72
Jul-07	2.12	195	203	32	4.8	5.38	219	262	26	4.9	2.34	3.76	6.10	0.00	2.01	2.01	2.00	0.73	1.82	0.95
Aug-07	2.80	145	182	25	3.9	6.54	200	229	23	4.2	2.99	5.90	8.89	0.00	1.25	1.25	2.05	1.02	2.06	0.81
Sep-07	2.57	149	187	29	4.5	5.83	171	255	26	4.2	2.47	5.01	7.48	0.00	1.31	1.31	2.19	0.73	3.15	0.78
Oct-07	2.55	150	201	34	5.1	6.07	174	258	29	5.5	2.44	4.67	7.11	0.00	1.58	1.58	2.00	0.72	3.18	0.93
Nov-07	2.50	185	255	39	4.8	5.62	184	304	31	5.4	2.21	4.15	6.36	0.00	1.76	1.76	2.00	0.78	3.11	0.82
Dec-07	2.50	203	249	39	6.9	5.79	195	322	32	6.1	2.22	3.69	5.91	0.00	1.31	1.31	2.00	0.70	2.36	0.67
Min.	2.12	145	182	25	3.9	4.91	171	229	23	4.2	2.21	3.20	5.63	0.00	0.41	0.41	2.00	0.55	1.40	0.17
Max.	3.02	204	258	43	6.9	6.54	244	322	32	6.1	3.25	5.90	8.89	0.00	2.01	2.01	2.19	1.15	3.18	0.95
Avg.	2.61	183	221	33	5.2	5.53	206	272	28	5.3	2.65	4.32	6.97	0.00	1.36	1.36	2.05	0.75	2.19	0.66
Jan-08	2.61	199	263	38	6.3	6.97	214	302	33	6.0	2.30	5.19	7.49	0.00	1.08	1.08	2.07	0.77	2.58	0.66
Feb-08	2.81	181	243	37	5.4	6.09	187	326	31	5.5	2.54	4.55	7.09	0.00	1.18	1.18	2.00	0.85	2.80	0.66
Mar-08	2.84	188	189	33	5.1	6.41	225	284	29	4.7	2.82	5.50	8.32	0.00	1.09	1.09	2.02	1.41	2.45	0.65
Apr-08	2.61	188	189	33	5.1	5.99	215	287	30	5.7	2.55	2.75	5.30	0.00	1.93	1.93	2.03	0.95	2.31	0.73
May-08	2.33	186	208	37	6.1	5.93	200	274	30	5.9	2.13	0.25	2.38	0.01	2.66	2.67	2.52	1.01	1.61	0.60
Jun-08	2.32	170	231	34	5.8	6.13	182	252	29	6.1	1.87	1.68	3.55	0.66	1.53	2.19	2.00	1.04	2.06	0.85
Jul-08	2.71	154	191	29	4.8	6.48	162	238	26	4.6	2.59	4.26	6.85	0.10	1.20	1.30	2.04	0.94	2.85	1.07
Aug-08	3.36	144	188	26	4.9	6.97	159	222	23	4.4	2.85	5.65	8.50	0.00	1.02	1.02	2.00	1.18	3.13	0.96
Sep-08	2.71	186	237	31	5.5	6.19	181	243	26	4.8	2.35	4.07	6.42	0.23	1.64	1.87	2.14	1.34	2.15	0.59
Oct-08	2.90	181	231	31	5.3	6.34	174	232	26	4.9	2.31	2.31	4.62	0.07	1.90	1.97	2.10	1.36	2.16	0.56
Nov-08	2.66	265	261	34	5.9	5.80	211	265	29	5.2	2.17	2.91	5.08	0.00	1.77	1.77	2.60	1.10	2.83	0.67
Dec-08	2.27	204	246	37	6.1	5.64	203	258	30	5.3	2.14	4.23	6.37	0.00	1.23	1.23	2.13	1.08	3.46	0.92
Min.	2.27	144	188	26	4.8	5.64	159	222	23	4.4	1.87	0.25	2.38	0.00	1.02	1.02	2.00	0.77	1.61	0.56
Max.	3.36	265	263	38	6.3	6.97	225	326	33	6.1	2.85	5.65	8.50	0.66	2.66	2.67	2.60	1.41	3.46	1.07
Avg.	2.68	187	223	33	5.5	6.25	193	265	29	5.3	2.39	3.61	6.00	0.09	1.52	1.61	2.14	1.09	2.53	0.74
Jan-09	2.29	191	257	37	6.1	5.45	202	255	29	5.5	2.19	4.23	6.42	0.00	1.20	1.20	2.42	1.16	3.46	0.92
Feb-09	2.49	199	252	35	5.8	5.44	202	271	28	5.2	2.30	4.36	6.66	0.00	1.08	1.08	3.07	1.36	2.86	0.60
Mar-09	2.10	199	254	37	5.8	5.10	227	392	29	6.9	2.01	2.02	4.03	0.05	1.74	1.79	2.15	1.23	2.30	0.33
Apr-09	1.83	210	275	38	6.6	4.58	193	263	30	4.9	1.73	1.38	3.11	0.00	1.84	1.84	2.73	1.10	2.78	0.73
May-09	1.81	185	283	35	6.0	4.57	193	268	30	5.5	1.75	2.33	4.08	0.34	1.31	1.65	2.52	1.15	2.31	0.84
Jun-09	1.76	167	244	33	5.1	5.05	170	291	27	4.7	1.73	1.01	2.74	0.44	2.02	2.46	3.59	1.59	1.96	0.89
Jul-09	2.27	133	186	29	4.0	5.51	155	201	26	3.8	2.21	4.14	6.35	0.00	0.89	0.89	2.81	1.25	2.92	0.82
Aug-09	2.22	137	187	28	4.5	5.38	162	210	27	4.1	2.21	3.79	6.00	0.00	1.01	1.01	2.45	1.30	2.97	0.49
Sep-09	2.22	131	182	28	4.2	5.62	154	222	25	4.0	2.31	4.64	6.95	0.00	1.02	1.02	2.55	1.13	2.87	0.35
Oct-09	1.88	151	200	36	5.0	4.91	166	219	29	4.4	1.82	1.76	3.58	0.00	1.32	1.32	2.38	1.38	2.71	0.40
Nov-09	1.87	189	235	40	5.4	4.76	188	229	31	4.3	1.66	1.45	3.11	0.10	1.58	1.68	2.30	1.30	2.57	0.29
Dec-09	2.16	152	182	34	5.3	4.91	183	245	30	4.8	2.02	4.81	6.83	0.00	1.08	1.08	2.18	1.13	3.29	0.38
Min.	1.76	131	182	28	4.0	4.57	154	201	25	3.8	1.66	1.01	2.74	0.00	0.89	0.89	2.15	1.10	1.96	0.29
Max.	2.49	210	283	40	6.6	5.62	227	392	31	6.9	2.31	4.81	6.95	0.44	2.02	2.46	3.59	1.59	3.46	0.92
Avg.	2.08	170	228	34	5.3	5.11	183	256	28	4.8	2.00	2.99	4.99	0.08	1.34	1.42	2.60	1.26	2.75	0.59
Jan-10	2.31	165	221	35	5.2	5.14	193	273	28	4.3	2.10	5.42	7.52	0.00	0.90	0.90	2.05	1.38	2.98	0.37
Feb-10	2.39	167	234	33	4.7	5.26	192	249	30	4.2	2.17	5.28	7.45	0.00	0.61	0.61	2.05	1.37	2.71	0.13
Mar-10	2.55	168	229	33	4.7	5.51	196	256	29	4.3	2.30	5.49	7.79	0.00	0.93	0.93	2.08	1.56	2.17	0.38
Apr-10	2.50	155	225	32	4.0	5.60	186	249	27	3.5	2.34	3.68	6.02	0.07	1.75	1.82	2.12	1.86	2.07	1.00
May-10	2.04	169	201	33	5.0	5.20	200	245	27	3.9	1.94	1.14	3.08	0.47	1.89	2.36	2.90	1.94	2.16	1.08
Jun-10	2.07	164	241	37	5.0	5.17	175	256	29	4.0	2.07	0.78	2.85	0.72	1.68	2.40	3.53	1.75	1.83	0.66
Min.	2.04	155	201	32	4.0	5.14	175	245	27	3.5	1.94	0.78	2.85	0.00	0.61	0.61	2.05	1.37	1.83	0.13
Max.	2.55	169	241	37	5.2	5.60	200	273	30	4.3	2.34	5.49	7.79	0.72	1.89	2.40	3.53	1.94	2.98	1.08
Avg.	2.31	165	225	34	4.8	5.31	190	255	28	4.0	2.15	3.63	5.79	0.21	1.29	1.50	2.46	1.64	2.32	0.60

8.4 COMPLIANCE WITH NITROGEN TMDL REQUIREMENTS AT CURRENT WASTEWATER FLOWS

The data presented in Table 2-2 shows that the combined monthly influent flows for the East and Northeast WRFs have ranged from 6.38 to 10.33 MGD over the recent 42-month period under consideration. The data also shows that the combined discharge flows have ranged from 2.38 to 8.89 MGD over the same 42-month period. During this time the composite effluent total nitrogen concentration varied between 1.40 and 3.46 mg/L and averaged 2.47 mg/L. The flow data shows fairly wide variations in the monthly influent flows and even wider variation in discharge flows. In general these flow variations are caused by seasonal fluctuations in rainfall. During the wet season increased rainfall leads to higher levels of infiltration and inflow (I/I), which causes significant increases in wastewater flow to the treatment facilities. Also, during periods of high rainfall reclaimed water demands are minimized due to minimal need for supplemental irrigation, which reduces the amount of effluent provided to customers within the City's service area and to Pinellas County. Since influent flows are elevated during the wet season and reclaimed water demands are lower during this time, discharge rates to Old Tampa Bay are significantly increased during periods of increased precipitation. In contrast with the influent flow and surface water discharge data, the TN data has a coefficient of variation of only 20% which indicates very consistent levels of nitrogen removal.

The TMDL regulations with respect to nitrogen are based on annual average mass loadings, therefore, monthly variations in discharge rates and minor excursions in effluent TN concentrations will not result in violations as long as the 12-month average loading is below 27.1 tons/year, or 148.5 lbs/day. It is important to note that annual average loadings are based on a 12-month running average and not on a calendar or fiscal year. This means that every month a mass loading value must be calculated based on the current month and the previous 11 months, and the resulting value will need to be included in the monthly discharge monitoring reports. This value will then be compared with the TMDL by FDEP to ascertain compliance with the mass loading limit.

The TMDL for TN has not yet been implemented; therefore, a compliance history cannot be established. Despite this fact, it is useful to examine historical flow and performance data for the East and Northeast WRFs and compare the historical mass discharge rates from the facilities with the TMDL. Accordingly, Figure 8-3 presents composite monthly historical data regarding flow, effluent TN concentration, and mass discharge of nitrogen, as well as 12-month running average data for nitrogen loading. For comparison, Figures 8-4 and 8-5 present similar composite data, however, in Figure 8-4 the reclaimed water demand has been removed to demonstrate the impact of effluent reuse and in Figure 8-5 the current reclaimed water demand has been replaced with a demand of 3.8 MGD to show the effect of a groundwater replenishment program.



**FIGURE 8-3
COMPOSITE FLOW & TN DATA FOR EAST & NORTHEAST
WATER RECLAMATION FACILITIES**

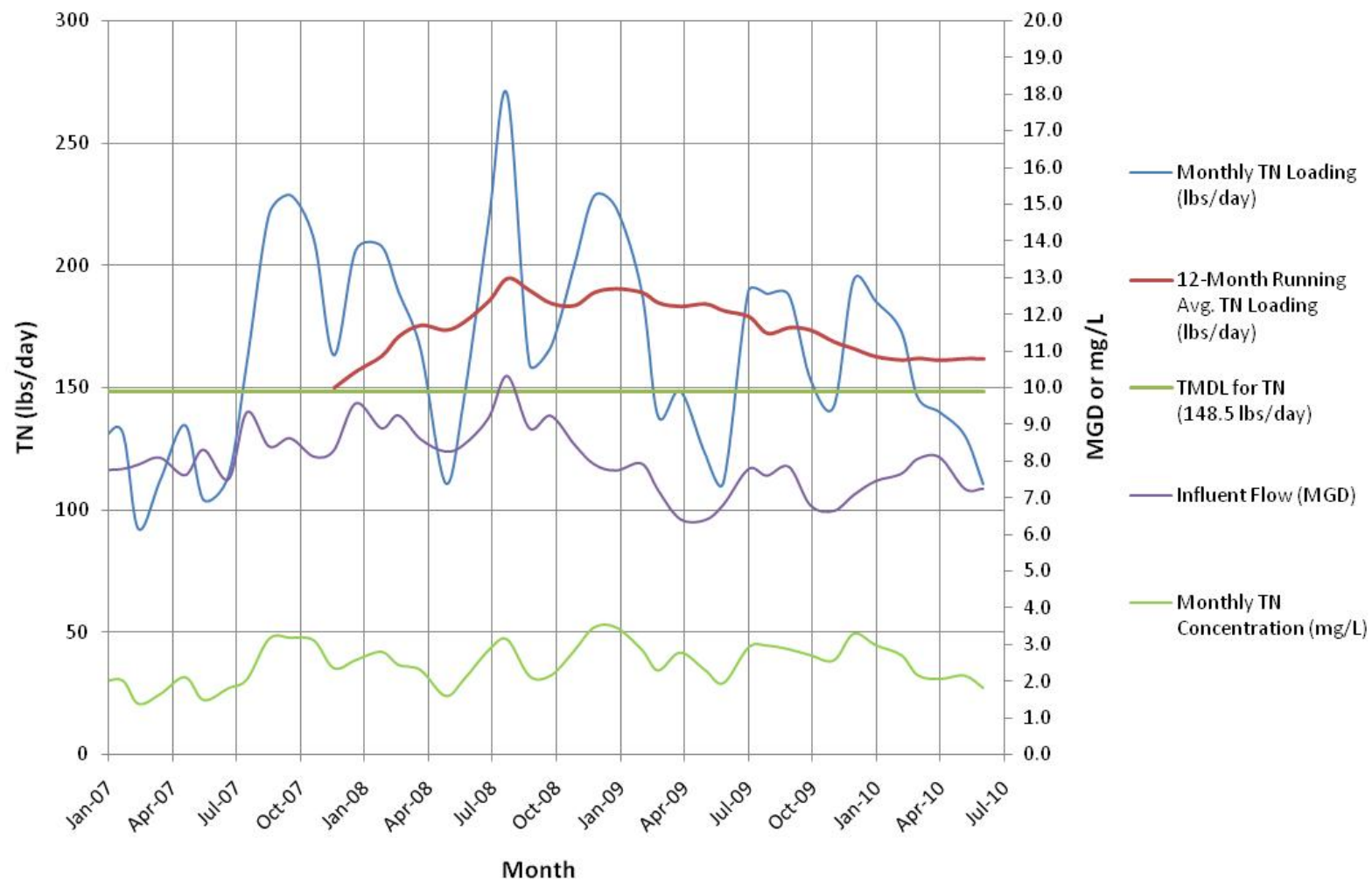
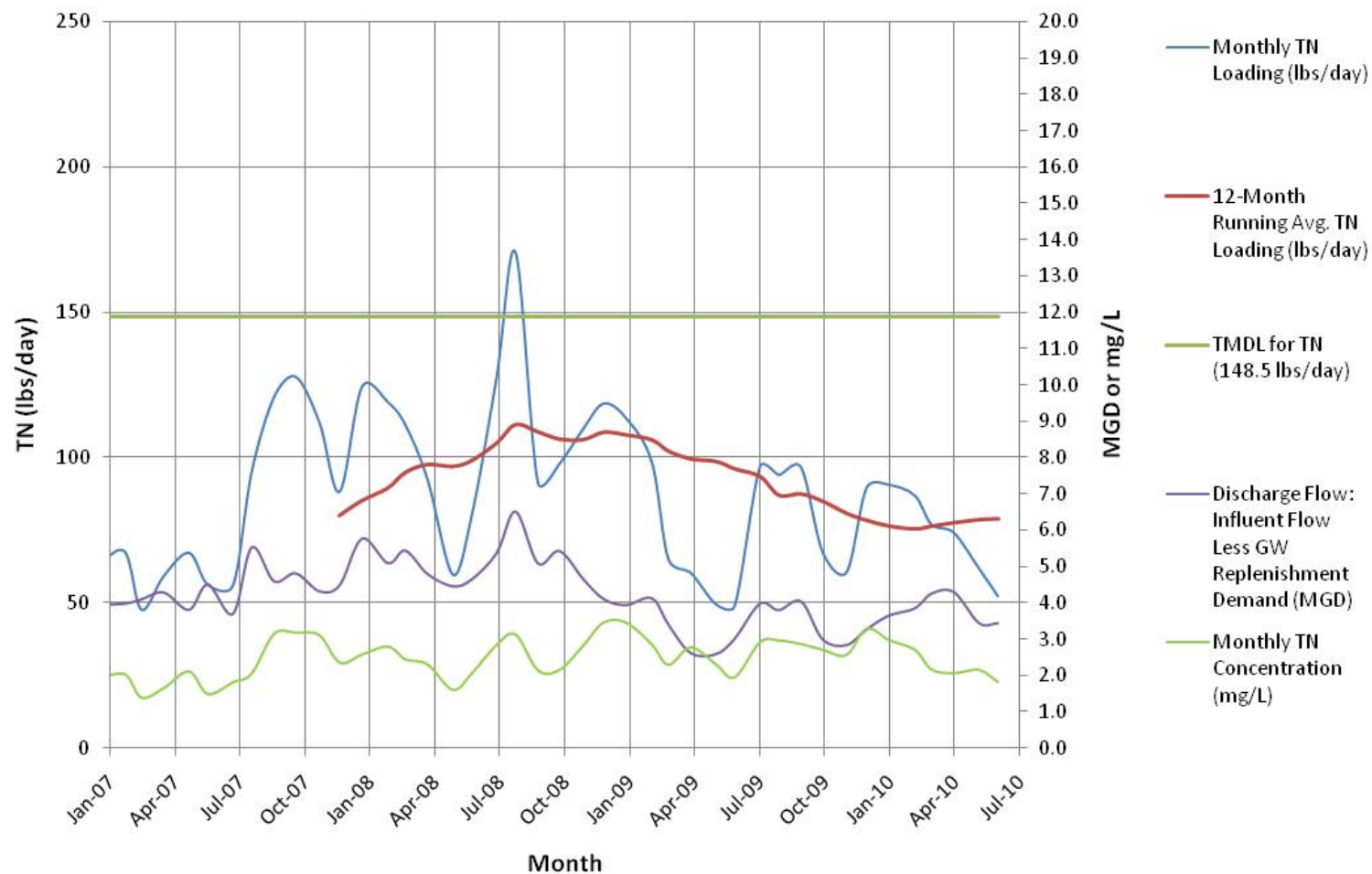


FIGURE 8-4
COMPOSITE FLOW & TN DATA FOR EAST AND NORTHEAST
WATER RECLAMATION FACILITIES WITHOUT REUSE DEMAND



**FIGURE 8-5
COMPOSITE FLOW & TN DATA FOR EAST & NORTHEAST WATER RECLAMATION FACILITIES
WITH 3.8 MGD GROUND WATER REPLENISHMENT
EFFLUENT DEMAND & NO REUSE DEMAND**

Based on the data presented in Figures 8-3 and 8-4, it is apparent that compliance with the nitrogen TMDL can be expected at current flows and treatment efficiencies, as long as reclaimed water demands remain near their current levels. Projections presented in the recent Capacity Analysis Reports (CARs) show that influent flows are not expected to increase significantly in the immediate future and the current levels of nitrogen removal are consistent with performance predicted by generally accepted performance models and are typical for well-operated 4-stage and 5-stage BNR facilities. In general, reclaimed water demands are not expected to decrease since there is considerable regulatory pressure to increase the beneficial reuse of treated effluent. In view of these factors it is reasonable to anticipate that no significant improvements to the existing East and Northeast WRFs will be necessary to comply with the nitrogen TMDL as long as influent flows and reclaimed water demand are maintained at near current levels.

8.5 COMPLIANCE WITH NITROGEN TMDL REQUIREMENTS AT PROJECTED WASTEWATER FLOWS

The current CARs for the East and Northeast WRFs include flow projections for each facility for a 10-year period starting in 2005. These projections were based on annual growth rates of 0.64 and 1.33 percent for the East and Northeast WRFs, respectively. The planning window for the CARs was 10 years pursuant to the requirements set forth in Florida Administrative Code (FAC) Chapter 62-600, therefore, the projections only extend to 2015. For this study it would be desirable to consider a planning horizon extending to 2020. The current economic climate has resulted in relatively low growth rates and it appears that development rates will remain depressed for several years. It is beyond the scope of this assignment to analyze economic conditions and population trends, however, it seems reasonable to assume that the growth rates set forth in the CARs would remain constant for the period from 2015 to 2020. Table 8-3 presents the flow projections for each facility under this assumption.

TABLE 8-3 PROJECTED ANNUAL AVERAGE WASTEWATER FLOWS			
Year	Projected AADF (MGD)		
	East WRF	Northeast WRF	Composite
2010	2.37	7.00	9.37
2015	2.44	7.48	9.92
2020	2.52	7.99	10.51

As shown in Table 8-3, the combined AADFs to the East and Northeast WRFs are expected to equal 10.51 MGD on annual average basis. This value represents the total amount of influent wastewater that is expected to flow into the treatment facilities on an annual average basis, however, it is important to consider reclaimed water demand within the City's service area and the bulk purchases by Pinellas County since these demands will decrease discharges to Old Tampa Bay and minimize nitrogen loads, which in turn, influences the maximum allowable effluent TN concentrations. Figure 8-6 presents the nitrogen TMDL and discharge flow versus nitrogen loading for various effluent TN concentrations to illustrate this relationship.

Over the last three calendar years reclaimed water demands have ranged from 1.36 to 1.61 MGD and have averaged 1.46 MGD. The bulk deliveries to Pinellas County were initiated in 2008 and over the last two years have ranged from 1.05 to 1.44 MGD and averaged 1.25 MGD. The levels of reclaimed water demand within the City's service area and Pinellas County are difficult to predict. In general, it would be expected that the City's demand for reclaimed water would remain fairly constant and probably increase modestly as new subdivisions are served. Likewise, the Pinellas County demand is difficult to ascertain, particularly if another source of reclaimed water becomes available to the County. To further complicate the issue, implementation of the groundwater replenishment program could reduce discharge flows by approximately 3.80 MGD.

In order to facilitate an evaluation of options for compliance with the nitrogen TMDL it is necessary to make some assumptions regarding the various demands that would mitigate surface water discharges and identify a range of possible scenarios. Since reclaimed water demands over the last three years have been fairly constant, the average demand of 1.46 MGD is considered adequate for this study. Similarly, the average bulk transfer rate of 1.25 MGD to Pinellas County is considered reasonable for this analysis. Finally, a reclaimed water demand of 3.80 MGD for the potential groundwater replenishment program appears to be a fairly accurate estimate based on an assumed process recovery rate of approximately 80 percent (95 percent recovery in the membrane filtration process and 85% recovery in the RO process). In order to examine a complete range of possibilities and resulting effluent TN limits, it is necessary to use the 10-year wastewater flow projections in conjunction with various reclaimed water demands described herein to create several potential scenarios. Accordingly, Table 8-4 presents a list of potential reuse/discharge scenarios.

TABLE 8-4 PROJECTED ANNUAL AVERAGE WASTEWATER FLOWS, EFFLUENT REUSE/DISCHARGE SCENARIOS & EFFLUENT TN LIMITS						
Scenario No.	Influent AADF (MGD)	Effluent Reuse/Disposal Flows (MGD)				Effluent TN Limit (mg/L)
		City Reuse	Pinellas County Reuse	GW Repl.	Surface Water Discharge	
1	10.51	-0-	-0-	-0-	10.51	1.69
2	10.51	1.46	-0-	-0-	9.05	1.96
3	10.51	1.46	1.25	-0-	7.80	2.28
4	10.51	1.46	-0-	3.80	5.25	3.39
5	10.51	1.46	1.25	3.80	4.00	4.45
Note: The effluent TN limits are based on a TMDL of 148.5 lbs/day and the estimated discharge flows.						

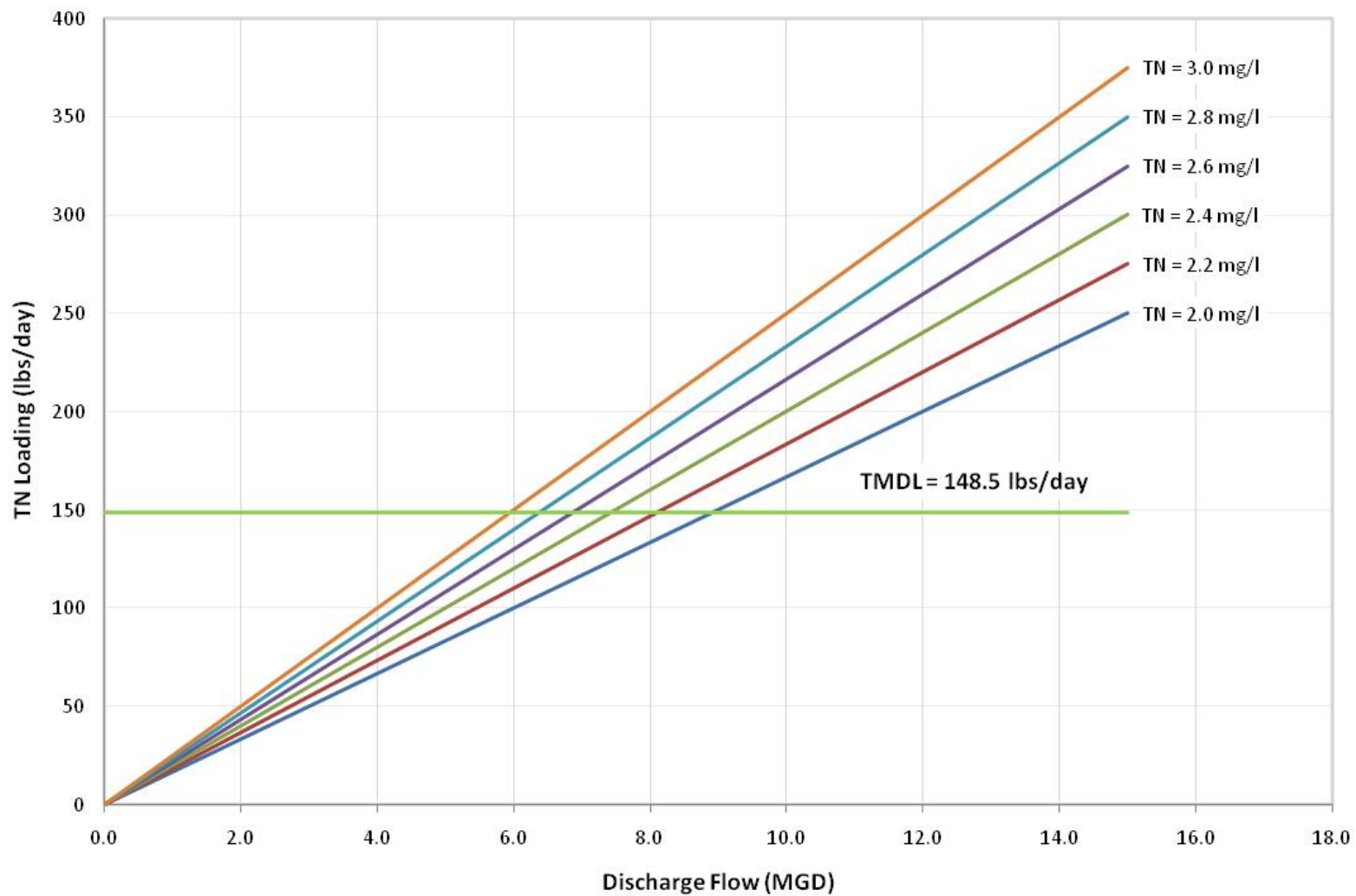


FIGURE 8-6
TN LOADINGS AT VARIOUS FLOW RATES & EFFLUENT TN CONCENTRATIONS

Scenario 1 appears to be highly unlikely considering the success of the City's reuse program and the trend towards increasing the beneficial reuse of reclaimed water, therefore, it is not worthwhile to consider process enhancements or improvements to meet a TN limit of 1.69 mg/L. Scenarios 4 and 5 represent fairly probable long-range outcomes and both scenarios do not necessitate process enhancements or improvement to achieve compliance with the nitrogen TMDL due to the low discharge flows. Scenarios 2 and 3 result in effluent TN limits ranging from 1.96 to 2.28 mg/L, which are slightly lower than the current average composite TN concentration of approximately 2.47 mg/L, therefore, some small amount of additional nitrogen removal will be necessary under either scenario.

Fractionation of the recent composite effluent samples from the existing facilities show the following concentrations.

- Ammonia: 0.03 mg/L
- Organic Nitrogen: 0.96 mg/L
- TKN: 0.99 mg/L
- Nitrite + Nitrate: 1.46 mg/L
- Total Nitrogen: 2.45 mg/L

The data presented above indicates a very high degree of nitrification, which is expected at conservatively designed facilities that are located in a warm climate. The value of 0.96 mg/L for organic nitrogen is in range of values normally observed at facilities that are designed for nitrification. The organic nitrogen fraction, which currently makes up approximately 40 percent of the total nitrogen, is essentially non-biodegradable and refractory with respect to BNR technologies. The nitrite and nitrate species are oxidized forms of nitrogen which can be removed via suspended growth or fixed growth denitrification processes. It is unlikely that a denitrification process enhancement would result in removing all of the nitrite and nitrate, however, removing an additional 0.2 to 0.5 mg/L to meet the limits associated with Scenarios 2 and 3 is within the realm of technical feasibility. Based on a review of the current facilities and generally accepted process technologies, it appears that there are three potential options for additional nitrogen removal:

- **Option 1: Install a continuous monitoring system to measure the influent and effluent concentrations of nitrite and nitrate in the second anoxic basins and feed methanol or another carbon source to these basins to enhance denitrification.** This option will necessitate the installation of two monitoring modules at each second anoxic basin and the provision of chemical storage and feed facilities for the carbon source. Also, a programmable logic controller (PLC) will be needed to adjust the chemical feed rate based on flow and nitrogen concentrations. The methanol dosage to remove nitrogen down to the target concentrations will probably be in the range of 10 to 15 mg/L, however, pilot testing would be necessary to establish the actual dosage requirements and confirm the effectiveness of this process enhancement. At the current AADF's, the combined methanol usage at the East and Northeast WRFs would probably be approximately

101 to 152 gallons per day (GPD). Bulk storage for methanol is usually based on the rated AADF capacity of the plant and provision of 30 days of storage. Under these criteria a 2,000 gallon Convault or equivalent product would be needed for the East WRF. Similarly, a 6,000 gallon storage vessel would be needed for the Northeast WRF. Feed facilities for the methanol would include a transfer pump, day tank, level monitoring system, standard chemical metering pumps and related piping and appurtenances.

- **Option 2: Modify the existing filters to provide fixed growth denitrification in addition to solids removal.** The existing filters at the East and Northeast WRFs are pulsed-bed sand filters (Hydro-Clear[®]) with fairly shallow media depths. The current configurations and media depths are not optimum for providing fixed growth denitrification, however, it appears that the existing structures could be retrofitted to achieve the nitrogen removals needed to comply with the TMDLs under Scenarios 2 and 3. The TETRA[®] Denite[®] filtration system offered by Severn Trent Services is the most widely used fixed film denitrification technology in municipal wastewater applications and the Florida representative for this product has indicated that retrofitting the existing Hydro-Clear[®] Filters to provide denitrification is a feasible concept. In general, the filter improvements would involve replacement of the underdrains, media, and backwash system, as well as some structural modifications. Also, methanol addition immediately upstream of the modified filter would be necessary. Severn Trent also offers a proprietary control system known as the TETRAPace[®] which is used to precisely control the methanol feed rate and with this system they will guarantee that effluent nitrate concentrations will not exceed 0.5 mg/L. In view of the potential for optimization of chemical feeding and the guarantee, the control system would be an advisable addition for this option. The methanol dosage under a fixed growth process will be lower than that for a suspend growth system, and in this case the methanol dosage would be in the range of 5 to 7 mg/L. At the current AADFs, the combined methanol usage at the East and Northeast WRFs would probably be approximately 51 to 71 gallons per day (GPD). As is the case with Option 1, bulk storage should be based on the rated AADF capacity of the plant and provision of 30 days of storage. Under these criteria a 1,000 gallon Convault or equivalent product would be needed for the East WRF. Similarly, a 3,000 gallon storage vessel would be needed for the Northeast WRF. As is the case with Option 1, feed facilities for the methanol would include a transfer pump, day tank, level monitoring system, standard chemical metering pumps and related piping and appurtenances.
- **Option 3: Replace the existing filters to provide fixed growth denitrification in addition to solids removal.** This alternative is nearly identical to Option 2, however, instead of retrofitting the existing filters, new denitrification filters would be provided to replace the existing units. The sizing, equipment, chemical feed requirement, and controls would be the same as for Option 2 and new structures would be provided to accommodate the filtration equipment. This option would be considerably more expensive, however, it would provide the benefit of having new structures that are specifically designed for the installed equipment.

In addition to the options described above, other “add-on” process alternatives could be considered such as reverse osmosis or ion exchange. These alternatives are very expensive and implementation at the capacities needed for the East and Northeast WRFs would result in capital expenditures comparable to the cost of the groundwater replenishment program. Also, if membrane treatment is implemented at the wastewater treatment facilities it would provide treatment consistent with a groundwater replenishment program, and discharging the product to surface waters would not be an optimum use of the resource. In view of these factors, provision of membrane treatment for compliance with a TMDL is not currently considered a feasible option.

As previously stated, compliance with the nitrogen TMDL at the projected 2020 wastewater flows can be achieved by increasing the reclaimed water demand or implementing the groundwater replenishment program, or through some combination of these two concepts. If none of these concepts are selected, Scenario 2 or Scenario 3 as described above will be the resulting outcome and necessitate the implementation of Option 1, 2, or 3. Clearly, the City needs to examine the relative costs associated with these alternatives, therefore, planning level cost estimates for these options have been prepared and presented in Table 8-5.

Based on the estimates presented in Table 8-5, it is apparent that Option 1 is the most economical option for compliance with the nitrogen TMDL under Scenarios 2 and 3. Unfortunately, predictive equations and performance models lack precision at the desired level of nitrogen removal, therefore, some pilot testing will be necessary to document performance. The need for testing does not mean that Option 1 has a low probability of providing the desired level nitrogen removal, it is simply a necessary step that must be completed due to uncertainties that exist in current predictive relationships. In contrast, the fixed growth denitrification filter concepts could be implemented with a process guarantee from a large reputable manufacturer although the capital cost would be substantially higher. If the City decides to move forward with a wastewater management concept that is consistent with Scenarios 2 or 3, it would be prudent to establish a budget corresponding to Option 2 and concurrently investigate the potential for successful implementation of the more economical configuration associated with Option 1.

Any additional operating costs associated with higher levels of nitrogen removal will primarily result from methanol addition. The unit cost for methanol varies widely and the pricing volatility is caused by several factors such as the type of product available (i.e. recycled or virgin methanol), market demand, energy prices, location of the production facility, bidding conditions, and the general state of the economy). For example, over the past three years the price for methanol has ranged from \$0.51 to \$3.03/gallon for the City of Tampa’s Howard F. Curren Advanced Wastewater Treatment Plant. For planning purposes, a unit cost of \$2.00/gallon should provide a reasonably conservative estimate considering the volatility in pricing. If a suspended growth concept is selected (Option 1), the combined annual chemical cost for both the East WRF and the Northeast WRF is expected to be in the range of \$74,000 to \$111,000/year at current

TABLE 8-5 ESTIMATED COSTS FOR ADDITIONAL NITROGEN REMOVAL OPTIONS		
Item	East Water Reclamation Facility	Northeast Water Reclamation Facility
Option 1: Methanol Feed & Suspended Growth Denitrification		
Methanol Storage Facilities	\$26,000	\$50,000
Methanol Day Tank & Feed System	\$53,000	\$53,000
Continuous Nitrogen Analyzers	\$90,000	\$180,000
Control System & SCADA Modifications	\$100,000	\$125,000
Electrical & Instrumentation	\$75,000	\$120,000
Sub-Total	\$344,000	\$528,000
Mobilization, Bonds, Permits, & General Conditions	\$21,000	\$32,000
Contingency (20%)	\$69,000	\$106,000
Engineering, Permitting, & Construction Administration (15%)	\$52,000	\$79,000
Total Estimated Capital Cost	\$486,000	\$745,000
Combined Cost for East and Northeast WRFs	\$1,231,000	
Option 2: Methanol Feed & Fixed Growth Denitrification (Modify Existing Filters)		
Methanol Storage Facilities	\$22,000	\$30,000
Methanol Day Tank & Feed System	\$53,000	\$53,000
Filter Modifications	\$600,000	\$1,200,000
Control System & SCADA Modifications	\$50,000	\$75,000
Electrical & Instrumentation	\$200,000	\$400,000
Sub-Total	\$925,000	\$1,758,000
Mobilization, Bonds, Permits, & General Conditions	\$56,000	\$105,000
Contingency (20%)	\$185,000	\$352,000
Engineering, Permitting, & Construction Administration (15%)	\$139,000	\$264,000
Total Estimated Capital Cost	\$1,305,000	\$2,479,000
Combined Cost for East and Northeast WRFs	\$3,784,000	
Option 3: Methanol Feed & Fixed Growth Denitrification (Replace Existing Filters)		
Methanol Storage Facilities	\$22,000	\$30,000
Methanol Day Tank & Feed System	\$53,000	\$53,000
Filter Replacement	\$1,500,000	\$3,000,000
Control System & SCADA Modifications	\$50,000	\$75,000
Electrical & Instrumentation	\$400,000	\$800,000
Sub-Total	\$2,025,000	\$3,958,000
Mobilization, Bonds, Permits, & General Conditions	\$122,000	\$237,000
Contingency (20%)	\$405,000	\$792,000
Engineering, Permitting, & Construction Administration (15%)	\$304,000	\$594,000
Total Estimated Capital Cost	\$2,856,000	\$5,581,000
Combined Cost for East and Northeast WRFs	\$8,437,000	

flows. The use of denitrification filters (Option 2 and 3) will result in lower chemical costs, which are expected to be in the range of \$37,000 to \$52,000/year.

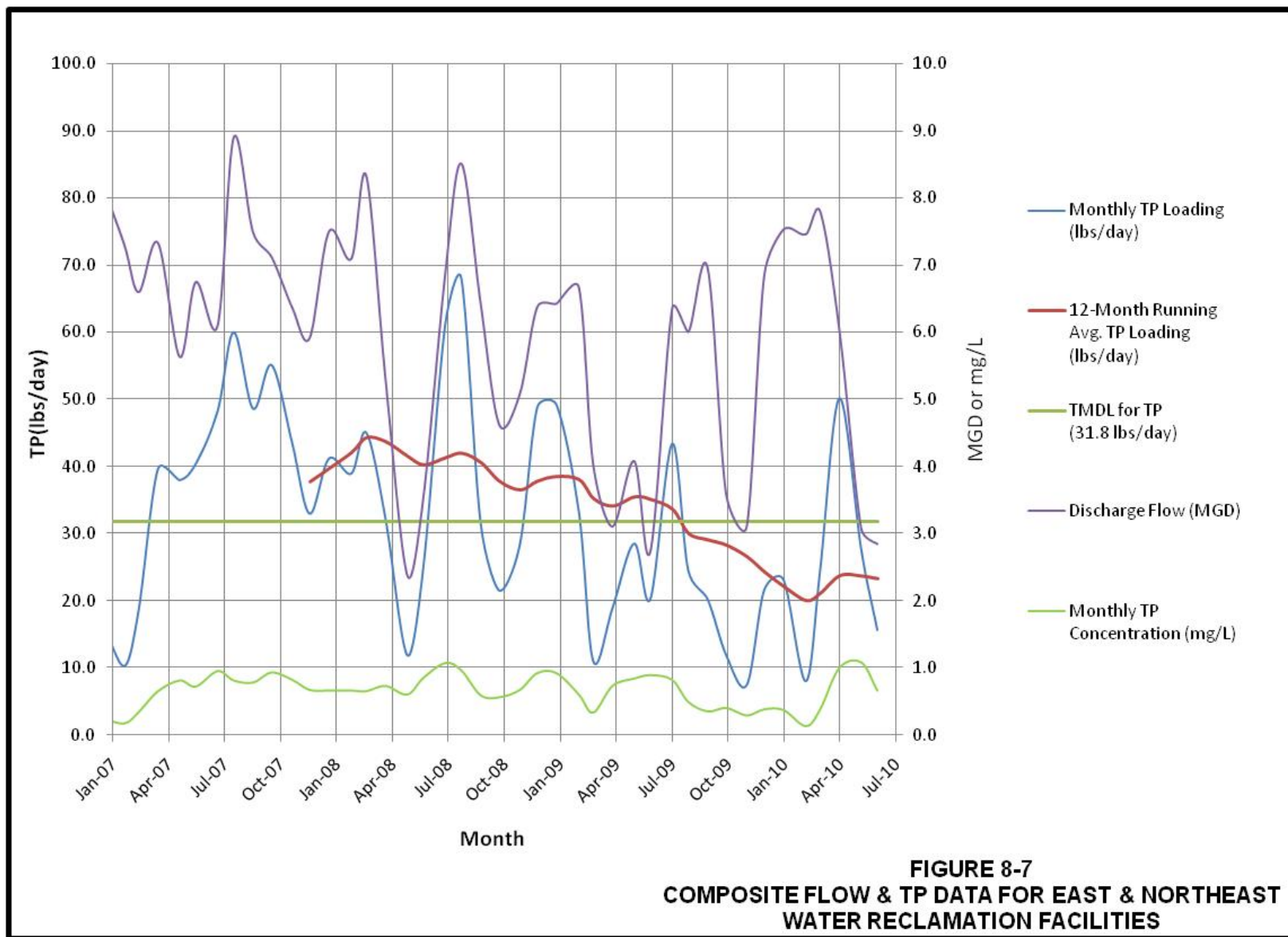
8.6 COMPLIANCE WITH PHOSPHORUS TMDL REQUIREMENTS AT CURRENT WASTEWATER FLOWS

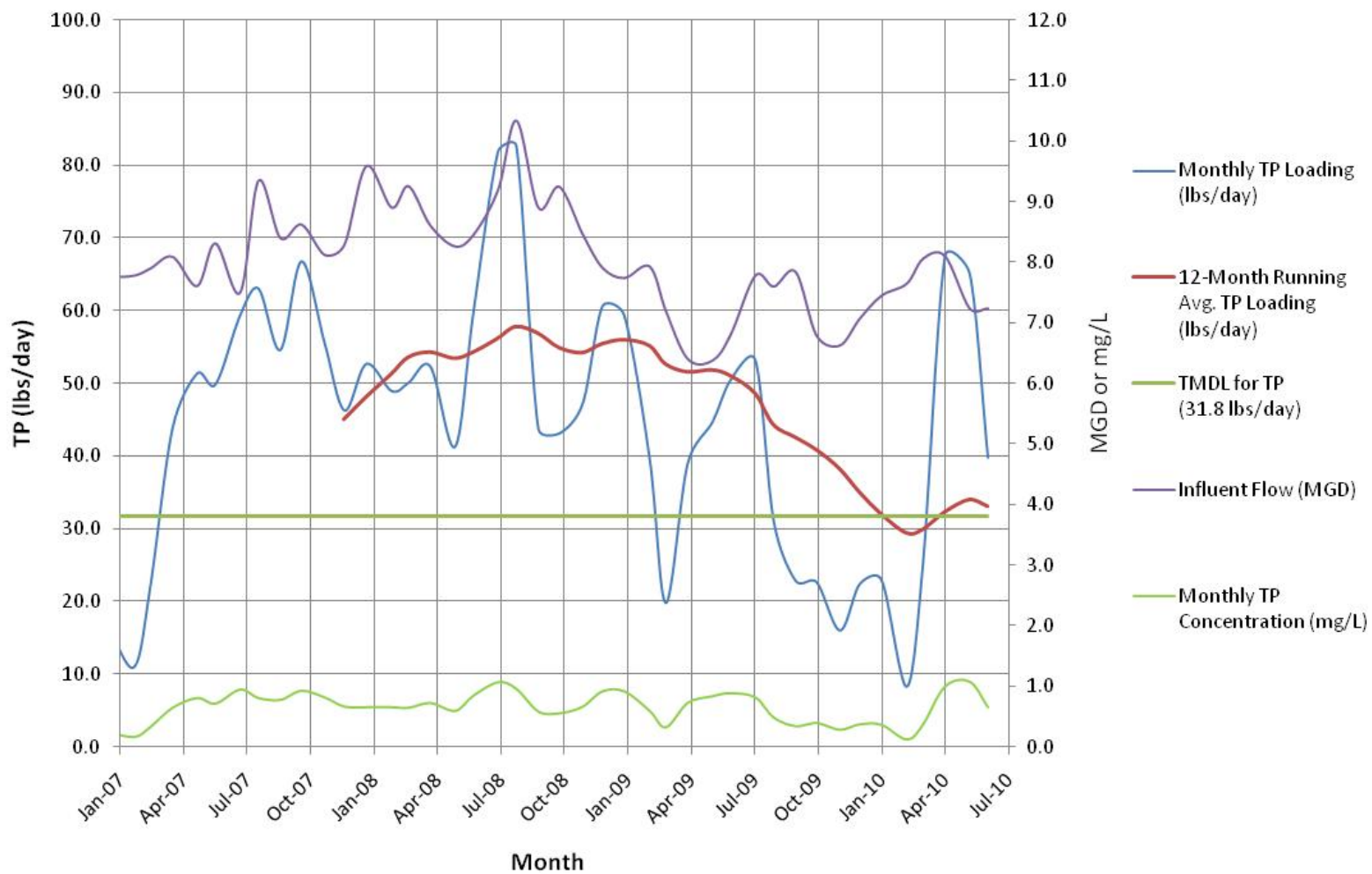
As stated in Section 8.3, there are no draft phosphorus TMDL values for the various entities that discharge treated effluent to Old Tampa Bay, however, a draft overall allocation of 104.0 tons/year for this water body is proposed by the Tampa Bay Nitrogen Management Consortium. Apparently, phosphorus loadings to Old Tampa Bay are less significant than nitrogen loadings with respect to water quality in the estuary.

The draft TP allocation of 104.0 tons/year may be revised and there does not appear to be any firm guidance with regard to the magnitude of the limit and the timing of its implementation. To facilitate a preliminary analysis, certain assumptions with regard to individual allocations must be made. In this particular case, the City's draft TN allocation of 27.1 ton/years makes up 5.58 percent of the total TN allocation for Old Tampa Bay. In the absence of other guidance it can be assumed that the TP allocation for the City will be consistent with the TN allocation, which results in a TMDL for phosphorus of 5.80 tons/year or 31.8 lbs/day. This assumption carries a significant degree of uncertainty; however, in the absence of more definitive guidance from FDEP it provides a reasonable basis for a preliminary assessment.

As is the case with TN, a compliance history cannot be established due to the nonexistence of actual TMDL criteria. Despite this fact it is useful to examine historical flow and performance data for the East and Northeast WRFs and compare the mass discharge rates from the facilities with the assumed TMDL. Accordingly, Figure 8-7 presents historical composite monthly data regarding flow, effluent TP concentration, and mass discharge of phosphorus, as well as 12-month running average data for phosphorus loading. For comparison, Figures 8-8 and 8-9 present similar composite data, however, in Figure 8-8 the reclaimed water demand has been removed to demonstrate the impact of effluent reuse and in Figure 8-9 the reclaimed water demand has been replaced with a demand of 3.80 MGD to show the effect of the groundwater replenishment program.

Based on the data presented in Figures 8-7 and 8-8, it is apparent that compliance with the phosphorus TMDLs can be expected at current flows and treatment efficiencies, as long as reclaimed water demands remain near their current levels. Flow projections in the current CARs indicate that influent flows should not increase significantly in the immediate future and the current levels of phosphorus removal are consistent with performance predicted by generally accepted performance models and are typical for well-operated 4-stage and 5-stage BNR facilities. In general, reclaimed water demands are not expected to decrease since there is considerable regulatory pressure to increase the beneficial reuse of treated effluent. In view of these factors it is





**FIGURE 8-8
COMPOSITE FLOW & TP DATA FOR EAST AND NORTHEAST
WATER RECLAMATION FACILITIES WITHOUT REUSE DEMAND**

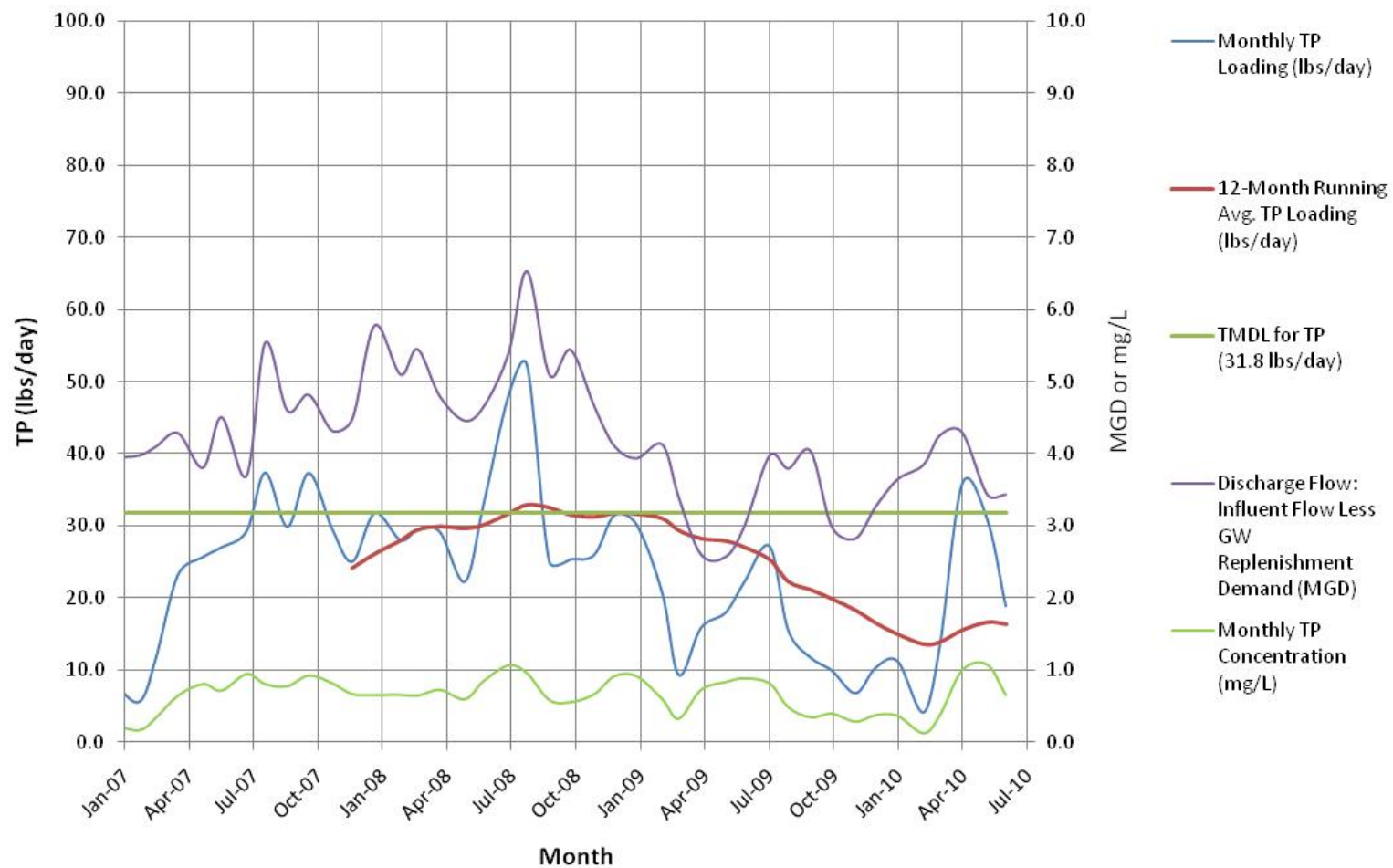
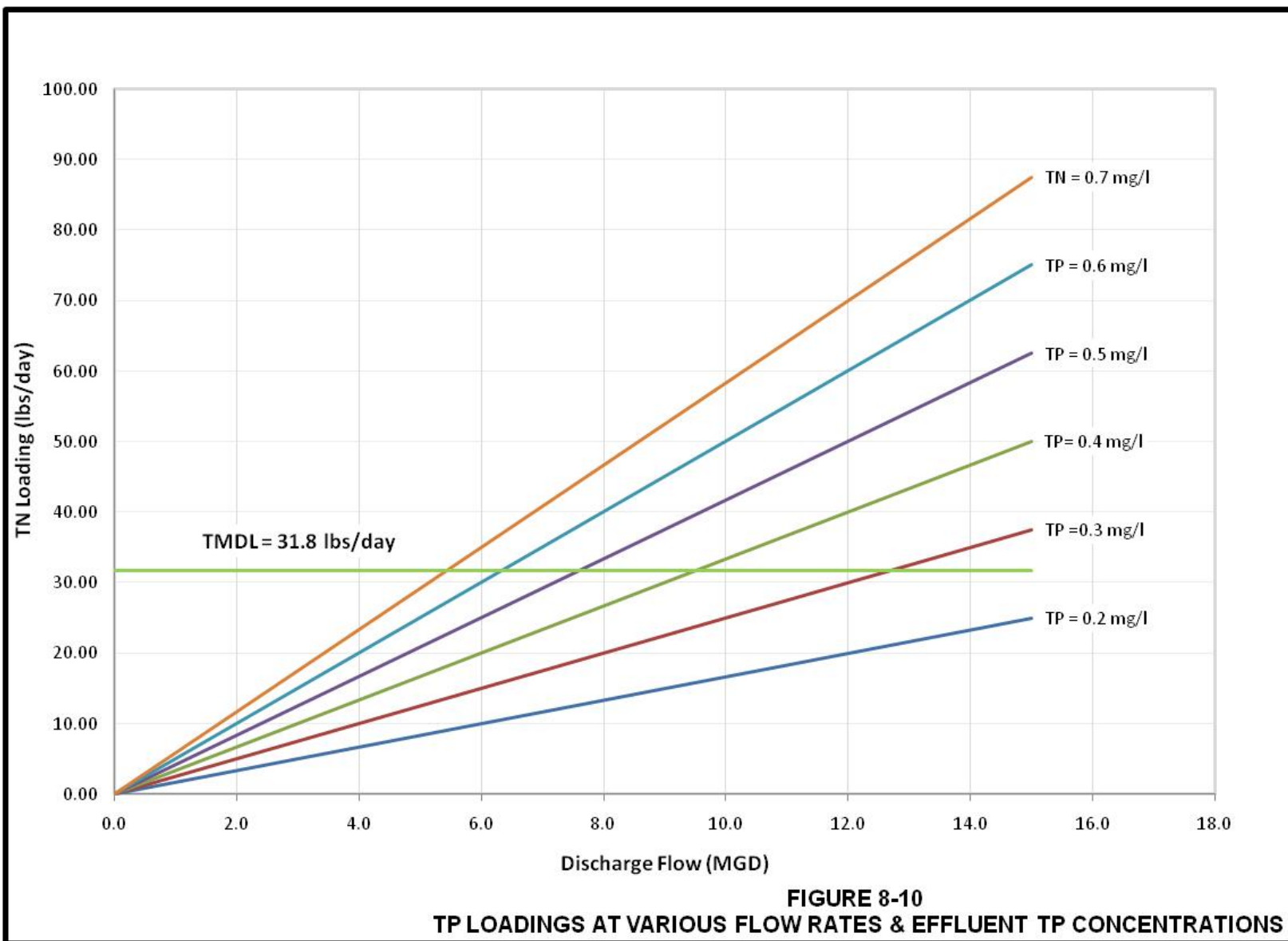


FIGURE 8-9
COMPOSITE FLOW & TP DATA FOR EAST & NORTHEAST WATER RECLAMATION FACILITIES
WITH 3.8 MGD GROUND WATER REPLENISHMENT
EFFLUENT DEMAND & NO REUSE DEMAND



reasonable to anticipate that no significant improvements to the existing East and Northeast WRFs will be necessary to comply with the assumed phosphorus TMDL as long as influent flows and reclaimed water demand are maintained at near current levels.

8.7 COMPLIANCE WITH PHOSPORUS TMDL REQUIREMENTS AT PROJECTED WASTEWATER FLOWS

As is the case with nitrogen, when considering the assumed phosphorus TMDL it is important to consider reclaimed water demand within the City's service area and the bulk purchases by Pinellas County since these demands will decrease discharges to Old Tampa Bay and minimize phosphorus loads, which in turn, influences the maximum allowable effluent TP concentrations. Figure 8-10 presents the assumed phosphorus TMDL and discharge flow versus phosphorus loading for various effluent TP concentrations to illustrate this relationship. Also, the same effluent reuse/discharge scenarios that are described in Section 8-5 are applicable to the evaluation of the phosphorus TMDL. Table 8-6 presents these scenarios along with estimated TP limits.

TABLE 8-6 PROJECTED ANNUAL AVERAGE WASTEWATER FLOWS, EFFLUENT REUSE/DISCHARGE SCENARIOS & EFFLUENT TP LIMITS						
Scenario No.	Influent AADF (MGD)	Effluent Reuse/Disposal Flows (MGD)				Effluent TP Limit (mg/L)
		City Reuse	Pinellas County Reuse	GW Repl.	Surface Water Discharge	
1	10.51	-0-	-0-	-0-	10.51	0.36
2	10.51	1.46	-0-	-0-	9.05	0.42
3	10.51	1.46	1.25	-0-	7.80	0.49
4	10.51	1.46	-0-	3.80	5.25	0.73
5	10.51	1.46	1.25	3.80	4.00	0.95
Note: The effluent TP limits are based on a TMDL of 31.8 lbs/day and the estimated discharge flows.						

Once again, Scenario 1 appears to be highly unlikely considering the success of the City's reuse program and the trend towards increasing the beneficial reuse of reclaimed water, however, a TP of 0.36 mg/L is readily achievable by adding a metal salt such as alum or ferrous sulfate to the reaeration basins at each WRF. Since BNR processes are already employed at the facilities, the chemical requirements would be very small, even under Scenario 1. For example an alum dosage of 7 to 10 mg/L should result in effluent TP concentrations of less than 0.36 mg/L. At existing flows this dosage range would result in a combined liquid alum feed rate of 86 to 123 GPD. As is the case with methanol, bulk storage for alum should be based on the rated AADF capacity of the plant and provision of 30 days of storage. Under these criteria a 2,000 gallon

polyethylene or fiberglass storage tank would be needed for the East WRF. Similarly, a 5,000 gallon storage vessel would be needed for the Northeast WRF. Feed facilities for liquid alum would include a transfer pump, day tank, level monitoring system, standard chemical metering pumps and related piping and appurtenances. Table 8-7 presents estimated costs for liquid alum storage and feed facilities for the East and Northeast WRFs.

TABLE 8-7 ESTIMATED COSTS FOR ADDITIONAL PHOSPHORUS REMOVAL		
Item	East WRF	Northeast WRF
Alum Storage Facilities	\$22,000	\$42,000
Alum Day Tank & Feed System	\$53,000	\$53,000
Control System & SCADA Modifications	\$50,000	\$75,000
Electrical & Instrumentation	\$35,000	\$50,000
Sub-Total	\$160,000	\$220,000
Mobilization, Bonds, Permits, & General Conditions	\$10,000	\$13,000
Contingency (20%)	\$32,000	\$44,000
Engineering, Permitting, & Construction Admin (15%)	\$24,000	\$33,000
Total Estimated Capital Cost	\$226,000	\$310,000
Combined Cost for East and Northeast APCFs	\$536,000	

As shown in Table 8-7, compliance with the “worst case” phosphorus limit results in a total capital expenditure of only \$536,000. It should be noted that it may be possible to modify the existing coagulant feed systems that are required for public-access reuse systems to comply with the lower phosphorus limits, which would significantly reduce the capital cost for increased levels of phosphorus removal.

As is the case with nitrogen removal, the major operating cost associated with additional phosphorous removal results from chemical addition. Pricing for liquid alum and other metal salts is more stable than pricing for methanol and a unit cost for liquid alum of \$0.90/gallon is considered a reasonable value for planning purposes. At current wastewater flows, it is anticipated that the combined annual cost for liquid alum addition at both the East WRF and the Northeast WRF would be in the range of \$28,000 to \$40,000/year.

8.8 SUMMARY

The TMDLs for nitrogen and phosphorus for discharge to Old Tampa Bay have not yet been finalized. Allocations for the various entities that discharge to this water body have been published for nitrogen, however, individual allocations have not been developed for phosphorus. Based on the draft nitrogen allocations, and reasonable assumptions regarding phosphorus, it appears that the East and Northeast WRFs will be in compliance with the TMDLs at existing flows as long as the current levels of treatment and reclaimed water demand are maintained.

Consideration of future conditions introduces a number of uncertainties with respect to compliance. Such uncertainties involve customer growth rates, wastewater flow projections, reclaimed water demands, and the potential implementation of a groundwater replenishment program. Under a 10-year planning window several possible scenarios can be developed to reflect varying levels of reclaimed water demand and the potential groundwater program. Under the most probable scenarios it appears that compliance with the nitrogen TMDL can be achieved without any improvements. The situation with the phosphorus TMDL is similar, however, the margin of safety is smaller.

If the City decides to move forward with wastewater management concepts that are consistent with Scenarios 2 or 3 as defined on Section 8.5, it would be prudent to establish a budget that reflects modifying the existing filters to provide fixed growth denitrification. Concurrently, it would be advisable to conduct some pilot testing to investigate the potential for using a more economical means of nitrogen removal involving suspended growth denitrification. For compliance with the phosphorus TMDL, the addition of a metal salt such as alum or ferrous sulfate will provide compliance with even the most stringent effluent limits. Current levels of phosphorus removal will not provide an acceptable margin of safety under Scenarios 2 and 3, therefore, it would be prudent to budget for the addition of chemical feed facilities at both WRFs. For general fiscal planning purposes, a cost of \$3,784,000 is considered adequate for the filter modifications while a cost of \$536,000 should be sufficient for the chemical feed facilities. Operating costs for any of the options would primarily result from chemical addition. For nitrogen removal, a budget of \$50,000/year should be adequate to address current flows assuming some sort of denitrification filter technology is utilized. Similarly, a budget of \$35,000/year should be adequate to address additional phosphorous removal at existing flows.

9.0 PRELIMINARY WATER QUALITY MONITORING PROGRAM

9.1 RECHARGE WATER

The quality of the purified water that will be used to recharge the aquifer will be required to be monitored for process control, to comply with regulatory requirements and to demonstrate that the recharge water is not adversely affecting the quality of the groundwater in the recharge zone. The regulatory requirements for monitoring of the water to be used for recharge are primarily contained in Rule 62-610.568, F.A.C. and supplemented by Rule 62-601, F.A.C. The regulatory requirements for monitoring are summarized below in Table 9-1.

Table 9-1. Recharge Water Sampling Program			
Parameter	Sample Type	Sample Location	Frequency
Turbidity	On-line	Prior to Application of Disinfectant	Continuous
Chlorine Residual	On-line	Compliance Monitoring Point	Continuous
Total Organic Carbon	24 hour composite	Prior to Injection	Daily
Total Organic Halide	24 hour composite	Prior to Injection	Daily
Total Coliforms	Grab	Prior to Injection	Daily
Total Suspended Solids	Grab	Prior to Injection	Daily
Primary Drinking Water Standards	24 hour composite	Prior to Injection	Monthly
Secondary Drinking Water Standards	24 hour composite	Prior to Injection	Quarterly
Cryptosporidium	Grab	Prior to Injection	Quarterly
Giardia	Grab	Prior to Injection	Quarterly

During the reclaimed water sampling program additional compounds may be determined as compounds of concern that should be added to the recharge monitoring program. This could include emerging contaminants of concern, such as 1,4 Dioxane or NDMA, or pharmaceutical compounds.

Monitoring of the purification process is recommended to occur in addition to the minimum regulatory requirements listed above in order to ensure that the various treatment processes proposed are operating as intended to provide the design treatment efficiencies. This monitoring will be continuous utilizing on-line monitoring equipment. For example, the primary purpose of the ultrafiltration (UF) process is the removal of very small particulates from the reclaimed water. Turbidity will be continuously monitored to so that the cleaning frequency of the UF system can be optimized. The sampling program for the treatment process is shown in Table 9-2 below.

Table 9-2. Process Treatment Sampling Program			
Parameter	Sample Type	Sample Location	Frequency
Turbidity	On-line	UF Filtrate	Continuous
pH	On-line	RO Feed	Continuous
pH	On-line	Membrane Contactor Feed	Continuous
pH	On-line	Prior to Injection	Continuous
Conductivity	On-line	RO Feed	Continuous
Conductivity	On-line	RO Permeate	Continuous
Calcium	Grab	UF Filtrate	Daily
Calcium	Grab	RO Permeate	Daily
Calcium	Grab	Prior to Injection	Daily
Alkalinity	Grab	RO Permeate	Daily
Alkalinity	Grab	Prior to Injection	Daily
Sodium	Grab	UF Filtrate	Weekly
Sodium	Grab	RO Permeate	Weekly
Chloride	Grab	UF Filtrate	Daily
Chloride	Grab	RO Permeate	Daily
TOC	Grab	Reclaimed Water	Weekly
TOC	Grab	RO Permeate	Weekly
Chlorine Residual	On-line	RO Feed	Continuous
Dissolved Oxygen	On-line	Prior to Injection	Continuous
ORP	On-line	Prior to Injection	Continuous

9.2 GROUNDWATER MONITORING

A groundwater monitoring program will be developed to establish background water quality in the recharge zone (Lower Zone A) and in the aquifer above the recharge zone (Upper Zone A), and to monitor the quality of the groundwater during operation of the recharge system to comply with regulatory requirements and to demonstrate that the recharge water is not adversely impacting the quality of the groundwater. The regulatory requirements for monitoring of the groundwater are contained in Chapters 62-520 (Groundwater Classes, Standards, and Exemptions), 62-522 (Groundwater Permitting and Monitoring Requirements), 62-528 (Underground Injection Control), 62-601 (Domestic Wastewater Treatment Plant Monitoring), and 62-610 (Reuse of Reclaimed Water and Land Application), F.A.C.

The recharge wells are Class V injection wells (Group 2 - Aquifer Recharge Wells) and shall follow the regulations stipulated in Chapter 62-528. Per Rule 62-528.615, F.A.C. (Monitoring Requirements for Class V Wells) "the need for monitoring shall be determined by the type of well, nature of the injected fluid, and water quality of the receiving and overlying aquifers."

Per Rule 62-520.600 (Groundwater Monitoring Requirements and Exemptions, adopted July 12th, 2009), unless otherwise exempted by Department rule, any installation discharging into groundwater shall establish a monitoring program as described in 62-520.600(3), F.A.C. Additionally, all field and laboratory activities performed under a monitoring program shall meet the quality assurance requirements in Chapter 62-160, F.A.C.

For new installations, the monitoring plan shall be submitted to the Department in conjunction with the installation's initial permit applications.

Per 62-520.600(3), F.A.C., "Design of a groundwater monitoring plan is variable and dependant on the complexity of the site hydrogeology, type of facility, and method and characteristics of the discharge. The Department's document, Guidance for Groundwater Monitoring Plan Design, 2008, is adopted as guidance to assist permittees and installation owners in designing and placing monitoring wells to demonstrate whether compliance with the requirements in this chapter are being achieved."

A Groundwater Monitoring Plan (GWMP) will be required for the Groundwater Replenishment (GWR) Project. Upon approval by the FDEP, the GWMP will become part of the facility permit for the GWR purification plant. The GWMP must be signed and sealed by the professional geologist or professional engineer who prepared or approved it. Data collection and reporting must meet the requirements of Chapter 62-160, F.A.C., the Quality Assurance rule. The GWMP provides reasonable assurance that groundwater standards will be met at the edge of the facility's zone of discharge or point of compliance, as applicable.

Per Rule 62-520.600(3), F.A.C., the GWMP shall:

(a) Describe the physical and hydrogeologic characteristics of the facility and surrounding area including:

1. Direction and rate of groundwater flow and ambient groundwater characteristics;
2. Primary and secondary porosity, and horizontal and vertical permeability for the receiving aquifer(s);
3. The depth to, and lithology of, the first confining bed(s);
4. Vertical permeability, thickness, competence, and extent of any confining beds;
5. Topography, soil information, and surface water drainage systems surrounding the site;

(b) Show the locations of the proposed monitoring wells labeled as background, intermediate, or compliance well;

(c) Provide construction and development details of the monitoring wells;

(d) Provide a water sampling and chemical analysis protocol;

(e) Provide a water sampling schedule;

(f) Demonstrate the quality of the receiving groundwater prior to discharge;

(g) Indicate how to determine natural background (where available) or background quality of the groundwater in the vicinity of the site and any deviations in the quality of the receiving groundwater in the downgradient monitoring wells;

- (h) Show the locations of all surface waters and their classifications including springs within a one mile radius of the site, and on-site sinkholes with depths exceeding the seasonal high water table or that are perched; and
- (i) Identify the location and use of all wells within 1000 feet of the site.

Regarding the implementation of the GWMP, the following applies per 62-520.600(5):

1. All groundwater monitoring wells shall be installed before the application of waste or wastewater; and
2. After well installation and well development, but before the application of the waste or wastewater for which the groundwater monitoring plan was required, the permittee shall sample one or more of the groundwater monitoring wells specified in the Department-approved monitoring plan or permit for the primary and secondary drinking water parameters included in Chapter 62-550, F.A.C. (excluding asbestos, acrylamide, Dioxin, butachlor, epichlorohydrin, pesticides, and PCBs, unless reasonably expected to be a constituent of the discharge or an artifact of the site). In addition, volatile organics and extractable semivolatile organics shall be analyzed. Results of this sampling shall be submitted to the Department within 60 days after sampling.

Rule 62-520.600(6), F.A.C., (Location, Design, and Construction of Monitoring Wells to Detect Migration of Contaminants) stipulates the following regarding the groundwater monitoring wells:

- (a) One upgradient well located as close as possible to the site, without being affected by that site's discharge, to determine the natural background quality where available, or background of the groundwater (background well);
- (b) One well downgradient from the site and within the zone of discharge designed to detect the chemical, physical, and microbiological characteristics of the discharge plume (intermediate well); and
- (c) One well at the edge of the zone of discharge downgradient from the site (compliance well);
- (d) Such other wells as are dictated by the complexity of the hydrogeology of the site, the magnitude and direction of the plume, or the likelihood of threat to the public health, to ensure adequate and reliable monitoring data in generally accepted engineering or hydrogeological practice. The Department shall exempt a facility from installing a background or intermediate well when not practicable or necessary because of site hydrogeology, effluent quality, site location, or surrounding land use;
- (e) The Department's Monitoring Well Design and Construction Guidance Manual, (2008), is adopted as guidance to assist permittees and installation owners in monitoring well design and construction. Copies of this document are available from the Department of Environmental Protection, Bureau of Water Facilities Regulation, MS 3580, 2600 Blair Stone Road, Tallahassee, Florida 32399-2400 or at the Department's Internet site:

<http://www.dep.state.fl.us/water/groundwater/pubs.htm>;

- (f) Monitoring well design shall be submitted to the Department;

- (g) Before construction of new groundwater monitoring wells, a soil boring shall be made at each new monitoring well location to properly determine monitoring well specifications such as well depth, screen interval, screen slot, and filter pack;
- (h) Before the installation of any monitoring well, the permittee shall give at least 72 hours notice to the appropriate permitting program at the Department's District office that issued the permit;
- (i) Within 60 days after installation of any monitoring well, a properly scaled figure depicting monitoring well locations (active and abandoned) with identification numbers shall be submitted to the appropriate permitting program at the Department's District office that issued the permit. The figure also shall include the monitoring well, top of casing, and ground surface elevations referenced to the National Geodetic Vertical Datum (NGVD) of 1929 or to the North American Vertical Datum (NAVD 1988) and measured to the nearest 0.01 foot, along with monitoring well location latitude and longitude to the nearest 0.1 seconds;
- (j) Within 30 days after installation of the monitoring wells, well completion reports and soil boring/lithologic logs shall be sent to the Department's District office that issued the permit. The information is to be submitted for each well on DEP Form 62-520.900(3), Monitoring Well Completion Report, incorporated herein and listed in Rule 62-520.900, F.A.C.

9.2.1 Preliminary Locations and Depths of Monitoring Wells

Five (5) recharge wells are currently proposed for this project. As discussed in Section 4, further testing of the aquifer is necessary before the layout of the recharge wells and the layout of the monitoring wells is finalized. Background, intermediate, and compliance wells will be installed per Rule 62-520.600(6), F.A.C. As shown in Figure 4-19, it is proposed for the exploratory/recharge testing program that one test well be installed, two (2) intermediate monitoring wells installed (one Upper Zone A well, one Lower Zone A well), and two (2) perimeter/compliance wells installed (one Upper Zone A well, one Lower Zone A well). The preliminary recharge well and monitoring well locations are illustrated in Figure 4-20. Background water quality information will be collected from each recharge well upon the completion of well construction and development and prior to recharge. The details of the monitoring wells will be outlined in the GWMP.

Hydraulic testing of the aquifer is proposed to be completed in the next phases (FY 2011 and 2012) of this project to confirm the hydrogeological characteristics of the aquifer. This information will be utilized to develop the distance between the recharge wells and the intermediate wells. The compliance wells are proposed to be located at the City's property boundaries.

9.2.2 Preliminary Groundwater Sampling Plan

The proposed groundwater sampling plan, as shown in Table 9-3, targets those parameters that are of most concern for this groundwater recharge project.

Table 9-3 Groundwater Sampling Plan				
Parameter	Compliance Well Limit	Units	Sample Type	Sampling Frequency
Groundwater Level Relative to NGVD	Report	Feet	In-situ	Monthly
Arsenic, Total Recoverable	Varies, Based on Pre-Recharge Value per Well	ug/L	Grab	Monthly
Solids, Total Dissolved (TDS)	Secondary MCL = 500 or Background	mg/L	Grab	Quarterly
pH	6.5-8.5	SU	In-situ	Quarterly
Molybdenum	Report	ug/L	Grab	Quarterly
Dissolved Oxygen	Report	mg/L	In-situ	Quarterly
ORP	Report	millivolts	In-situ	Quarterly
Conductivity	Report	μs/cm	In-situ/ Grab	Monthly
Calcium	Report	mg/L	Grab	Monthly
Alkalinity	Report	mg/L	Grab	Monthly
Sodium	Primary MCL = 160 or Background	mg/L	Grab	Monthly
Chloride	Secondary MCL = 250 or Background	mg/L	Grab	Monthly

As discussed previously, additional compounds could be discovered during the reclaimed water sampling program that would be added to the recharge monitoring program. It is not anticipated that these compounds would be added to the groundwater sampling plan as it would be demonstrated that they are removed through the purification process, however the potential to add these compounds to the groundwater sampling plan exists there should any detection of these compounds during the sampling of the recharge water.

9.2.3 Development of Groundwater Monitoring Plan

The GWMP will be developed in a next phase of the project. The GWMP will be submitted with the Water Purification Plant permit application.

10.0 PUBLIC OUTREACH RECOMMENDATIONS

10.1 PUBLIC OUTREACH

Public outreach is a critical part of an indirect potable reuse project. Successfully implementing this type of project requires a clear understanding of how it will initially be perceived, how to describe its value, and how to conduct an effective outreach program. Other indirect potable reuse projects across the country have invested substantial resources to provide comprehensive public outreach programs to engage the public in the understanding and development of these projects. The City of Clearwater is committed to the development of a public outreach program that begins during the design of the City's Groundwater Replenishment Project and continues through the construction of the project.

FDEP regulations for groundwater replenishment also address the requirements for public notification and public education/participation. Public notification and public education/participation requirements are detailed in 62-610.574 F.A.C. According to 62-610.574(2) F.A.C., public notification is required for projects involving underground injection, including the requirement for opportunities for a public meeting as outlined in 62-528 F.A.C. 62-610.574(3) F.A.C., requires permittees developing groundwater recharge or indirect potable reuse project that will be regulated under Part V of Chapter 62-610 F.A.C. to implement public education and public participation programs during the planning stages of the program and requires the public education and public participation programs to be described in detail in the engineering report. Finally, 62-610.574(4) requires the written notification to affected public water supply utilities within the area to be affected by the proposed project.

For this Feasibility Study, two public outreach activities were completed:

1. Collaborative Workshop with City Staff
2. Development of an Investment Executive Summary

10.2 COLLABORATIVE WORKSHOP

Tetra Tech and team member Resource Trends prepared for and facilitated a public outreach collaborative workshop for City staff on July 16th, 2010 at the City's Public Works classroom. The interactive workshop was designed to help the City efficiently and cost-effectively implement an outreach process so that a strong foundation for future outreach efforts is developed. This process focuses on building important community relationships and helping policy makers feel safe to support potable reuse.

The workshop brought together City staff from several different departments (water, wastewater, reclaimed water, and public communications) to discuss the Groundwater Replenishment project. The workshop content was based on research conducted by Resource Trends through the WateReuse Foundation and experience with the branding

of utilities and recycled water. The agenda from the Workshop is included in Appendix B. Topics such as the following were discussed:

- Fundamental Principles of Public Perceptions and Branding
- How Recycled Water is “Branded,” and Building a Positive Brand
- Different Grades of Recycled Water and Specific Perception Issues
- Creating Water Quality Confidence
- Ensuring Good Policy Decisions
 - o Working with Elected Officials
- Managing Disagreement and Conflict
 - o Addressing the Disproportionate Influence of Vocal Opponents
 - o Addressing the “Growth” Issue
- Case Studies of Past Projects (Positive and Negative Outcomes)
- Discussing the Unique Issues Facing the City
 - o Making the Case for Investing in Groundwater Replenishment
- Effective Public Outreach Strategies
 - o Avoiding the “Decide, Announce, Defend” Approach
 - o Building Relationships with Active and Important Community Members
 - o Getting Feedback from the Community
 - Customer Surveys, Focus Groups, Listening
 - o Focusing on the Relationship with Policy Makers

10.3 INVESTMENT EXECUTIVE SUMMARY

Based on the insights gathered during the Workshop, specific recommendations have been developed to help the City lead a productive dialogue with the community and the region as the GWR Project proceeds. The details of the recommendations are included in Appendix B. The primary recommendations from the Workshop are:

1. Create a timeline.
2. Develop the case for investment.
3. Make sure desalination is included in the alternatives.
4. Be rigorous on withdrawal credits and aquifer hydrology.
5. Address conflict in the planning stage.
6. Understand and avoid environmental justice problems.
7. Build relationships and build support.
8. Develop of close relationship with City Council on outreach.
9. Observe and learn from the upcoming Tampa vote.
10. Separate the drinking water facility from the reclamation facility.

It is recommended that the City proceed with public outreach activities in the next 12 months to not only advance the public outreach for the Groundwater Replenishment Project, but also to update the public on the City’s water programs. Recommended public outreach activities include:

- a. Providing a public viewing area at the Pilot GWR Purification Plant.

- b. Developing a page on the City's website dedicated to discussing the City's Integrated Water Management Strategy, including the Groundwater Replenishment Project.
- c. Collaborating with the SWFWMD and the FDEP on regional public outreach for indirect potable reuse projects.

11.0 SUMMARY AND RECOMMENDATIONS

11.1 SUMMARY

This feasibility study has included the results of the continued investigation into the feasibility of the City of Clearwater utilizing reclaimed water from the NEWRF as a source water for groundwater replenishment following a treatment process that results in a highly purified water. This study included a review of historical reclaimed water quality, preliminary reclaimed water sampling, a review of historical groundwater quality, preliminary groundwater sampling, groundwater modeling, and geochemical modeling that were used to update the recommendations and cost opinions presented in the Preliminary Feasibility Study that was submitted to the City in a letter reported dated September, 15, 2009. This feasibility study also included a preliminary design of a pilot GWR purification plant, a review of the proposed TMDLs for the City's surface water discharge for reclaimed water and its impact on the EWRF and NEWRF, and the development of a public information program for the early phases of this project.

Results from the feasibility study indicate that the proposed facilities summarized below are a feasible approach to providing a water supply that is safe and meets or exceeds drinking water standards prior to injection and will provide a benefit to groundwater levels in the surrounding area.

- Five (5) groundwater recharge wells and associated monitoring wells located near the NEWRF (two recharge wells located on-site and three recharge wells located within the golf courses to the west, Chi Chi Rodriguez and Countryside Country Club).
- A proposed treatment process located on the property of the NEWRF that includes a supply of approximately 3.8 MGD of treated effluent from the NEWRF and the following processes:
 - o Chemical Pretreatment (conversion to chloramines)
 - o Strainers
 - o Microfiltration
 - o Reverse Osmosis
 - o Advanced Oxidation (hydrogen peroxide and UV oxidation).
 - o Stabilization (carbon dioxide and calcium hydroxide addition)
 - o Dissolved Oxygen Removal
 - o Chemical Post treatment (ferrous sulfate and sodium bisulfide addition)

Verification and refinement of these facilities will be a step-wise approach as the City continues to move forward with implementation of groundwater replenishment. Additional reclaimed water and groundwater sampling to better characterize each, along with pilot testing, construction of preliminary monitoring wells, and an exploratory well will be the next steps in confirming the treatment process and post treatment requirements for the groundwater replenishment process as well as confirming the rate of injection.

Implementation of a groundwater recharge system will include monitoring protocols on the treated water prior to injection and in the groundwater to address any water quality issues that may arise during operation. A summary of the proposed monitoring protocols was provided in Section 9.

The preliminary costs opinions discussed in Section 6 for the groundwater replenishment program are summarized in Table 11-1.

Table 11-1. Conceptual Cost Opinion Summary for GWR Facilities	
Capital Cost Opinion	\$28,580,000
O&M Cost Opinion	\$1,960,000/year
Capital Cost per Thousand Gallons ¹	\$2.28/kgal
O&M Cost per Thousand Gallons	\$1.79/kgal
Total Cost per Thousand Gallons ¹	\$4.07/kgal

1. Based on 20 years and 6%.

In order to achieve compliance with total maximum daily load (TMDL) regulations, three alternatives for the additional nitrogen removal required at the EWRF and the NEWRF based analysis provided in Section 8 is provided in Table 11-2. Additionally, the costs for additional phosphorus removal based on the draft overall allocation proposed by the Tampa Bay Nitrogen Management Consortium is also included in Table 11-2 for the EWRF and the NEWRF. The cost for additional phosphorus removal would be in addition to the selected option for increased nitrogen removal. These upgrades would not be required with the implementation of the GWR program due to the amount of flow diverted from the effluent based on the projections and historical nitrogen and phosphorus concentrations in the effluent when compared to the proposed limits.

Table 11-2. Estimated Costs for Additional Nitrogen and Phosphorus Removal Options				
Item	Capital Cost for EWRF	Capital Cost for NEWRF	Combined Capital Cost for EWRF and NEWRF	O&M Costs
<u>Option 1:</u> Methanol Feed & Suspended Growth Denitrification	\$486,000	\$745,000	\$1,231,000	\$100,000/year
<u>Option 2:</u> Methanol Feed & Fixed Growth Denitrification (Modify Existing Filters)	\$1,305,000	\$2,479,000	\$3,784,000	\$50,000/year
<u>Option 3:</u> Methanol Feed & Fixed Growth Denitrification (Replace Existing Filters)	\$2,856,000	\$5,581,000	\$8,437,000	\$50,000/year
Additional Phosphorus Removal	\$226,000	\$310,000	\$536,000	\$35,000/year

11.2 RECOMMENDATIONS

Based on the findings of this evaluation, this project continues to appear to be a technically feasible alternative to more fully utilize the City's water resources. In addition, the TMDLs for Tampa Bay may necessitate the reduction or elimination of surface water discharge from the City's East and Northeast WRFs or expensive upgrades to those treatment plants to reduce the nitrogen and phosphorus discharges. A groundwater replenishment system would help the City to reduce the discharges to Tampa Bay. As the City moves forward with developing this groundwater recharge system the following future steps will be required prior to full-scale implementation.

- **Pilot Testing** – Based on the groundwater samples taken, the TDS of the proposed injection zone is greater than 500 mg/L. Therefore, pilot testing for a minimum of 12 months will be required by FDEP prior to issuing a permit for injection of the recharge water. Included in the pilot testing would be the design of the pilot unit, bidding and construction of the pilot unit, development of a pilot test plan and protocol, operation of the pilot unit and sampling during pilot testing operations.
- **Reclaimed Water Sampling**- Analysis of the existing reclaimed water quality will be required to confirm the design parameters presented in this study as well as observe variations in the water quality in the reclaimed water. A proposed reclaimed water sampling plan was provided in Section 3.
- **Preliminary Monitoring Wells** – Construction monitoring wells in locations where the permanent monitoring wells are anticipated to be located, will allow for sampling of the groundwater around the injection zone to further characterize the groundwater. The monitoring wells could also be used to extract cores from the local formation for testing.
- **Groundwater Sampling** – Additional groundwater sampling will be required to further characterize the groundwater in the injection zone. The preliminary monitoring wells and the existing inactive test ASR well at the NEWRF can be used to pull groundwater samples. Groundwater quality with respect to minerals and metals will be important to fully characterize as the implementation of a groundwater replenishment program continues.
- **Exploratory Well** – A UIC permit will be required to drill an exploratory well. The exploratory well could be located at one of the proposed recharge well locations so it could be converted to a recharge well following construction of the purification process. The exploratory well could be used to do both aquifer performance testing and injection testing.
- **UIC Permit for Recharge Wells** – Permits will be required from FDEP and the SWFWMD for drilling/operating recharge wells for groundwater recharge. Involving regulatory agencies early in the planning process can help streamline the permitting

process. The UIC permit process for the recharge wells should be started following injection testing on the exploratory well.

- **Purification WTP Permitting** – Following piloting of the purification process, the permitting process for construction the purification process should begin. A permit for disposal of the concentrate should also be applied for at the same time.
- **Preliminary Design** – A preliminary design report will fully define the process design of the groundwater replenishment system, serving as the basis of design and providing documentation for permitting applications.
- **Public Participation** – Public education and input early in the process can help with public acceptance and support of the project. Items that can be included in a public participation plan include surveys, public notices, e-mails and mail-outs, flyers and fact sheets, public meetings, websites, and media liaisons. A public education/information center could be included as part of the pilot testing program as a way for the public to learn more about the proposed process and the testing done by the City prior to implementation. Public education and input will also continue through each step of the project to keep the public informed throughout the development of the groundwater replenishment system.

A proposed work flow chart outlining the various steps in implementing the groundwater replenishment program is provided in Figure 11-1.

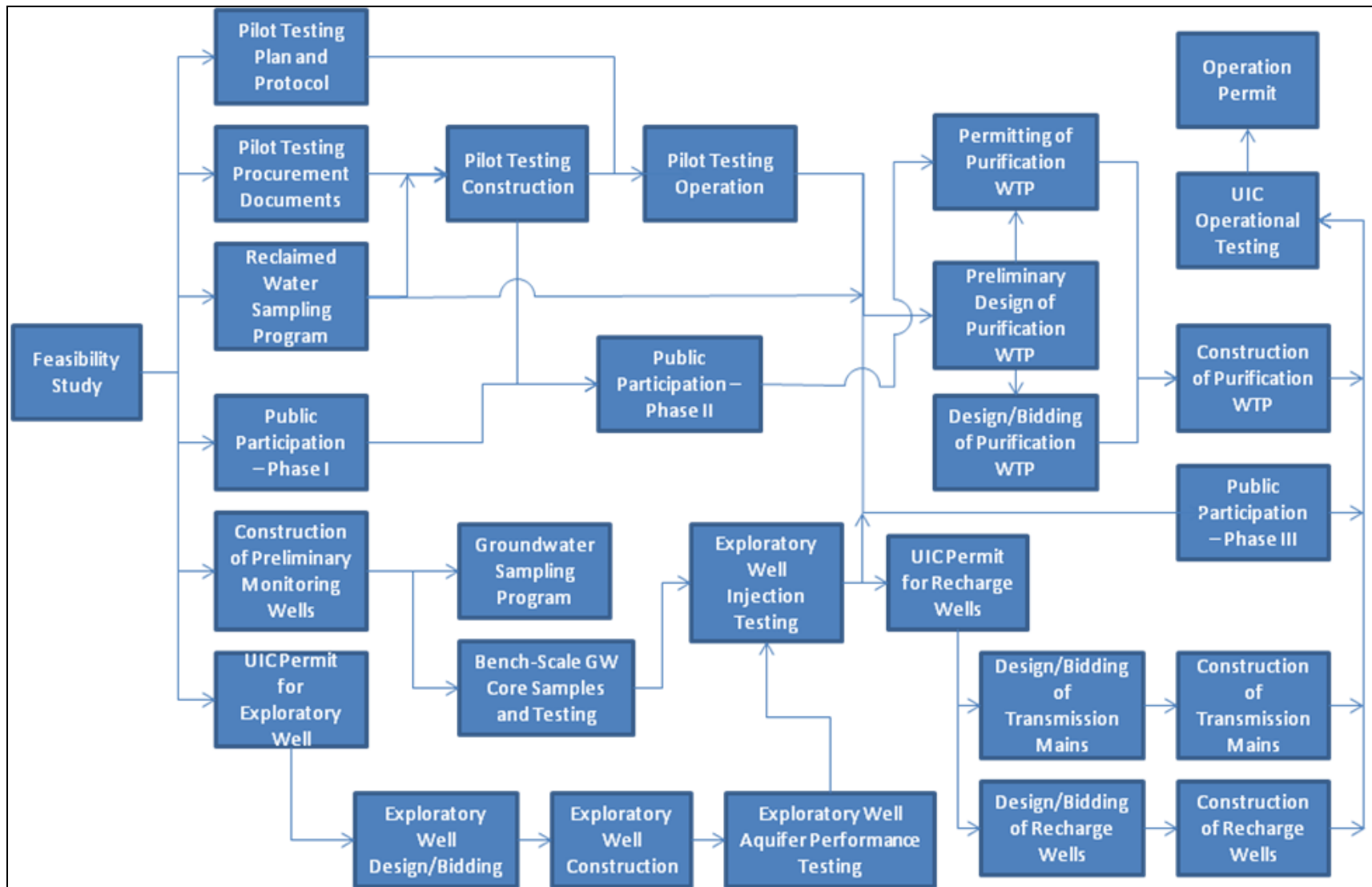


Figure 11-1. City of Clearwater Groundwater Replenishment Program Implementation Flow Chart

12.0 REFERENCES

Aquifer Storage and Recovery Systems, 2007, Evaluation of Arsenic Mobilization Processes Occurring During Aquifer Storage and Recovery Activities (H064): Consulting report prepared for Southwest Florida Water Management District.

Arthur J. D., Cowart J. B., and Dabous, A.A., 2001. Florida Aquifer Storage and Recovery Geochemical Study: 1999 Progress Report. Tallahassee, Florida Geological Survey, pp 1-49.

Arthur J. D., Cowart J. B., and Dabous, A.A., 2002. Mobilization of arsenic and other trace elements during aquifer storage and recovery, southwest Florida. Submitted for publication in a USGS report on proceedings of the USGS Artificial Recharge.

Asano, T. and Cotruvo, J.A., Groundwater Recharge with Reclaimed Municipal Wastewater: Health and Regulatory Considerations. Water Research, January 2004.

Bell, K., Wiseman, L., and Turner, L., Designing Pretreatment to Control Arsenic Leaching in ASR Facilities. JAWWA, June 2009.

Bethke, C.M., and Yeakel, S., 2010, The Geochemist's Workbench Reference Manual and GWB Essentials Guide, Release 8.0. Hydrogeology Program, University of Illinois at Urbana-Champaign.

Black, Crow, and Eidness, 1978, Drilling and Testing of the Monitoring and Injection Wells at the Southwest Wastewater Treatment Plant for the City of St. Petersburg, Florida, Consultant Report.

Broska, J.C. and Barnette, H.L., 1999, Hydrogeology and Analysis of Aquifer Characteristics in West-Central Pinellas County, Florida, U.S.G.S Open-File Report 99-185.

Casseaux, K.W., 1895, The Surficial Aquifer in Pinellas County, Florida, U.S.G.S. Water Resources Investigation Report 82-4289.

CH2MHill. 2007, Final Technical Report Arsenic Mobilization in Two Suwannee Limestone Aquifer Storage Recovery Systems.

Cherry, R.N., Wright, A.P. and Weitzner, M.I., Water Resources of Clearwater-Dunedin Area, Florida.

ENTRIX, undated PowerPoint Presentation, ASR Using Sodium Bisulfide Treatment for Deoxidation to Prevent Arsenic Mobilization. Unpublished PowerPoint presentation developed for St. Johns River Water Management District and City of DeLand.

ENTRIX, undated memorandum, Alternative Methodology to Control Leaching of Arsenic During Aquifer Storage and Recovery Using A Chemical Reduction Process.

Faure, G. (1991), Principles and Applications of Inorganic Geochemistry. MacMillan Publishing Co., 626 p.

Hem, J.D., 1985, Study and Interpretation of the Chemical Characteristics of Natural Water, 3rd ed.: U.S. Geological Survey Water-Supply Paper 2254, 263 p.

Hickey, J.J., 1982, Hydrogeology and results of injection tests at waste-injection sites in Pinellas County, Florida: U.S. Geological Survey Water-Supply Paper 2183.

Hutchinson, C.B. and Stewart, J.W., 1978, Geohydrologic Evaluation of a landfill in a coastal area, St. Petersburg, Florida, U.S.G.S. Water Resources Investigation Report 77-78.

Knochenmus, L. A. and Swenson, E. S., 1996, Assessment of the Fresh- and Brackish-Water Resources Underlying Dunedin and Adjacent Areas of Northern Pinellas County, Florida, U.S.G.S. Water Resources Investigation Report 96-4164.

LBG, 2010, City of Clearwater Well Field Expansion Report.

Mirecki, J.K., Bednar, A.J., Arthur, J.D., and Molina, L.R. (2005), Trends in Arsenic and Radium Geochemistry During Aquifer Storage and Recovery in the Upper Floridan Aquifer, Lee County, Florida. In Abstract Book - 2005 NGWA Naturally Occurring Contaminants Conference: Arsenic, Radium, Radon, and Uranium, pp. 165 - 167. NGWA Press.

M.P. Brown and Associates, 1986, Hydrogeological Investigation for the Development and Management of the Floridan Aquifer, City of Dunedin, Florida, Consultants Report.

MWH, Feasibility of Using Reclaimed Water for Aquifer Recharge. SWFWMD, March 2009.

MWH, 2009, Feasibility of Aquifer Recharge Using Reclaimed Water in the Tampa Bay Area, Consultant Presentation.

Pankow, J. (1991), Aquatic Chemistry Concepts. Lewis Publishers, 673 p.

Parkhurst, D.L., 1995, User's Guide to PHREEQC – a Computer Program for Speciation, Reaction-Path, Advective-Transport, and Inverse Geochemical Calculations. USGS Water-Resources Investigations Report 95-4227.

Parkhurst, D.L., and Appelo, A.A.J., 1999, User's Guide to PHREEQC (version 2) – A Computer Program for Speciation, Batch-Reaction, One-Dimensional Transport, and

Inverse Geochemical Modeling. USGS Water Resources-Investigations Report 99-4259.

PBS&J, 2006, City of Clearwater Reclaimed Water ASR Exploratory Well Program, Consultant Report.

Price, R. and Pichler, T., 2002, Naturally occurring arsenic in the Upper Floridan Aquifer, southwest Florida: Implications for aquifer storage and recovery. in Kenny, J. F. Ed. GroundWater/Surface Water Interactions, American Water Resources Association, Middleburg, Virginia, TPS-02-2, p. 387-392.

Price, R and Pichler, T, Arsenic and ASR in Southwest Florida: Source, Abundance, and Mobilization Mechanism, Suwanee Limestone, Upper Floridan Aquifer: poster located at: <http://www.dep.state.fl.us/geology/geologictopics/asr4/posters/Price.pdf>.

Pichler, T., Hendry, M. J., Hall, G. E. M., 2000 The mineralogy of arsenic in uranium mine tailings at the Rabbit Lake In-pit Facility, northern Saskatchewan, Canada. Journal of Environmental Geology. vol 40, pp 495-506.

Piper, A.M., 1944, A Graphic Procedure in the Geochemical Interpretation of Water Analyses: American Geophysical Union Transactions, v. 25, p. 914 – 923.

SDI, Inc, 1993, Groundwater in the Vicinity of the City of Clearwater, Florida, Consultants Report.

Seaburn And Robertson, Inc., 1983, Results of the Hydrologic Testing Program for the City of Clearwater Water Supply Investigation, Consultants Report.

Sinclair, W.C., 1974, Hydrogeologic Characteristics of the Surficial Aquifer in Northwest Hillsborough County, Florida, Florida Bureau of Geology Information Circular No. 86.

Southwest Florida Water Management District, 1988, Ground-Water Resource Availability Inventory, Pinellas County, Florida.

Workshop, Sacramento, California, April 2002 Green, R., Arthur, J. D., and DeWitt, D., 1995, Lithostratigraphic and hydrostratigraphic cross sections through Pinellas and Hillsborough Counties, southwest Florida: Florida Geological Survey Open File Report 61, pp 26.

APPENDIX A
GROUNDWATER SAMPLING LOGS AND GEOCHEMICAL ANALYSIS
TABLES AND FIGURES

Table A-1. Summary of Water Analyses

Analyte	NEASR-1	NEASR-2	NEASR-3	NEASR-4	Rech1	Rech2	Rech3	Rech4	Rech5	Blend1	Blend2
Ca(2+)	76	71	83	80	1.483	1.483	3.69	15.95	35.2	142	155
Mg(2+)	17	16	18	17	0.216	0.216	0.216	0.216	0.216	25	64
Na(+)	173.5	170.3	158.5	164.5	3.6	7.5	3.6	3.6	3.6	191	612
K(+)	3.9	3.7	4.6	4.3	0.6	0.6	0.6	0.6	0.01	2.4	14
HCO3-	207.4	195.2	195.2	195.2	7.198	17.45	13.91	51.24	109.8	242.8	190
SO4(2-)	15	15	15	16	0.9	0.9	0.9	0.9	0.9	5.4	140
Cl(-)	330	320	330	330	4.1	4.1	4.1	4.1	4.1	475	1208
Fe(2+)	0.04	0.06	0.09	0.09	ND	ND	ND	ND	ND	ND	ND
Fe(tot)	0.02	0.02	0.02	0.02	ND	ND	ND	ND	ND	0.271	0.053
As(tot)	0.001	0.001	0.001	0.001	ND	ND	ND	ND	ND	ND	ND
TDS	820.8	789.1	802.3	805	17.49	38.01	30.11	77.36	152.7	1245	2428
pH	7.58	7.54	7.53	7.53	6.76	9.9	9.58	8.38	7.77	7.87	7.7
Temp (°C)	24.56	24.57	24.54	24.66	25.00	25.00	25.00	25.00	25.00	25.00	25.00

Note: Dissolved Solids in mg/L
ND: No Data

Table A-2. Summary of Geochemical Properties

Sample	SI-calcite	Sat/Unsat	pe	Water Type
Ground Water	0.2994	Saturated	-1.83	Na-Cl
RW-1	-3.513	Unsaturated	12.846	Na-Cl
RW-2	-0.0553	Unsaturated	9.706	Na-HCO ₃
RW-3	0.0165	~Saturated	10.026	Ca-HCO ₃
RW-4	0.0672	Saturated	11.226	Ca-HCO ₃
RW-5	0.0883	Saturated	11.836	Ca-HCO ₃
BW-1	0.9331	Saturated	12.2002	Na-Cl
BW-2	0.562	Saturated	12.4159	Na-Cl

Table A-3. pH of RW4:BW1 mixtures

Ratio ¹	pH ²	Moles of NaHS					
		6e-4	5e-4	4e-4	3e-4	2e-4	1e-4
95:05	8.302	8.301 (7.664)	8.301 (7.664)	8.301 (7.664)	8.301 (7.664)	8.297 (7.663)	
90:10	8.242	8.240 (7.670)	8.240 (7.670)	8.241 (7.670)	8.238 (7.669)		
85:15	8.201	8.199 (7.676)	8.199 (7.676)	8.199 (7.676)	8.191 (7.675)		
80:20	8.167	8.167 (7.681)	8.165 (7.681)	8.161 (7.680)			
75:25	8.139	8.137 (7.688)	8.137 (7.688)	8.129 (7.687)			
95:05	8.302	8.301 (7.664)	8.301 (7.664)	8.301 (7.664)	8.301 (7.664)	8.297 (7.663)	
90:10	8.242	8.240 (7.670)	8.240 (7.670)	8.241 (7.670)	8.238 (7.669)		
85:15	8.201	8.199 (7.676)	8.199 (7.676)	8.199 (7.676)	8.191 (7.675)		

¹Ratio of RW-4 to BW-1 in blend²All pH values adjusted for charge balance

*Numbers in parentheses represent pH at 50% mixture with groundwater.

Table A-4. pe of RW4:BW1 Mixtures

Ratio ¹	pe ²	Moles of NaHS					
		6e-4	5e-4	4e-4	3e-4	2e-4	1e-4
95:05	11.47	-4.934 (-4.082)	-4.909 (-4.057)	-4.974 (-4.022)	-4.806 (-3.954)	0.924 (1,312)	
90:10	11.59	-4.850 (-4.080)	-4.819 (-4.049)	-4.765 (-3.995)	0.375 (1.140)		
85:15	11.67	-4.787 (-4.077)	-4.745 (-4.035)	-4.595 (-3.885)	1.273 (1.723)		
80:20	11.73	-4.731 (-4.070)	-4.671 (-4.010)	0.629 (1.372)			
75:25	11.78	-4.678 (-4.061)	-4.546 (-3.929)	1.149 (1.720)			

¹Ratio of RW-4 to BW-1 in blend²All pH values adjusted for charge balance.

*Numbers in parentheses represent pe at 50% mixture with groundwater.

Table A-5. pH of RW5:BW1 Blends

Ratio ¹	pe ²	Moles of NaHS					
		6e-4	5e-4	4e-4	3e-4	2e-4	1e-4
95:05	7.806	7.806 (7.621)	7.806 (7.621)	7.806 (7.622)	7.806 (7.622)	7.805 (7.621)	
90:10	7.838	7.838 (7.634)	7.837 (7.634)	7.837 (7.633)	7.837		
85:15	7.863	7.861 (7.644)	7.858 (7.645)	7.853 (7.647)			
80:20	7.870	7.856 (7.646)	7.869 (7.646)	7.867 (7.871)			
75:25	7.889	7.889 (7.659)	7.889 (7.659)	7.884 (7.889)			

¹Ratio of RW-5 to BW-1 in blend²pH values all adjusted for charge balance

*Numbers in parentheses represent pH calculated at 50% blend with groundwater.

Table A-6. pe of RW5:BW1 Blends

Ratio ¹	pe ²	Moles of NaHS					
		6e-4	5e-4	4e-4	3e-4	2e-4	1e-4
95:05	11.96	-4.382 (-4.036)	-4.358 (-4.011)	-4.324 (-3.977)	-4.260 (3.913)	2.038 (1.343)	
90:10	11.99	-4.401 (-4.041)	-4.371 (-4.010)	-4.319 (-3.959)	1.281 (1.113)		
85:15	12.08	-4.343 (-3.975)	-4.368 (-3.998)	1.485 (1.510)			
80:20	12.03	-4.391 (-4.036)	-4.341 (-3.985)	1.485 (1.510)			
75:25	12.03	-4.400 (-4.028)	-4.256 (-3.884)	1.810 (1.808)			

¹Ratio of RW-5 to BW-1 in blend²pH values all adjusted for charge balance.

*Numbers in parentheses represent pe calculated at 50% blend with groundwater.

Table A-7. pH of RW4:BW2 Blends

Ratio ¹	pe ²	Moles of NaHS					
		6e-4	5e-4	4e-4	3e-4	2e-4	1e-4
95:05	8.300	8.828 (7.659)	8.828 (7.659)	8.828 (7.659)	8.299 (7.659)	8.298 (7.658)	
90:10	8.247	8.245 (7.663)	8.245 (7.663)	7.855 (7.663)			
85:15	8.205	8.202 (7.666)	8.202 (7.666)	8.200 (7.665)			

¹Ratio of RW-4 to BW-2 in blend²pH values all adjusted for charge balance**Table A-8. pe of RW4:BW2 Blends**

Ratio ¹	pe ²	Moles of NaHS					
		6e-4	5e-4	4e-4	3e-4	2e-4	1e-4
95:05	11.510	-4.823 (-4.054)	-4.795 (-4.026)	-4.751 (-3.982)	-4.562 (-3.793)	11.426 (1.786)	
90:10	11.630	-4.715 (-4.027)	-4.671 (-3.983)	0.173 (0.407)			
85:15	11.710	-4.626 (-3.998)	-4.523 (-3.985)	11.551 (1.994)			

¹Ratio of RW-4 to BW-2 in blend²pH values all adjusted for charge balance

Table A-9. pH of RW5:BW2 Blends

Ratio ¹	pe ²	Moles of NaHS					
		6e-4	5e-4	4e-4	3e-4	2e-4	1e-4
95:05	7.854	7.854 (7.633)	7.854 (7.633)	7.854 (7.633)	7.853 (7.632)	7.853 (7.632)	
90:10	7.856	7.855 (7.635)	7.858 (7.635)	7.855 (7.635)			
85:15	7.859	7.858 (7.638)	7.857 (7.638)	7.857 (7.637)			

¹Ratio of RW-5 to BW-2 in blend²pH values all adjusted for charge balance**Table A-10. pe of RW5:BW2 Blends**

Ratio ¹	pe ²	Moles of NaHS					
		6e-4	5e-4	4e-4	3e-4	2e-4	1e-4
95:05	11.95	-4.328 (-4.026)	-4.301 (-3.999)	-4.259 (-3.957)	-4.128 (-3.828)	11.857 (1.796)	
90:10	12.02	-4.208 (-3.998)	-4.237 (-3.954)	0.752 (0.087)			
85:15	12.06	-4.238 (-3.936)	-4.106 (-3.832)	11.911 (2.139)			

¹Ratio of RW-5 to BW-2 in blend²pH values all adjusted for charge balance

Table A-11. pH of RW-4 and RW-5 After Titration With NaHS

RW	pH ¹	Moles of NaHS					
		6e-4	5e-4	4e-4	3e-4	2e-4	1e-4
RW-4	8.38				8.38 (7.66)	8.38 (7.66)	8.37 (7.66)
RW-5	7.77				7.77 (7.61)	7.77 (7.61)	7.77 (7.61)

¹All pH values adjusted for charge balance

²Numbers in parentheses represent pH at 50% mixture with groundwater.

Table A-12. pe of RW-4 and RW-5 After Titration With NaHS

RW	pe ¹	Moles of NaHS					
		6e-4	5e-4	4e-4	3e-4	2e-4	1e-4
RW-4	11.23				-4.957 (-4.00)	-4.899 (-3.942)	11.001 (0.602)
RW-5	11.84				-4.277 (-3.947)	-4.219 (-3.889)	11.611 (0.719)

¹Numbers in parentheses represent pe at 50% mixture with groundwater.

Figure 1. Blending of Groundwater and Mixture of 95% RW-4 and 05% BW-1
Durov Diagram (Left) and Schoeller Diagram (Right)

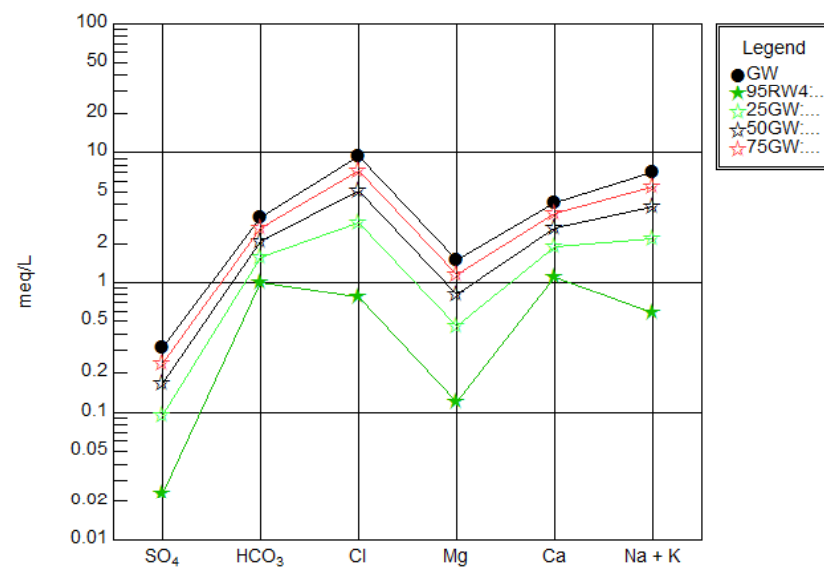
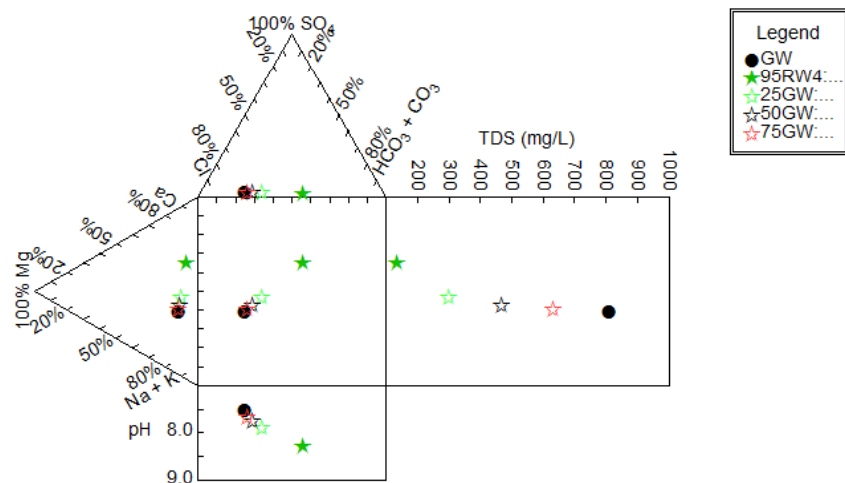


Figure 2. Blending of Groundwater and Mixture of 90% RW-4 and 10% BW-1
Durov Diagram (Left) and Schoeller Diagram (Right)

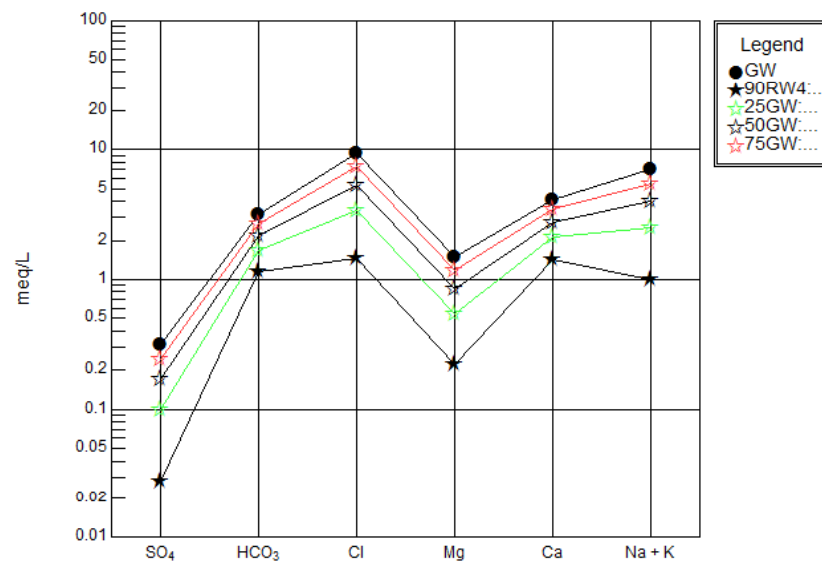
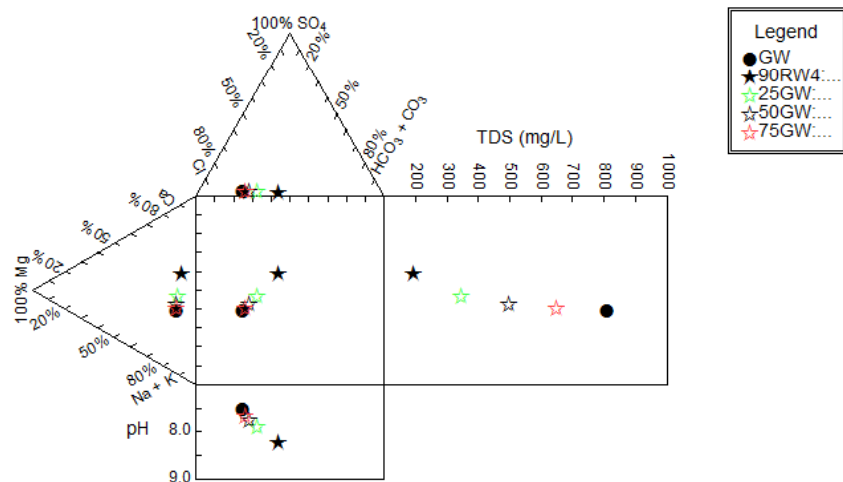


Figure 3. Blending of Groundwater and Mixture of 85% RW-4 and 15% BW-1
Durov Diagram (Left) and Schoeller Diagram (Right)

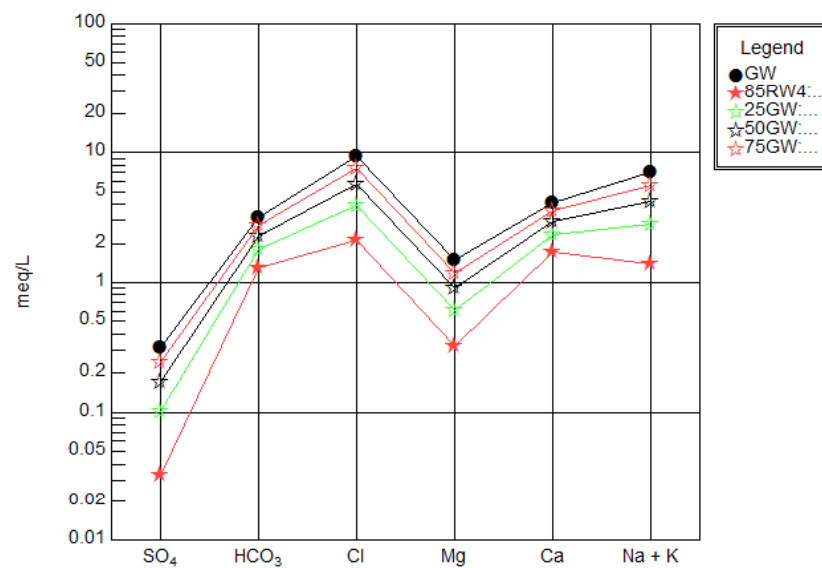
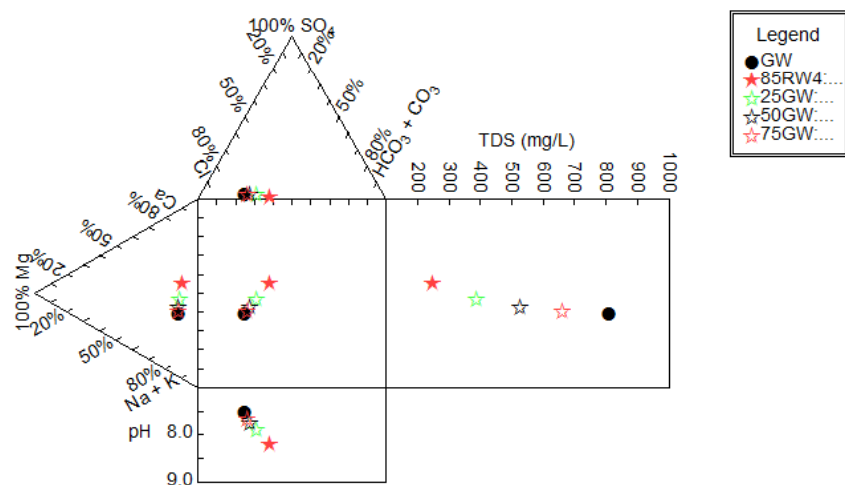


Figure 4. Blending of Groundwater and Mixture of 95% RW-5 and 05% BW-2
Durov Diagram (Left) and Schoeller Diagram (Right)

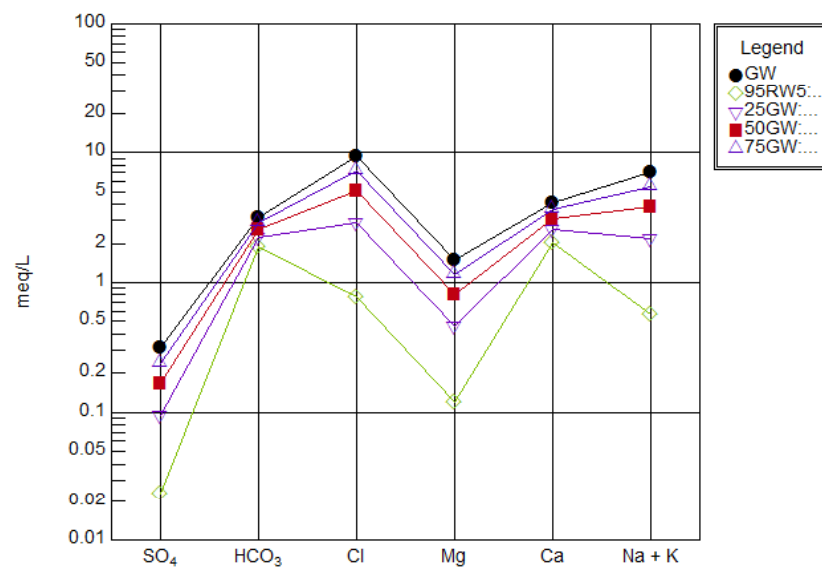
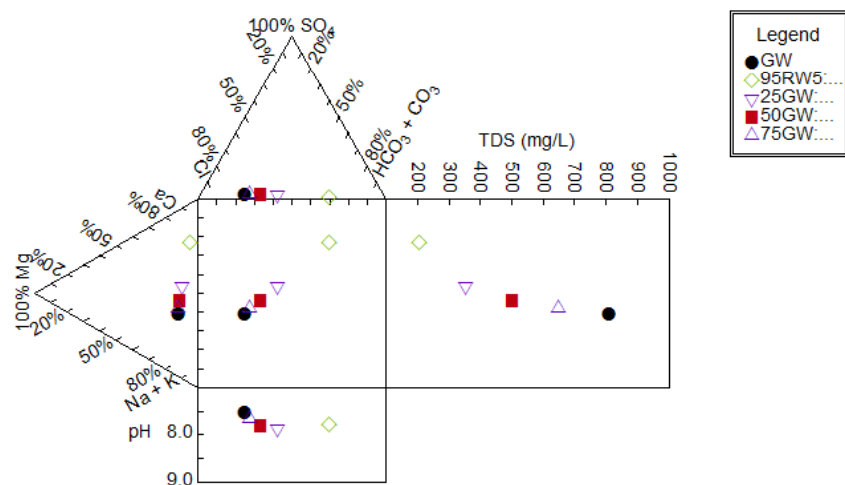


Figure 5. Blending of Groundwater and Mixture of 90% RW-5 and 10% BW-1
Durov Diagram (Left) and Schoeller Diagram (Right)

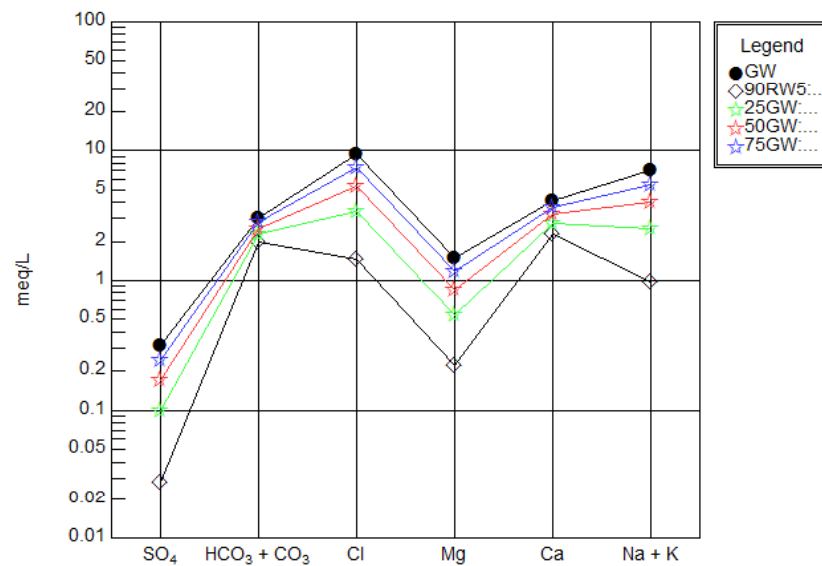
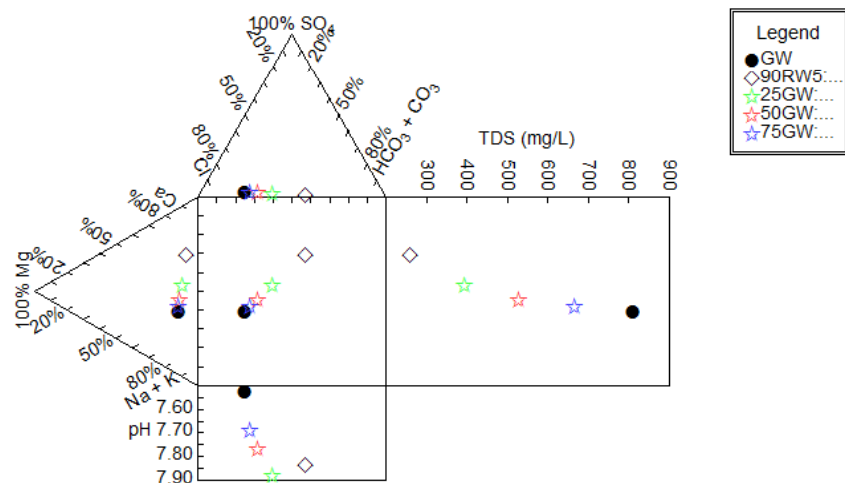


Figure 6. Blending of Groundwater and Mixture of 85% RW-5 and 15% BW-1
Durov Diagram (Left) and Schoeller Diagram (Right)

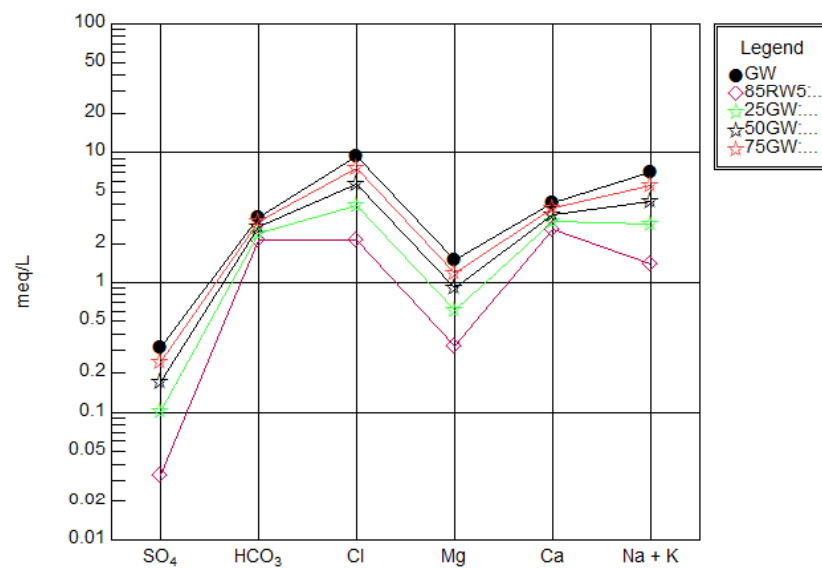
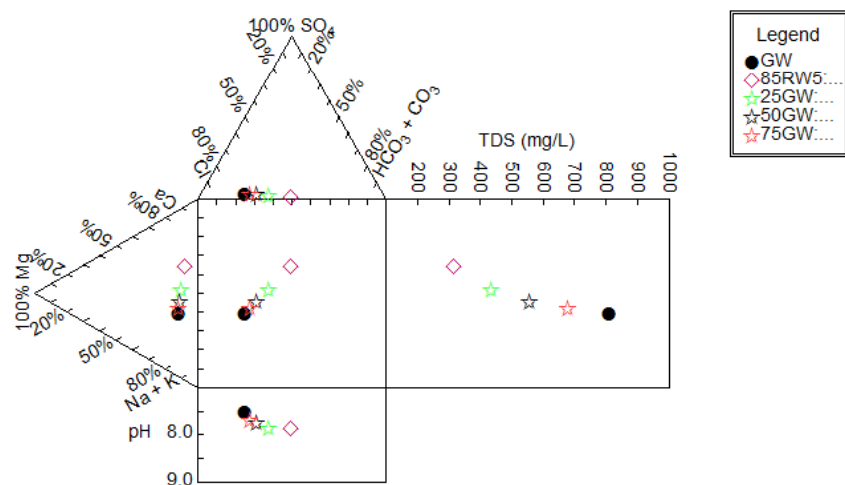


Figure 7. Blending of Groundwater and Mixture of 95% RW-4 and 05% BW-2
Durov Diagram (Left) and Schoeller Diagram (Right)

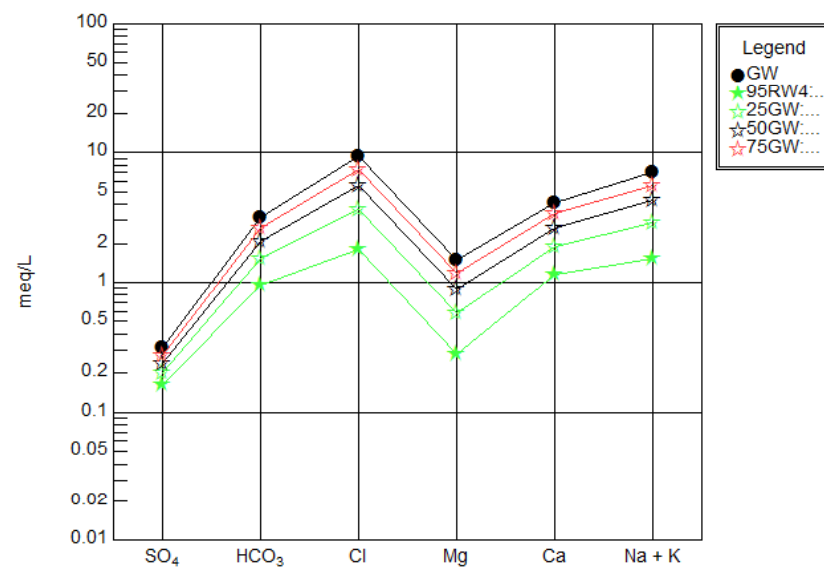
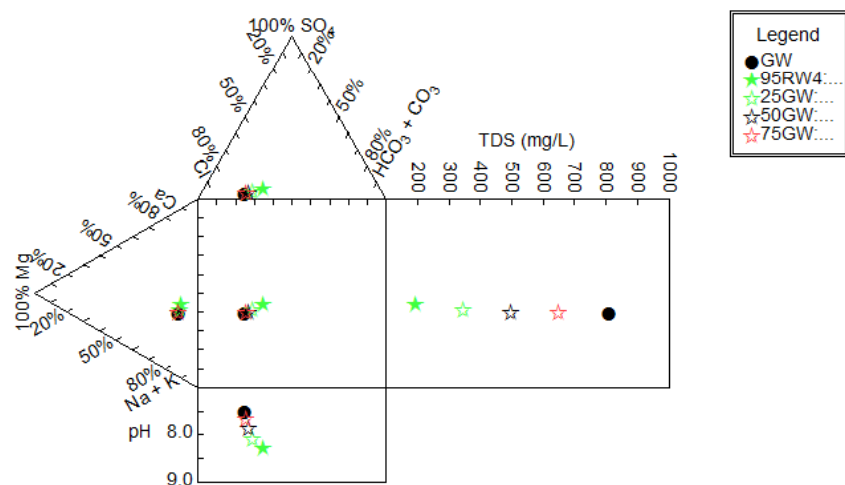


Figure 8. Blending of Groundwater and Mixture of 90% RW-4 and 10% BW-2
Durov Diagram (Left) and Schoeller Diagram (Right)

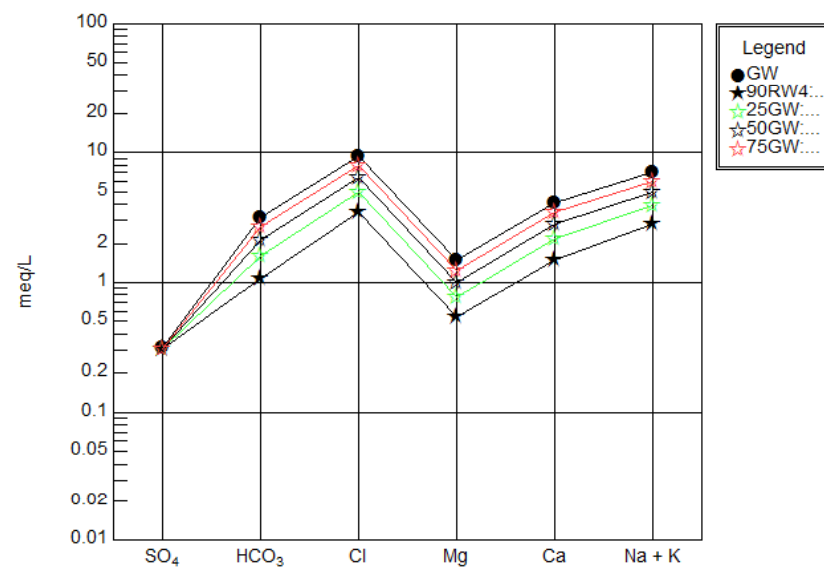
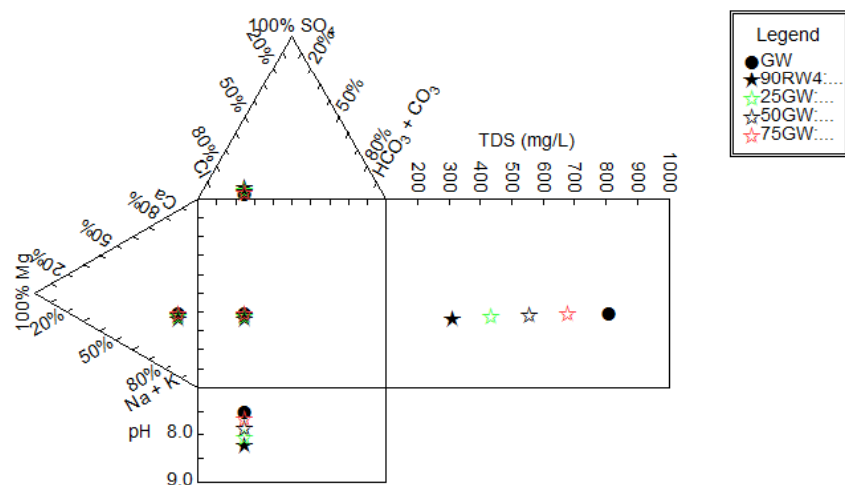


Figure 9. Blending of Groundwater and Mixture of 85% RW-5 and 15% BW-2
Durov Diagram (Left) and Schoeller Diagram (Right)

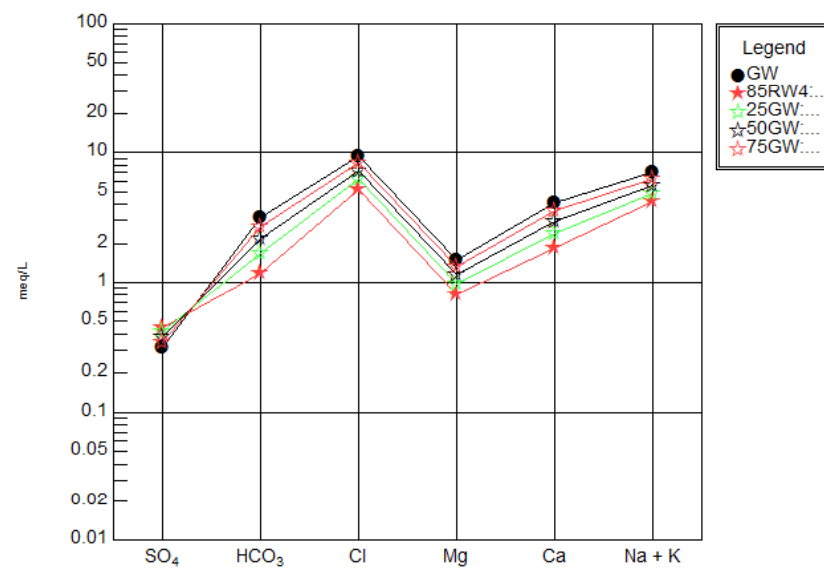
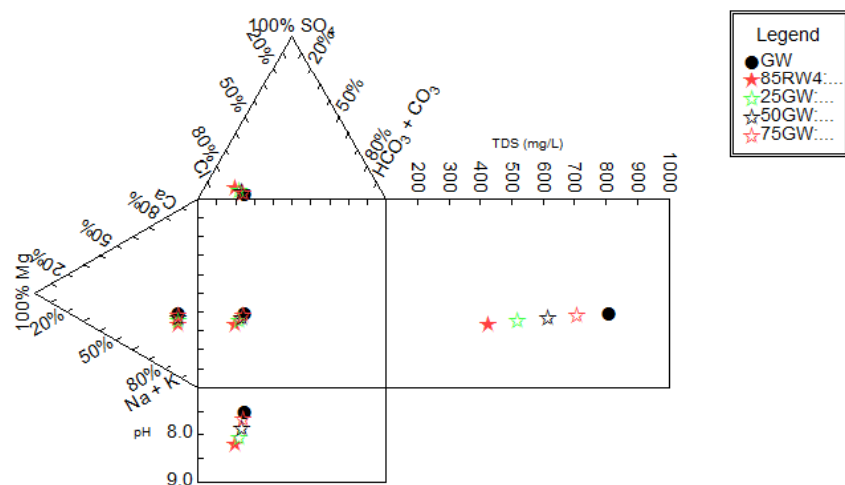


Figure 10. Blending of Groundwater and Mixture of 95% RW-5 and 05% BW-2
Durov Diagram (Left) and Schoeller Diagram (Right)

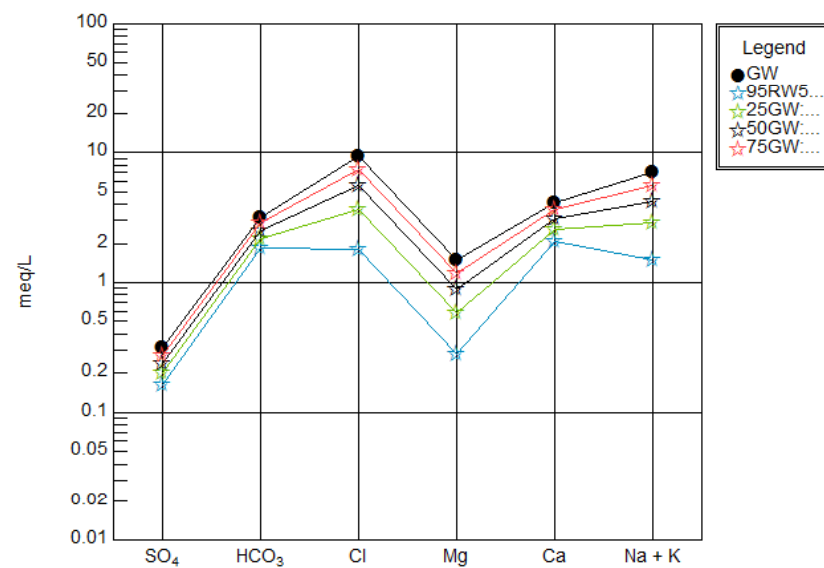
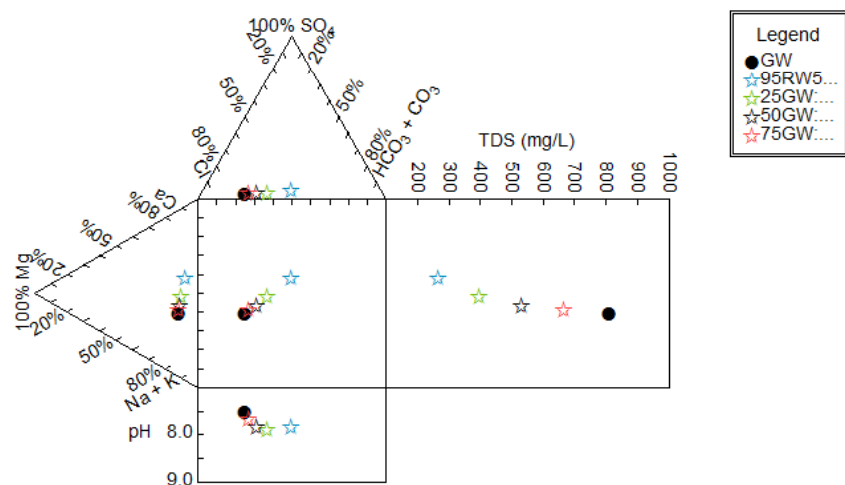


Figure 11. Blending of Groundwater and Mixture of 90% RW-5 and 10% BW-2
Durov Diagram (Left) and Schoeller Diagram (Right)

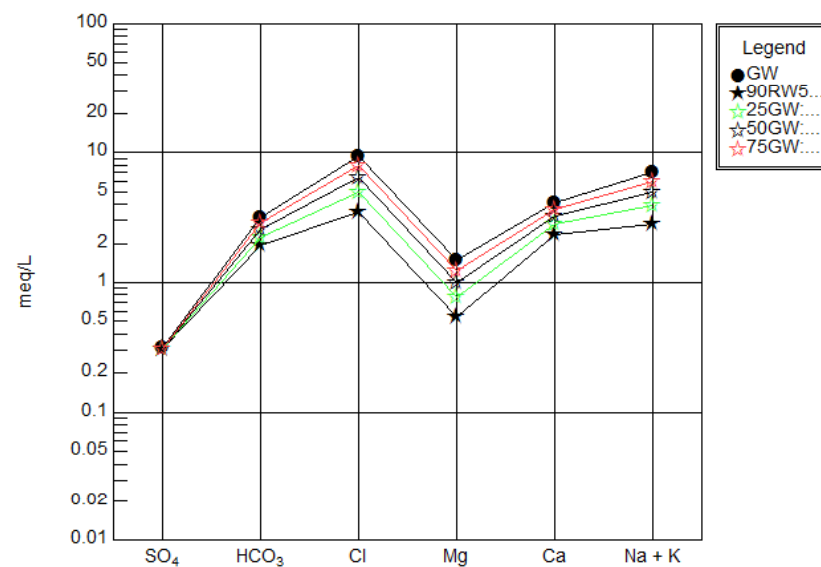
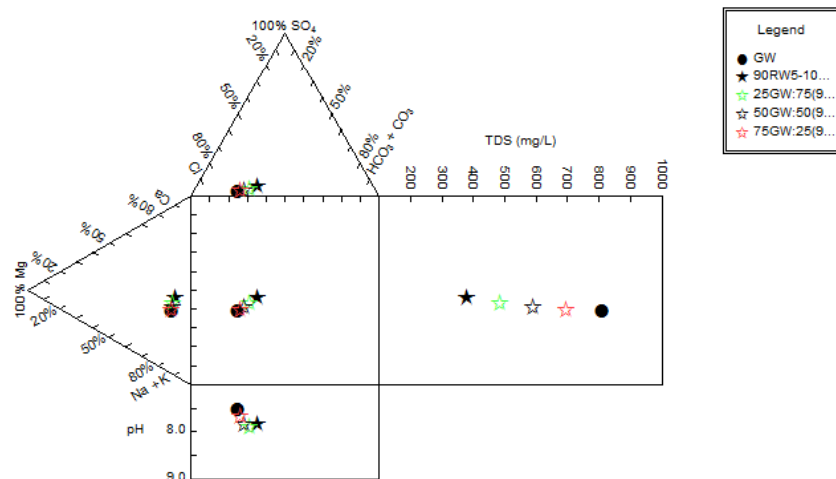
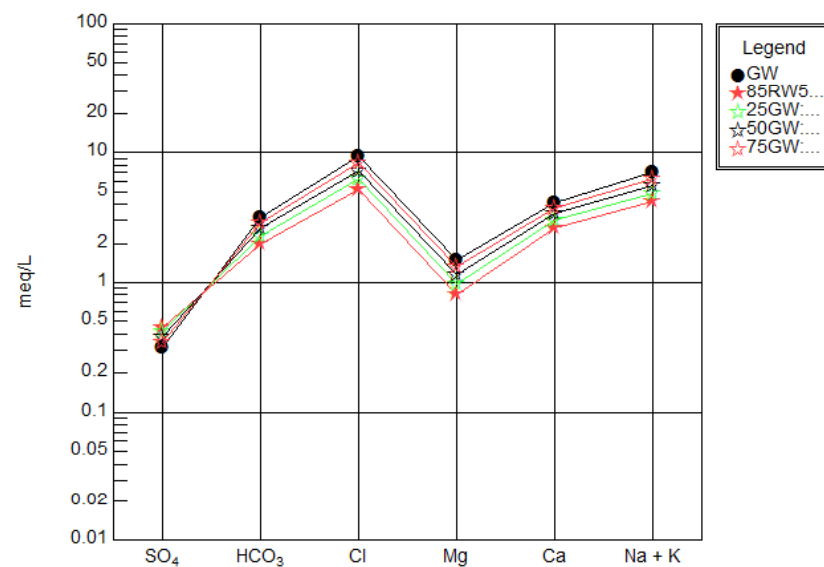
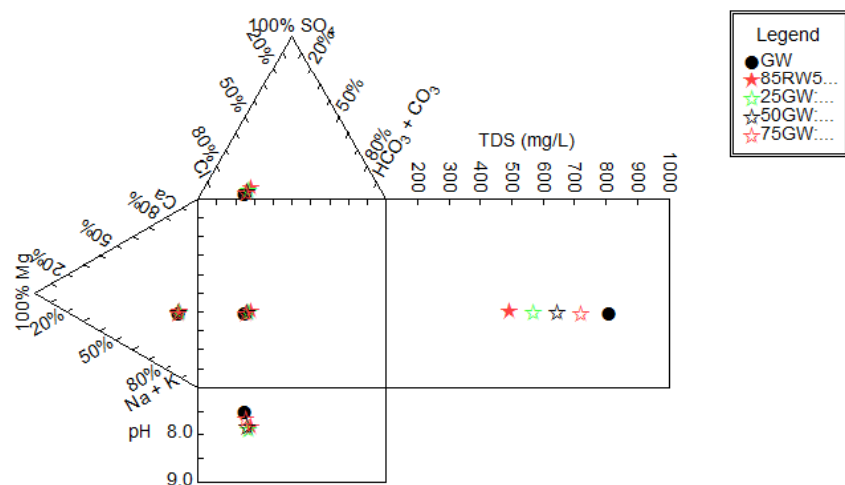


Figure 12. Blending of Groundwater and Mixture of 85% RW-5 and 15% BW-2
Durov Diagram (Left) and Schoeller Diagram (Right)



Leggette, Brashears and Graham, Inc.
10014 N. Dale Mabry Rd.
Tampa, FL 33618-

October 21, 2010
Project No: 105519
Revised

Laboratory Report

Project Name **Clearwater Groundwater Analyses**

Parameters	Units	Results	Method	Detection Limit	Date/Time Analyzed	Date/Time Prep	Analyst
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Sample Description	NEASR-1
Matrix	Groundwater
SAL Sample Number	105519.01
Date/Time Collected	09/23/10 12:30
Date/Time Received	09/23/10 15:35

Inorganics

Total Alkalinity as CaCO ₃	mg/l	170	SM 2320B	2	09/24/10 13:30		KTC
Bicarbonate Alkalinity as CaCO ₃	mg/l	170	SM 2320B	2	09/24/10 13:30		KTC
Chloride	mg/l	330	EPA 300.0	0.05	09/27/10 22:20		MEJ
Nitrate (as N)	mg/l	0.01 U	EPA 300.0	0.01	09/24/10 15:49		MEJ
Sulfate	mg/l	15	EPA 300.0	0.2	09/25/10 15:32		MEJ
Total Dissolved Solids	mg/l	620	SM 2540C	10	09/29/10 14:00	09/28/10 15:00	MJV

Metals

Arsenic	mg/l	0.001 U	SM 3113 B	0.001	09/29/10 11:08	09/28/10 17:00	VWC
Calcium	mg/l	76	EPA 200.7	0.01	10/04/10 15:27		HWS
Iron	mg/l	0.02 U	EPA 200.7	0.02	09/30/10 22:24	09/30/10 07:45	HWS
Potassium	mg/l	3.9	EPA 200.7	0.01	10/04/10 15:27		HWS
Magnesium	mg/l	17	EPA 200.7	0.01	10/04/10 15:27		HWS
Sodium	mg/l	170	EPA 200.7	0.01	10/04/10 15:27		HWS

Sample Description	NEASR-2
Matrix	Groundwater
SAL Sample Number	105519.02
Date/Time Collected	09/23/10 13:30
Date/Time Received	09/23/10 15:35

Inorganics

Total Alkalinity as CaCO ₃	mg/l	160	SM 2320B	2	09/24/10 13:30		KTC
Bicarbonate Alkalinity as CaCO ₃	mg/l	160	SM 2320B	2	09/24/10 13:30		KTC
Chloride	mg/l	320	EPA 300.0	0.05	09/27/10 22:37		MEJ
Nitrate (as N)	mg/l	0.014 I	EPA 300.0	0.01	09/24/10 16:57		MEJ
Sulfate	mg/l	15	EPA 300.0	0.2	09/25/10 16:57		MEJ
Total Dissolved Solids	mg/l	640	SM 2540C	10	09/29/10 14:00	09/28/10 15:00	MJV

Metals

Arsenic	mg/l	0.001 U	SM 3113 B	0.001	09/29/10 11:08	09/28/10 17:00	VWC
Calcium	mg/l	71	EPA 200.7	0.01	10/04/10 15:27		HWS
Iron	mg/l	0.02 U	EPA 200.7	0.02	09/30/10 22:24	09/30/10 07:45	HWS
Potassium	mg/l	3.7	EPA 200.7	0.01	10/04/10 15:27		HWS
Magnesium	mg/l	16	EPA 200.7	0.01	10/04/10 15:27		HWS
Sodium	mg/l	150	EPA 200.7	0.01	10/04/10 15:27		HWS

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Revised

Laboratory Report

Project Name **Clearwater Groundwater Analyses**

Parameters	Units	Results	Method	Detection Limit	Date/Time Analyzed	Date/Time Prep	Analyst
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Sample Description	NEASR-3						
Matrix	Groundwater						
SAL Sample Number	105519.03						
Date/Time Collected	09/23/10 14:30						
Date/Time Received	09/23/10 15:35						

Inorganics

Total Alkalinity as CaCO ₃	mg/l	160	SM 2320B	2	09/24/10 13:30		KTC
Bicarbonate Alkalinity as CaCO ₃	mg/l	160	SM 2320B	2	09/24/10 13:30		KTC
Chloride	mg/l	330	EPA 300.0	0.05	09/27/10 22:54		MEJ
Nitrate (as N)	mg/l	0.01 U	EPA 300.0	0.01	09/24/10 17:14		MEJ
Sulfate	mg/l	15	EPA 300.0	0.2	09/25/10 17:14		MEJ
Total Dissolved Solids	mg/l	760	SM 2540C	10	09/29/10 14:00	09/28/10 15:00	MJV

Metals

Arsenic	mg/l	0.001 U	SM 3113 B	0.001	09/29/10 11:08	09/28/10 17:00	VWC
Calcium	mg/l	83	EPA 200.7	0.01	10/04/10 15:27		HWS
Iron	mg/l	0.02 U	EPA 200.7	0.02	09/30/10 22:24	09/30/10 07:45	HWS
Potassium	mg/l	4.6	EPA 200.7	0.01	10/04/10 15:27		HWS
Magnesium	mg/l	18	EPA 200.7	0.01	10/04/10 15:27		HWS
Sodium	mg/l	180	EPA 200.7	0.01	10/04/10 15:27		HWS

Sample Description	NEASR-4						
Matrix	Groundwater						
SAL Sample Number	105519.04						
Date/Time Collected	09/23/10 13:38						
Date/Time Received	09/23/10 15:35						

Inorganics

Total Alkalinity as CaCO ₃	mg/l	160	SM 2320B	2	09/24/10 13:30		KTC
Bicarbonate Alkalinity as CaCO ₃	mg/l	160	SM 2320B	2	09/24/10 13:30		KTC
Chloride	mg/l	330	EPA 300.0	0.05	09/27/10 23:11		MEJ
Nitrate (as N)	mg/l	0.01 U	EPA 300.0	0.01	09/24/10 17:31		MEJ
Sulfate	mg/l	16	EPA 300.0	0.2	09/25/10 17:31		MEJ
Total Dissolved Solids	mg/l	770	SM 2540C	10	09/30/10 15:00	09/28/10 15:00	MJV

Metals

Arsenic	mg/l	0.001 U	SM 3113 B	0.001	09/29/10 11:08	09/28/10 17:00	VWC
Calcium	mg/l	80	EPA 200.7	0.01	10/04/10 15:27		HWS
Iron	mg/l	0.02 U	EPA 200.7	0.02	09/30/10 22:24	09/30/10 07:45	HWS
Potassium	mg/l	4.3	EPA 200.7	0.01	10/04/10 15:27		HWS
Magnesium	mg/l	17	EPA 200.7	0.01	10/04/10 15:27		HWS
Sodium	mg/l	170	EPA 200.7	0.01	10/04/10 15:27		HWS

SOUTHERN ANALYTICAL LABORATORIES, INC.

110 BAYVIEW BOULEVARD, OLDSMAR, FL 34677 813-855-1844 fax 813-855-2218



Leggette, Brashears and Graham, Inc.
10014 N. Dale Mabry Rd.
Tampa, FL 33618-

October 21, 2010
Project No: 105519
Revised

Laboratory Report

Project Name Clearwater Groundwater Analyses

Footnotes

- # Questions regarding this report should be directed to Client Services at 813-855-1844.
- * Test results presented in this report meet all the requirements of the NELAC standards. Test results within this report relate only to these samples.
- ** A statement of estimated uncertainty of test results is available upon request.
- *** For methods marked with ***, all QC criteria have been met for this method which is equivalent to a SAL certified method.
- I The reported value is between the laboratory method detection limit and the laboratory practical quantitation limit.
- U Analyte was undetected. Indicated concentration is method detection limit.

SAL Project No.

105519

Chain of Custody.xls
Rev. Date 11/19/01



DAILY ACTIVITY LOG

PROJECT: Clearwater WWTP
ASR Well-NE Plant
RECORDED BY: Richard Coter
LOCATION: Clearwater, FL

DATE: 9-23-10
JOB CODE: CLWGRF
CLIENT CODE: _____
PAGE 1 OF 1

TIME	ACTIVITY
0730	Leave office for Southern Analytical Labs to pick-up sample kit
0800	Pick-up sample kit and ice
0805	Arrive on-site at Northeast WWTP in Clearwater, ASR Well.
	Greg Turman and 5 man crew inserting submersible pump down ASR Well to a depth of 80 ft. b.t.c
	Casing (12-inch) is 2 ft 0.5 and 207 ft 6.5.
	Total Well depth is 275 ft 6.5
	Static Water Level = 53.15 ft. b.t.c
0815	Start pump. Measure flow rate of pump by timing flow discharge into a 5 gallon bucket
	15.01 seconds to fill = 20 gpm
	* 3 well volumes = 3,915 gallons
	Must pump 20 gpm for 3.25 hours
1130	Finish pumping 3 well volumes
1230	Collect 1 st water sample - NEASR-1 *
1330	Collect 2 nd water sample - NEASR-2 *
1338	Duplicate sample NEASR-4 *
1430	Collect 3 rd water sample - NEASR-3 *
1435	Stop Pump. Take Photos
	* all sample on ice
1500	Leave site
1535	Drop off samples @ Southern Anal. Lab.

Form FD 9000-24
GROUNDWATER SAMPLING LOG

SITE NAME: <u>Clearwater NEWWTP</u>	SITE LOCATION: <u>Clearwater, FL</u>
WELL NO: <u>ASR</u>	SAMPLE ID: <u>NEASR-1</u> DATE: <u>9-23-10</u>

PURGING DATA

WELL DIAMETER (inches): <u>12.0</u>	TUBING DIAMETER (inches):	WELL SCREEN INTERVAL DEPTH: feet to feet	STATIC DEPTH <u>53.15</u> TO WATER (feet):	PURGE PUMP TYPE OR BAILER:
WELL VOLUME PURGE: 1 WELL VOLUME = (TOTAL WELL DEPTH - STATIC DEPTH TO WATER) X WELL CAPACITY (only fill out if applicable) = (<u>275.0</u> feet - <u>53.15</u> feet) X <u>5.88</u> gallons/foot = <u>1305</u> gallons				
EQUIPMENT VOLUME PURGE: 1 EQUIPMENT VOL. = PUMP VOLUME + (TUBING CAPACITY X TUBING LENGTH) + FLOW CELL VOLUME (only fill out if applicable) = gallons + (gallons/foot X feet) + gallons = <u>3 well volume</u>				
INITIAL PUMP OR TUBING DEPTH IN WELL (feet):	FINAL PUMP OR TUBING DEPTH IN WELL (feet):	PURGING INITIATED AT: <u>0815</u>	PURGING ENDED AT: <u>1130</u>	TOTAL VOLUME PURGED (gallons): <u>3915</u>

TIME	VOLUME PURGED (gallons)	CUMUL. VOLUME PURGED (gallons)	PURGE RATE (gpm)	DEPTH TO WATER (feet)	pH (standard units)	TEMP. (°C)	COND. (µmhos/cm or µS/cm)	DISSOLVED OXYGEN (circle mg/L or % saturation)	TURBIDITY (NTUs)	Ferrous Iron mg/L	ORP
<u>0815</u>	<u>-</u>	<u>-</u>	<u>-</u>	<u>53.15</u>	<u>-</u>	<u>-</u>	<u>-</u>	<u>-</u>	<u>-</u>	<u>-</u>	<u>-</u>
<u>1130</u>	<u>3915</u>	<u>3915</u>	<u>20.0</u>	<u>58.30</u>	<u>-</u>	<u>-</u>	<u>-</u>	<u>-</u>	<u>-</u>	<u>-</u>	<u>-</u>
* <u>1135</u>	<u>Flow Cell</u>	<u>1.0</u>			<u>7.67</u>	<u>24.52</u>	<u>1391</u>	<u>1.11</u>	<u>2.28</u>	<u>0.01</u>	<u>-270.8</u>
<u>1140</u>					<u>7.67</u>	<u>24.56</u>	<u>1400</u>	<u>1.08</u>	<u>1.94</u>	<u>0.01</u>	<u>-274.9</u>
<u>1145</u>					<u>7.64</u>	<u>24.33</u>	<u>1405</u>	<u>1.11</u>	<u>1.77</u>	<u>0.00</u>	<u>-277.9</u>
<u>1150</u>					<u>7.63</u>	<u>24.54</u>	<u>1410</u>	<u>1.13</u>	<u>1.80</u>	<u>0.00</u>	<u>-280.4</u>
<u>1155</u>					<u>7.62</u>	<u>24.57</u>	<u>1416</u>	<u>1.16</u>	<u>1.83</u>	<u>0.03</u>	<u>-283.0</u>
<u>1200</u>					<u>7.64</u>	<u>24.49</u>	<u>1423</u>	<u>1.21</u>	<u>1.68</u>	<u>0.04</u>	<u>-285.6</u>
<u>1205</u>					<u>7.59</u>	<u>24.56</u>	<u>1430</u>	<u>1.22</u>	<u>1.88</u>	<u>0.03</u>	<u>-288.4</u>
<u>1210</u>					<u>7.62</u>	<u>24.50</u>	<u>1439</u>	<u>1.26</u>	<u>1.70</u>	<u>0.02</u>	<u>-290.6</u>

WELL CAPACITY (Gallons Per Foot): 0.75" = 0.02; 1" = 0.04; 1.25" = 0.06; 2" = 0.16; 3" = 0.37; 4" = 0.65; 5" = 1.02; 6" = 1.47; 12" = 5.88
TUBING INSIDE DIA. CAPACITY (Gal./Ft.): 1/8" = 0.0006; 3/16" = 0.0014; 1/4" = 0.0026; 5/16" = 0.004; 3/8" = 0.006; 1/2" = 0.010; 5/8" = 0.016

SAMPLING DATA

SAMPLED BY (PRINT) / AFFILIATION:				SAMPLER(S) SIGNATURE(S):				SAMPLING INITIATED AT:		SAMPLING ENDED AT:	
PUMP OR TUBING DEPTH IN WELL (feet):				TUBING MATERIAL CODE:		FIELD-FILTERED: Y N Filtration Equipment Type:		FILTER SIZE: _____ µm			
FIELD DECONTAMINATION: PUMP Y N TUBING Y N (replaced)				DUPLICATE: Y N							

SAMPLE CONTAINER SPECIFICATION				SAMPLE PRESERVATION			INTENDED ANALYSIS AND/OR METHOD	SAMPLING EQUIPMENT CODE	SAMPLE PUMP FLOW RATE (mL per minute):
SAMPLE ID CODE	# CONTAINERS	MATERIAL CODE	VOLUME	PRESERVATIVE USED	TOTAL VOL ADDED IN FIELD (mL)	FINAL pH			

REMARKS:
* Y valve used to divert flow thru flow cell

MATERIAL CODES: AG = Amber Glass; CG = Clear Glass; PE = Polyethylene; PP = Polypropylene; S = Silicone; T = Teflon; O = Other (Specify)

SAMPLING EQUIPMENT CODES: APP = After Peristaltic Pump; B = Bailor; BP = Bladder Pump; ESP = Electric Submersible Pump; RFPP = Reverse Flow Peristaltic Pump; SM = Straw Method (Tubing Gravity Drain); O = Other (Specify)

NOTES: 1. The above do not constitute all of the information required by Chapter 62-160, F.A.C.

2. STABILIZATION CRITERIA FOR RANGE OF VARIATION OF LAST THREE CONSECUTIVE READINGS (SEE FS 2212, SECTION 3)

pH: ± 0.2 units Temperature: ± 0.2 °C Specific Conductance: ± 5% Dissolved Oxygen: all readings ≤ 20% saturation (see Table FS 2200-2); optionally, ± 0.2 mg/L or ± 10% (whichever is greater) Turbidity: all readings ≤ 20 NTU; optionally ± 5 NTU or ± 10% (whichever is greater)

Revision Date: February 12, 2009

PURGING DATA

SAMPLING DATA

NOTES: 1. The above do not constitute all of the information required by Chapter 62-160, F.A.C.

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Revision Date: February 12, 2009

PURGING DATA

WELL CAPACITY (Gallons Per Foot): 0.75" = 0.02; 1" = 0.04; 1.25" = 0.06; 2" = 0.16; 3" = 0.37; 4" = 0.65; 5" = 1.02; 6" = 1.47; 12" = 5.88							
TUBING INSIDE DIA. CAPACITY (Gal./Ft.): 1/8" = 0.0006; 3/16" = 0.0014; 1/4" = 0.0026; 5/16" = 0.004; 3/8" = 0.006; 1/2" = 0.010; 5/8" = 0.016							

SAMPLED BY (PRINT) / AFFILIATION:				SAMPLER(S) SIGNATURE(S):			SAMPLING INITIATED AT:		SAMPLING ENDED AT:	
PUMP OR TUBING DEPTH IN WELL (feet):				TUBING MATERIAL CODE:		FIELD-FILTERED: Y N Filtration Equipment Type:		FILTER SIZE: _____ µm		
FIELD DECONTAMINATION: PUMP Y N TUBING Y N (replaced)						DUPLICATE: Y N				
SAMPLE CONTAINER SPECIFICATION				SAMPLE PRESERVATION			INTENDED ANALYSIS AND/OR METHOD	SAMPLING EQUIPMENT CODE	SAMPLE PUMP FLOW RATE (mL per minute):	
SAMPLE ID CODE	# CONTAINERS	MATERIAL CODE	VOLUME	PRESERVATIVE USED	TOTAL VOL ADDED IN FIELD (mL)	FINAL pH				
REMARKS: <i>* Y valve used to divert flow thru flow cell</i>										
MATERIAL CODES: AG = Amber Glass; CG = Clear Glass; PE = Polyethylene; PP = Polypropylene; S = Silicone; T = Teflon; O = Other (Specify)										
SAMPLING EQUIPMENT CODES: APP = After Peristaltic Pump; B = Bailor; BP = Bladder Pump; ESP = Electric Submersible Pump; RFPP = Reverse Flow Peristaltic Pump; SM = Straw Method (Tubing Gravity Drain); O = Other (Specify)										

NOTES: 1. The above do not constitute all of the information required by Chapter 62-160, F.A.C.

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pH: ± 0.2 units Temperature: ± 0.2 °C Specific Conductance: $\pm 5\%$ Dissolved Oxygen: all readings $\leq 20\%$ saturation (see Table FS 2200-2); optionally, ± 0.2 mg/L or $\pm 10\%$ (whichever is greater) Turbidity: all readings ≤ 20 NTU; optionally ± 5 NTU or $\pm 10\%$ (whichever is greater)

Revision Date: February 12, 2009

GROUNDWATER SAMPLING LOG

PURGING DATA

PURGING DATA

SAMPLING DATA

REMARKS:

* Samples filtered in field using 0.45 micron in line filter

MATERIAL CODES: AG = Amber Glass; CG = Clear Glass; PE = Polyethylene; PP = Polypropylene; S = Silicone; T = Teflon; O = Other (Specify)

SAMPLING EQUIPMENT CODES: APP = After Peristaltic Pump; B = Bailor; BP = Bladder Pump; ESP = Electric Submersible Pump;
RFPF = Reverse Flow Peristaltic Pump; SM = Straw Method (Tubing Gravity Drain); O = Other (Specify)

NOTES: 1. The above do not constitute all of the information required by Chapter 62-160, F.A.C.

2. STABILIZATION CRITERIA FOR RANGE OF VARIATION OF LAST THREE CONSECUTIVE READINGS (SEE FS 2212, SECTION 3)

pH: ± 0.2 units **Temperature:** ± 0.2 °C **Specific Conductance:** $\pm 5\%$ **Dissolved Oxygen:** all readings $\leq 20\%$ saturation (see Table FS 2200-2); optionally, ± 0.2 mg/L or $\pm 10\%$ (whichever is greater) **Turbidity:** all readings ≤ 20 NTU; optionally ± 5 NTU or $\pm 10\%$ (whichever is greater)

Revision Date: February 12, 2009

GROUNDWATER SAMPLING LOG

SITE NAME: Clearwater NEWUTP		SITE LOCATION: Clearwater FL	
WELL NO: ASR	SAMPLE ID: NEASR-3	DATE: 9-23-10	

PURGING DATA

WELL						TUBING		WELL SCREEN INTERVAL		STATIC DEPTH		PURGE PUMP TYPE OR BAILER:	
DIAMETER (inches):						DIAMETER (inches):		DEPTH: feet to feet		TO WATER (feet):			
WELL VOLUME PURGE: I WELL VOLUME = (TOTAL WELL DEPTH - STATIC DEPTH TO WATER) X WELL CAPACITY (only fill out if applicable) = (275.0 feet - 53.15 feet) X 5.88 gallons/foot = 1305 gallons													
EQUIPMENT VOLUME PURGE: I EQUIPMENT VOL. = PUMP VOLUME + (TUBING CAPACITY X TUBING LENGTH) + FLOW CELL VOLUME (only fill out if applicable) = gallons + (gallons/foot X feet) + gallons = gallons													
INITIAL PUMP OR TUBING DEPTH IN WELL (feet):				FINAL PUMP OR TUBING DEPTH IN WELL (feet):			PURGING INITIATED AT:		PURGING ENDED AT:		TOTAL VOLUME PURGED (gallons): 6315		
TIME	VOLUME PURGED (gallons)	CUMUL. VOLUME PURGED (gallons)	PURGE RATE (gpm)	DEPTH TO WATER (feet)	pH (standard units)	TEMP. (°C)	COND. (µmhos/cm or µS/cm)	DISSOLVED OXYGEN (circle mg/L or % saturation)	TURBIDITY (NTUs)	Ferric Iron mg/L	ORP		
1330	6315	6315	20.0	59.30									
1335	Flow Cell		1.0		7.52	24.53	1457	0.48	1.58	0.06	-309.2		
1340					7.57	24.55	1456	0.45	1.49	0.06	-310.3		
1345					7.59	24.57	1458	0.44	1.80	0.06	-399.9		
1350					7.54	24.59	1456	0.38	1.44	0.08	-307.2		
1355					7.54	24.51	1453	0.36	1.44	0.06	-308.0		
1400					7.54	24.58	1452	0.35	1.43	0.07	-307.8		
1405					7.54	24.58	1452	0.33	1.49	0.07	-307.9		
1410					7.55	24.48	1452	0.32	1.43	0.09	-307.7		
1415					7.51	24.54	1452	0.32	1.44	0.07	-307.5		
WELL CAPACITY (Gallons Per Foot): 0.75" = 0.02; 1" = 0.04; 1.25" = 0.06; 2" = 0.16; 3" = 0.37; 4" = 0.65; 5" = 1.02; 6" = 1.47; 12" = 5.88 TUBING INSIDE DIA. CAPACITY (Gal./Ft.): 1/8" = 0.0006; 3/16" = 0.0014; 1/4" = 0.0026; 5/16" = 0.004; 3/8" = 0.006; 1/2" = 0.010; 5/8" = 0.016													

SAMPLING DATA

[illegible]

NOTES: 1. The above do not constitute all of the information required by Chapter 62-160, F.A.C.

2. STABILIZATION CRITERIA FOR RANGE OF VARIATION OF LAST THREE CONSECUTIVE READINGS (SEE FS 2212, SECTION 3)

pH: ± 0.2 units **Temperature:** ± 0.2 °C **Specific Conductance:** $\pm 5\%$ **Dissolved Oxygen:** all readings $\leq 20\%$ saturation (see Table FS 2200-2); optionally, ± 0.2 mg/L or $\pm 10\%$ (whichever is greater) **Turbidity:** all readings ≤ 20 NTU; optionally ± 5 NTU or $\pm 10\%$ (whichever is greater)

Revision Date: February 12, 2009

Form FD 9000-24

SITE NAME: Clearwater NEWHTP		SITE LOCATION: Clearwater FL	
WELL NO: ASR	SAMPLE ID: NEASR-3		DATE: 9-23-10

PURGING DATA

WELL DIAMETER (inches):	12.0	TUBING DIAMETER (inches):		WELL SCREEN INTERVAL DEPTH: feet to feet	STATIC DEPTH TO WATER (feet):	PURGE PUMP TYPE OR BAILER:
WELL VOLUME PURGE: 1 WELL VOLUME = (TOTAL WELL DEPTH - STATIC DEPTH TO WATER) X WELL CAPACITY (only fill out if applicable)						
= (275.0 feet - 53.15 feet) X 5.88 gallons/foot = gallons						
EQUIPMENT VOLUME PURGE: 1 EQUIPMENT VOL. = PUMP VOLUME + (TUBING CAPACITY X TUBING LENGTH) + FLOW CELL VOLUME (only fill out if applicable)						
= gallons + (gallons/foot X feet) + gallons = gallons						

INITIAL PUMP OR TUBING DEPTH IN WELL (feet):	FINAL PUMP OR TUBING DEPTH IN WELL (feet):	PURGING INITIATED AT:	PURGING ENDED AT:	TOTAL VOLUME PURGED (gallons): 7515
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TIME	VOLUME PURGED (gallons)	CUMUL. VOLUME PURGED (gallons)	<i>Sample</i> PURGE RATE (gpm)	DEPTH TO WATER (feet)	pH (standard units)	TEMP. (°C)	COND. (µmhos/cm or µS/cm)	DISSOLVED OXYGEN (circle mg/L or % saturation)	TURBIDITY (NTUs)	<i>Ferric Iron mg/L</i>	<i>ORP</i>
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1420	Flow Cell	1.0	7.53	24.57	1452	0.31	1.35	0.09 - 307.4
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1425				7.53	24.57	1457	0.31	1.35	2.09	307.7
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1430	1200	7515	1.0	58.30	7.53	24.54	1452	0.30	1.38	0.09	307.1
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[illegible][illegible][illegible][illegible][illegible][illegible][illegible]

WELL CAPACITY (Gallons Per Foot): 0.75" = 0.02; 1" = 0.04; 1.25" = 0.06; 2" = 0.16; 3" = 0.37; 4" = 0.65; 5" = 1.07; 6" = 1.47; 12" = 5.88

TUBING INSIDE DIA. CAPACITY (Gal./Ft.): 1/8" = 0.0006; 3/16" = 0.0014; 1/4" = 0.0026; 5/16" = 0.004; 3/8" = 0.006; 1/2" = 0.010; 5/8" = 0.016

SAMPLING DATA

SAMPLED BY (PRINT) / AFFILIATION: <i>Richard Cofer / LBG</i>	SAMPLER(S) SIGNATURE(S): <i>Richard Cofer</i>	SAMPLING INITIATED AT: <i>1430</i>	SAMPLING ENDED AT: <i>1430</i>
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PUMP OR TUBING DEPTH IN WELL (feet):	TUBING MATERIAL CODE: 5	FIELD-FILTERED: ☒ Y ☐ N Filtration Equipment Type: DISPOS-9-FILTER	FILTER SIZE: 0.45 μ m
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FIELD DECONTAMINATION: PUMP Y N TUBING Y N (replaced) DUPLICATE: Y N

SAMPLE CONTAINER SPECIFICATION	SAMPLE PRESERVATION	INTENDED	SAMPLING	SAMPLE PUMP
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SAMPLE ID CODE	# CONTAINERS	MATERIAL CODE	VOLUME	PRESERVATIVE USED	TOTAL VOL ADDED IN FIELD (ml)	FINAL pH	ANALYSIS AND/OR METHOD	EQUIPMENT CODE	FLOW RATE (ml per minute)
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			USED	RODED IN FIELD (MILE)	PH		USED	(MILE PER MINUTE)
1	PE		NORP	-		Time taken ESP	10.13	

	PE	HNO ₃	NH ₄ P	M ₁₄₋₁₀	FSP	1.0 g/g
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[illegible][illegible][illegible][illegible]

REMARKS:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
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* Sample filtered in field using 0.45 micron in line filter

MATERIAL CODES: AG = Amber Glass; CG = Clear Glass; PE = Polyethylene; PP = Polypropylene; S = Silicone; T = Teflon; O = Other (Specify)

SAMPLING EQUIPMENT CODES: APP = After Peristaltic Pump; B = Bailer; BP = Bladder Pump; ESP = Electric Submersible Pump;
 FBPP = Reverse Flow Peristaltic Pump; GM = Gravity Meter; H = Hand Pump; HSP = Hand Submersible Pump;

NOTES: 1. The above do not constitute all of the information required by Chapter 62-160, F.A.C.

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2. STABILIZATION CRITERIA FOR RANGE OF VARIATION OF LAST THREE CONSECUTIVE READINGS (SEE FS 2212, SECTION 3)

pH: ± 0.2 units Temperature: ± 0.2 °C Specific Conductance: $\pm 5\%$ Dissolved Oxygen: all readings $\leq 20\%$ saturation (see Table FS 2200-2); optionally, ± 0.2 mg/L or $\pm 10\%$ (whichever is greater) Turbidity: all readings ≤ 20 NTU; optionally ± 5 NTU or $\pm 10\%$ (whichever is greater)

Revision Date: February 12, 2009

110 BAYVIEW BOULEVARD, OLDSMAR, FL 34677 813-855-1844 fax 813-855-2218

SAL Project No.

Chain of Custody.xls
Rev.Date 11/19/01

ASR well

12' casing
207 ft

182	187	SAA except less gray limestone (trace only)	BB
187	205	ROCK SHAKER PLUGGED UP - No samples	BB
205	210	LIMESTONE, very clayey; moderately hard to hard, fine - grained (micritic), light gray-beige; much light gray clay	BB
210	220	LIMESTONE, soft to friable, fine-grained (micritic), tan to white, weathered; some limey clay content	CT
220	225	LIMESTONE, soft to friable, fine-grained (micritic), tan to white, weathered; much limey clay content; trace amounts of blue green clay	CT
225	240	LIMESTONE, soft to friable, fine-grained (micritic), tan to white, moderately hard; some limey clay; trace amounts of blue green clay	CT
241	254	LIMESTONE, bio-micritic (many organisms embedded within fine grained matrix), tan; organisms include gastropods and mollusks; trace amounts of chert, sand to gravel sized; trace amounts of limey clay	CT
255	269	LIMESTONE, bio-micritic, weathered, hard to moderate, tan; some chert, sand to gravels sized pieces; some lime mud $\leq 20\%$	CT
270	284	LIMESTONE, bio-micritic, weathered, hard to moderate, tan to white; some large shell fragments; trace amounts of chert	CT
285	294	LIMESTONE, bio-micritic, weathered, hard to moderate, tan; Some dark chert, sand sized to gravels sized pieces, trace amounts of large shell fragments	CT
295	305	SAA	CT
305	317	LIMESTONE, micritic, soft to friable, tan; decreased amount of shell fragments, trace amounts of phosphate; some limey clay	CT
317	327	LIMESTONE, micritic, soft to friable, tan; shell fragments, some limey clay	CT
327	330	LIMESTONE, micritic, soft to friable, tan; some shell fragments, trace amounts of corral decreased amount of lime clay	CT
330	335	SAA	CT
336	355	LIMESTONE, bio-micritic, soft to friable, tan; some shell fragments, trace amounts of lime mud	CT
356	360	SAA except for trace amounts of blue green clay	CT
361	366	LIMESTONE, weathered, bio-micritic, friable, tan; trace amounts of shell fragments, brown clay and lime mud	CT
366	371	LIMESTONE, weathered, fractured, hard to moderate with much lime clay	CT
371	376	LIMESTONE, tan, very hard, bio-turbated (crab burrows), micritic over lying a very soft to friable, micritic LS; some lime mud and shell fragments	CT

275'
TD



U.S. Environmental
Rental Corporation

Calibration Report

Parameter

Conductivity 1000us/cm

PH 7 4 10

Lot Number

Reading Before

Reading After

8074
1074
1000

(Accuracy Range: +/- .5% of reading)

7833	8074	7796
7.55	4.16	9.66
7.00	4.00	10.00
-37.9	122.5	-178.6

PH mV

Parameter

ORP

D.O. 100% @ 760mmHg

0% D.O. Check

100mv xxx Zobell

Lot Number

Reading Before

Reading After

10G100197
197.8
235.0

(Accuracy Range: +/- 20 mV)

N/A
8485.6
100.0

(Accuracy Range: +/- 2%)

2808100

1.96

(Accuracy Range: +/- 2%)

Parameter

Turbidity

0 NTU 123 NTU

Lot Number

Reading Before

Reading After

NA	NA
NA	NA
NA	NA

(Accuracy Range: +/- 5% of reading)



DATE: 9/23/10

JOB CODE: _____

RECORDED BY:

CLIENT CODE: _____

LOCATION: _____

PAGE OF

TIME	ACTIVITY
	<u>Meters Used</u>
LBG	Hach DR 890 Colormeter - Ferrous Iron
LBG	Hach Turbidity 2100P - Turbidity
Rental	YSI 556 Multi-Meter - pH
↓	" " " - Conductivity
	" " " - Temperature
	" " " - DO
↓	" " " - ORP
	All meter calibrated prior to testing

APPENDIX B

PUBLIC OUTREACH WORKSHOP AGENDA

Clearwater Florida

Groundwater Replenishment Planning/Outreach Workshop

AGENDA

July 16, 2010

Location

Public Utilities - 1650 N. Arcturas Ave., Bldg A

Facilitator

John Ruetten - Resource Trends, Inc.

July 16, 2010

8:30 – 8:45

Opening Remarks – Objectives

- Fair Consideration of GWR Using Reclaimed Water
- Keeping Things Simple, Effective, and Cost Effective

8:45 – 9:15

Review of Branding Principles – Why Branding?

- Value, Trust, Market Share, and Price
- The Power of Branding
- Branding of Utilities, Tap Water, and Reclaimed Water
- Proper Definition and “Positioning” of Reclaimed Water

9:15 – 9:45

Groundwater Replenishment Best Practices

- Investing in Water Reliability
- Creating Water Quality Confidence
- Managing Disagreement and Conflict
 - Vocal Opponents, Growth, Embracing Conflict
- Ensuring Good Policy Decisions
 - Meeting the Needs of Elected Officials, Policy Makers

9:45 – 10:15

Outreach that Focuses on Policy Decisions and Policy Makers

- Focused Relationship Building – Not Just Brochures
- Listening and Sharing Feedback with Policy Makers

10:15 – 10:30

Break

10:30 – 10:45

Case Study Review

- San Diego, Tampa, Dublin San Ramon
- Scottsdale, Orange County, Fairfax County Virginia
- Los Angeles Department of Water and Power

10:45 – 11:45

Discussion of Clearwater Issues

- Need for GWR – Investment in Water Resources
- Reputation of Sponsoring Utility – The Source of Quality
- Previous Negative Branding or City Conflicts
- ??????

11:45 – 12:00

Wrap-Up and Next Steps

Clearwater Florida Groundwater Replenishment

Value and Outreach Recommendations – August 2010

The following recommendations were developed as a result of the workshop held with the City of Clearwater on July 16, 2010 covering the value and the public dialogue about groundwater replenishment (GWR). The recommendations were prepared by John Ruetten of Resource Trends, Inc. in partnership with Tetra Tech.

The recommendations are based on principles developed as part the WaterReuse Foundation project on perceptions of indirect potable reuse, the experiences of Resource Trends related to branding and people's perceptions of value and risk, and Clearwater's specific circumstances.

Create a Timeline – When communicating with anyone, context is everything. Value, benefits, and problem solving provide the context for investment and accepting risk. Similarly, a timeline provides a context for understanding key project decision points and phases of the outreach process. Clearwater should develop a timeline of key milestones for GWR. An important benefit of a timeline is that it makes clear what has or has not been decided and that early outreach is a dialogue about challenges and investing in water reliability and quality. One of the best ways to incite conflict is to reach out to people after all the decisions have been made and it is clear that their input will not impact the course of action.

Develop the Case for Investment – The process for getting fair consideration for an indirect potable reuse project begins with recognizing that you are asking your community to invest in solving a problem and/or creating benefits. Make sure that it is clear to community members that the commitment of the City is to invest in solving the problem, not a specific method. In that light, GWR is not a fundamental value of the City, but a recommended solution to a problem or path to compelling benefits. The case for investment starts with articulating the problem that needs to be solved and includes alternatives for solving the problem. Experience tells us that water reliability benefits are a much stronger and more logical case for GWR than the need to dispose of wastewater or meet discharge quality requirements. Finally, sharing alternatives is critical, but the City should make a recommendation. People expect a recommendation from the experts and they expect an explanation why a specific course of action is being proposed.

Make Sure Desalination is Included in the Alternatives – Even though ocean water desalination may not be the best or even a practical alternative, it should definitely be included in the alternatives. This is because there is enough public awareness about desalination (especially in Tampa) that people will think something is missing if it is not covered. When people perceive one thing is missing, they start to wonder what else is missing or what else should have been considered. This is not conducive to building trust.

Be Rigorous on Withdrawal Credits and Aquifer Hydrology – A key to the value of groundwater replenishment is the benefits of increasing the locally-controlled water supply. How does more local supply benefit Clearwater or how does it save money on water purchases? This will be one of the important points in the evaluation of alternatives described in the case for investment. Given this, it is important that the withdrawal credits are defined and real, and the hydrology of the aquifer can sustainably support the beneficial withdrawals of water.

Address Conflict in the Planning Stage – Any proposed investment (or spending of money) can energize conflict. Add to this the fact that GWR is still somewhat provocative, and it becomes imperative to expect and plan for conflict. When planning the relationship-building process, identify past conflicts and the people involved. Use this information to ensure that your

Clearwater Florida Groundwater Replenishment

Value and Outreach Recommendations – August 2010

outreach process develops relationships with potential opponents. Find potential opponents early. Along these lines, addressing the issue of sink holes in the Clearwater area should be part of the outreach process. With meaningful and relevant information, and the time to build relationships, opponents can become strong supporters.

Understand and Avoid Environmental Justice Problems – For Clearwater, the most obvious environmental justice risks will come from perceived inequities in who is being asked to drink the recycled water, and who appears to be exempt. This will be affected by the recharge points, the hydrology of the aquifer, and perceptions about who will be using the water. It may be technically convenient to put an injection well at a certain location, but every location should be reviewed from an environmental justice perspective. Avoiding real or perceived injustices is a wise investment and can be a critical factor in the success of a project. Ignoring these issues, even if they seem too simple or not technically sound, is risky.

Specifically, it is important to reach out to and address the concerns of neighboring communities, the most important of which is Dunedin. If it is apparent or even just perceived that recycled water is moving into Dunedin's section of the aquifer, and they aren't receiving benefits from the project, conflict is likely. If there are no clear benefits to Dunedin, the Clearwater project will look like 100% risk with no reward. In general, when there are no benefits, any amount of risk will seem excessive.

Build Relationships and Build Support – Outreach efforts should be thought of as building relationships and not as "public education." The idea of building relationships helps us focus on specific individuals and to listen to those we reach. Good relationships are always based on a balance of informing and listening. Develop a list of people to reach out to, including potential opponents. Ask for written support, document feedback, and share feedback with policy makers on an ongoing basis. Although it is important to reach out to potential opponents early, you can begin with more friendly audiences to test the case for investment and the clarity of your message. Even if the audience is friendly, make sure to solicit feedback so you can improve your message and approach. Remember, the goal is to build relationships. Fancy publications are not as important as the quality of your message and your behavior (attitude, willingness to listen, and response to differing opinions). A brief PowerPoint presentation and fact sheet are adequate, especially early in the process. Building trust does not require a large investment, and spending a lot does not guarantee success.

Develop a Close Relationship with the City Council on Outreach – The most important objective of community relationship building is to help policy makers feel safe to support an investment in solving the problem and to support GWR. It follows that they should be kept well informed and if possible become part of the process. The City Council should understand the objectives of each phase of the outreach process. Some council members may be hesitant to support early outreach because of perceived political risks. Despite this possibility, it is important to get their permission to start the dialogue with the community early. Make it clear to council members that you are introducing a problem, recommending an investment in solving the problem, and getting feedback from the community. If you are clearly "discussing and listening," then political risks are reduced and council members will be more likely to support an outreach process that starts early.

Clearwater Florida Groundwater Replenishment

Value and Outreach Recommendations – August 2010

Observe and Learn from the Upcoming Tampa Vote – A negative outcome in the Tampa vote is not necessarily an indicator of outcomes in Clearwater if the City executes a good plan. This includes proposing compelling value, creating water quality confidence, building relationships and support, and managing conflict. However, the Tampa vote is an opportunity to learn about overall public sentiments and the energy level and messages of opponents.

Separate the Drinking Water Facility from the Reclamation Facility – You don't hire an electrician to do plumbing work. Having a reclamation facility on the same site as the groundwater replenishment facility is not a problem as long as there is some physical separation and separation of management and operations. The additional treatment facility required for groundwater replenishment should have its own name and be managed and operating by trained drinking-water professionals. When creating and naming the new facility you may want to rename the wastewater treatment plant. It now has a new function; providing water resources for drinking and other applications.