Prepared for

City of Hallandale Beach

Preliminary Assessment of a Hydrostatic Salinity Barrier for Wellfield Protection

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BUILDING A BETTER WORLD

April 2013

Table of Contents

1 Project Overview 1-1
2 Characterization of Existing Wellfield and Aquifer Conditions 2-1
2.1 Review of Existing Well Locations, Capacities, and Allocations 2-1
2.2 Historic Water Quality 2-1
2.2.1 USGS Monitoring Wells Water Quality 2-1
2.2.2 Production Well Water Quality 2-8
2.3 Regulatory Environment 2-10
2.4 Land Availability for Salinity Barrier System 2-11
3 Literature Review and Case Study Assessment 3-1
3.1 USGS Salinity Investigations 3-1
3.2 SWFWMD Aquifer Recharge Feasibility Study 3-2
3.3 Recharge Case Studies 3-4
3.3.1 Orange County Groundwater Replenishment System 3-4
3.3.2 West Basin Regional Water District 3-6
3.3.3 City of Hollywood Case Study 3-7
3.4 Regulatory Considerations for Reclaimed Water Aquifer Recharge 3-9
4 Evaluation of Aquifer Recharge Alternatives for Salinity Barriers 4-1
4.1 Direct Surface Delivery 4-1
4.1.1 Background 4-1
4.1.2 Case Study 4-1
4.1.3 Potential Impacts 4-1
4.1.4 Regulatory Concerns 4-1
4.2 Other Salinity Barrier Methods 4-2
4.2.1 Injection-Extraction Systems 4-2
4.2.2 Extraction Barriers 4-2
4.2.3 Subsurface Barriers 4-3
4.3 Observation Wells 4-3
4.3.1 Existing Wells 4-3
4.3.2 New Observation Wells 4-4
4.4 Existing Flood Control Wells for Aquifer Recharge 4-4
5 Agency Meetings and Summary of Key Findings 5-1

5.1 Project Meetings 5-1
5.1.1 FDEP UIC Meeting 5-1
5.1.2 BCEPGMD Meeting 5-1
5.1.3 SFWMD Meeting 5-1
5.2 Summary of Key Findings 5-2
5.3 Recommendations for Subsequent Phases 5-2

References

Attachment A – Agency Meeting Agendas and Meeting Minutes

List of Figures

Figure 2-1 Well Locations Map 2-2
Figure 2-2 Position of the Saltwater Interface 2-3
Figure 2-3 Delineation of Saltwater Intrusion 2-4
Figure 2-4 Monthly Wellfield Pumpage 2-5
Figure 2-5 USGS Monitoring Well G-2477 Chloride Concentrations 2-5
Figure 2-6 USGS Monitoring Well G-2478 Chloride Concentrations 2-6
Figure 2-7 Test Boring Locations 2-7
Figure 2-8 Wellfield Pumpage and Chloride Concentrations 2-9
Figure 2-9 Wellfield Pumpage and PW-7 Chloride Concentrations 2-9
Figure 2-10 Wellfield Pumpage and PW-8 Chloride Concentrations 2-10
Figure 2-11 City of Hallandale Beach Land Availability 2-12
Figure 3-1 Injection of Fresh Water Creating Salinity Barrier ..... **Error! Bookmark not defined.**
Figure 3-2 Orange County Water District Groundwater Replenishment System Schematic ..3-6
Figure 3-3 Model-Predicted Chloride Concentration 3-8
Figure 3-4 Simulated Freshwater Heads after 30 Days of Injection 3-8
Figure 4-1 Injection–Extraction in an Unconfined Aquifer 4-2
Figure 4-2 Alamitos Barrier Improvement Project Mounding Analysis ... **Error! Bookmark not defined.**

List of Tables

Table 2-1 Production Well Construction Details 2-3
Table 2-2 Summary of Test Boring Water Quality Results 2-8
Table 3-1 Groundwater Recharge Treatment and Disinfection Requirements 3-10

1 Project Overview

The City of Hallandale Beach, which owns and operates a drinking water treatment facility, has experienced the impacts of long term saltwater intrusion on some of its Biscayne aquifer drinking water production wells. The City has been working to minimize the effects of the encroaching salinity front by controlling groundwater water withdrawals, abandoning some production wells, and complying with regulatory withdrawal limitations. While working in the development of some alternatives to address this intrusion issue, the City is investigating options to preserve the current water supplies and infrastructure investments by evaluating saltwater intrusion control methods.

Salinity incursions have been occurring in this area over the past 75 years and have been well documented by the United States Geologic Survey (USGS). In 1938, the USGS started investigations to monitor the position of the salinity front in the coastal Biscayne aquifer of southeastern Florida (Merritt, 1996). Numerous studies have been conducted following this initial investigation regarding locating, tracking, and slowing the inland ingress of the salinity front caused by coastal freshwater withdrawals in order to assess the impacts to drinking water supplies in the region.

The City is preparing to install a new stormwater system along NE 14th Avenue with pipelines, 2 pumping stations, and up to 16 new drainage wells which parallel the coastline. The project is being partially funded by the Federal Emergency Management Agency (FEMA) to assist with flooding concerns. In addition to the flood control benefit, these drainage wells may be capable of providing an additional benefit as a salinity barrier to the City by using available reclaimed water from the City of Hollywood during dry periods when no stormwater is entering the drainage wells.

This document presents a preliminary evaluation into creating a hydrostatic salinity barrier focusing on the use of the new stormwater system the City is preparing to install. The introduction of available reclaimed water from the City of Hollywood during dry periods when no storm water is entering the drainage wells may be capable of providing an additional benefit as a salinity barrier to the City.

This study was initiated by collecting, compiling, and analyzing information characterizing historical and existing wellfield and Biscayne aquifer conditions. This study also considered regulatory limits and constraints related to wellfield operations and water quality as well as a review of land availability for a salinity barrier and monitoring well system. A literature search and investigations conducted by the USGS, local agencies, and other entities dealing with saltwater intrusion conditions similar to those the City is encountering were reviewed. Alternative methods of creating a salinity barrier using reclaimed water were also explored. Such as the use of direct surface delivery, injection-extraction systems, extraction barriers, and subsurface barriers. Finally, the potential effects of using the flood control stormwater wells as salinity barrier wells was also reviewed for initial applicability.

As part of this preliminary evaluation, a series of meetings were held with various regulatory agencies including the Broward County Environmental Protection and Growth Management Division (EPGMD), the Florida Department of Environmental Protection (FDEP), and the South Florida Water Management District (SFWMD). A meeting was also held with representatives of the City of Hollywood. The purpose of these meetings was to discuss the conceptual aspects of the potential salinity barrier project and document concerns and conflicts the various entities may have moving forward.

2 Characterization of Existing Wellfield and Aquifer Conditions

2.1 Review of Existing Well Locations, Capacities, and Allocations

The City is served by the Hallandale Beach Wellfield and the Broward County South Regional Wellfield. The City of Hallandale Beach operates under South Florida Water Management District (SFWMD) Water Use Permit (WUP) Number 06-00138-W approved June 14, 2001. The SFWMD Water Use Permit expired in 2006. Since this time the District has granted several extensions to the City as a regional water supply plan was being developed. The City is currently operating under an extension of Permit Number 06-00138-W.

The City of Hallandale Beach Wellfield originally had a withdrawal allocation from the SFWMD for 3.5 million gallons per day (MGD) however in 2007 the allocation was reduced to 3.0 MGD and has remained at this level. The wellfield consists of 4 production wells; PW-3, PW-5, PW-7, and PW-8 shown on **Figure 2-1**. This figure also presents the locations of the existing stormwater drainage wells, test borings, monitor well G-2477, and proposed drainage wells. Production well construction details and well capacities are presented in **Table 2-1.**

The City's water supply agreement with Broward County provides an additional capacity of 6.2 MGD. The total allocated capacity of 9.2 MGD exceeds the current raw water demand of 6.27 MGD the City is currently experiencing. The City's last Water Use Permit (WUP #06-00138-W) allocated an additional 2.8 MGD of Biscayne Aquifer water through the Broward County Regional Water Supply transmission system.

2.2 Historic Water Quality

2.2.1 USGS Monitoring Wells Water Quality

The USGS maintains a salinity monitoring network to document the movement of the salinity interface in the area. These wells are sampled or measured on a quarterly or semi-annual schedule in order to track the salinity interface on a regional level. The location of the saltwater interface in relation to the Hallandale Wellfield is presented in **Figure 2-2** (Dausman & Langevin, 2005)**.** The delineation of saltwater intrusion as reported in March of 2000 by the Enhanced Salt Water Intrusion Monitoring Program is presented in **Figure 2-3** (Enhanced Salt Water Intrusion Monitoring Program, 2000).

Due to high chloride concentrations, Well PW-5 has not been online for approximately 10 years. Well PW-3 has not been online since 2005, although currently monitored for quality, due to increasing chloride results from samples collected from a close proximity USGS monitor well. At this time, almost all groundwater withdrawals are from Well PW-8. Well PW-7 is considered a standby well and is only placed online as a backup well when Well PW-8 is nonoperational. The monthly pumpage from wells PW-7 and PW-8 individually and the total monthly wellfield pumpage from October 2007 to September 2012 is presented in **Figure 2-4**.

Chloride concentration data was readibly available for USGS monitoring well G-2477 from March 1988 to September 2012 and well G-2478 from January 1988 to September 2012. Well G-2477 is located to the east of Well PW-7 and is used to monitor the

Biscayne aquifer water quality to a depth of 80 feet below land surface (bls). Beginning in July 2002, the well exhibited an increasing chloride concentration and the trend continued until pumping from PW-7 was reduced in 2007. As seen in **Figure 2-5**, the chloride concentration rapidly decreased following the reduction in pumpage but has since then continued to show an increasing trend.

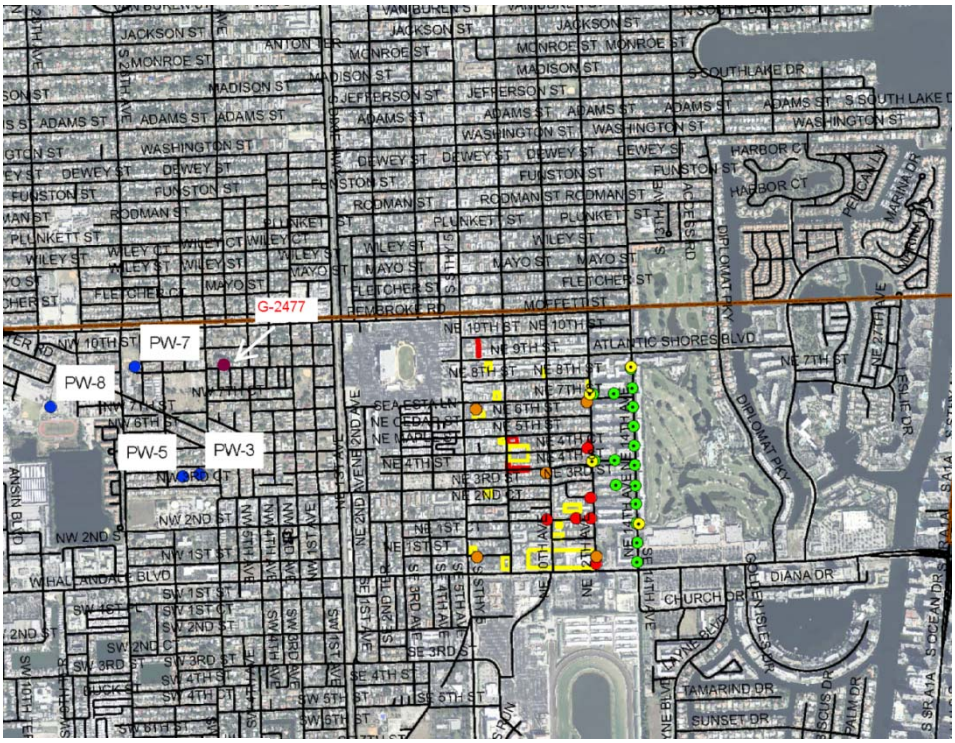

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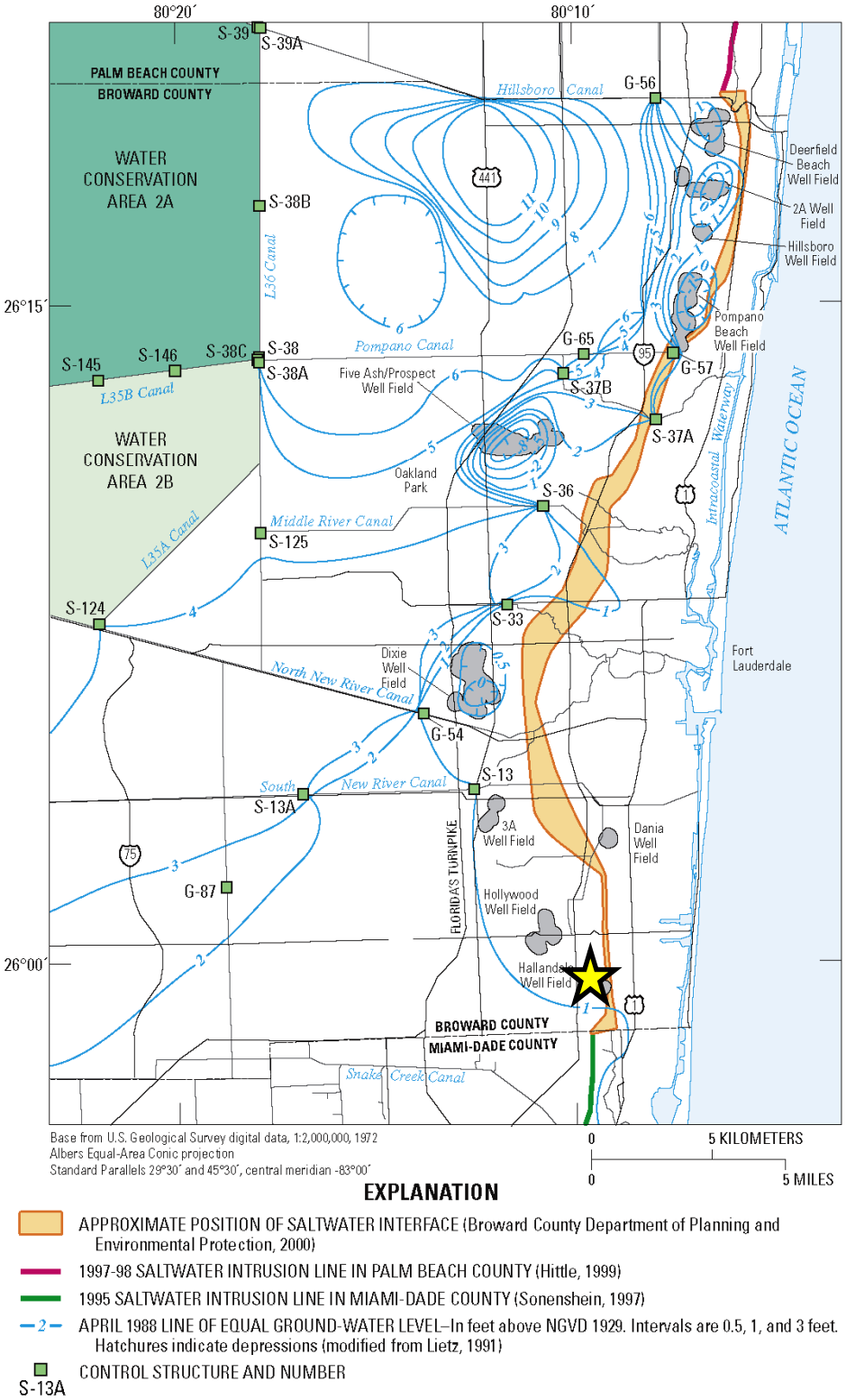
Figure 2-1
Hallandale Beach Wellfield Map

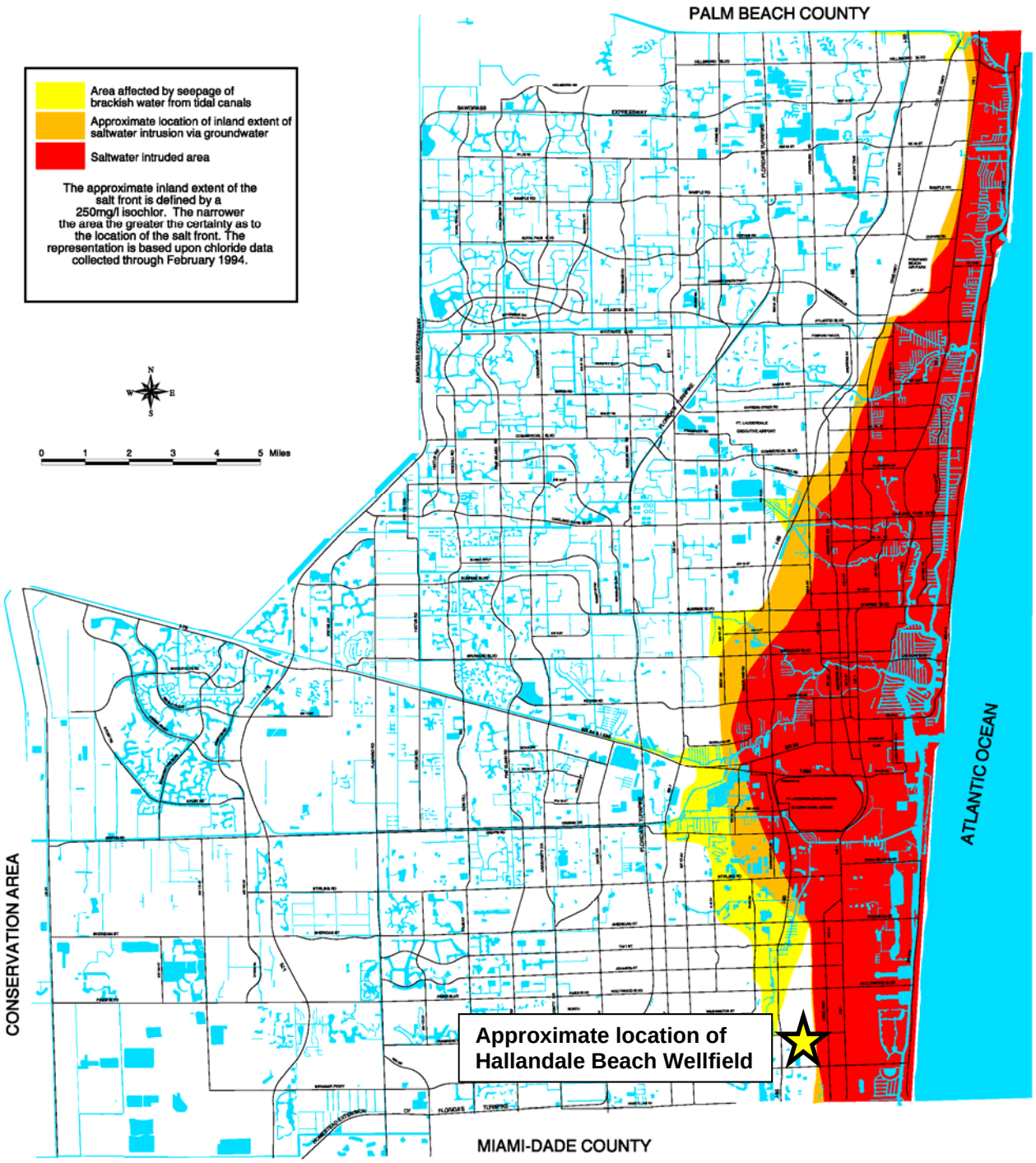
Table 2-1
Production Well Construction Details

Well	Casing Diameter (inches)	Total Depth (feet bls)	Capacity (MGD)	Status
PW-3	12	125	1.5	offline
PW-5	12	85	1.5	offline
PW-7	18	87	2.7	standby
PW-8	20	107	3.0	online



Source (Dausman & Langevin, 2005)

Figure 2-2
Position of the Saltwater Interface near the Hallandale Beach Wellfield



Source (Enhanced Salt Water Intrusion Monitoring Program, 2000)

Figure 2-3
Delineation of Saltwater Intrusion near the Hallandale Beach Wellfield

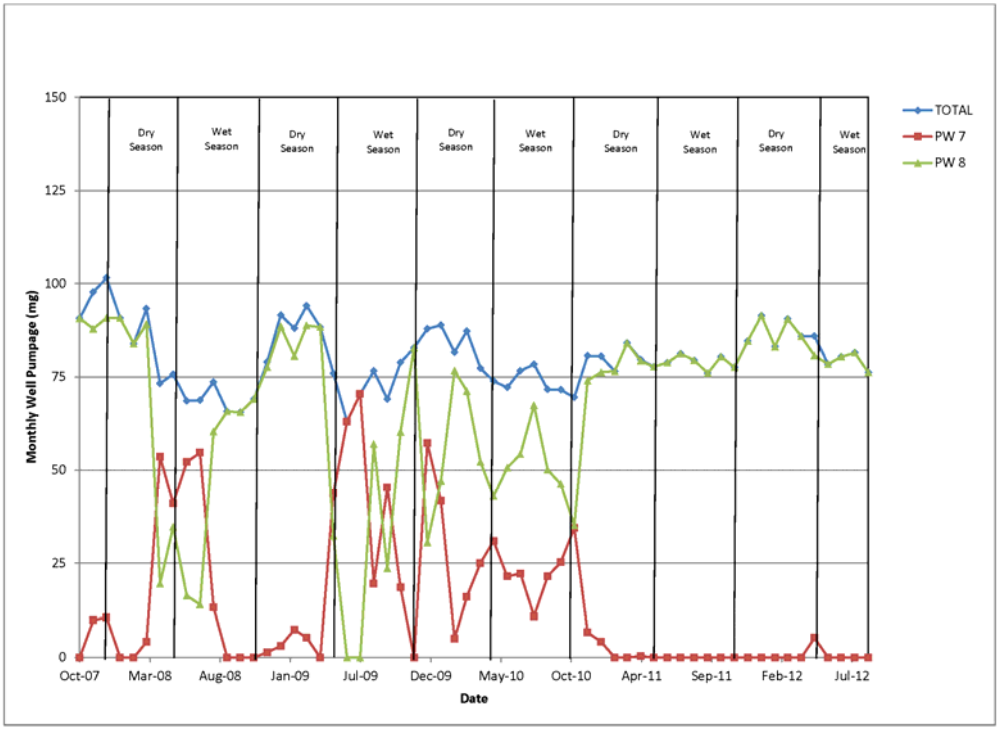


Figure 2-4
Monthly Wellfield Pumpage from Active Production Wells

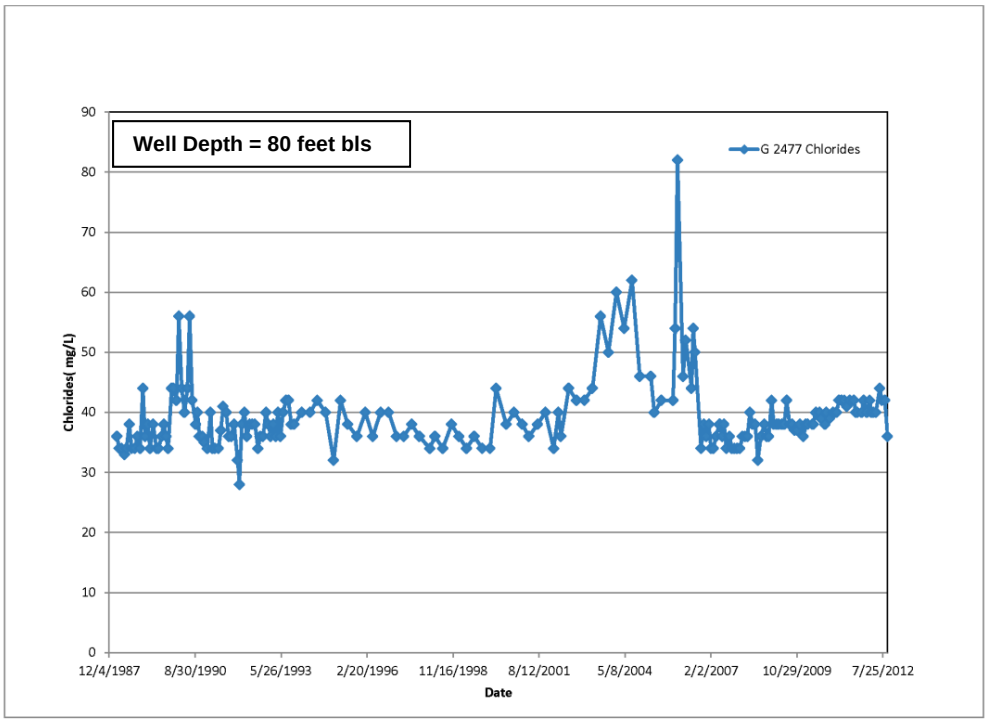


Figure 2-5
USGS Monitoring Well G-2477 Chloride Concentrations

USGS monitoring well G-2478 is located next to well G-2477 (in close proximity to Well PW-7) and is used to monitor the Biscayne aquifer quality to a depth of 200 feet bls. Beginning in October 2001 the chloride concentration of samples collected from this well began to increase at a rapid rate. As shown in **Figure 2-6**, between approximately March 2005 and July 2010 the chloride concentration initially decreased then increased at a slower rate. Following this period the chloride concentration has increased at a significant rate to approximately 1,700 mg/L chlorides (approximately 3,060 mg/L total dissolved solids [TDS]) in September 2012. Further investigation is needed to determine the causes of the chloride concentration changes but is beyond the scope of this study.

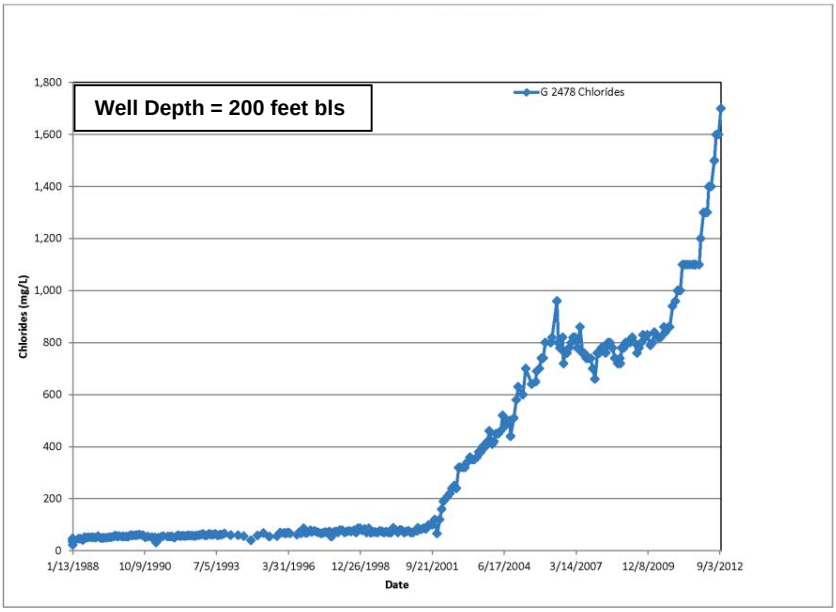
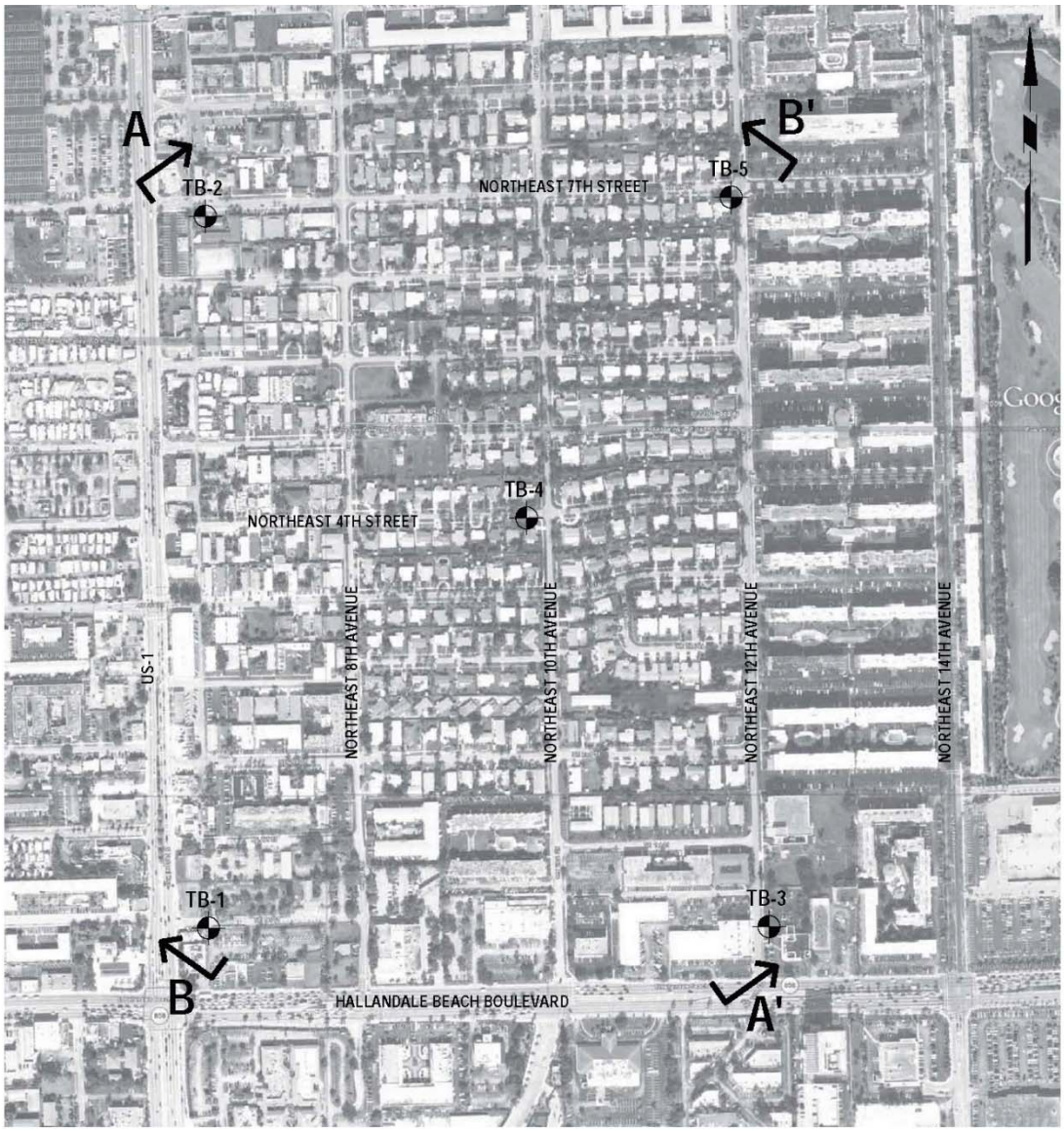


Figure 2-6
USGS Monitoring Well G-2478 Chloride Concentrations

As part of the permitting process for the construction and operation of the Hallandale Beach Class V, Group 6 stormwater drainage wells, Langan Engineering & Environmental Services prepared a Reasonable Assurance Report (RAR) regarding the unintended movement of the stormwater injected into the drainage wells. As part of the RAR, 5 test borings were drilled at the locations shown on **Figure 2-7.** Geotechnical standard penetration tests were conducted during the drilling of the borings to evaluate the density of subsurface material and groundwater samples were collected for laboratory TDS analysis. A summary of the laboratory TDS concentration results is presented in **Table 2-2**. The results show that the water quality is fresh to an approximate depth of 50 feet in the west borings with TDS concentrations significantly increasing with depth to near seawater quality. The test borings in the middle and east area indicate saline water in the shallow depths with TDS concentrations increasing to near seawater quality at depth.

The geotechnical test boring and water quality study identified a lower permeability (considered a semi-confining layer) recommended that the stormwater wells be cased at least 20 feet below the G-II/G-III (these groundwater classes are defined in **Section 2.3**) interface and suggested that the wells be cased to -80 feet National Geodetic Vertical Datum (NGVD) on the projects eastern side, -100 feet NGVD in the central area of the project and -120 feet NGVD on the projects western side, well into the top of the identified semi-confining layers (predominantly calcareous sandstone) in order to provide reasonable assurance that proper construction of the drainage wells should minimize the potential for vertical migration of the discharged stormwater and affect a Class G-II aquifer system, surface water body, or cause water mounding at land surface (Langan Engineering & Environmental Services, 2010).



Source (Langan Engineering & Environmental Services, 2010)

Figure 2-7
Stormwater Drainage Well System Test Boring Locations

Table 2-2
Summary of Test Boring Water Quality Results

Sample Interval (feet bls)	Geotechnical Test Borings Groundwater TDS Concentrations (mg/L)				
	TB-1	TB-2	TB-3	TB-4	TB-5
25-30	280	-	-	-	-
30-35			3,700	1,100	3,200
35-40	-	280	-	-	-
40-45	-	-	-	4,600	-
45-50	400	-	-	-	-
50-55	-	-	11,000	-	19,000
55-60	-	-	-	12,000	-
60-65	-	-	-	-	20,000
65-70	5,800	1,000	28,000	19,000	-
70-75	-	-	-	-	-
75-80	17,000	4,000	-	-	-
80-85	-	-	-	-	30,000
85-90	-	13,000	-	-	-
90-95	-	-	-	-	-
95-100	21,000	21,000	-	25,000	-

Source (Langan Engineering & Environmental Services, 2010)

2.2.2 Production Well Water Quality

The City of Hallandale Beach collects samples regularly for chloride analysis from production wells PW-3, PW-7 and PW-8. Since being taken out of service, Well PW-5 has not been accessible for sampling. The total pumpage from the wellfield and the chloride concentrations for each well are presented in **Figure 2-8**. As may be seen in this figure, the chloride concentration for Well PW-3 is elevated above the chloride concentrations detected in wells PW-7 and PW-8, however, still very fresh (chlorides generally less than 50 mg/L). The Well PW-3 chloride concentrations do fluctuate and show a slight correlation with the Well PW-8 chloride concentrations despite the fact that the well has not been used since 2005. **Figure 2-9** presents the PW-7 chloride concentration data and total wellfield pumpage. As noted above, PW-7 has been used very sparingly since February 2011. It appears that there may be some correlation between wellfield pumpage and the variations of chloride concentration in PW-3, however, the chlorides on Well PW-7 shows less of a correlation to wellfield pumpage. It also appears that there is a stronger correlation between Well PW-8 chloride fluctuations and Well PW-3 chloride fluctuations but Well PW-7 chloride concentrations correlate to a much lesser degree. Further investigation is necessary to make a definitive determination. Although used almost exclusively since February 2011 the chloride concentration of well PW-8 has remained generally stable, however a slowly increasing trend is shown in **Figure 2-10.**

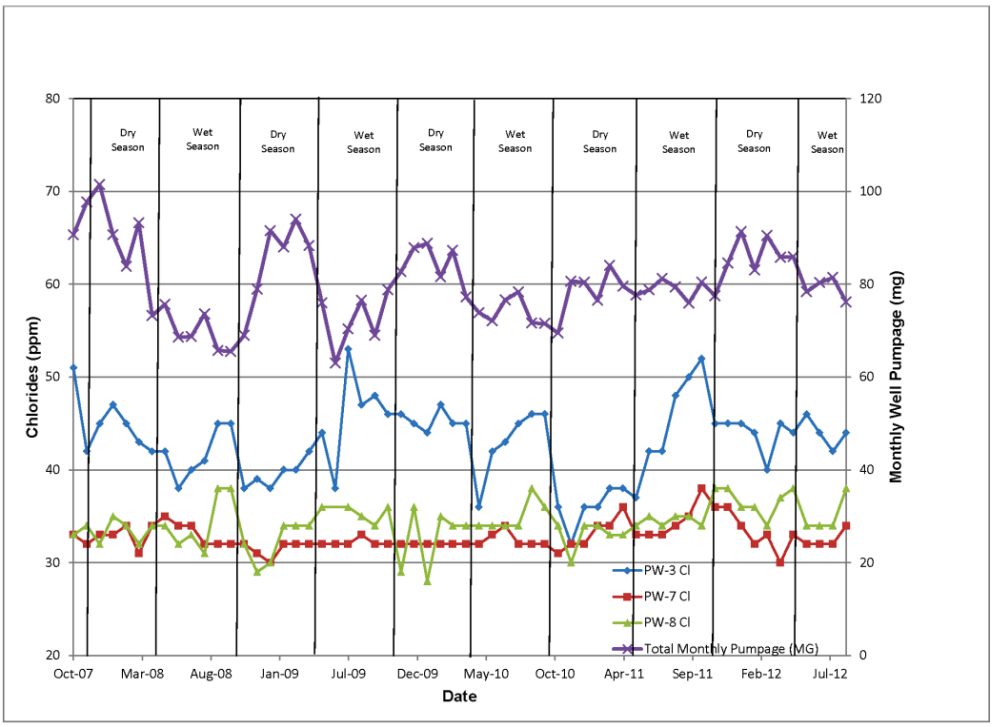


Figure 2-8

Wellfield Pumpage and Chloride Concentrations

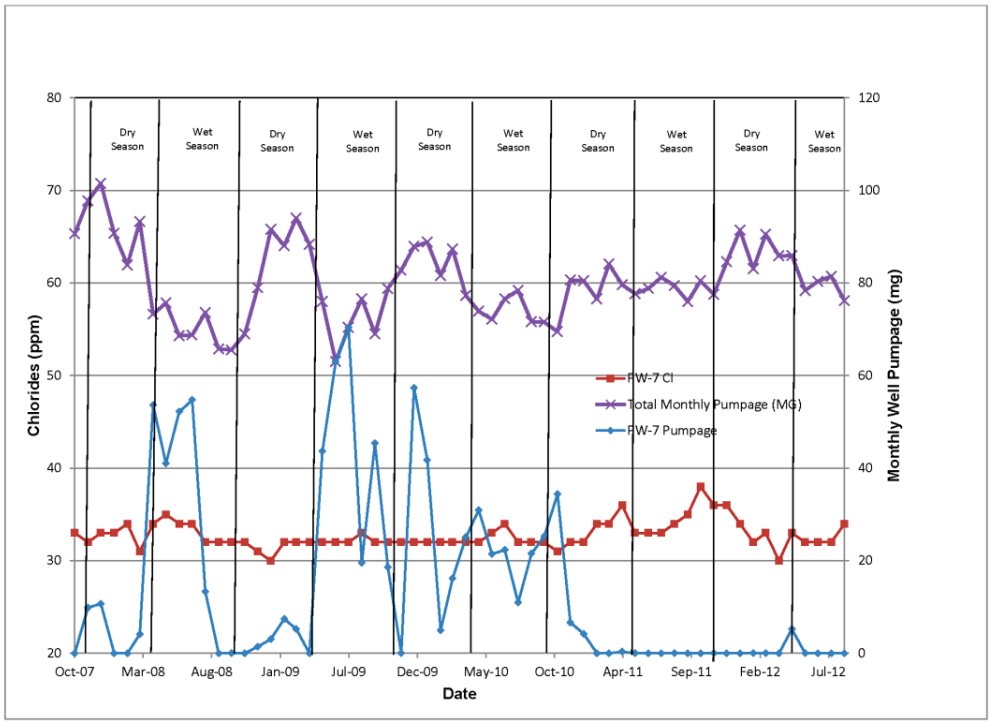


Figure 2-9

Wellfield Pumpage and Well PW-7 Chloride Concentrations

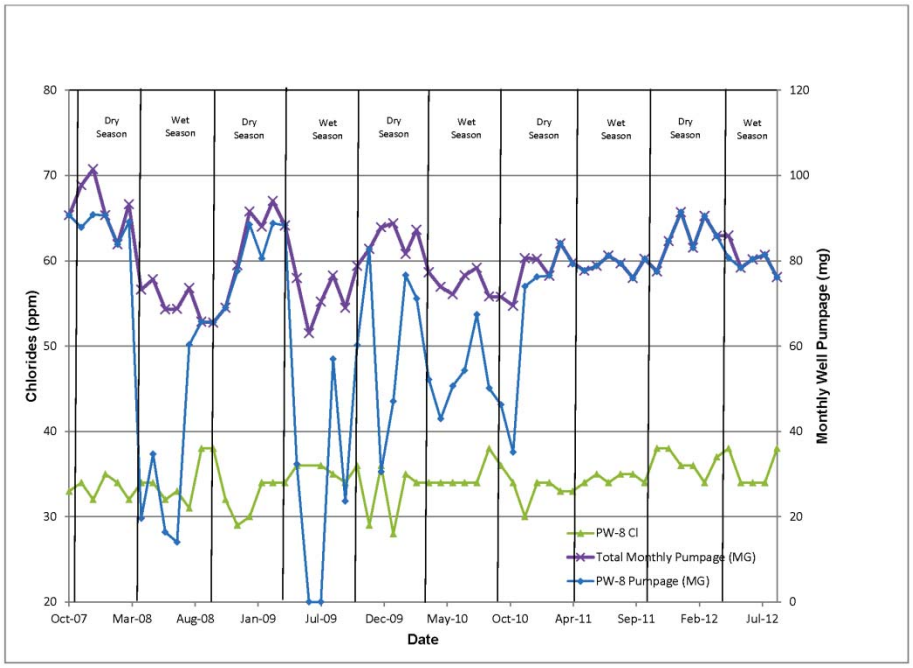


Figure 2-90

Wellfield Pumpage and Well PW-8 Chloride Concentrations

2.3 Regulatory Environment

The SFWMD is a regional agency that is responsible for managing and protecting water resources and issue Water Use Permits for the region. The SFWMD does this by working to balance and improve water quality, flood control, natural systems and water supplies in all or part of the 16 counties within the District boundaries (BCEPD, 2007). Broward County is located in Service Area 2 of the SFWMD's Lower East Coast Regional Water Supply Planning Area (SFWMD, 2006).

Chapter 373 of Florida Statutes (FS) and Chapters 40E and 62-40 of the Florida Administrative Code (FAC) are the primary regulatory tools for water supplies and water usage. FS 373.709 designates the legal authority and requirements for water supply planning. Additional guidance is provided in Chapters 187 and 430 FS (SFWMD, 2012). Wellfield operations are also regulated under Broward County Code Chapter 27 – Pollution Control.

The City's stormwater drainage wells are regulated under Chapter 62-528, F.A.C. Underground Injection Control (UIC) as Class V, Group 6 wells (lake level control and stormwater drainage wells). The purpose of Chapter 62-528, F.A.C. is to protect the quality of the State's underground sources of drinking water (USDW – defined as groundwaters with less than 10,000 mg/L TDS) and to prevent degradation of the quality of other aquifers adjacent to the injection zone that may be used for other purposes.

In Chapter 62-528, F.A.C. Groundwater Classes, Standards, and Exemptions, the groundwater of Florida is classified based on water quality and aquifer type. The general definitions of G-II. G-III, and G-IV are provided below:

G-II: Potable water use, ground water in aquifers which has a TDS content of less than 10,000 mg/L.

G-III: Non-potable water use, ground water in unconfined aquifers which has a TDS content of 10,000 mg/L or greater.

G-IV: Non-potable water use, ground water in confined aquifers which has a TDS content of 10,000 mg/L or greater.

Within the unconfined Biscayne aquifer which is highly utilized for public water supply, is predominantly considered a G-II aquifer except along the coast where saltwater intrusion has occurred and caused the TDS concentrations to exceed 10,000 mg/L. These stormwater drainage wells must be constructed in groundwater classified as G-III (non-potable unconfined aquifer impacted by saltwater) and not impact the groundwater classified as G-II which is protected.

2.4 Land Availability for Salinity Barrier System

A preliminary review of the City owned property and vacant land was conducted for this study. These land sites may be available for future well sites and are shown in **Figure 2-11**. The potential locations are generally located to the west of the existing and proposed storm drainage wells. These locations may be useful for the installation of new observation wells, to be used in concurrence with the existing USGS monitoring wells, to monitor changes occurring in the salinity front as well as influences to the saltwater wedge resulting from the introduction of fresh water into the storm water drainage wells. The land review was conducted by utilizing available aerial photographs and MWH's knowledge of the surrounding area. A future more detailed real estate investigation will provide more information regarding the potential availability of the property by identifying the land owner via property tax records. Final monitoring well locations will depend on acquiring easements on such property.

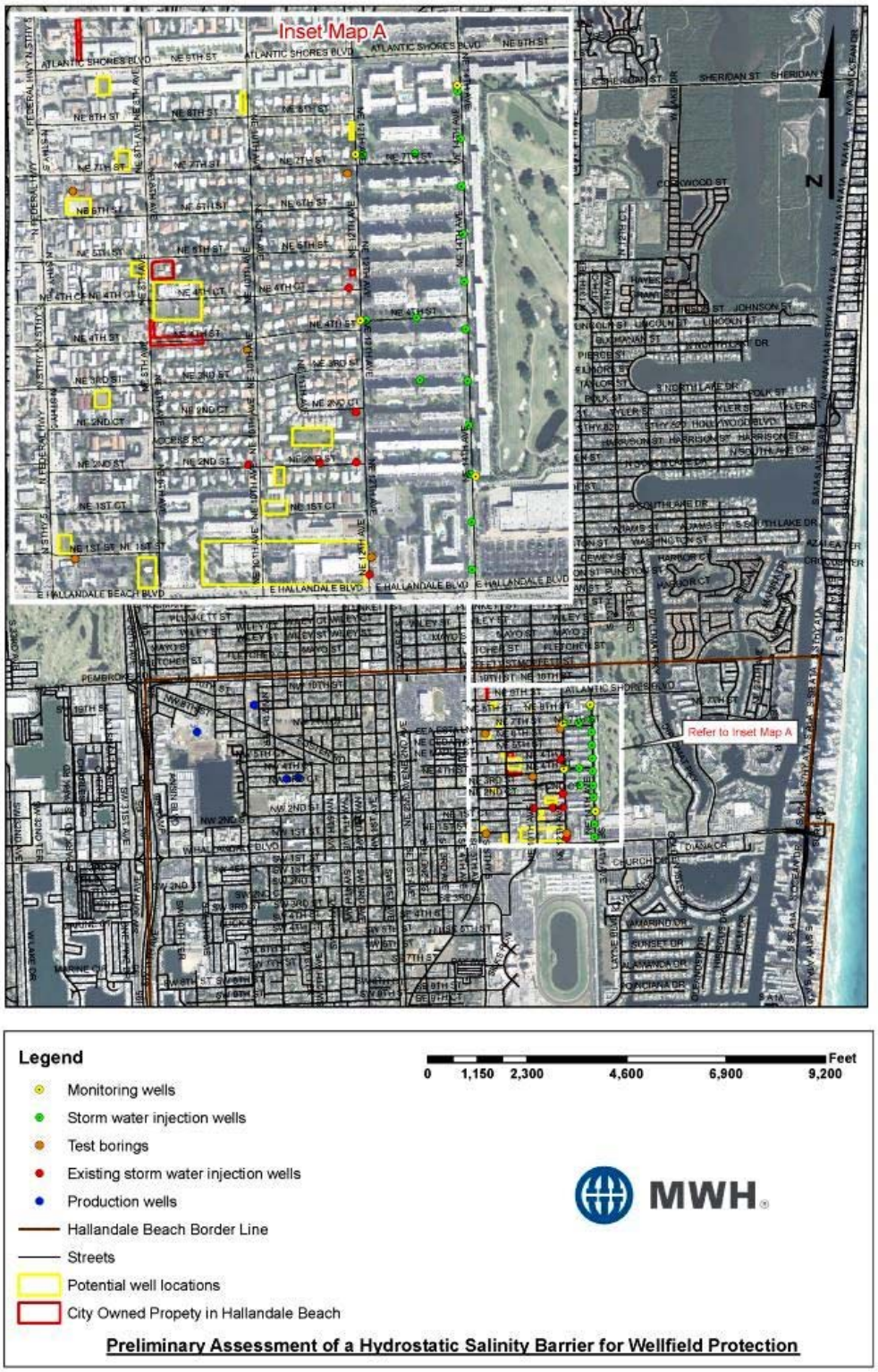


Figure 2-101

City of Hallandale Beach Land Availability for Future Well Construction

3 Literature Review and Case Study Assessment

The investigation and documentation of saltwater intrusion into U.S. drinking water aquifers has been in progress for a period of over 100 years by the USGS. Numerous studies have been conducted and documents prepared that document the movement of the saltwater interface in various parts of the US. Some municipalities have conducted their own studies and have initiated options, such as salinity barriers, to minimize or mitigate saltwater intrusion effects. Some of these studies are summarized here.

3.1 USGS Salinity Investigations

The USGS reviewed literature that has been published related to the occurrence and intrusion of saltwater along the United States Atlantic coast and produced a bibliography of published literature presented as USGS Open-File Report 02-235 *Bibliography on the Occurrence and Intrusion of Saltwater in Aquifers along the Atlantic Coast of the United States* (USGS, 2002). The report presents separate bibliographies for each state along the Atlantic coast with the section devoted to Florida containing over 200 entries with 9 of these entries containing information related to the injection of treated wastewater. (Hickey, 1977) (USGS, 1979) (USGS, 1981) (USGS, 1982) (WRR, 1989) (Hickey & Barr, 1979) (Hickey, J; Ehrlich;, 1984) (Hickey, J; Spechler, R, 1979) (USGS, 1992)

The USGS, in cooperation with Broward County, the City of Fort Lauderdale, the City of Hollywood, the City of Dania Beach, and the City of Hallandale, is currently conducting a research project titled *Factors affecting the position of the freshwater-saltwater interface in Central and Southern Broward County, Florida* (Hughes & White, 2010). This ongoing project is scheduled to be completed in September 2014, therefore, information related to this project is not yet available. As stated by the USGS (Hughes & White, 2010):

> The purpose of this study was to evaluate the ability of a variable-density groundwater flow and solute transport model to simulate the historical pattern and rate of saltwater intrusion in Central and Southern Broward County, Florida. Specific project objectives were to:
>
> 1. Develop a three-dimensional dispersive saltwater intrusion model for the central and southern part of Broward County to simulate hydrologic conditions for the period from the early 1900's to the present
>
> 2. Use the historical data record (groundwater heads and salinities) to history match aquifer flow and transport parameters and determine if a parsimonious numerical model is capable of representing the observed saltwater intrusion patterns
>
> 3. Conduct a formalized sensitivity analysis to determine the types of field data that are most useful for calibrating the

numerical model, as well as the model parameters that have the most influence on the simulated saltwater intrusion patterns.

4. Quantify the relative importance of various hydrologic mechanisms for causing movement of the transition zone between freshwater and saltwater.

3.2 SWFWMD Aquifer Recharge Feasibility Study

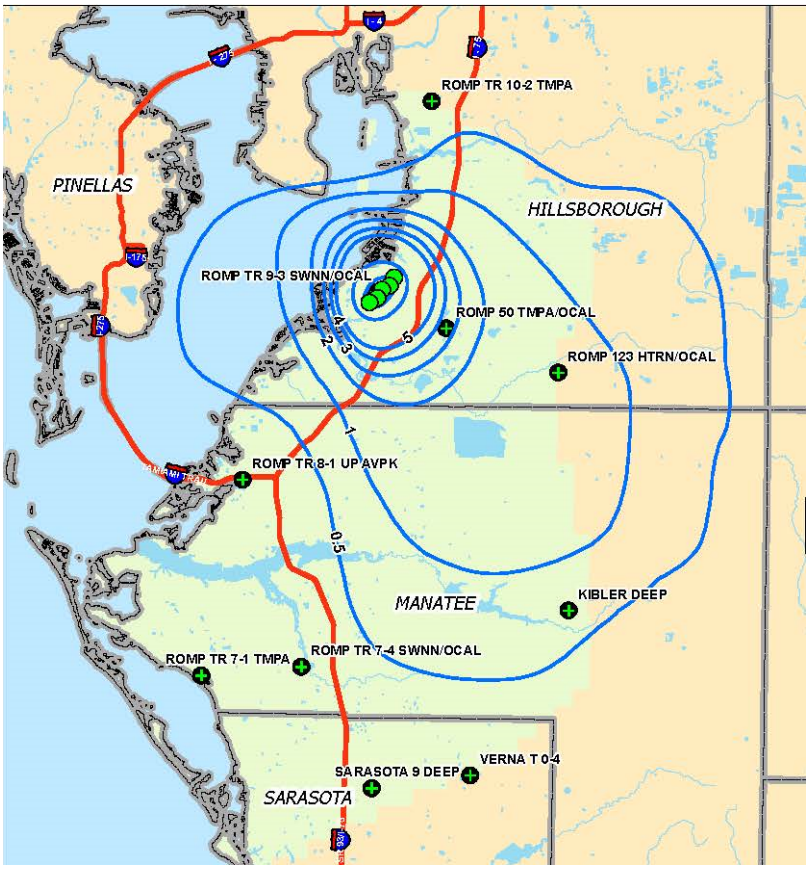
In 2009, MWH completed a feasibility study for the Southwest Florida Water Management District (SWFWMD) which focused on using locally available reclaimed water, currently discharged to Tampa Bay, for aquifer recharge for the (MWH, 2009). The study investigated the potential of using available reclaimed water that had been treated to meet regulatory standards in order to indirectly or directly recharge the Upper Floridan aquifer in southern Hillsborough and western Polk counties in Florida. The project included three detailed technical memorandums and a final summary report. Technical Memorandum Number 1 addressed the regional hydrogeology, water quality and permitting issues. Technical Memorandum Number 2 focused on water level improvements and impacts using numerical groundwater modeling and provided a selection ranking for the most viable recharge configurations. Technical Memorandum Number 3 provided an economic analysis on the most viable configurations (MWH, 2009).

Indirect aquifer recharge involves the use of rapid infiltration basins (RIBs) to recharge the Upper Florida aquifer in areas where there is good communication between the surficial aquifer and Upper Florida aquifer. Direct aquifer recharge involves the use of recharge wells to directly recharge the Upper Florida aquifer. Direct aquifer recharge techniques may require additional treatment of the reclaimed water since the regulatory framework has specific treatment requirements related to the water quality of the target aquifer.

Regional predevelopment aquifer levels were able to maintain a hydraulic gradient such that dominant fresh water flows from the recharge area in the middle of Florida to the coastline, keeping saltwater intrusion controlled. Over stressing coastal aquifers causes declining inland water levels, resulting in a reversal in the hydraulic gradient along the coast such that saltwater is the dominant flow gradient and saltwater intrusion inland occurs. Salinity barriers have been constructed in some salinity impacted areas to restore degrading groundwater quality. The direct aquifer recharge salinity barrier projects studied suggest that using reclaimed water treated to levels that meet or exceed drinking water standards may assist in managing water supplies (MWH, 2009). These projects are generally designed and constructed as a line of injection wells paralleling the coast which create a water level mounding ridge which restores the gradient to the ocean.

For recharge of G-IV groundwater in Tampa Bay (non-potable with TDS concentrations greater than 10,000 mg/L TDS), there was no additional treatment needed of the local reclaimed water sources reviewed. Therefore, the focus of this feasibility study was regarding a salinity barrier concept for the Tampa Bay area. **Figure 3-1** provides a numerical groundwater model simulation of a 10 MGD recharge salinity barrier scenario

and the water level mounding results. These contours show that the groundwater flow is towards the Bay west of the recharge wells. This system can be easily expanded as additional reclaimed water flow and partners are identified.



Source (MWH, 2009)

Figure 3-1

Tampa Bay Aquifer Recharge Mounding Analysis (10 MGD Recharge)

The MWH identified benefits of the salinity barrier recharge concept included:

- Helps the SWFWMD move closer towards the goal of meeting minimum aquifer levels of the Most Impacted Area (MIA) of the Southern Water Use Caution Area (SWUCA).
- Helps other local municipalities develop future groundwater within the SWUCA which were forbidden unless water level improvements to the MIA were first established.
- Helps to create a salinity barrier by creating a coastal water level mounding ridge effect which reverses the hydraulic gradient from inland (allowing saltwater to move inland) towards the Bay.
- Helps provide a wet weather use of the highly treated water.

- Removes the nitrogen loaded reclaimed water flows currently discharged to the Bay by creating a more beneficial use for the highly treated water. It was identified that a 50 MGD salinity barrier recharge system can eliminate 200 tons of nitrogen to the Bay annually.
- Provides a cost effective solution which addresses numerous environmental concerns.
- Openly supported by FDEP and SWFWMD and is seriously being considered by other regulatory agencies in Florida as a solution to lake level restoration, spring flow restoration, and salinity barriers.

3.3 Recharge Case Studies

Several systems, predominantly located in water limited western US states, have demonstrated that the injection of highly treated reclaimed water may be a critical component in the management of water supplies. Some of these projects have also assisted with preventing the further degradation and depletion of drinking water aquifers (MWH, 2009).

Reuse water for direct aquifer recharge has been implemented in several projects including the Kanapaha Water Reclamation Facility Injection Well of the Gainesville Regional Utilities (GRU) in Florida and the City of El Paso Texas Fred Hervey Water Reclamation Plant Hueco Bolson Recharge Project Recharge Wells (MWH, 2009).

The Gainesville Regional Utilities Kanapaha WRF Injection Well was constructed in 1972 and is operated under an FDEP Class V recharge well permit. The FDEP operating permit which allows the facility to recharge 14.9 MGD of highly treated domestic wastewater requires that reclaimed water directed to the injection well meet primary and secondary drinking water standards (Hua, et al., 2012).

The Fred Hervey Water Reclamation Plant in El Paso Texas uses reclaimed water treated to drinking water quality level standards to recharge the Hueco Bolson Basin. The reclaimed water is injected directly into the aquifer using a series of injection wells and indirectly using infiltration basins. In 2010, the system returned more than 500 million gallons of water to the Hueco Basin (EPWSPSB, 2011).

Other direct aquifer recharge projects using reclaimed water include the Scottsdale Arizona aquifer recharge program. This system injects highly treated wastewater into the unsaturated vadose zone recharge wells which allows for additional treatment prior to the water encountering the unconfined aquifer. They system also uses aquifer storage and recovery (ASR) wells (SWRD, 2012).

3.3.1 Orange County Groundwater Replenishment System

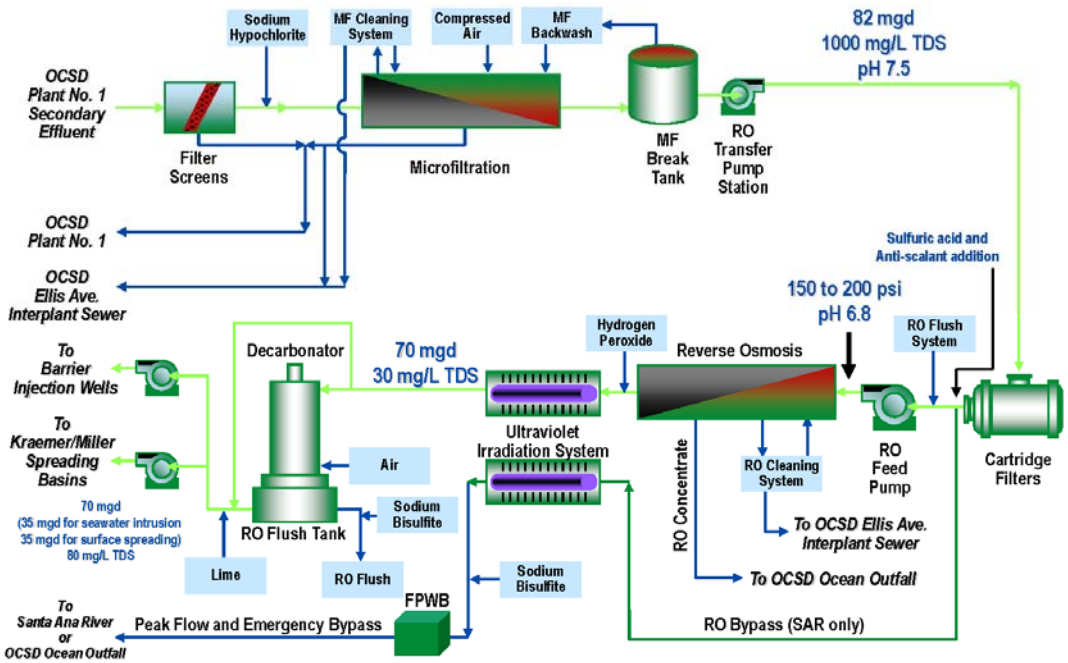
Southern California has been faced with water shortages for many years. Maintaining and increasing their water supply to meet population demands has caused the state to adopt unique strategies for water management. Do to the high cost of other options such as additional very large diameter pipelines (expansion of the Aqueduct and surface water reservoir system) to import water from the Northwestern states and the Colorado River and seawater desalination plants, Southern California decided it was more cost effective to take advantage of the reclaimed water flows and purifying 70 MGD of it for

more beneficial use with slightly less expensive additional treatment compared to the other options.

Southern California has constructed several salinity barriers to protect the groundwater aquifers from intruding saltwater. These systems include 229 injection wells that protect 15 miles of coastal Los Angeles County from salt water encroachment. The Los Angeles Metropolitan Water District provides a treated blend of drinking and surface water imported from the California Aqueduct and the Colorado River. Secondary effluent is pumped from the City of Los Angeles Hyperion Treatment Plant to the West Basin Municipal Water District Water Recycling and Barrier Treatment Facility and subject to further advanced treatment prior to being blended with the MWD water and injected through the salt water barrier intrusion well system. During 1998, Los Angeles County injected approximately 8,287 million gallons of water into the wells (USEPA, 1999).

The method of creating a freshwater ridge by direct recharge has been employed by the Groundwater Replenishment (GWR) system sponsored by the Orange County Water District (OCWD) and the Orange County Sanitation District (OCSD) in southern California. The GWR system, one of the largest in the world, was designed to retard groundwater degradation due to saltwater intrusion as well as providing a source of recharge for the local water supply aquifer (USEPA, 2004). Pumping of the local aquifer caused the water table elevation to be lowered. The GWR creates a freshwater mound that is higher than sea level reducing the ability of saltwater to migrate into the aquifer. The GWR system also eliminated the immediate need for an additional ocean outfall by providing a peak reclaimed water flow alternative (USEPA, 2004).

Since the GWR system is partially designed for indirect potable reuse by recharging a fresh drinking water aquifer inland using indirect aquifer recharge, the GWR system must provide an ultra-high level of additional water treatment (commonly called "purification" by the managers) on the reclaimed water prior to use for the salinity barrier or rapid infiltration basins (percolation ponds or spreading basins). Following initial treatment, wastewater effluent undergoes additional high level treatment using microfiltration, reverse osmosis, and disinfection using ultraviolet light and hydrogen peroxide. The process produces water of a quality that exceeds all Federal and California drinking water standards (GWRS, 2012). A schematic of the process is presented in **Figure 3-2.** Approximately 35 MGD of purified water is pumped into more than 23 seawater barrier injection wells providing a protective hydraulic barrier defending and recharging the aquifers underlying Orange County (GWRS, 2012).



Source: (Argo, Veerapaneni, Wang, Patel, & Deshmukh, 2010)

Figure 3-2
Orange County Water District Groundwater Replenishment System Schematic

3.3.2 West Basin Regional Water District

The West Basin Regional Water District located in El Segundo, California also injects highly treated wastewater to create salinity barriers preventing saltwater intrusion into the drinking water aquifer. The West Basin Water Recycling Facility produces reclaimed water of several qualities designed for a variety of uses such as irrigation, industrial use and highly treated water to be injected into saltwater intrusion barrier wells (MWH, 2009).

The Los Angeles County Flood Control District (LACFCD) owns, operates, and maintains a salinity barrier system. The water required for the barrier system is purchased by the Water Replenishment District of Southern California (WRD). Groundwater recharge, retardation of saltwater intrusion, and groundwater quality monitoring are conducted by the WRD. Two seawater barriers; the West Coast Basin Seawater Barrier and the Dominguez Gap Barrier, receive a combination of highly treated water from the West Basin Water Recycling Facility (WBMWD, 2011).

The West Coast Basin Seawater Barrier wells receive highly treated wastewater and imported water. Improvements to the water recycling facility have permitted a decrease in the amount of imported needed to be injected into the salinity barrier wells from 50 to 25 percent. In order to further decrease the demand for imported water, West Basin and WRD are working together to increase the injected recycled water to 100 percent of that needed for the barrier well operation (WBMWD, 2011).

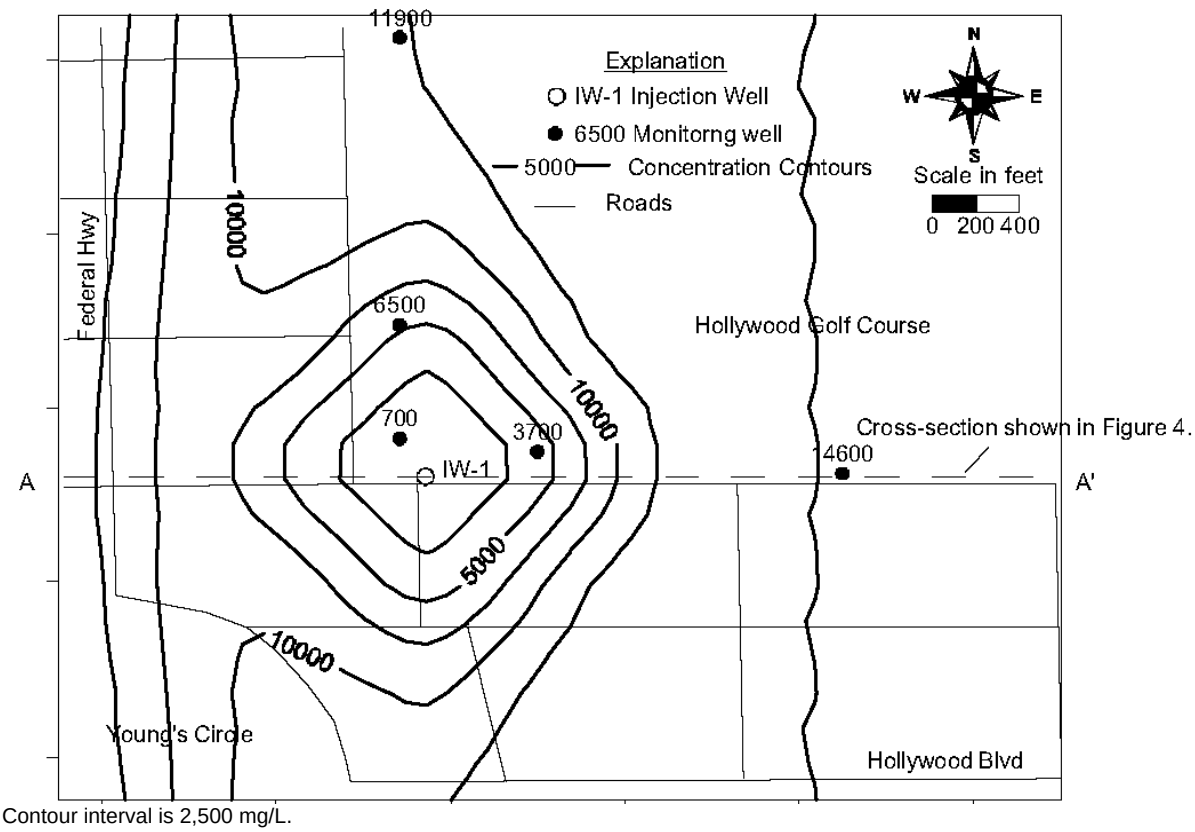
Similar to the West Coast Barrier is the associated Dominguez Gap Barrier system where clean water is injected in order to prevent seawater from impacting the drinking water

supply. The Dominguez Gap Barrier receives approximately 3.25 million gallons of high quality reclaimed water each year. It is anticipated that the West Basin Water Recycling Facility will be able to provide 1 MGD of high quality reclaimed water providing approximately 50 percent of the volume required for the barrier wells (WBMWD, 2011).

The Talbert Barrier Project, a series of 23 multi-point injection wells operated by the Orange County Water District (OCWD) in California, injects water into several geological horizons in order to recharge four coastal aquifers (Talbert, Alpha, Beta, and Lambda aquifers). Highly treated wastewater mixed with other water is used as the recharge water. OCWD was accepting up to 15 MGD of secondary-treated municipal wastewater from the County Sanitation District of Orange County's Fountain Valley plant as of 1991, for advanced treatment at Water Factory 21 in the City of Fountain Valley (USEPA, 1999). The Factory 21 project has provided advanced treated reclaimed water to maintain the salinity barrier for more than 25 years. (MWH, 2009)

3.3.3 City of Hollywood Case Study

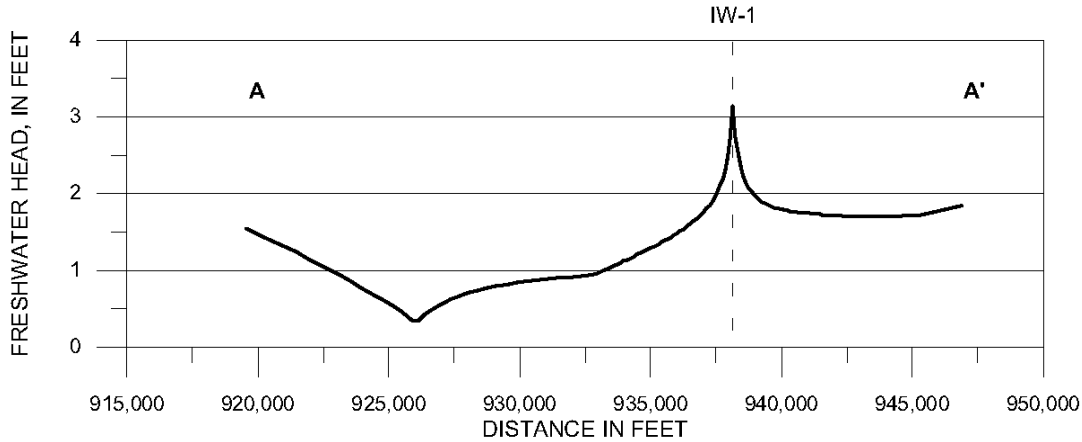
The City of Hollywood Florida has experienced saltwater intrusion as a result of the lowering of freshwater levels by approximately four feet in the area (Bloetscher, 2000). The City tested the concept of using treated wastewater to protect existing water supplies from additional intrusion. The project used potable water as the recharge source in order to assess the potential benefits and to explore the migration of pathogens to existing wells (USEPA, 1999). For 14 days, between January 6, and February 10, 2000, a short-term injection test with potable water was conducted on Well IW-1 at an average injection rate of approximately 1,130 gallons per minute (gpm) with a nearly constant flow rate. Following this test, a numerical groundwater model was developed to simulate the test and full scale injection. The three-dimensional groundwater model consisted of five layers representing the surficial aquifer, a semi-confining layer the shallow production zone of the Biscayne aquifer, the deep production zone of the Biscayne aquifer and a deeper semi-confining layer. The groundwater model was calibrated using the collected field data from the injection test. The modeling results suggested the injection of water into the deep production zone of the Biscayne aquifer would increase local water levels and form a hydraulic barrier preventing further inland movement of the saltwater/freshwater interface (Guo, Langevin, & Bennett, 2001). **Figure 3-3** shows the model-predicted chloride concentration (mg/L) after 7 days of recovery following the 14-day injection test. **Figure 3-4** presents simulated freshwater levels after 30 days of injection along an east-west cross-section.



Contour interval is 2,500 mg/L.
Source (Guo, Langevin, & Bennett, 2001)

Figure 3-3

City of Hollywood Simulated Chloride Concentration



Source (Guo, Langevin, & Bennett, 2001)

Figure 3-4

City of Hollywood Simulated Freshwater Heads after 30 Days of Injection

3.4 Regulatory Considerations for Reclaimed Water Aquifer Recharge

In 1999, the USEPA conducted a study of Class V underground injection wells. Volume 20 of this report covered Class V saltwater intrusion barrier wells (USEPA, 1999). When the report was published, there were 315 documented saltwater intrusion barrier wells in the United States, however it was estimated that the total number of wells used for retarding saltwater intrusion was greater than 607. According to the Underground Injection Control (UIC) regulations in 40 CFR 146.5(e)(7), "Salt water intrusion wells used to inject water into a fresh water aquifer to prevent the intrusion of salt water into the fresh water" are designated as Class V injection wells. This includes saltwater intrusion barrier wells that inject mixtures of treated wastewater and ground or surface water (USEPA, 1999).

Chapter 62-610, FAC contains specific additional requirements for salinity barrier wells, recharge wells, and ASR wells that use reclaimed water as the source water. Additional groundwater discharge rules are contained in Chapter 62-520 and 62-522, FAC. Chapter 62-600, FAC has additional rules regarding groundwater discharges including systems discharging to aquifers containing less than 500 mg/L total dissolved solids (TDS) concentration (MWH, 2009). The SWFWMD aquifer recharge feasibility study conducted for southern Hillsborough and western Polk Counties identified 14 chapters of the FAC, which are the applicable to the permitting requirements of reclaimed water recharge projects (MWH, 2009).

The City of Hallandale Beach stormwater drainage wells are being completed in the Biscayne aquifer already impacted by seawater (classified as a G-III groundwater containing groundwater with TDS concentration greater than 10,000 mg/L), which only require secondary treatment for injection. As the receiving aquifer water quality becomes more fresh, groundwater recharge treatment, disinfection, and testing requirements for various types of recharge systems become significantly more expensive. MWH compiled the existing rules and treatment requirements for reclaimed water aquifer recharge during the SWFWMD Aquifer Recharge Feasibility study. The FDEP required treatment levels and the applicable rules are presented in **Table 3-1.**

Per the FAC, reclaimed water can be used as a water source for a salinity barrier in areas where the aquifer water is between 1,000 and 3,000 mg/L TDS as long as the groundwater is not intended for potable purposes. This category suggests that the FDEP sees reclaimed water as a beneficial source to mitigate saltwater intrusion effects. However, stormwater drainage wells must be located in G-III groundwaters and must not degrade G-II groundwaters per FDEP to issue a Class V Well Construction Permit.

Table 3-1

Groundwater Recharge Treatment and Disinfection Requirements

Type of Recharge System	Required Treatment Level	Comments and Applicable Rules
Injection to G-II in the Floridan aquifer or Biscayne aquifer (≤500 mg/L TDS)	Secondary treatment & filtration TOC: The lesser of 5 mg/L average or background; 9 mg/L max TOX: 0.2 mg/L average, 0.3 mg/L max. TN: 10 mg/L (average) Drinking water standards and HLD Multiple barriers (for organics & pathogens) Mutagenicity testing approved by FDEP. Activated carbon adsorption or approved alternative. Full scale pilot testing for 1 year. Approved standby disposal or storage facilities. 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*).	*Rule 62-600.540(3), FAC*. *Rule 62-520.420, FAC* at a minimum. Possible pilot testing reductions are outlined in *Rule 62-610.564(5), FAC*. ERC will hold a public meeting following pilot testing or full scale operational testing. Full-scale operational testing complete and national expert review before any permit is issued.
Injection to G-I, F-I, G-II (<3000 mg/L TDS)	Secondary treatment & filtration TOC: 3 mg/L average, 5 mg/L max. TOX: 0.2 mg/L average, 0.3 mg/L max. TN: 10 mg/L (average) Drinking water standards and HLD Multiple barriers (for organics & pathogens) Pilot testing for 1 year. 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*).	Alternate TOC and TOX limits can be obtained if all public supply wells within 1 mile are owned by applicant, and other users are prohibited or have RO treatment in place (*Rule 62-610.563(3), FAC*). Possible pilot testing reductions are outlined in *Rule 62-610.564(5), FAC*.

Table 3-1(Continued)

Groundwater Recharge Treatment and Disinfection Requirements

Type of Recharge System	Required Treatment Level	Comments and Applicable Rules
ASR using G-I, F-I, G-II (<3000 mg/L TDS)	Secondary treatment & filtration TOC: 3 mg/L average, 5 mg/L max. TOX: 0.2 mg/L average, 0.3 mg/L max. TN: 10 mg/L average DWSs and HLD Multiple barriers (for organics & pathogens)	Lesser standards (principal treatment; see >3000 mg/L below) if applicant can demonstrate that the groundwater is between 1,000 and 3,000 mg/L, not currently used as a source of public water supply and is not reasonably expected to serve as a future source of public water supply. Secondary DWSs, TN limit, and HLD fecal coliform standards shall not apply in this case. (*Rule 62-610.466(9), FAC*). Recovered water must demonstrate standards for BOD5 (20 mg/L), TSS (5 mg/L), and FC (absence).
Injection to G-II (>3000 mg/L TDS)	Secondary treatment & filtration Primary DWSs and drinking water disinfection ZOD for secondary DWSs TN: 10 mg/L average	Applies to all F-I, G-I, & G-II (except as described above)
Injection for salinity Barriers (G-II having TDS 1000-3000 mg/L & not used for potable purposes)	Secondary treatment & filtration Primary DWSs and drinking water disinfection ZOD for secondary DWSs TN: 10 mg/L average) 1000 ft. setback from potable supply wells	Treatment requirements are consistent with injection to G-II having TDS > 3000 mg/L.

Table 3-1 (Continued)

Groundwater Recharge Treatment and Disinfection Requirements

Type of Recharge System	Required Treatment Level	Comments and Applicable Rules
Part IV systems (e.g., RIBs) in unfavorable conditions such as highly karstic or over-lying public water supplies	Secondary treatment & filtration Primary and secondary DWSs and HLD TN: 10 mg/L average	Rule 62-610.525, FAC. Also applies to RIBs with loading rates >9"/day. Projects are considered as reuse for groundwater recharge. Allows ZOD for secondary DWSs with affirmative demonstration (Rule 62-610.525(8)(b), FAC).
Discharge to wetlands that percolate to ground water	Wetlands discharges are regulated under Chapter 62-611, FAC Percolation can be regulated under ground water rules.	Chapter 62-611, FAC.
RIBs and other rapid-rate systems with favorable conditions	Secondary treatment (BOD5 and TSS <20 mg/L) Basic disinfection (FC <200 cfu/100 mL; CR >0.5 mg/L) Nitrate: 12 mg/L (max. as N).	Demonstration of <10 mg/L nitrate at edge of ZOD may allow nitrate limit of 12 mg/L to be waived (Rule 62-610.510(1), FAC).
Injection into G-III aquifer (>10,000 mg/L TDS)	Secondary treatment	

Note: *Modified from FDEP website (October 2008).* ***Acronyms used:*** *Aquifer Storage Recovery (ASR); Biochemical Oxygen Demand (BOD5); Colony Forming Units (cfu); Chlorine Residual (CR); Drinking Water Standards (DWSs); Environmental Regulation Commission (ERC); Florida Administrative Code (FAC); Fecal Coliform (FC); High Level Disinfection (HLD); Rapid Infiltration Basins (RIBs); Total Dissolved Solids (TDS); Total Nitrogen (TN); Total Organic Carbon (TOC); Total Organic Halogen (TOX); Total Suspended Solids (TSS); Zone of Discharge (ZOD).*

4 Evaluation of Aquifer Recharge Alternatives for Salinity Barriers

A number of aquifer recharge methods were identified and evaluated which may be applicable to the City of Hallandale Beach.

4.1 Direct Surface Delivery

4.1.1 Background

Direct surface delivery of reclaimed water for use as a salinity barrier would depend on several factors. The location of the surface recharge areas, sediments that allow for rapid percolation of the water to the surficial aquifer as well as the length of time that the water is in contact with the soil are some of the most important features (Asano, 1985). Several methods of direct surface recharge may be used including flooding, ditch and furrow, basins, stream channel modifications, stream augmentation and over-irrigation. For this preliminary assessment only rapid infiltration basins (RIBs) will be investigated. For the purposes of protection from saltwater intrusion, direct surface delivery is commonly used as a part of a saltwater intrusion control project including direct injection and indirect recharge (Finlayson & Hill, 1975).

4.1.2 Case Study

MWH prepared a saline water test barrier preliminary groundwater model evaluation for the City of Pompano Beach (MWH, 2010). The project objective was to investigate the possibility of raising the water table using direct surface delivery to create a hydraulic barrier to control the movement of saltwater inland. The test barrier was designed to be a trench 4 to 5 feet deep, filled with gravel approximately 600 feet long and eight feet wide. The proposed trench was based on a seepage rate of 0.1 gallons per minute per foot of trench with a flow rate of 100,000 gallons per day (MWH, 2010). The study results indicated that the modeled simulation indicated mounding in the surficial aquifer water levels to a distance of approximately 400 feet from the basin (MWH, 2010).

4.1.3 Potential Impacts

Other legal users of groundwater may be affected by the introduction of reclaimed water via direct surface delivery, particularly those in the locality of the salinity barrier. The aquifer water level mounding caused by recharge would have caused a reverse localized groundwater gradient to mitigate saltwater intrusion. Depending on the location of the recharge basin, increasing groundwater levels within the saline impacted zone of the receiving aquifer may cause unintentional movement of saline water laterally inland (MWH, 2009).

4.1.4 Regulatory Concerns

Local regulations regarding direct surface delivery for the purpose of saltwater intrusion mitigation are presented in the Broward County Code of Ordinances Part II Code of Ordinances Chapter 27 Pollution Control Section 27-200. The regulations require in part that saltwater entrapped in the basin, as the result of inland migration of saltwater

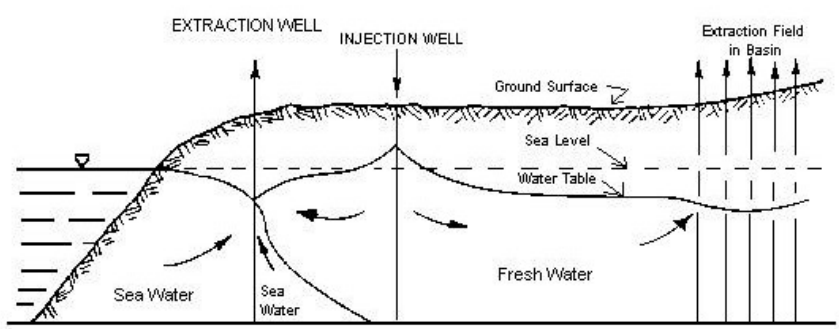
during a hurricane or tidal event, not impact existing legal water users and that the discharge to excavations having poorer water quality in terms of chloride concentration not adversely impact legal water users. The regulations also state "Geologic testing may be required, as well as monitoring well construction, in order to establish the nature of the strata that will be penetrated by a proposed excavation. Applications for excavations into highly pervious limestone that may cause undesirable hydraulic connections between sections of the aquifer or between the aquifer and surface water may be denied." (Broward County, 2012). Considering that a salinity barrier is an environmental benefit, this restriction may not be directly applicable and worthy of a variance from the regulations. A full review of the regulatory requirements for direct surface delivery of reclaimed water for the purpose of creating a salinity barrier is beyond the scope of this assessment.

4.2 Other Salinity Barrier Methods

The focus for this study was to consider the direct surface delivery method for a salinity barrier. Other methods do exist that could be applicable to the City.

4.2.1 Injection-Extraction Systems

Injection-extraction systems are another method used to control salt water intrusion. As shown in **Figure 4-1,** this method uses coastal wells for injection to create a hydraulic barrier but also incorporates extraction (withdrawal) wells installed in the saltwater impacted area. This method evacuates saltwater simultaneously with freshwater injection allowing for a quicker improvement of impacted water qualities (USEPA, 1999).



Source (USEPA, 1999)

Figure 4-1
Injection–Extraction in an Unconfined Aquifer

4.2.2 Extraction Barriers

Extraction barriers, consisting of a line of wells parallel to the coastline are pumped in order to form a trough at the groundwater level. The pumping causes the saltwater piezometric head to be lower than that of the fresh water protecting the fresh water aquifer (USEPA, 1999). In Florida, where saltwater intrusion is caused by over stressing

aquifers along the coast, this is not a viable option since the pumping stresses would be compounded.

4.2.3 Subsurface Barriers

Physical subsurface barriers may be constructed in order to restrict the movement of seawater inland. This practice is common on contamination sites and construction areas to restrict water movement. Slurry walls, grout cutoffs, and steel sheet piles are the three main types of barrier walls.

A slurry wall is constructed by placing a water and bentonite clay slurry into a narrow deep trench. Injecting a liquid, slurry, or emulsion under pressure into the soil creates a grout cutoff. The pore spaces within the soil are filled with the injected fluid and solidify to form an impermeable wall. Sheet piles are driven lengths of steel that connect together. They are placed into the ground to form a thin impermeable barrier to flow (USEPA, 1999). The limitation of this type of system is that all subsurface barriers must penetrate an underlying low permeability zone in order to prevent saltwater from migrating inland from below the barrier (Atkinson, Miller, & Curry, 1986). For coastal areas, the slurry wall must also be long enough to restrict water movement along the length of the coast. A short slurry wall will not work as intended.

4.3 Observation Wells

4.3.1 Existing Wells

In an effort to record data related to the movement of the saltwater interface in southeast Florida, the USGS maintains a salinity monitoring well network. These wells are sampled or measured on a quarterly or semi-annual schedule in order to track the movement of the salinity interface on a regional level. Wells used for an investigative study of the saltwater interface in Broward County were required to meet specific conditions (Dausman & Langevin, 2005). The 17 monitoring wells selected for the 2005 study met the following conditions:

- Wells near the coast—Monitoring wells had to be located within the freshwater/saltwater transition zone for fluid electrical conductivity monitoring to be meaningful.
- Wells within 4 kilometers (km) from canals—Monitoring wells close to canals were used to establish the relation between canal stages and movement of the saltwater interface.
- Wells within 4 km from control structures—Monitoring wells near control structures were used to determine the effects that structure openings had on the movement of the saltwater interface.
- Fully cased wells with open-hole or short-screened interval—Fully cased wells were required to ensure data reliability and eliminate the possibility for inter-well flow and ambiguous data.

- Wells open to the Biscayne aquifer—Wells had to be located within the highly permeable aquifer for short-term data to show changes in fluid conductivity.
- Wells open to the most inland part of the freshwater/saltwater transition zone (chloride concentrations between 250 and 2,250 mg/L)—Monitoring wells in areas where the saltwater interface is most likely to show movement. The 250 mg/L chloride concentration is the upper limit for potable water, therefore, of critical concern to water managers (Dausman & Langevin, 2005).

4.3.2 New Observation Wells

Many of the criteria for monitoring wells selected by Dausman and Langevin (2005) for their study are applicable to wells that would be constructed to monitor a salinity barrier implemented by using the flood control wells and reclaimed water. The wells should be fully cased which will allow for sampling of discrete horizons in the vicinity of the salinity barrier and provide increased confidence in the quality of the collected data. The wells need to be located within highly permeable zones of the aquifer in order for monitoring to allow rapid detection of changes in water quality and surface level elevations resulting from the salinity barrier.

The locations of the new monitoring wells will be dependent on the location and type of salinity barrier constructed. In general, the wells will need to be placed parallel and perpendicular to the barrier. Wells placed parallel to the salinity barrier will provide information related to the local impacts of the salinity barrier including water levels, mounding, and chloride concentrations. Wells will also need to be installed perpendicular to the salinity barrier in order to monitor the reaction to mitigation activities on a more regional level allowing potential impacts to existing wellfields approximately 1.5 miles away to be detected.

Additional monitoring wells will need to be located within the freshwater/saltwater transition zone. This zone contains a chloride concentration of approximately 250 mg/L. This is the upper limit for potable water, and therefore, of critical concern to water managers. These wells will be located in areas where the saltwater interface is most likely to show movement in either a horizontal or vertical direction. The wells shall be monitored for water levels and fluid conductivity.

4.4 Existing Flood Control Wells for Aquifer Recharge

Use of the existing flood control wells as salinity barrier wells will have potential effects on groundwater flow and the elevation of piezeometric surfaces as a means to mitigate and control seawater intrusion. As part of the SWFWMD Reclaimed Water Aquifer Recharge Feasibility study, a groundwater mounding analysis was conducted to assess the impacts of salinity barrier injection (MWH, 2009). A numerical groundwater flow model was used to determine the potential groundwater elevation changes as shown in **Figure 4-2.** A similar analysis could yield useful information regarding mounding resulting from the use of the stormwater wells as salinity barrier wells.

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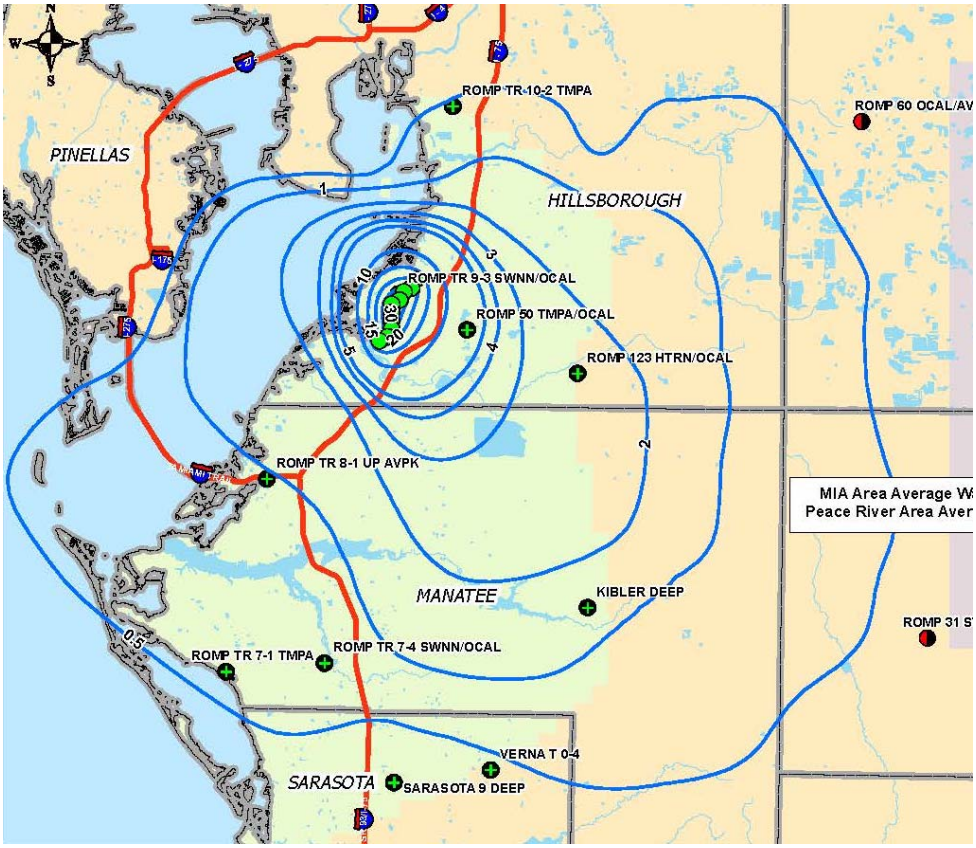

Source (MWH, 2009)

Figure 4-2

Tampa Bay Aquifer Recharge Mounding Analysis (20 MGD Recharge)

Mentioned previously, as part of the permitting process for installing and using the Hallandale Beach Class V, Group 6 stormwater drainage wells, Langan Engineering & Environmental Services prepared a RAR regarding the unintended movement of the stormwater injected into the drainage wells. It was concluded that the five test borings completed during the investigation provided reasonable assurance that a hard calcareous sandstone layer exhibited semi-confining properties which would likely impeded upward movement of injected water into G-II waters. The report recommended that the stormwater wells be cased at least 20 feet below the G-II/G-III interface, well into the top of the semi-confining layers in order to provide reasonable assurance that proper construction of the wells would minimize the potential for discharged stormwater to migrate vertically (Langan Engineering & Environmental Services, 2010).

It is important to note that the Langan report was prepared assuming that the wells would only be used for stormwater disposal. While addressing vertical migration and mounding under stormwater disposal conditions, the report does not consider the possibility of the wells being used for the purpose of creating a salinity barrier and did not address lateral movement of injected fluids. Additional data and modeling is required in order to assess the potential impacts of using the flood control wells as salinity barrier wells.

5 Agency Meetings and Summary of Key Findings

5.1 Project Meetings

Representatives of the City of Hallandale Beach and MWH met with FDEP UIC staff, Broward County Environment Protection and Growth Management Division (BCEPGMD), and the SFWMD to understand each agency's concerns and considerations for the potential of utilizing the City of Hallandale Beach drainage well system as a salinity barrier to inject reclaimed water from the City of Hollywood. Copies of the agendas and meeting minutes for the three meetings are included in **Attachment A**.

5.1.1 FDEP UIC Meeting

On January 8, 2013, a meeting was held at the FDEP's Southeast District office to discuss the salinity barrier project. In summary, the FDEP was supportive of the project. During the SWFWMD Reclaimed Water Aquifer Recharge Feasibility study (2008 and 2009) and the Hillsborough County South Hillsborough Aquifer Recharge Program (SHARP) (2010 and ongoing), MWH conducted numerous high level meetings with Tallahassee FDEP Executives. FDEP understands the challenges Florida faces and believes that aquifer recharge has numerous benefits and their agency is being proactive in supporting these types of projects.

From discussions with FDEP, the City will need to model the impacts to the aquifer using a density dependent numerical model to simulate long-term injection of low-salinity reclaimed water into a high-salinity groundwater and the potential impacts to the overlying and inland G-II aquifers. The City will need to perform aquifer performance or injection tests to evaluate localized mounding and may need to install additional monitor wells to better characterize the impacts to the aquifer. The groundwater modeling will also help the City design the salinity barrier to meet concerns and requirements.

5.1.2 BCEPGMD Meeting

On March 7, 2013, the City of Hallandale Beach and MWH met with representatives of the BCEPGMD to discuss the project. BCEPGMD is currently working with the USGS to develop a calibrated density dependent SEAWAT model of the Biscayne aquifer for southeastern Broward County. The model results are due to be released in Summer 2014. BCEPGMD's primary concerns for the feasibility of a salinity barrier project using reclaimed water are the potential for localized flooding and the water quality fate and transport impacts to both adjacent aquifers and surface water bodies. Simulations utilizing the calibrated SEAWAT model may support a variance for the injectate water quality from the existing Broward County Chapter 27 limitations for nutrient concentrations, which do not distinguish between varying groundwater classes.

5.1.3 SFWMD Meeting

On April 2, 2013, a meeting was held at the SFWMD office in West Palm Beach, FL with representatives of the SFWMD's reclaimed water and consumptive use permitting

divisions and the City of Hallandale Beach to discuss the salinity barrier project. The SFWMD supported the conceptual approach of the project and provided a number of ideas related to better evaluating the project for future approval. The SFWMD insisted that detailed model simulations be performed under both drainage and recharge conditions to determine impacts to the aquifer and the potential for developing a barrier or negatively impacting the City's existing wellfield. The SFWMD encouraged the City of Hallandale Beach to work directly with the City of Hollywood to develop a joint plan for addressing the recharge project as it relates to the City of Hollywood's ocean outfall reduction of secondary effluent from the City of Hollywood Wastewater Treatment Plant.

5.2 Summary of Key Findings

The use of the City of Hallandale Beach drainage well system as a salinity barrier utilizing reclaimed water may provide a means of protecting the City's wellfield, possibly reversing existing salinity changes, and simultaneously providing a beneficial use for reclaimed water currently being discharged through ocean outfall. MWH is providing engineering support to Hillsborough County who is currently construting a salinity barrier in southern Hillsborough County. The system should be online in mid-2014. The previous evaluations suggest that this is a viable option that can provide numerous regional benefits, however, is very site specific related to the geology, aquifer water quality, and reclaimed water quality.

The G-III aquifer that is currently being used for the drainage well system does not require any additional treatment beyond reclaimed water standards to meet state requirements, but may require a variance to comply with Broward County Chapter 27 requirements. The City will need to better evaluate the reclaimed water quality from the City of Hollywood Wastewater Treatment Plant to determine the salinity and nutrient content of the potential recharge water.

The USGS SEAWAT model for southeastern Broward County is currently being calibrated and is due for release in Summer 2014. The groundwater model will provide the City a working tool to help evaluate the hydraulic responses of a salinity barrier.

The City of Hallandale Beach Drainage Well System is under construction and is due to be completed in Fall 2013. Aquifer Performance Testing and injection testing of the system will be required to evaluate mounding and the competency of the semi-confining units within the aquifer and their ability to impede upward migration of injectate.

5.3 Recommendations for Subsequent Phases

The City of Hallandale Beach drainage well system provides a unique opportunity to investigate the use of an existing drainage well system as a hydrostatic salinity barrier using reclaimed water. To further evaluate the feasibility for permitting and operation the following steps are recommended:

- Contour the existing aquifer water quality historical and current condition from the coastline to the wellfield using available wells. An evaluation can be conducted to determine the time when the remaining production wells will be

impacted by saltwater intrusion to give the City an estimate of when their water supply may be impacted beyond potable use.

- Hydrologic testing of the drainage well system using existing monitoring wells. This information is critical to understand the hydraulic response of the drainage wells as salinity barrier wells.
- Identification of available land to assist the City in locating future monitoring wells and possibly drainage wells.
- Evaluation of reclaimed water quality from the City of Hollywood Wastewater Treatment Plant and cost analysis for improvements to treatment levels.
- Evaluation of conveyance modifications to route reclaimed water from the City of Hollywood to the City of Hallandale Beach drainage well pumping stations and evaluation of hydraulics for pumping to the drainage wells.
- The USGS SEAWAT model for southeastern Broward County will be available for review as a tool for the City. The discretization and applicability of the model for running simulations of the drainage well/recharge well system must be evaluated to determine if it will adequately simulate the localized impacts of aquifer recharge on adjacent aquifers, water bodies, and the City of Hallandale Beach wellfield.
- Conduct numerical groundwater modeling to evaluate the regional water level and water quality response to both high-flow, low duration storm events and low-flow, long duration recharge events.
- Work with the MWH aquifer recharge team and coordinate meeting(s) with FDEP Tallahassee Executives to discuss the project and benefits to the City. This may help with negotiations with BCEPGMD and provide a more positive path towards an operating system.

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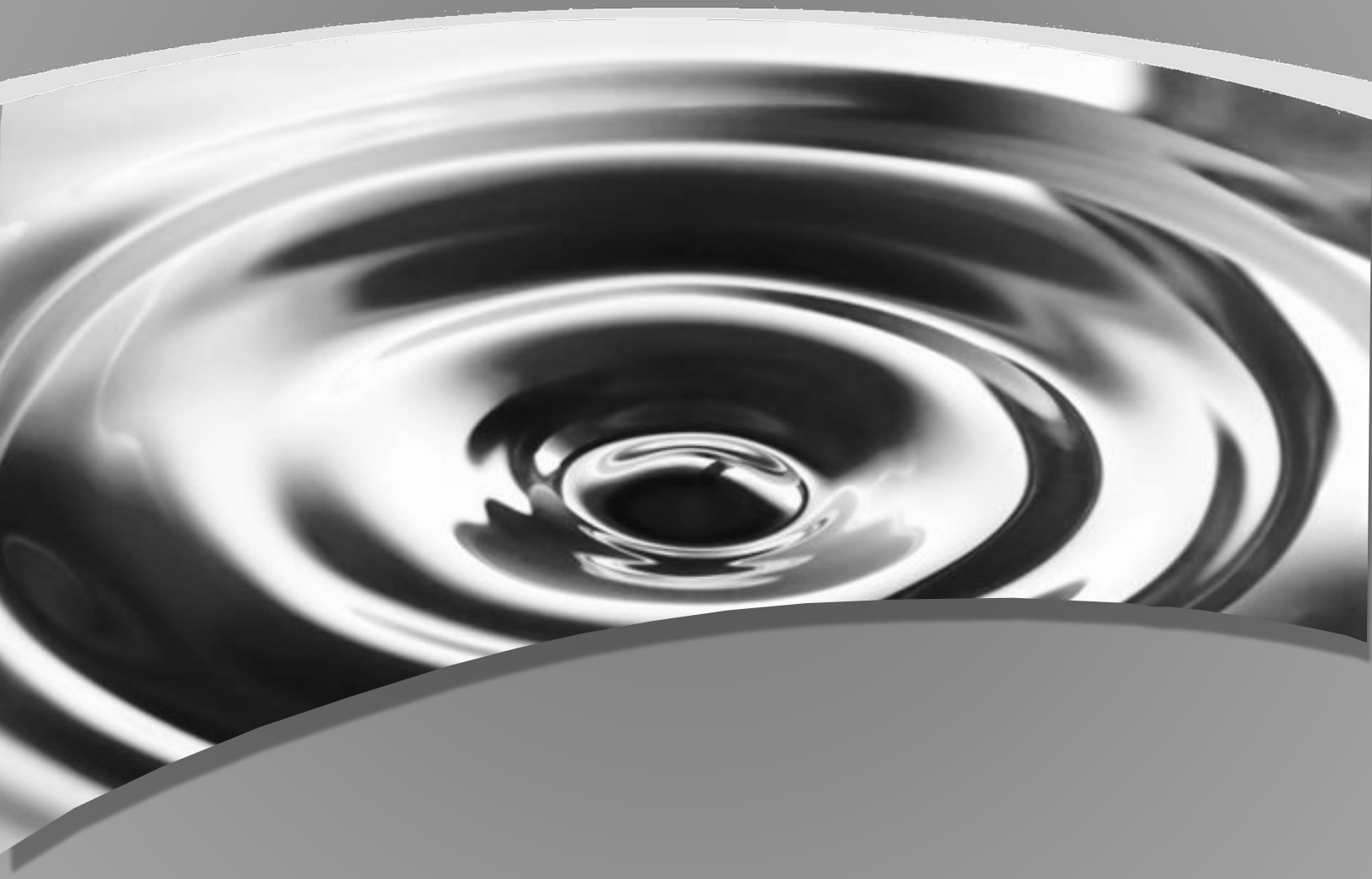
Attachment A
Agency Meeting Agendas and Meeting Minutes



MWH

BUILDING A BETTER WORLD

M E E T I N G A G E N D A

MWH

BUILDING A BETTER WORLD

Date/Time: **January 8, 2013 2:00 PM**

Location: **Florida Department of Environmental Protection (FDEP)**
WFA Conference Room
400 North Congress Avenue
West Palm Beach, FL 33416

Attendees:

City of Hallandale Beach	**FDEP**	**MWH**
Earl King	Joe May	Neil Johnson
Richard Labinsky	Heidi Vandor	
Cameron Benson	Gardner Strasser	
	Joe Haberfeld	

Subject: **City of Hallandale Beach Reclaimed Water Salinity Barrier**

1. Introductions and Overview
2. Production Well System
3. New Stormwater Drainage Well System
    a. Location
    b. Capacity
    c. Design
    d. Construction and testing permit issuance
4. Hydrostatic Salinity Barrier Considerations
    a. General Plan
    b. Regulatory and Permit considerations
5. Other Items
6. Adjourn

M E E T I N G M I N U T E S

MWH

BUILDING A BETTER WORLD

Date: January 8, 2013

Time: 2:00 PM

Location: Florida Department of Environmental Protection (FDEP)
WFA Conference Room
400 North Congress Avenue
West Palm Beach, FL 33416

Subject: City of Hallandale Beach Reclaimed Water Salinity Barrier

Attendees:

Hallandale Beach

Earl King, Acting Public Works/Utility Director

Rick Labinsky, City Engineer

Cameron Benson, SAI

Hector Castro

Harold Aiken, MWH

Neil Johnson, MWH

FDEP

Joe Haberfeld

Joe May

Cathy McCarty

Mark Silverman

Gardner Strasser

Heidi Vandor

1. Following introductions by attendees, Mr. Labinsky described the upcoming drainage project and some features of its design, capacity and location. Mr. Labinsky described the City's flooding challenges and the FEMA funding that is supporting the new drainage well system.
2. Mr. Johnson stated that the City would seek an additional permit or classification of the currently permitted Class V-Group 6 drainage wells as Class V-Group 2 Salinity Barrier Wells.
3. Mr. May stated that it would be better to issue a stand-alone Class V-Group 2 permit rather than combining due to the distinct nature of the two injectate streams and purposes.

4. Mr. May stated that a density dependent model (SEAWAT) would be necessary to sufficiently simulate the movement of the groundwater in the region and its potential impact to adjacent Underground Sources of Drinking Water (USDWs). Mr. May requested that the City contact the USGS regarding the discretization of the current model.
5. Mr. May referenced the cooling canal system at Florida Power and Light's Turkey Point Power Plant, where the supersaturated cooling water in the canals was creating a horizontal lens of groundwater movement. He would also like the City to provide a detailed description of monitoring well locations for looking at the mounding impacts.
6. Mr. Haberfeld questioned whether the receiving aquifer was a G-III with an overlying G-II. Mr. Strasser confirmed that was the case. Mr. Johnson inquired if freshening of the G-III aquifer from the drainage wells would change the classification of the G-III aquifer. Mr. Haberfeld stated that the preexisting classification would not change due to operation of the drainage well system.
7. Mr. Haberfeld asked if this reclaimed for injection was related to the ocean outfall considerations for the City of Hollywood. Mr. King confirmed that it was.
8. Ms. McCarty asked if the City had met with Broward County. Mr. Castro confirmed that the City had met with Broward and would schedule a second meeting after this meeting was concluded.
9. Mr. May asked if Broward County had commented on the pharmaceutical content of the injectate. Mr. Silverman asked if the Broward County Health Department had been contacted.
10. Mr. Haberfeld stated that all Class I and Major Class V wells would now be permitted through Tallahassee.

Summary and Action Items:

- The idea of utilizing a drainage well system for a salinity barrier is intriguing.
- The existing system will allow the City to collect data and perform an Aquifer Performance Test or injection test at a regional scale.
- The City will need to investigate additional monitor well locations.
- The City will need to coordinate with the USGS and Broward County regarding the SEAWAT model.
- The City will need to check the Biscayne Landing injection well system water quality results with regard to ammonia concentrations.

M E E T I N G A G E N D A

MWH

BUILDING A BETTER WORLD

Date: March 7, 2013

Time: 10:30 AM

Location: Broward County East Government Center
Room 329
115 S. Andrews Ave
Fort Lauderdale, FL 33301

Subject: City of Hallandale Beach Reclaimed Water Salinity Barrier

1. Introductions and Overview
2. Production Well System
3. New Stormwater Drainage Well System
    a. Location
    b. Capacity
    c. Design
    d. Construction and testing permit issuance
4. Hydrostatic Salinity Barrier
    a. General Plan
    b. Regulatory and Permit Considerations
5. Steps Forward
6. Adjourn

M E E T I N G M I N U T E S

MWH

BUILDING A BETTER WORLD

Date: March 7, 2013

Time: 10:30 AM

Location: Broward County East Government Center
Room 329
115 S. Andrews Ave
Fort Lauderdale, FL 33301

Subject: City of Hallandale Beach Reclaimed Water Salinity Barrier

Attendees:

Hallandale Beach

Renee Crichton, City Manager

Daniel Rosemond, Assist. City Manager

Earl King, Acting Public Works/Utility Director

Rick Labinsky, City Engineer

Hector Castro. Past Utility Director

Cameron Benson, SAI

Harold Aiken, MWH

Neil Johnson, MWH

Broward County NRPMD

Jennifer Jurado, PhD

Barbara Powell

Elissa Taylor

Michael Zygnerski

1. Following introductions by attendees, an overview of the concept and rationale for the project was presented to the County.
2. A brief discussion of the saltwater intrusion that is impacting the City's production wells including approximate extent of the 10,000 TDS encroachment was discussed.

3. The City described the on-going drainage project and some features of its design, capacity and location.
4. The synergistic opportunity of using the drainage system as both a flood protection system and a saltwater intrusion was presented. The concept is to use the drainage system infrastructure during dry weather to inject reuse water to maintain a slight positive head to counteract the saltwater.
5. Since the City views this project as a cutting edge the request to the County was to become an active stakeholder in the project. Particularly, assistance with density dependent modeling of the Biscayne aquifer in an effort to provide some predictive results, prior to significant capital investment.
6. The County was open to participation, cautioning that the model for the southern and central part of Broward County was still being calibrated and was not expected to be released until Summer 2014.
7. The County further inquired about the level of treatment planned for the reuse. When it was explained that current thinking was for HLD, suitable for irrigation, Dr. Jurado provided a cautionary comment that the new nutrient criteria for estuarine systems might require more treatment than HLD. She also mentioned concern for endocrine disruptors that might leach into the inner coastal waters.
8. The City expressed appreciation for the meeting, explained that this project was a work in progress and each step would be planned, tested and evaluated before next steps taken and that the County would be a partner throughout the process.

M E E T I N G A G E N D A

MWH

BUILDING A BETTER WORLD

Date/Time: **April 2, 2013 3:00 PM**

Location: **South Florida Water Management District (SFWMD)**
B-1 3A Conference Room
3301 Gun Club Road
West Palm Beach, FL 33416

Attendees:

City of Hallandale Beach	**SFWMD**	**MWH**
Earl King	Mark Elsner	Neil Johnson
Richard Labinsky	Rick Nevulis	
	Karin Smith	

Subject: **City of Hallandale Beach Reclaimed Water Salinity Barrier**

1. Introductions and Overview
2. Production Well System
3. New Stormwater Drainage Well System
    a. Location
    b. Capacity
    c. Design
    d. Construction and testing permit issuance
4. Hydrostatic Salinity Barrier Considerations
    a. General Plan
    b. Regulatory and Permit considerations
5. Other Items
6. Adjourn

M E E T I N G M I N U T E S

MWH

BUILDING A BETTER WORLD

Date: April 2, 2013

Time: 3:00 PM

Location: South Florida Water Management District (SFWMD)
B-1 3A Conference Room
3301 Gun Club Road
West Palm Beach, FL 33416

Subject: City of Hallandale Beach Reclaimed Water Salinity Barrier

Attendees:

Hallandale Beach

Earl King, Acting Public Works/Utility Director

Rick Labinsky, City Engineer

Neil Johnson, MWH

SFWMD

Mark Elsner

Rick Nevulis

Karin Smith

Andy Steiner

1. Following introductions by attendees, Neil Johnson presented an overview of the project to the SFWMD. Mr. Johnson showed the location of the City's production wellfield and the new drainage well system, along with the location of the saltwater intrusion interface.
2. Rick Labinsky described the on-going drainage project and some features of its design, capacity and location. Mr. Labinsky described the City's flooding challenges and the FEMA funding that is supporting the new drainage well system.
3. Mr. King stated that the City has 4 Biscayne wells. Two are operational and two are standby. The City is able to meet demand using a combination of these wells and raw water from Broward County Southern Regional Wellfield.

4. Mark Elsner asked what recharge volumes were under consideration. Earl King stated that the City's current discharge to Hollywood was approximately 10 mgd. This volume would assist in offsetting the City's portion going to ocean outfall. Mr. Elsner felt this project may be a great opportunity to help Hollywood with the outfall issues.
5. Ms. Smith inquired about the status of the USGS SEAWAT model of the Biscayne Aquifer in Southeast Broward. Mr. Johnson stated that the model was in calibration and due for release in Summer 2014.
6. Ms. Smith asked about the City's projected demand for 2030, and if it was still less than 10 MGD. Mr. King confirmed that was correct.
7. Mr. Labinsky stated that the City was planning for additional reuse. Mr. King stated that the City had received a grant from Broward County to offset costs.
8. Ms. Smith stated that model simulations for the system need to include both drainage events at high injection rates and recharge periods at lower injection rates to fully evaluate movement of the injectate and ambient waters.
9. Mr. Nevulis stated that the City of Hollywood was submitting their reuse and outfall plan in July 2013 and encouraged the City of Hallandale Beach to work with Hollywood.

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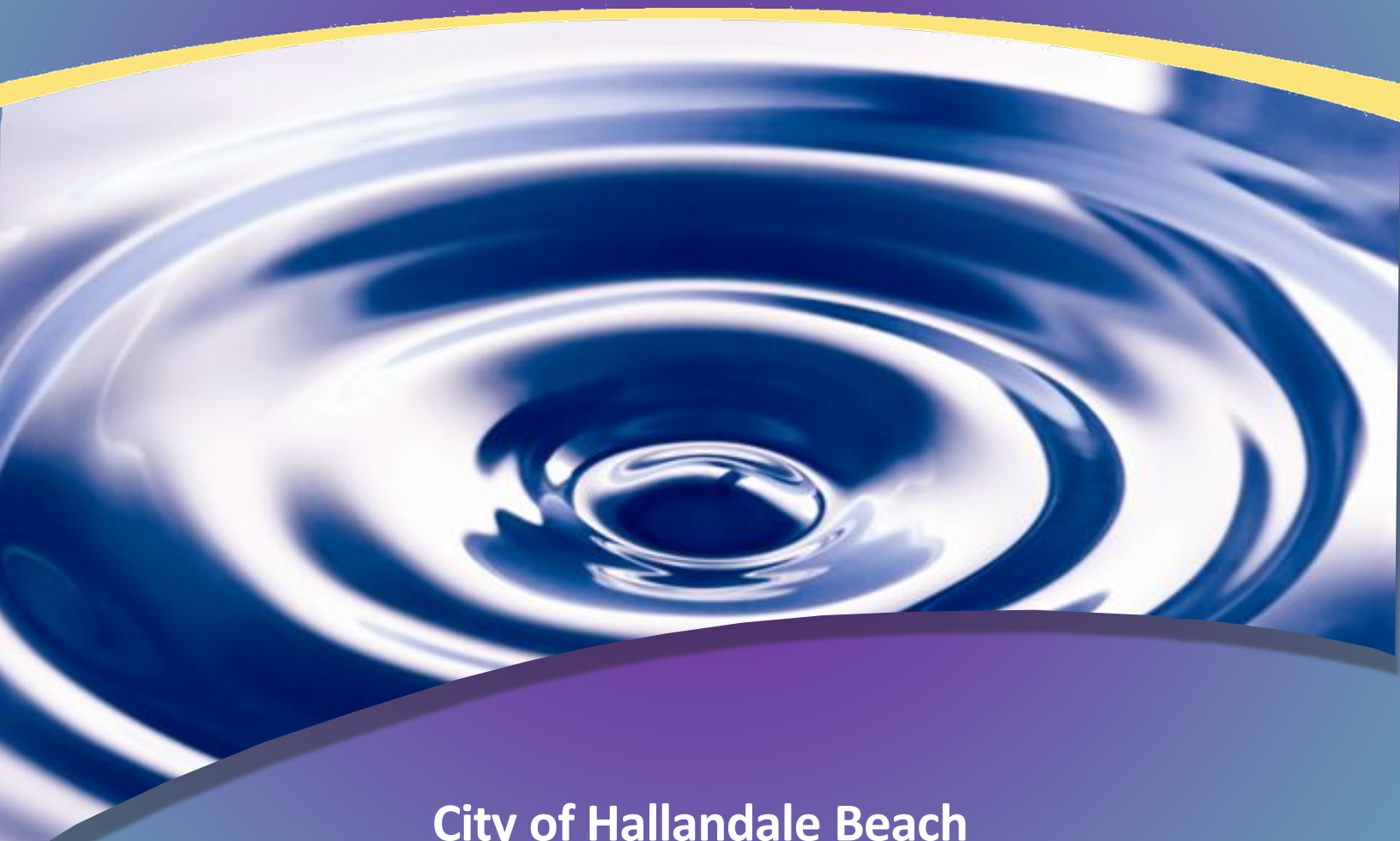

City of Hallandale Beach

Preliminary Assessment of a Hydrostatic Salinity Barrier for Wellfield Protection

Prepared by MWH
490 Sawgrass Corporate Parkway, Suite 300,• Sunrise, Florida 33325
TEL (954) 846-0401

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