UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

Before the Atomic Safety and Licensing Board

In the Matter of	)	
	)	Docket Nos. 52-040-COL
Florida Power & Light Company	)	52-041-COL
	)	
Turkey Point Units 6 and 7	)	ASLBP No. 10-903-02-COL
(Combined License Application)	)	

PRE-FILED DIRECT TESTIMONY OF DR. ROBERT G. MALIVA

Introduction

Please state your name and business address.

1. My name is Dr. Robert G. Maliva. My business address is 1567 Hayley Lane, Suite 202, Fort Myers, FL 33907.

Please describe your professional credentials and experience.

2. I am currently a Principal Hydrogeologist at WSP | Parsons Brinkerhoff, where I have worked since August 2016. As a Principal Hydrogeologist, I manage and provide technical leadership on alternative water supply and disposal projects, such as injection well systems. I have a Bachelor's degree in Biological and Geological Sciences from the State University of New York at Binghamton, a Master's degree in Geology from Indiana University Bloomington, and a Ph.D. in Geology from Harvard University. I was a Research Associate at the Department of Earth Sciences, University of Cambridge, England (1989-1990) and the Rosenstiel School of Marine and Atmospheric Sciences, University of Miami (1990-1992), where I conducted research on carbonate diagenesis

projects. My detailed Curriculum Vitae and summary of injection well experience are included as Attachments 1 and 2 to this Testimony.

3. I have worked as a hydrogeologist and principal hydrogeologist specializing in the geology of Florida for a variety of companies since 1992, including: ViroGroup, Inc. (1992-1994); Missimer International, Inc. (1994-1997); CDM (1997-2006); and Schlumberger Water Services (2006-2016). In my work as a hydrogeologist, I have managed water supply, injection well, and aquifer storage and recovery projects. I also have researched carbonate sedimentology and diagenesis. As a principal hydrogeologist at Schlumberger Water Services, I managed water supply, injection well, and aquifer storage and recovery projects.

4. I am the senior author of three books, including "Aquifer Storage and Recovery and Managed Aquifer Recharge Using Wells" and "Aquifer Characterization Techniques." I have authored over 60 journal publications and book chapters, many of which are on deep well injection, and aquifer storage and recovery. I am a member of the National Ground Water Association, the International Association of Hydrogeologists, American Water Works Association, and SEPM - the Society for Sedimentary Geology. I am currently an Associate Editor of the journal "Groundwater."

5. Throughout my professional career, I have worked on many deep injection well projects in Florida for the disposal of municipal wastewater and desalination concentrate, a few of which include:

- Project Manager for the Palm Beach County, Florida, Lake Region Water Treatment Plant's brackish-water production wells and injection well design and permitting;

- Designing and preparing technical specifications for the:
  - Hialeah Reverse-Osmosis Water Treatment Plant injection wells IW-1 & IW-2;
  - Collier South County Regional Water Treatment Plant injection well IW-1 and South County Water Reclamation Facility injection well IW-2;
  - City of West Palm Beach East Central Regional Wastewater Treatment Plant injection well IW-7;
  - City of Clewiston injection well IW-1 and production wellfield;
  - Tampa Bay Water Mid-Pinellas Brackish Water Desalination facility's injection well system;
  - Palm Beach County Water Utilities Department's Southern Region Operations Center single-zone monitor well;
  - Tropicana Products, Inc. Bradenton, Florida's, injection well IW-2; and
  - City of Deerfield Beach's injection well system.

I have performed confinement analyses for seven deep injection well systems that are currently operating in Florida, as is noted in my personal injection well project experience list. *See* Attachment 2. I have also performed project-independent investigations of confinement and fluid migration in South Florida injection well systems, the results of which have been published in an international peer-reviewed journal and conference proceedings. *See* Injection Well Publications List, Attachment 2.

Do you have any professional registrations or certifications in your area of expertise?

6. I am a Registered Professional Geologist in Florida and Texas.

What has been your role in the Turkey Point Units 6 and 7 project?

7. In connection with Turkey Point 6 and 7, I performed an independent confinement analysis for the Turkey Point site, in support of the project's Nuclear Regulatory Commission (NRC) license application and the State of Florida's Site Certification

Proceedings. The confinement analysis was based on a review of the well construction and testing data for Turkey Point exploratory well EW-1 and the data available from the injection well systems for the Miami-Dade South District Water Treatment Plant (South District Plant) and the Florida Keys Aqueduct Authority J. Robert Dean Water Treatment Facility (Dean Water Treatment Facility). I also represented Florida Power & Light Co. (FPL) at the NRC's Advisory Committee on Reactor Safeguards hearings, and provided testimony for the State Site Certification Hearing for Turkey Point Units 6 and 7.

What is the purpose of your Testimony?

8. The purpose of my Testimony is to address the question of whether there will be human or ecological exposure to wastewater injected in the proposed Class I injection wells at the Turkey Point site.

What did you rely upon to form your opinions?

9. I relied on my educational training, my knowledge and experience as a Professional Geologist practicing in South Florida for nearly 25 years, and a variety of documents and data, including the following:

- Data collected during the drilling and testing of Turkey Point exploratory well EW-1. These data include the well completion report and suite of geophysical logs run during drilling and testing of the well. *See generally* FPL-005.
- Available data on the construction and testing of the injection well systems at the Miami-Dade South District Wastewater Treatment Plant and the Dean Water Treatment Facility, *see generally* FPL-006. The reviewed data from the South District Wastewater Treatment Plant include geophysical, geological, hydraulic testing and monitoring data obtained from the South Florida Water Management

District DBHYDRO[1] and the Florida Department of Environmental Protection Oculus[2] internet sites and data in published reports.[3]

- Miami-Dade County Wellfield Protection Area map showing locations of existing wellfields. *See* Attachment 7.

- Miami-Dade Water and Sewer Department 20-Year Water Supply Facilities Work Plan (2014-2033) (November 2014). FPL-017.

- Published reports on deep well injection in South Florida (listed in Attachment 3 to my Testimony, which includes full references to each of the reports that I cite below).

Summary

Please summarize your opinions.

10. In my professional opinion:

- No plausible pathway exists for significant human or ecological exposure to the wastewater injected into the Boulder Zone at the Turkey Point site, and therefore the public health is protected, given: (1) the geological confinement that exists between the injection zone and aquifer zones used for potable water supply at the Turkey Point site; and (2) the geographic separation and divergent groundwater flow directions between Turkey Point and existing and planned Floridan Aquifer wellfields.

- It is inconceivable that potable public water supply wells would ever be installed close enough to Turkey Point to result in the contamination of potable drinking water due to wastewater injected from the proposed plant.

- FPL does not need to perform additional studies regarding the injection wells at Turkey Point. The Turkey Point injection well system impact analysis that FPL performed to support the Florida Department of Environmental Protection's (FDEP) permitting process, and upon which the Final Environmental Impact Statement (FEIS) prepared by the NRC in this proceeding relies in part, exceeds the typical industry practice in Florida. Moreover, the FDEP permitting process will require FPL to collect additional data on confinement during the drilling and testing of the planned additional injection wells (and associated dual-zone monitor wells). Drilling additional exploratory wells is unnecessary. Indeed, more than

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[1] South Florida Water Management District, DBHYDRO (Environmental Data) (available at https://www.sfwmd.gov/science-data/dbhydro).

[2] Florida Department of Environmental Protection, Electronic Document Management System (OCULUS) (available at https://depedms.dep.state.fl.us/Oculus/servlet/login).

[3] *See generally* FPL-009, FPL-029, FPL-028, FPL-024.

one exploratory well has *never* been drilled for any Class I injection well system in the State of Florida.

- The positions to the contrary taken by Joint Intervenors' witness (Mr. Quarles) thus far in this proceeding are based on the distortion of scholarly articles. Mr. Quarles has misinterpreted and exaggerated the papers that he cites, coming to conclusions that differ from those of the report's authors. The studies do not support a lack of confinement at Turkey Point, and Mr. Quarles has provided no new information or technical insights to justify his alternative interpretations and conclusions. In fact, it is my opinion that the regional and local studies support a finding of confinement at Turkey Point, given the lack of significant fracturing identified in the confining strata in EW-1.

- Based on the above, I agree with the FEIS's conclusion that "significant upwelling of injected wastewater is not likely at the Turkey Point site and that, if upwelling did occur it would not noticeably impact overlying USDW aquifers." NRC-008A at 5-21.

- I also agree with the FEIS that the environmental impact of injected wastewater from Turkey Point will be "small" (*see* NRC-008A at 5-39 to 42), if any.

Discussion

What is the risk that the wastewater from Turkey Point that is injected into the Boulder Zone will have an impact on public health?

11. Previous investigations have concluded that the disposal of municipal wastewater in deep injection wells completed in the Boulder Zone of South Florida poses a low risk. For example, the USEPA Relative Risk Assessment of Management Options for Treated Wastewater in South Florida concluded that, for all wastewater disposal options, including deep well injection, "there is either low or no risk." FPL-027 at 300. Additionally, Englehardt, et al. (2001) concluded in a relative risk assessment of municipal wastewater disposal options that "[i]n general, injection wells were assessed to represent lower health risks, assuming potential changes in Floridan Aquifer water quality in the vicinity of injection wells." FPL-012 at 005.

12. As my Testimony explains in detail, there are multiple barriers specific to the Turkey Point site that will protect public health.

13. First, the combined thickness of strata present at the Turkey Point site between the top of the injection zone (the Boulder Zone) and the base of the deepest underground source of drinking water (USDW) has characteristics indicative of effective vertical confinement, particularly the presence of thick intervals of unfractured rock with low vertical hydraulic conductivities. This type of unfractured confining strata is highly effective in preventing vertical migration of injected wastewater into USDWs in South Florida. Additionally, detailed modeling that I performed for the Turkey Point site (using conservative assumptions) indicates that the top of the injected water will be *at least* 1,000 feet below the base of the lowest USDW after 100 years.

14. Second, even if the injected water were to somehow reach the USDW, which in my professional opinion is a very low probability, distance and the direction of groundwater flow would prevent contamination of the public water supply. In Miami-Dade County, the only plausible avenue for human or ecological exposure to injected wastewater is via public supply wells (which produce brackish water) and perhaps aquifer storage and recovery wells in the Upper Floridan Aquifer. There are no such wells near enough to Turkey Point to create the risk of any potential exposure. The nearest existing or planned Floridan Aquifer public supply wells are located over 10 miles west of the Turkey Point site, in the up-gradient direction, opposite from the direction of groundwater flow.[4] In addition, it is highly unlikely that any future potable water supply wellfields will be

[4] The groundwater flow direction in the USDWs at Turkey Point is toward the southeast (offshore) away from human and environmental receptors, and away from all existing and planned future potable water supply wellfields.

placed closer to or to the east of Turkey Point, due to the presence of the plant and proximity to the coast.

15. As the USEPA observed in its South Florida risk assessment, "if there is no contact or co-occurrence between the stressor [i.e., the entity that can cause an adverse response] and the receptor, then there is no risk." FPL-027 at 019. Here, if there is no possible route for wastewater injected at Turkey Point to enter the potable water supply and contact humans, then there is no risk. This is consistent with South Florida's over 70 years of experience injecting liquid wastes into the Boulder Zone. Since wastewater injection began in South Florida in 1943, there has been no suggestion that *any* water injected into the Boulder Zone has ever migrated upward and actually entered a potable water supply well or a surface environment.[5]

16. Ultimately, in my professional opinion, deep well injection is the safest way to dispose of wastewater in South Florida.

What did you rely on to form your opinions?

17. Independent of my work on the Turkey Point project, I have published papers reviewing the vertical migration of wastewater in South Florida (for example, FPL-013 (Maliva, et al. 2007); FPL-014 (Maliva and Walker 1998); FPL-015 (Maliva and Walker 2000)), and I have over 20 years of experience designing, permitting, and supervising the construction and testing of injection wells in South Florida. My opinion is also based on a review of the local geology at Turkey Point, the EW-1 data collected by Mr. McNabb in this proceeding, a confinement analysis that I performed (which included a

[5] As I explain in subsequent sections, some wastewater has migrated into USDWs. However, this is not the same as entering a potable water supply, as most USDWs are not a source of potable water.

hydrogeological evaluation of the EW-1 data), and a groundwater model of vertical confinement. The groundwater model of vertical confinement was prepared under my supervision by my colleague, Dr. Weixing Guo, at my former employer, Schlumberger Water Services.

<u>The Use of EW-1 Data to Support My Opinion</u>

Did well EW-1 provide sufficient data to support your analysis?

18. Yes. Consistent with industry and state regulatory standards, the data from EW-1 (the exploratory well that FPL drilled to evaluate the local hydrogeology in connection with its proposed injection system) is more than sufficient to determine the hydraulic characteristics of the Turkey Point site. The scope of work implemented at EW-1 exceeds prevailing industry standards in Florida and elsewhere in the United States. The the FDEP reviewed the testing program and deemed it satisfactory when it issued a permit to construct the Class V, Group 9 Exploratory Well designated EW-1 (permit #0293962-001-UC, issued on May 5, 2010).[6] Numerous geological investigative activities were independently implemented in well EW-1, including:

- Natural gamma ray logging,[7]
- Borehole temperature and fluid resistivity/conductivity logging,[8]
- Compensated sonic porosity logging (used instead of neutron and density logs, which are seldom run in aquifers in Florida because of the use of radioactive sources),[9]
- Resistivity (dual induction) and spontaneous potential logging,[10]
- Preparation of core porosity versus hydraulic conductivity transforms,[11]

[6] This permit can be found in FPL-005A at 060.
[7] *See* FPL-005C at Appendix L.
[8] *See id.*
[9] *See id.*
[10] *See id.*
[11] Attachment 5 at 2, 3.

- Whole core samples, descriptions, and analyses,[12]
- Calculation of hydraulic conductivity profiles from sonic log-derived porosity,[13]
- Calculation of equivalent vertical and hydraulic conductivities,[14]
- Flowmeter logging,[15]
- Packer testing,[16] and
- Density-dependent solute-transport numerical modeling of vertical fluid migration.[17]

19. It is also my professional opinion that one exploratory well alone is sufficient to evaluate the hydrogeological conditions of the site. While one can always argue that more data could be accumulated, the cost and value of obtaining additional data must be considered. Each exploratory well to the Boulder Zone costs millions of dollars to drill and test, so drilling multiple dedicated exploratory wells is not practicable. Indeed, more than one exploratory well has *never* been drilled for any Class I injection well system in the State of Florida.

20. The added value of additional wells is also doubtful. Even if FPL were to drill 10 or 100 exploratory wells, those wells would be just as likely to miss a hypothetical fault that is only a few inches to a few feet wide. Drilling additional exploratory wells, regardless of the number, could never identify every geological feature of the site. However, the type of widespread fracturing responsible for vertical fluid migration is readily recognized in borehole geophysical logs. This type of fracturing is not present at the Turkey Point site, and there is no firm evidence of unrecognized faults or fractures extending upwards from

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[12] FPL-005B at Appendices M & P.
[13] Attachment 5 at 4.
[14] Attachment 5 at 5.
[15] FPL-005C at Appendix L.
[16] FPL-005A at 026-029.
[17] Attachment 5 at 5-9.

the Boulder Zone that would allow for vertical migration of fluids into a USDW at any injection well site in South Florida.

21. Regardless, FPL will obtain additional data. An extensive hydrogeological characterization must be performed during the construction of the planned additional injection wells and associated dual zone monitor wells. That data will be included in a future, updated confinement analysis: as part of the FDEP's operating permit requirements applicants are required to provide the FDEP with an updated confinement analysis including operational testing data.

Did any of the EW-1 data undermine a finding of confinement?

22. No. The multiple data sources evaluated in the confinement analysis, including cuttings (fragments of rock recovered during drilling), geophysical logs, cores, and packer tests, indicated the presence of adequate confinement with the limitations of each method appropriately considered.

23. Of course, each source of data does have natural limitations. These are unavoidable and are considered in the data analysis. For example, Mr. Quarles has argued in this proceeding that a low percentage of core sample recovery is suggestive of voids in the bedrock. Quarles Third Affidavit at ¶ 18. However, low core sample recovery is more suggestive of common problems during well drilling, with a variety of possible causes[18] unrelated to confinement properties. Indeed, poor core recovery is a common

[18] Poor core recovery may be caused by the cored material falling out of the core barrel during recovery of the core, or if the core barrel becomes clogged during drilling by a piece of harder rock jammed in the barrel.

occurrence. If large voids actually existed, there would be corresponding examples of bit drop.[19] But there were none here.

24. It is also common for packer tests[20] to fail. While Mr. Quarles argues that certain of the packer tests may have failed due to hydraulic connections through voids and fractures in the bedrock (Quarles Third Affidavit at ¶¶ 20-21), that is unlikely. The failure of a packer to isolate a test interval could be due to multiple reasons, such as leakage between the packer and borehole wall or bypass flow within the formation around a packer element. No inferences on aquifer properties can be made from the fact that a test interval could not maintain pressure.

Local Geology at the Turkey Point Site

Please describe the geology at the Turkey Point site.

25. South Florida contains two aquifer systems; the Surficial Aquifer System (which includes the Biscayne Aquifer), and the Floridan Aquifer System. The two aquifer systems are separated by the Intermediate Confining Unit. A geological and hydrogeological diagram for the Turkey Point site can be seen in Figure 1 below, which is adapted from FEIS (NRC-008A) Figure 2-19. The Biscayne Aquifer extends from land surface to about 140 feet below land surface, and is the primary water source for the Miami-Fort Lauderdale-Palm Beach Metropolitan area. The Biscayne Aquifer contains saline water at the Turkey Point project site due to its proximity to the coast, but contains freshwater in inland areas.

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[19] Bit drop is a rapid drop in the drill bit, indicative of the drill bit passing through an open water-filled void instead of through solid rock.

[20] A packer or drill-stem test involves the setting of one or two inflatable packers inside a borehole to isolate a specified interval of the borehole. The isolated interval is pumped and the pressure response recorded to quantify aquifer hydraulic properties.

26. The Intermediate Confining Unit in the Turkey Point area, consists of approximately 800 feet of clay-rich strata that forms a highly effective confining unit between the Biscayne Aquifer and the Floridan Aquifer System. Thus, the Biscayne Aquifer and Floridan Aquifer System are not hydraulically connected in the relevant area (FPL-019A at 007) and, therefore, water quality changes in the Floridan Aquifer System will not impact the Biscayne Aquifer freshwater resources.

27. The Floridan Aquifer System in South Florida consists of the Upper Floridan Aquifer, the Middle Confining Unit, and the Lower Floridan Aquifer and is composed mainly of the Suwanee Limestone, Avon Park, and Oldsmar Formations. The overall aquifer system is highly heterogeneous in that it contains intervals of relatively high transmissivity rock, which form aquifers, and intervals of low transmissivity rocks, which form confining units.

28. In southeast Florida, the Upper Floridan Aquifer contains brackish water that requires advanced treatment (membrane desalination) before potable use. At the bottom of the Upper Floridan Aquifer is the base of the USDW (which is defined by the Code of Federal Regulations as having less than 10,000 mg/L total dissolved solids),[21] which at well EW-1 is at a depth of approximately 1,450 feet.

29. The Middle Confining Unit separates the Lower Floridan Aquifer in South Florida from the Upper Floridan Aquifer. Both the Middle Confining Unit and the Lower Floridan Aquifer contain saline water and are not part of the USDW.

[21] 40 C.F.R. § 144.3.

30. The Lower Floridan Aquifer contains an extremely high transmissivity interval referred to as the "Boulder Zone." The Boulder Zone consists mainly of fractured dolomites in which caverns may develop during drilling. The name "Boulder Zone" was given to the interval by early oil well drillers because they found drilling through the blocks of dolomite that fell into the well was like drilling through boulders. The Boulder Zone is the injection zone used in all deep (Class I) injection wells in South Florida. The top of the Lower Floridan Aquifer (containing the Boulder Zone) occurs at 2,915 feet in well EW-1.

31. The confinement of liquid wastes injected into the Boulder Zone is collectively provided by all strata between the Lower Floridan Aquifer and the base of the USDW at the bottom of the Upper Floridan Aquifer. The confining strata at the Turkey Point site are approximately 1,465 feet thick. The confining properties of the 1,465 feet of strata are variable, with the greatest contribution provided by beds with very low vertical hydraulic conductivities.

HYDRO-GEOLOGIC UNIT	TOP DEPTH (ft)	Aquifer Systems	
Biscayne Aquifer	0 - 3	Surficial Aquifer System	
Intermediate Confining Unit	140	Intermediate Confining Unit	
Upper Floridan Aquifer (USDW)	1010		Floridan Aquifer System
Middle Floridan Confining Unit	1450	Middle Confining Unit	
APPZ (?)	(1700)		
Middle Floridan Confining Unit	1930		
Lower Floridan Aquifer	2915		
Boulder Zone	3030		

APPZ (?) denotes uncertainty

Figure 1. Geology at EW-1 (Derived from FEIS (NRC-008A) Figure 2-19).

Determination of Confinement

Why do you believe that the geology at Turkey Point is sufficient to confine the injected wastewater below the USDW?

32. First, my hydrogeological analysis of the data collected during the drilling and testing of well EW-1 on the 1,465 feet of confining strata present between the base of the USDW and top of Lower Floridan Aquifer (from a depth of 1,450 feet to a depth of 2,915 feet) indicates the presence of effective vertical confinement at the Turkey Point site. Second, my groundwater model of the injection system indicates that there is a very low likelihood that injected wastewater will migrate vertically into the USDW.

Confinement Analysis 1: Hydrogeological Analysis

How does your hydrogeological analysis of the EW-1 data support a finding of confinement below the USDW?

33. In studies I performed prior to my involvement in the Turkey Point project, I developed a series of criteria to be used to determine the likelihood of effective confinement at injection well system sites based on a site's hydrogeological data. When I became involved with Turkey Point, I applied these criteria to the data collected from EW-1 as part of a hydrogeological analysis and determined that the EW-1 data supports a finding of confinement.

34. Specifically, my previous investigations into the cause(s) of upward migration of municipal wastewater in South Florida were published in the international peer-reviewed journal "Hydrogeology Journal" (*see generally* FPL-013 (Maliva et al. 2007); FPL-014 (Maliva and Walker 1998)), including my criteria for recognizing both confining strata and zones of enhanced hydraulic conductivity in the Floridan Aquifer System. My

criteria for recognizing confining strata was also presented at the 2000 Ground Water Protection Council Annual Forum. *See generally* FPL-015 (Maliva and Walker 2000). The criteria are based on data collected during injection well drilling and testing in South Florida, including borehole geophysical logs, lithological logs, core analyses results and packer test results, and operational data (whether or not injected water was detected in monitor zones). Injection wells were studied at sites in which significant upwards migration did, and did not, occur. Ultimately, I determined that confinement is provided by intervals of unfractured strata with relatively low vertical hydraulic conductivities. Upwards migration of injected municipal wastewater occurred where the strata above the Boulder Zone has a high degree of fracturing, which is readily identifiable using geophysical log data.

35. Using these criteria, I performed an analysis of the EW-1 data evaluating the degree to which the strata in well EW-1 have characteristics indicative of the presence of effective confinement. This analysis demonstrated effective confinement at EW-1.

36. Strong evidence of the absence of fracturing at EW-1 is demonstrated by the EW-1 borehole geophysical logs, particularly the sonic log. Fractured rock is characterized by long sonic transit times, as can be seen in a demonstrative sonic log of the Clewiston, Florida IW-1 injection well, provided in Attachment 4, where fracturing is well developed. The sonic log from well EW-1, also shown in Attachment 4, lacks the very high transit time peaks indicative of fracturing (evident in the Clewiston log), showing that the confining strata at well EW-1 are largely intact. This sonic log demonstrates that the cumulative strata between 1,450 feet (near the base of the USDW) and 2,915 feet

(near the injection zone) in well EW-1 have characteristics indicative of effective vertical confinement.

Confinement Analysis 2: Groundwater Model

You stated above that, in addition to your hydrogeological analysis, your groundwater model also supports confinement below the USDW. Please explain.

37. In addition to my hydrogeological analysis, in order to support the Turkey Point license application I performed a variety of groundwater modeling simulations. *See* Attachment 5. Those simulations indicated that the top of the injected wastewater (i.e., top of mixed wastewater/native groundwater zone) will, 100 years after the start of injection, be located over 1,000 feet below the base of the USDW at the Turkey Point site. This large simulated separation indicates a substantial safety factor.

Please describe your groundwater model.

38. My groundwater model was designed to determine the amount of vertical migration of injected water that might occur over the potential 60-year operational life of Units 6 and 7. The simulations also included a subsequent 40-year period without injection for a total simulation duration of 100 years. The groundwater modeling used SEAWAT, a density-dependent, solute-transport code that was developed by the United States Geological Survey for the simulation of water flow and solute transport in aquifers with significant salinity (and thus density) differences. I used version 4 of SEAWAT in this investigation, because it incorporates temperature effects on buoyancy. A summary of the model layers and parameters is provided in the following Table 1:

Table 1: Model Summary							
Model layer	Confining zone	Elevations (ft bls)		Thickness (ft)	Total dissolved solids (mg/L)	Vertical hydraulic conductivity (ft/d)*	Horizontal hydraulic conductivity (ft/d)*
		Top	Bottom				
1	CZ6	1350	1450	100	5,700	31.0	310.0
Base of the USDW							
2	CZ5	1450	1495	45	13,890	0.0012	18.6
3		1495	1540	45	13,890	0.0012	18.6
4	CZ4	1540	1595	55	20,927	45.29	77.0
5		1595	1650	55	27,963	1.177	98.86
6	CZ3	1650	1706	56	35,000	0.0048	15.85
7		1706	1762	56	35,000	0.0091	17.48
8		1762	1818	56	35,000	0.0035	45.48
9		1818	1874	56	35,000	0.0019	10.23
10		1874	1930	56	35,000	0.7926	6.61
11	CZ2	1930	2064	134	35,000	0.0076	11.84
12		2064	2198	134	35,000	0.1678	8.39
13		2198	2332	134	35,000	0.1051	2.37
14		2332	2466	134	35,000	0.1811	5.06
15		2466	2600	134	35,000	0.2144	6.85
16	CZ1	2600	2631	31	35,000	0.0490	9.47
17		2631	2676	45	35,000	0.0171	11.30
18		2676	2721	45	35,000	0.0297	0.23
19		2721	2766	45	35,000	0.0037	26.88
20		2766	2811	45	35,000	0.0105	0.207
21		2811	2856	45	35,000	0.0026	0.109
22		2856	2915	59	35,000	0.0142	0.206
23	Injection zone	2915	3175	260	35,000	20.0	196.2
* Calculated for confining zones from core porosity versus permeability transforms applied to sonic log porosity values.							

Did the groundwater model consider local geology?

39. Yes. The model simulated the injection zone (Boulder Zone), confining zone, and basal part[22] of the USDW. Inasmuch as the focus of the modeling was on travel distance towards the base of the USDW, it was not necessary to simulate the entire USDW (above 1,450 feet). Accordingly, the top of the model is 1,350 feet.

What was the source of your model's data?

40. The model is based largely on data collected from well EW-1. There are no borehole geophysical logs that provide a direct measure of hydraulic conductivity (or permeability), the key variable in controlling groundwater flow rates. Instead, as is standard practice, I generated hydraulic conductivity versus depth profiles from other petrophysical properties. Specifically, transforms (cross plots) of porosity versus vertical and hydraulic conductivity were generated from EW-1 core data. I also used core data from the Dean Water Treatment Facility injection well IW-1 (FPL-006) in order to increase the number of data points and the range of porosity and hydraulic conductivity values. I then applied the transforms to porosity data obtained from the borehole sonic log. Effective vertical and horizontal hydraulic conductivity values were calculated for each model layer.

Did you use conservative assumptions in your model?

41. Yes. Using conservative assumptions is important to provide reasonable assurance that the proposed injection will not cause adverse impacts. I used a conservative approach in

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[22] The basal part of the USDW is the strata between depths of 1,350 and 1,450 feet. The strata above 1,350 feet are not relevant to this modeling investigation because the issue of concern is whether or not the injected water will reach the base of the USDW.

the data analysis to prevent biasing the model towards under-predicting vertical migration rates. For example, I determined that the sonic transit time values were too low (based on a comparison of log-derived porosity values with core values), which would give artificially low log-derived porosity values and in turn decrease hydraulic conductivity and vertical flow velocity values. So I corrected the transit time data upwards, which had the net effect of increasing modeled vertical fluid migration rates.

42. I also reduced excessively high porosity values (> 50%) from thin fractured or vuggy zones[23] to 50% in order to avoid excessively and incorrectly high horizontal hydraulic conductivity values. If the hydraulic conductivity values calculated from these high sonic porosity intervals were incorporated into the model, they would result in a greater modeled horizontal flow and lesser upwards flow (i.e., a lesser amount of upwards migration). However, this correction turned out to be immaterial since the wastewater did not reach most of the layers in question.

43. Vertical travel distances were based on the first appearance of wastewater mixed with native groundwater, not the presence of "pure" wastewater. The concentration of wastewater constituents (e.g., chemicals) in the mixed water would be substantially less than the concentration in the original wastewater due to mixing.

Did your model include a sensitivity analysis?

44. Yes. There is always some uncertainty in the values used for the various model parameters. As a result, I performed a sensitivity analysis by running simulations using variables that would tend to result in greater vertical migration rates (e.g., effective

[23] A vuggy zone has a numerous small voids (large pores) formed by the local dissolution of the rock.

porosity was reduced to 0.1, vertical hydraulic conductivity of confining zone strata increased by a factor of 2).

What were the results of your simulations?

45. As I stated above, the results of all my simulations indicate that the top of the injected wastewater will be located *at least* over 1,000 feet below the base of the USDW at the Turkey Point site after a hundred years. This simulated separation demonstrates a substantial safety factor. These simulations and their results are further described in my report, which is included as Attachment 5 to this Testimony.

<u>Effect of Migration on Impact to Drinking Water</u>

Notwithstanding the results of your simulations, what would happen if the injected wastewater were to migrate into the Upper Floridan Aquifer?

46. Even if the wastewater were to somehow migrate vertically through the approximately 1,465 feet of confining rock and into the Upper Floridan Aquifer, it would not result in the contamination of anyone's potable water. Not all water designated as a USDW in the Upper Floridan Aquifer is used as drinking water. All groundwater in Florida with a total dissolved solids concentration of less than 10,000 mg/L is automatically considered from a regulatory perspective to be a USDW, regardless of whether or not the groundwater is now or might conceivably be used in the future as a local potable water supply.

47. Realistically, however, there is no potable water supply wellfield close enough to Turkey Point to be contaminated by the injected water. The closest Floridan Aquifer System potable water supply well is about 11 miles west of Turkey Point, in the direction

opposite of the groundwater flow in the Floridan Aquifer System from Turkey Point.[24] The groundwater flow direction in the Floridan Aquifer System, towards the southeast, is away from all known and planned future potable public water supply wellfields. Therefore, no plausible exposure scenario exists whereby treated wastewater injected at the Turkey Point site could enter a potable public water supply.

48. In short, the geographic separation and groundwater flow direction provide independent barriers (in addition to the geological barriers described above) to ensure that public health will be protected.

How do you know that the groundwater will flow away from public water supply wellfields?

49. Pre-development (groundwater pumping) and recent (2014) potentiometric surface maps of the Upper Floridan Aquifer prepared by the U.S. Geological Survey and Florida Geological Survey show that the groundwater horizontal flow direction in southeastern Miami-Dade County, including the Turkey Point area, is to the southeast, in the offshore direction. *See* Attachment 6. I confirmed the locations of existing public water supply wells in Miami-Dade County from the Wellfield Protection Area map. *See* Attachment 7. And I determined the planned future wellfield locations using the Miami-Dade WASD 2014 Water Supply Facilities Work Plan. *See* FPL-017 at 057-064. As can be seen in those references, all existing and planned Upper Floridan Aquifer wellfields are located

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[24] Ocean Reef Club, located on North Key Largo, approximately 7.7 miles south-southeast of Turkey Point, has several Upper Floridan Aquifer production wells that are used to a supply a reverse-osmosis water treatment plant for *irrigation* water supply. Ocean Reef Club is supplied potable water by the Florida Keys Aqueduct Authority from off-island sources.

well inland of the Turkey Point site. There are no existing or planned wellfields in the Lower Floridan Aquifer.

50. The nearest Upper Floridan Aquifer potable water wellfield is located at the Dean Water Treatment Facility, which is approximately 11 miles west of the Turkey Point site. *See* Attachment 8. The groundwater flow direction in the Upper Floridan Aquifer at the Turkey Point site is away from the Dean plant. Thus, water in the Upper Floridan Aquifer (including the USDW) below Turkey Point flows away from the nearest wellfield.

51. Water flow in the Boulder Zone is different; while it may go horizontally towards the Dean Water Treatment Facility wellfield, it moves at a crawl. While limited information on groundwater flow in the Boulder Zone suggests that flow is in a westward (inland) direction, it occurs at an extremely slow rate, less than 60 feet per year or 1.1 miles per century.[25] FPL-022 at 028. At this rate, it would take centuries before the injected wastewater could even flow to an area below a wellfield, and it would then have to travel upward through the confining unit to reach the area where the USDW may be drawn for use as potable water. This is unrealistic.

52. In addition, it is inconceivable that potable water supply wells would ever be installed close enough to Turkey Point to result in the contamination of potable drinking water

[25] As the FEIS discusses, FPL performed a horizontal flow analysis as part of the FSAR radiological exposure analysis. *See* NRC-008A, FEIS at 5-27. This analysis determined that it would take years for the injectate to flow 2.2 miles away, and the injectate would not reach a distance of 7 miles. *See* NRC-008A, FEIS at 5-27. This analysis used a number of "conservative assumptions that would tend to maximize the migration of effluent," (NRC-008C, FEIS at G-48) and ultimately the NRC Staff determined that "[t]he conditions and parameters in this scenario . . . are not reasonably foreseeable based on the hydrogeology at the Turkey Point site." NRC-008A, FEIS at 5-27. I agree that this extent of horizontal migration is unlikely.

because FPL owns a large portion of that area, and the distance from Turkey Point to existing and planned water distribution infrastructure is significant.

Protection of Surficial/Biscayne Aquifer

Is there any possibility that the wastewater may penetrate beyond the Upper Floridan Aquifer into the Biscayne Aquifer?

53. No. There is no plausible scenario for injected wastewater from Turkey Point to migrate from the Boulder Zone, through the Floridan Aquifer System, and then through the Intermediate Confining Unit into the Biscayne Aquifer. First, any such scenario assumes that the wastewater will migrate vertically through the 1,645 foot confining zone. Second, as noted above, the Intermediate Confining Unit consists of approximately 800 feet of clay-rich strata that would further prevent migration into the Biscayne Aquifer. Third, because water in the Upper Floridan Aquifer is under higher pressure than water in the Biscayne Aquifer, and would naturally flow into the latter given the chance, the Biscayne Aquifer would already be contaminated with upwardly migrating brackish water if any breach existed. It is not so contaminated, and no such pathway exists.

54. There is also no plausible scenario for the wastewater to leak from a Turkey Point injection well into the Biscayne Aquifer. The Biscayne Aquifer is sealed off from South Florida Class I injection wells with three separate cemented-in-place steel casings (injection, intermediate, and surficial casings). There has never been a leak from an injection well into the Biscayne Aquifer, and such a leak is inconceivable in an appropriately constructed well.

55. Finally, there is no data that suggests a leak into the Biscayne Aquifer from either upwards migration or a well leak at *any* South Florida injection well site. There is no reason to believe that Turkey Point would be the first.

56. It is also worth noting that, as mentioned above, the Biscayne Aquifer contains saline water at the Turkey Point project site due to its proximity to the coast. As a result, it is not used as a source of drinking water near Turkey Point.

Joint Intervenors' Claims

Joint Intervenors' Claims Regarding the South District Plant

According to the Joint Intervenors in this proceeding, historical experience at the South District Plant shows that significant upward migration may occur at Turkey Point. Quarles First Affidavit at ¶¶ 10-20. Do you agree?

57. No. First, as I describe below, none of the upward movement at the South District Plant has resulted in contamination of an actual potable water source. It is a huge jump from the entry of wastewater into the lower part of the USDW at a wastewater treatment plant site to contamination of the potable water supply. Second, the upwards movement of wastewater that has occurred at the South District Plant is likely not due to migration through the confining strata. The prevailing opinion is that this upward movement was likely due to well construction issues rather than hydrogeological issues (e.g., breaches in the confining layer). In my professional opinion, the presence of multiple spatially isolated "plumes" of wastewater in the lower USDW at the South District Plant is much more consistent with well construction issues than natural breaches in the confining strata.

58. Such a problem will not occur at Turkey Point. As the FEIS recognizes, current injection well construction techniques are designed to avoid the well construction problems that appear to have occurred at the South District Plant. NRC-008A, FEIS at 2-56. The South District Plant injection wells were drilled using older, now obsolete, procedures, which likely contributed to the detected vertical fluid migration. Specifically, the pilot hole was not cemented in earlier constructed wells, which can lead to a vertical flow pathway if the reamed hole does not track the pilot hole. Pilot holes are now cemented before the start of reaming operations to avoid this possibility. The well construction methods employed in EW-1, and future Turkey Point injection wells, are designed to avoid the possibility of vertical migration. Mr. McNabb's Testimony in this proceeding addresses this in more detail.

59. The geology at Turkey Point also has features that are more favorable for deep well injection than at the South District Plant. Specifically, the total thickness of confining strata between the top of the Boulder Zone and the base of the USDW is much greater at Turkey Point than at the South District Plant. The base of the USDW at the South District Plant is located at depths of about 1,640 feet. FPL-023 at 035. Fractured rock at the South District Plant occurs upwards to depths as shallow as about 2,450 feet, and some injection wells are cased as shallow as 2,392 feet. *See* FPL-029 at 007, 009. Hence, the thickness of the confining strata at the South District Plant is approximately 810 feet, which is nearly half the 1,465 feet of confining strata encountered in Turkey Point well EW-1. The greater confining zone thickness at Turkey Point provides an additional barrier against upwards migration of injected fluids.

You say that the upward movement at the South District Plant is due to well construction issues. However, Mr. Quarles has asserted in this proceeding that "[t]he MDWASD, the Idaho Lab, and EPA Risk Assessment all concluded that large joints are the likely contaminant pathway to the upper aquifer." Quarles First Affidavit at ¶ 24. Do you agree?

60. No. Mr. Quarles' statement is false. No study has come to that conclusion. In fact, the authors of the studies to which he refers were careful not to make claims about the cause of the rapid vertical flow at the South District Plant that could not be definitely supported by the data. The Idaho study even affirmatively concluded that "the data do not allow a distinction to be made between migration through inadequately sealed wells or through natural features." FPL-026 at 049.

61. Mr. Quarles has also failed to address other articles that conflict with his interpretation. For example, the U.S. Geological Survey concluded that "[c]onstruction related issues may be more likely than hydrogeologic heterogeneity for some of the vertical migration, particularly in the areas where effluent is observed in upper monitoring zones, but not in the adjacent lower monitoring zones." FPL-009 at 013.

62. While large vertical joints that penetrate through the confining strata, if present, could indeed result in rapid vertical migration of injected wastewater from the Boulder Zone, there is no suggestion that such features are present in Miami-Dade County, including at the South District Plant. There are only limited, isolated examples in South Florida of discrete natural features providing a vertical conduit for flow from the APPZ or Boulder Zone through much of the thickness of the Floridan Aquifer System (i.e., Warms Springs in Sarasota County (*see generally* FPL-016) and the "mud hole" located in the Gulf of

Mexico off of Lee County (*see generally* FPL-021)). Neither of these isolated examples is in the area of interest in this case.

63. Mr. Quarles claims that "[t]he complex, cavernous nature of the bedrock in the Boulder Zone means that large amounts of water from interconnected bedrock above that zone have historically resulted in large solution-enlarged channels." Quarles First Affidavit at ¶ 24. It is a common misconception that the Boulder Zone is "cavernous." The Boulder Zone consists mainly of fractured dolostone in which large cavities develop during drilling as the result of borehole collapse. *See, e.g.*, FPL-025 at 005; FPL-010 at 005; FPL-014 at 004. Actual open cavities, as indicated by bit drops during drilling, are uncommonly encountered, and there is no evidence of such open cavities at the Turkey Point site.

64. An investigation that I performed (prior to my involvement in the Turkey Point project) of the cause of rapid migration of municipal wastewater in injection well systems in South Florida revealed that rapid vertical migration occurs as a result of pervasive fracturing of usually dolomitic confining strata, which is readily recognizable in borehole geophysical logs. *See* FPL-013 at 007, 009. Pervasive fracturing of the type associated with vertical fluid migration is not evident in the Turkey Point exploratory well (EW-1).

But Mr. Quarles also asserts that Walsh and Price concluded that contamination at the South District Plant is related to the "the occurrence of vertical fractures (or joints) in the lower aquifer." Quarles First Affidavit at ¶ 13. *See also* Quarles Second Affidavit at ¶ 18. How do you reconcile this with your opinion?

65. Contrary to Mr. Quarles' assertions, Walsh and Prince stated that "*no fracturing of the confining strata at either the NDWWTP or the [South District Plant] has been reported*."

FPL-028 at 013. While noting that vertical pathways existed, Walsh and Price stated that they could be due to well construction issues or natural features. FPL-028 at 013. The water chemistry data indicate only that the transport was rapid. As I have stated above, the prevailing opinion is that the upwards migration at the South District Plant was due to well construction issues and that current injection well construction methods (such as those to be employed at Turkey Point) will avoid past problems.

66. There is no study of which I am aware that has provided evidence demonstrating that upwards migration at the South District Plant was caused by adverse hydrogeological conditions (e.g., fracturing in the Middle Confining Unit) or provided evidence indicating that fractures or joints were the likely cause of vertical migration. As I noted before, the water quality monitoring data only indicate that upward migration was localized and occurred rapidly.

Mr. Quarles also claims that the Upper Floridan Aquifer has been contaminated with wastewater at the South District Plant. Quarles First Affidavit at ¶ 15, Second Affidavit ¶¶ 11-15. Do you agree?

67. Not at all. The Avon Park Permeable Zone has been contaminated at the South District Plant, but that Zone is not located in the Upper Floridan Aquifer. Mr. Quarles' use of the Idaho National Engineering and Environmental Laboratory (INEEL) definition of the aquifer depths (FPL-026 at 013) to assert that the Avon Park Permeable Zone is in the Upper Floridan Aquifer is incorrect. The INEEL hydrostratigraphic interpretations are inconsistent with now widely accepted interpretations by experts very familiar with Florida hydrogeology. The U.S. Geological Survey (FPL-024 at 007) clearly describes that the Avon Park Permeable Zone is located in the Middle Confining Unit, below the

Upper Floridan Aquifer.[26] The USGS, in what is perhaps now the definitive reference on the hydrostratigraphy of South Florida, specifically states that:

> The middle confining unit of the Floridan aquifer system underlies the Upper Floridan aquifer, and in most of the study area, is divided into upper (MC1) and lower (MC2) parts that are separated by the Avon Park permeable zone.

FPL-024 at 049. Accordingly, any wastewater that has migrated into the Avon Park Permeable Zone is still located in the Middle Confining Unit, not the Upper Floridan Aquifer. Walsh and Price acknowledge this in their study, correctly concluding that wastewater had not entered the Upper Floridan Aquifer at the South District Plant. FPL-028 at 012, 015.

<u>Joint Intervenors' Claims Regarding the Uncertainty of Confinement</u>

Please address Mr. Quarles' claims in this proceeding that the EPA has determined that "18 deep well injection well sites in Florida have already contaminated USDWs." Quarles First Affidavit at ¶ 17. *See also* Quarles Second Affidavit at ¶ 41; Quarles Third Affidavit at ¶ 40.

68. Contrary to Mr. Quarles' assertions, the EPA never reached that conclusion. The EPA's data compilation identified 18 instances in which water migrated out of an injection zone, *not* instances in which drinking water aquifers have been contaminated. The USEPA concluded that contamination of USDWs actually occurred at three sites and probably occurred at six other sites, far short of the eighteen sites referenced by Mr. Quarles. FPL-027 at 104. Mr. Quarles also failed to note that, as shown in the USEPA report (Figure 4-

[26] As described by the U.S. Geological Survey (FPL-024 at 041) the Upper Floridan Aquifer at the South District Plant (injection well 12 ("MDS-I12")) is located at depths of 970 to 1,080 feet, and the Avon Park Permeable Zone (APPZ) is located at depths between 1,430 and 1,560 feet within the Middle Confining Unit. The APPZ is actually a formal name for what was previously referred to as the middle Floridan Aquifer. It has never been considered part of the Upper Floridan Aquifer.

4), six of the nine sites with known or suspected contamination of the USDWs are located in Pinellas County, Florida, in which a different, shallower injection zone is used with geological conditions that are very different from those encountered in South Florida injection wells, including at Turkey Point. The remaining three sites identified in the USEPA report are the D.B. Lee well in Brevard County (adverse geological conditions – no confinement due to extensive fracturing), the Seacoast Utilities well in Palm Beach County (cause uncertain), and the South District Plant, in which, I previously noted, upwards migration was likely due to well construction issues. Importantly, the potable water supply was not compromised in *any* of those cases.

69. Ultimately, in the report cited by Mr. Quarles, the USEPA concluded that there is "low or no risk" for municipal wastewater disposal in South Florida, considering the quality of the injected water, contaminant attenuation processes underground after injection, and the lack of potential pathways to the public water and environment. FPL-027 at 300.

Is the degree of confinement provided by confining units below the Upper Floridan Aquifer "uncertain?" Quarles Third Affidavit at ¶ 29.

70. No. On the contrary, Mr. Quarles referred to the report by Reese and Richardson, which concluded that:

> This report provides an improved understanding of the hydrogeologic linkage within the Floridan aquifer system between central and southern Florida and between west and east coastal areas; however, the hydraulic connectivity of the aquifers and permeable zones mapped, particularly those below the Upper Floridan aquifer, remains uncertain *in some areas*. The degree of confinement provided by confining units mapped between these permeable zones in some areas is also uncertain.

FPL-024 at 064 (emphasis added).

71. Mr. Quarles omits the key phrase "in some areas." There are indeed some areas in Florida where confinement is questionable or does not exist (e.g., parts of the Melbourne area). These areas are not relevant here because they are located far (over 100 miles) from the Turkey Point site. Reese and Richardson came to no specific conclusions regarding the presence of confinement in the Turkey Point area. *See generally* FPL-024. However, as I describe above, site-specific and area data, as well as my own analyses, support the presence of effective confinement at the Turkey Point site. As also described above, the confinement analysis performed for the Turkey Point site considered site-specific data collected from well EW-1, data from nearby injection well sites, experiences from injection well sites throughout South Florida, and published studies on confinement issues in South Florida. Based on all of these data, which are not contradicted by Reese and Richardson (or anyone else with sufficient expertise in the field), in my professional opinion there is effective confinement at the Turkey Point site.

Did Cunningham identify bedrock structural systems that could potentially create vertical pathways for groundwater across confining layers? Quarles Third Affidavit at ¶¶ 30-34, 37.

72. No. There is no evidence that the types of structural feature documented by Cunningham (tectonic faults and ancient karst collapse structures) are hydraulically active and may act as vertical flow conduits from the Boulder Zone. Both Cunningham (FPL-008A at 028) and I (FPL-020 at 452) concluded that the detected subsurface deformation is of Miocene to Early Pliocene age, and thus occurred several million years ago. Cunningham et al. (2012) (FPL-007 at 001) and Cunningham (2015) (FPL-008A at 028) *speculated* that the structural features could be hydraulically active, but provided no evidence to that effect

and did not collect any data with respect to the hydraulic properties of the features detected. Mr. Quarles, likewise, is merely speculating.

73. Other studies have indicated that such features have no impact on groundwater flow. For example, Miller (1986) observed that "[s]everal faults shown along Florida's eastern coast [] are of limited extent and generally show little vertical displacement. These small faults do not appear to have any effect on ground-water flow in the Floridan aquifer system." FPL-018 at 020. Additionally, Duncan et al. (1994) (FPL-011) reported a subsurface structural feature at the East Coast Regional Wastewater Treatment plant deep injection wellfield in Palm Beach County, located between injection wells only 500 feet apart, that is characterized by counter-regional (east to west) dips in the upper Oldsmar Formation and Avon Park Formation. This structural feature was interpreted to be either a fault or monoclinal fold that passes through that wastewater treatment plant's injection wellfield. *See* FPL-011 at 008. Monitoring data and data collected during the subsequent construction of the seventh injection well (IW-7) at that site indicate that the feature is not hydraulically active as there has been minimal vertical migration of injected wastewater at the site.

74. Mr. Quarles' suggestion that FPL should perform at Turkey Point an investigation similar to the Cunningham investigation to fully determine the confining nature of the bedrock (Quarles Third Affidavit at ¶ 38) would be useless. A seismic reflection survey that can penetrate through to the Boulder Zone, comparable to the marine surveys performed by Cunningham, would provide no data on the confining properties of the bedrock. Seismic reflection surveys can identify subsurface structures, but they provide no information on their hydraulic properties for use in a confinement analysis.

75. Additionally, FPL did not ignore the bedrock structural features identified by Cunningham; FPL and its consultants (including me) are well aware of and evaluated them. It has long been known that there are subsurface structural features in Florida, including faults. In 2004, I performed a review of subsurface structures in Florida, which included a segment of seismic reflection profile showing a buried fault similar to that subsequently documented by Cunningham. FPL-020 at 013. I concluded that structural deformation may be responsible for the fracturing observed in some strata, including the Boulder Zone. FPL-020 at 015. Accordingly, in 2007 I noted that confinement analyses should focus on identification of fractured and unfractured intervals. FPL-013 at 009. This is exactly what I did for the Turkey Point EW-1 confinement analysis. The structural features observed by Cunningham were noted in the FEIS, NRC-008A (at 5-25), which correctly concluded that

> In order for rapid flow of injected effluent to occur from the Boulder Zone through the MCU as a result of these natural features, they would have to occur within the zone of influence of an injection site and create a set of pathways that compromise the approximately 1500 ft thick MCU. However, characterization data indicates that these features are not evident at the site and modeling suggests that the expected zone of influence of injected wastewater is not expected to extend far beyond the boundaries of the Turkey Point site.

<u>Conclusions</u>

Please summarize your conclusions.

76. In summary, I find it highly unlikely that the injected wastewater, disposed via deep well injection at Turkey Point, might upwell into a USDW and enter into an actual potable water supply. My hydrogeological analysis and groundwater model both demonstrate that there is a very low probability that wastewater will migrate into a USDW. Even if the wastewater were to migrate into the USDW at the Turkey Point site, it would travel in

the opposite direction of the closest drinking water well. In my professional opinion, it would be nearly impossible for the injected wastewater to enter the public drinking supply and have any impact on public health.

77. Accordingly, the deep well injection at Turkey Point poses no risk to the public health. My analysis was based on sufficient data obtained from EW-1, and Mr. Quarles has provided no analysis or modeling to contradict my conclusions. He has only provided misstatements and exaggerations, none of which change my conclusions.

78. Based on all of the above, I agree with the FEIS's conclusion that "significant upwelling of injected wastewater is not likely at the Turkey Point site and that, if upwelling did occur it would not noticeably impact overlying USDW aquifers." NRC-008A, FEIS at 5-21. I also agree with the FEIS that the environmental impact of injected wastewater from Turkey Point will be "small" (*see* NRC-008A, FEIS at 5-41 to 42), if any.

I, Robert G. Maliva, swear under penalties of perjury that the foregoing testimony is true and correct to the best of my knowledge and belief.

Signature

3-1-17

Date

ROBERT G. MALIVA LICENSE No. 1549 STATE OF FLORIDA PROFESSIONAL GEOLOGIST

Attachment 1

Dr. Robert Maliva, P.G.
Principal Hydrogeologist

BIO

Dr. Maliva has over 25 years of international research and consulting experience in groundwater resources management, subsurface geology and fluid flow investigations. Prior to joining WSP | Parsons Brinckerhoff, Dr. Maliva was a Principal Hydrogeologist at Schlumberger Water Services and CDM and held research positions at Harvard University, the University of Cambridge (England), and the University of Miami. His areas of specialization include the design and permitting of injection wells, aquifer storage and recovery, and managed aquifer recharge systems, production wellfield design and testing, water resources evaluations, aquifer characterization, stratigraphy and sedimentology, sedimentary geochemistry, geophysical log interpretation, and aqueous geochemical modeling.

QUALIFICATIONS

Dr. Maliva has been the Project Manager or technical lead for 14 aquifer storage and recovery projects.

Dr. Maliva has been the Project Manager or technical lead in the design, permitting and/or construction of 9 Class I injection wells in South Florida. He has also designed and permitted Class II and Class V disposal wells in Florida. Dr. Maliva has prepared operation permit applications and managed mechanical integrity tests for numerous Class I injection wells in Southwest Florida.

Dr. Maliva has been involved in numerous hydrogeological investigations involving the assessment, development, and management of groundwater resources, including alternative water supply projects.

Dr. Maliva is the senior author of three books: "Aquifer Storage and Recovery and Managed Aquifer Recharge Using Wells: Planning, Hydrogeology, Design, and Operation," "Arid Lands Water Evaluation and Management," and "Aquifer Characterization Techniques."

PROFESSIONAL REGISTRATIONS

Professional Geologist - Florida No. 1549

Professional Geologist – Texas No. 410

PROFESSIONAL EXPERIENCE

8/1/2016 – Present: Principal Hydrogeologist, WSP | Parsons Brinckerhoff

1/1/2007 - 2016: Principal Hydrogeologist, Schlumberger Water Services USA

1992 – 2006: Hydrogeologist, ViroGroup, Missimer International, CDM, Missimer Groundwater Science, Inc.

1991 – 1992: Research Associate, University of Miami, Florida

1989 – 1991: Research Associate, University of Cambridge, England

EDUCATION

1988: Doctorate, Geology, Harvard University, Massachusetts, USA

1984: Masters, Geology, Indiana University at Bloomington, Indiana, USA

1982: Bachelors, Geology, State University of New York at Binghamton, New York, USA

PROFESSIONAL AFFILIATIONS

National Ground Water Association

International Association of Hydrogeologists

American Water Works Association

SEPM – Society for Sedimentary Geology

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BOOKS

Maliva, R.G., 2016, Aquifer Characterization Techniques: Springer, Berlin, 617 pp.

Missimer, T.M., Jones, B., and Maliva, R.G., (Eds.) 2015, Intakes and Outfalls for Seawater Reverse-Osmosis Desalination Facilities: Springer, Berlin, 544 pp.

Maliva, R.G., and Missimer, T.M., 2012, Arid Lands Water Evaluation and Management: Springer, Berlin, 1076 pp.

Maliva, R. G., and Missimer, T. M., 2010, Aquifer Storage and Recovery and Managed Aquifer Recharge Using wells: Planning, Hydrogeology, Design, and Operation: Methods in Water Resources Evaluation Series No. 2, Schlumberger Corporation, 578 pp.

RECENT PROJECT EXPERIENCE

City of Hialeah Reverse-Osmosis Desalination System Class I Injection Well System

Technical/Task Manager – Dr. Maliva designed, prepared permit application, supervised construction, and prepared completion report for two Class I injection wells in Miami-Dade, Florida, used for disposal of desalination concentrate.

Florida Power & Light Nuclear Power Plant Expansion

Technical Specialist – Dr. Maliva provide technical support and performed an impact analysis for a Class I injection well system that will be used for disposal of cooling water for two new nuclear power plant units in Miami-Dade, Florida.

Dan A. Hughes Company Class II Injection Well Systems

Project Manager - Dr. Maliva designed and permitted three Class II injection wells systems in Collier County, Florida, that will be used for the disposal of oilfield produced waters.

Destin Water Users, Inc. (DWU) Reclaimed Water Aquifer Storage and Recovery System

Project Manager - Dr. Maliva designed, permitted, supervised construction, and subsequently operationally permitted a groundbreaking ASR system in Northwest Florida. The DWU ASR system is the first operational ASR system in Florida that stores reclaimed water in a shallow sand and gravel aquifer in an environmental sensitive area.

Seminole Tribe of Florida Brighton Reservation and City of Daytona Beach (Florida) ASR systems

Project Manager – Dr. Maliva performed feasibility studies, designed and supervised test well programs, and permitted aquifer storage and recovery systems for the Seminole Tribe of Florida and City of Daytona Beach.

Palm Beach County, Florida, Lake Region Water Treatment Plant and City of Clewiston Water Treatment Plant

Project Manager. Dr. Maliva designed and permitted injection wells systems used for the disposal of desalination concentrate.

Other Injection Well Projects

Designed and prepared technical specifications for the Collier SCRWTP injection well IW-1 and SCWRF IW-2, City of West Palm Beach ECRWWTP injection well IW-7, Tampa Bay Water Mid-Pinellas Brackish Water Desalination Facility, Palm Beach County Water Utilities Department SROC single-zone monitor well, Tropicana Products, Inc. Bradenton, Florida, injection well IW-2, and the City of Deerfield Beach IW-1 injection well systems.

PEER-REVIEWED PUBLICATIONS AND BOOK CHAPTERS

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Maliva, R.G., and Missimer, T.M., 2015, Well intake systems for SWRO systems: design and limitations. In Missimer, T.M., Jones, B., and Maliva, R.G., (Eds.), Intakes and Outfalls for Seawater Reverse-Osmosis Desalination Facilities, Springer, Berlin, p. 147-162.

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ATTACHMENT 2
ROBERT MALIVA DEEP INJECTION WELL EXPERIENCE

Robert Maliva Personal Deep Disposal Injection Well Project Experience		
Facility	**Task**	**Year**
Florida Power & Light, Turkey Point Nuclear Power Plant injection well system.	Permitting support, impact assessment, confinement analysis, and regulatory support	2012-2014
Dan A. Hughes Company Class II injection well systems (oilfield brines), Collier County, Florida	Design and permitting	2013-2104
Ashghal Drainage Affairs, Doha, Qatar (four systems)	Design, environmental impact assessment, and regulatory support	2009-2012
City of Hialeah (Florida) RO Plant (concentrate disposal) Injection wells IW-1 and IW-2	Feasibility study, design, permitting, construction supervision, and confinement analysis	2008-2010
Collier County (Florida) SCWRF IW-1	Mechanical integrity test	2006
Collier County (Florida) NCRWTP IW-2	Mechanical integrity test	2006
City of Clewiston WTP concentrate disposal IW-1	Design, permitting	2006
Palm Beach County Southern Region Pumping Facility IW-1	Design and permitting of tubing replacement	2006
Tropicana Products, Inc., industrial waste Class V Injection Well IW-2 (Bradenton, Florida)	Design, permitting, supervision of construction, and confinement analysis	2005
Palm Beach County (Florida) Lake Region WTP desalination concentrate IW-1	Design and permitting	2005
City of Deerfield Beach desalination concentrate IW-1	Design and permitting	2004
Palm Beach County Southern Region Operation Center SZMW-1	Design, permitting and construction supervision; confinement analysis	2004
Collier County South County WRF (municipal wastewater) IW-2	Design, permitting, construction supervision, and confinement analysis	2004

West Palm Beach (Florida), ECRWWTP IW-7 & DZMW-4 (municipal wastewater)	Design, permitting and construction supervision	2004
Collier County SCWRF IW-1	Operation permit renewal	2004
Collier County NCRWTP (desalination concentrate) IW-1	Design and permitting of tubing replacement and mechanical integrity testing	2004
Island Water Association IW-1	Mechanical integrity test	2004
Village of Royal Palm Beach IW-1	Operation permit renewal	2001
Collier County SCWRF IW-1	Mechanical integrity test	2001
Collier County North County Regional Water Treatment Plant IW-1	Mechanical integrity test	2001
Island Water Association (Sanibel, Florida) desalination concentrate IW-1	Design, permitting, construction supervision, and confinement analysis	1999
Collier County SCWRF IW-1 (municipal wastewater)	Design, permitting, construction supervision, and confinement analysis	1999
Collier County NCRWTP desalination concentrate IW-2	Design, permitting, construction supervision	1996

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ATTACHMENT 3
REVIEWED PAPERS ON SOUTH FLORIDA CLASS I INJECTION WELLS[1]

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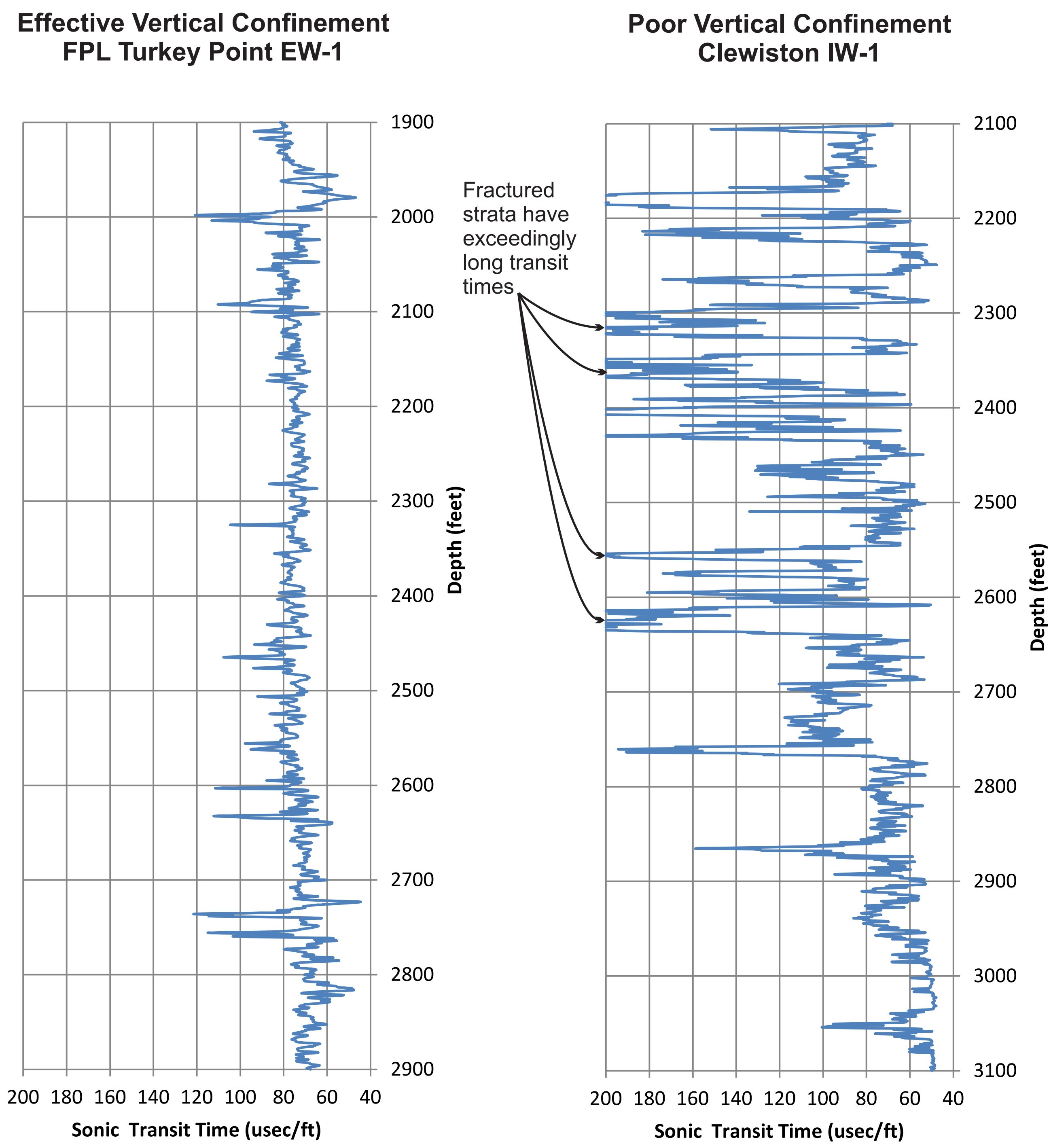
Attachment 4

Comparison of the Sonic Logs for Strata Showing Characteristics Indicative of Effective and Poor Vertical Confinement



Groundwater Modeling Investigation of Vertical Confinement
Proposed Turkey Point Units 6 & 7 Injection Well Systems

Robert G. Maliva
December 9, 2013

Introduction

Density-dependent, solute-transport modeling was used to evaluate the potential rate and distance of the vertical migration of injected wastewater from the proposed FPL Turkey Point Units 6 and 7. The key regulatory issue is whether or not the injected water may enter and, as a result, potentially endanger underground sources of drinking water (USDWs). The base of the USDW is considered to be the 10,000 mg/L total dissolved solids (TDS) isopleth in the Floridan Aquifer System, based on definition in Rule 62-528.200, Florida Administrative Code. Vertical migration of injected wastewater, in general, is controlled by the hydraulic properties of the injection zone and confining strata, injection rate, and density differences between the injected water and native groundwater. The most important hydraulic parameter controlling the vertical migration of injected waters is the vertical hydraulic conductivity of the confining strata. Density differences are due primarily to differences in salinity and temperature, and will be significant where relatively fresh reclaimed water is injected into the saline injection zone (the Boulder Zone of the Lower Floridan Aquifer).

The groundwater modeling performed for this investigation included two main elements. First was the processing of hydrogeological data collected during the drilling of exploratory well EW-1 to obtain a hydraulic conductivity versus depth profile of the confining strata between the injection zone and the base of the USDW. The data from EW-1 was obtained from the well completion report (McNabb Hydrogeological Consulting Inc., 2012 that was provided to the FDEP. Second was the actual running of the groundwater model using best estimated values of hydraulic parameters and performing a sensitivity analysis to evaluate the robustness of the model.

Procedure

There are no borehole geophysical logs that provide a direct measure of hydraulic conductivity (or permeability). Instead, hydraulic conductivity versus depth profiles are generated from other petrophysical properties, such as total porosity. A commonly used procedure is to generate a porosity versus hydraulic conductivity transform (cross plot) from core analysis data. The transform is then applied to porosity data obtained from borehole geophysical logs, such as a sonic porosity log. The core porosity-hydraulic conductivity transform procedure was used to evaluate the borehole geophysical log data from the confining zone of well EW-1

Core data from the Florida Keys Aqueduct Authority (FKAA) J. Robert Dean Water Treatment Plant injection well IW-1 were also used in this study in order to increase the number and range of porosity and hydraulic conductivity data points. The FKAA site is located less than 12 miles from Turkey Point Units 6 and 7 site. The FKAA data were obtained from the well completion report (AECOM, 2009), which is available on the SFWMD DBHYDRO database.

The core porosity versus hydraulic conductivity relationship between the two sites is very similar, likely because the sites have had similar burial and diagenetic (i.e., post-burial geochemical) conditions.

The use of the FKAA data is conservative in that it provides greater hydraulic conductivity values at intermediate (15% to 30%) porosity values. A regression line generated using only the EW-1 data would give incorrectly low hydraulic conductivity values at low and intermediate porosity values, as can be seen by performing a linear regression of the high (> 35%) porosity data on Figure 1.

The best-fit regression obtained for the data is a polynomial regression of log hydraulic conductivity to porosity (Figure 1), which has the form:

$$\mathrm{Log}K_z = 0.004\varphi^2 - 0.0665\varphi - 7.0432$$

where K_z = vertical hydraulic conductivity (cm/s) and φ = porosity (percent). The equation for horizontal hydraulic conductivity ($K_{x,y}$) is(Figure 2):

$$\mathrm{Log}K_{x,y} = 0.0027\varphi^2 - 0.0435\varphi - 5.8461$$

A linear regression using only the limestone and dolomitic limestone samples (samples with greater than 25% porosity in Figures 1 and 2) would incorrectly give much too low hydraulic conductivity values at lower porosities (< 25%). The polynomial regression shows vertical hydraulic conductivity increasing with decreasing porosity below about 7%, which is not realistic. However, none of the EW-1 confining zone strata have porosities below 7%.

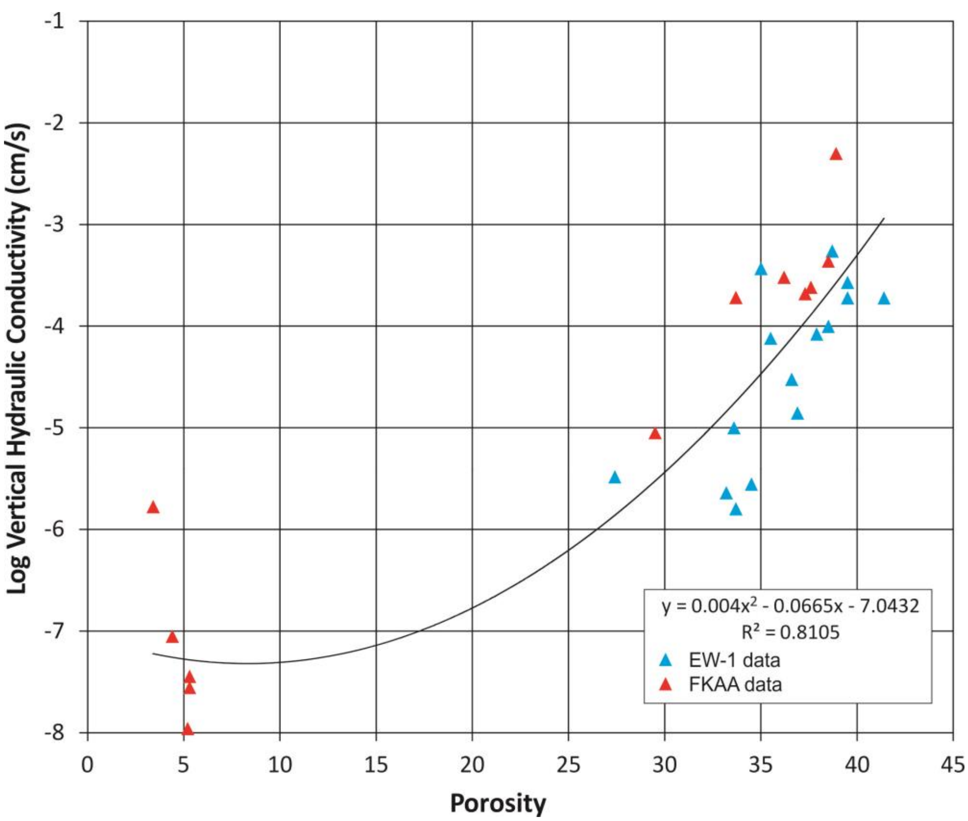


Figure 1. Porosity versus vertical hydraulic conductivity transform.

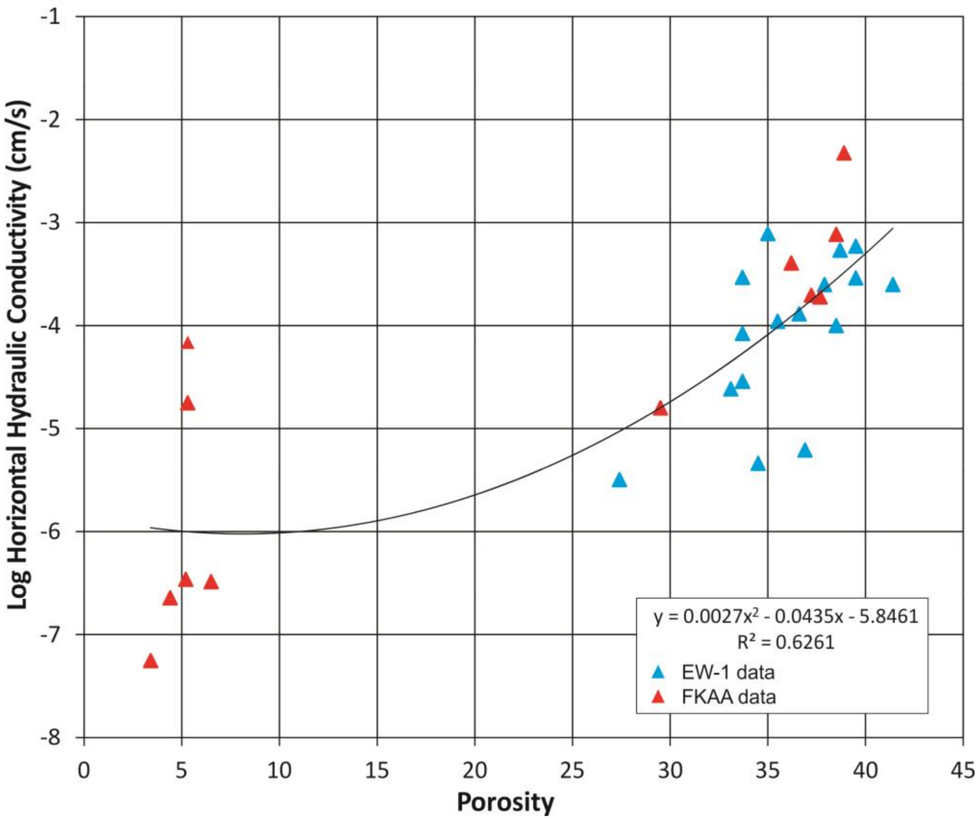


Figure 2. Porosity versus horizontal hydraulic conductivity transform

The sonic log for the confining zone strata from EW-1 gave porosity values that were too low compared to core analyses from the same depth interval, which may be due to an enlarged borehole. Similarly, comparison of the EW-1 sonic log with the sonic log for the same interval for FKAA IW-1 indicates that the EW-1 travel times are approximately 25 µsec/ft too low. The EW-1 data were thus corrected by uniformly adding 25 µsec/ft to all values. By applying the correction factor, the sonic porosity values from EW-1 are consistent with both the core porosity values from EW-1 and sonic transit time and porosity values from FKAA IW-1.

Porosity values were then calculated from the corrected EW-1 transit times using the Wyllie formula, as follows:

$$\phi = \frac{\Delta t_{\log} - \Delta t_{ma}}{\Delta t_f - \Delta t_{ma}}$$

where

Δt_{log} = interval transit time of the formation (measured),
Δt_{ma} = interval transit time of the matrix (47.6 µsec/ft used)
Δt_f = interval transit time in the wellbore fluid (189 µsec/ft using for saline water).

Inserting the constant values for Δt_{ma} and Δt_f gives the equation

$$\varphi = (\Delta t_{log} - 47.6)/141.4$$

The calculated porosity values were compared with core analysis results for the same depth interval and were found to be similar. An exact match would not be expected and did not occur due to core shift (i.e., difference between actual depth of core samples and log depths).

Hydraulic conductivity values were calculated for each sonic transit time measurement, which were obtained for every 0, 0.2, 0.5, and 0.7 ft (4 measurements per ft). A plot the vertical hydraulic conductivity data versus depth is provided as Figure 3. The equivalent vertical hydraulic conductivities of depth intervals were calculated as the harmonic mean of the values for each interval.

Intervals with secondary porosity (fractured horizons) have very long sonic transit times, which result in an over estimation of porosity values and, in turn, exceeding high (and hydrogeologically unreasonable) hydraulic conductivity values. Inasmuch as the equivalent vertical hydraulic conductivity of a sequence of strata is the harmonic mean of the values for individual beds, the incorrectly high vertical hydraulic conductivity values would not materially impact equivalent vertical hydraulic conductivity values. On the contrary, equivalent horizontal hydraulic conductivity is the arithmetic mean of the individual beds and, therefore, the incorrectly high values would have a great effect on effective horizontal hydraulic conductivity values. The uncorrected data would thus tend to result in simulations that overestimate horizontal flow at the expense of vertical flow (i.e., resulted in lesser simulated upwards migration).

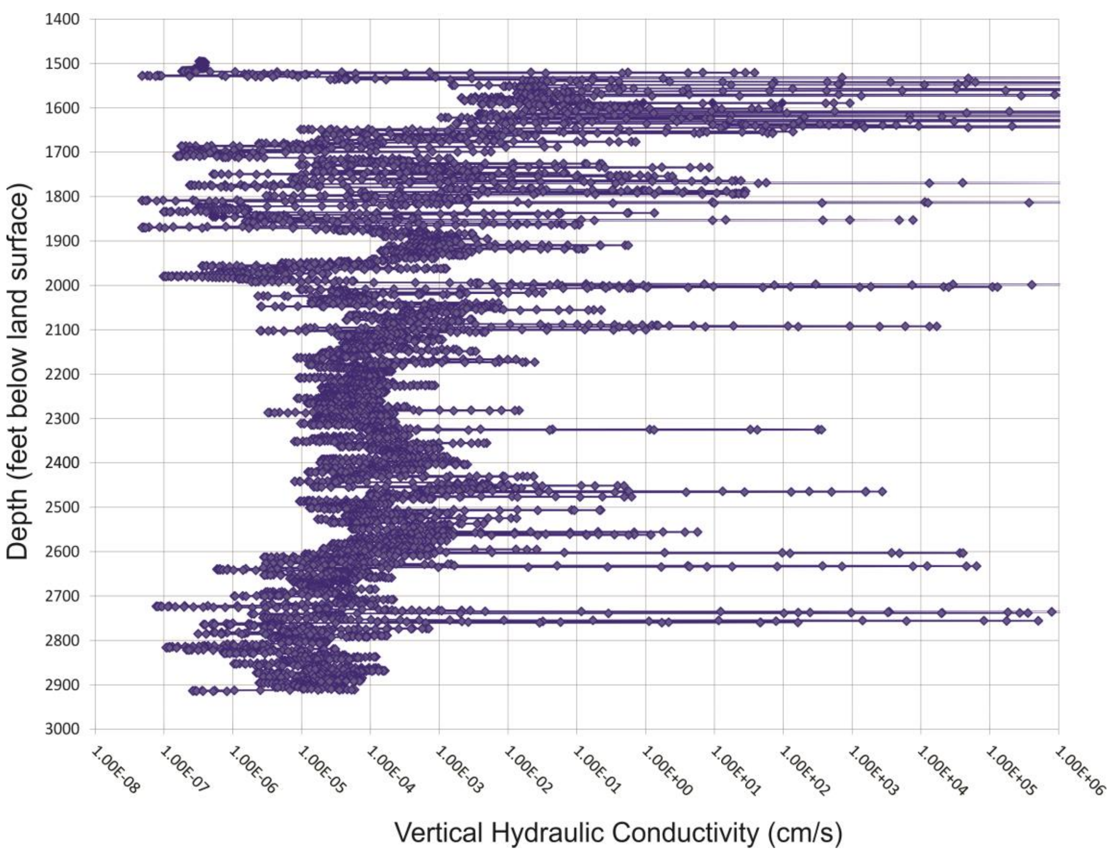


Figure 3. Vertical hydraulic conductivity versus depth profile for well EW-1

Schlumberger
Water Services

As a conservative measure, the data were corrected by capping porosity at 50%. The 50% cap was chosen because it is the approximate normal upper limit on porosity in the Floridan Aquifer System in South Florida, based on examination of core data from numerous injection systems. Intervals with calculated porosity values of greater than 50% were assigned a porosity of 50%. This correction would act to increase the amount of simulated vertical fluid migration compared to the uncorrected scenario.

The strata between the top of the injection zone (2915 ft below land surface; bls) and base of the USDW (1450 ft bls) in EW-1 is subdivided into five confining zones based on general confining properties, as indicated by the borehole geophysical logs. The confining zones and their equivalent vertical and horizontal hydraulic conductivity are summarized in Table 1.

Table 1: Confining zones and equivalent hydraulic conductivity values

Zone	Depths (ft/d)	Equivalent hydraulic conductivity (ft/d)	
		Vertical	Horizontal
CZ5	1450 – 1540	$1.19\text{x}10^{-3*}$	18.5*
CZ4	1540 – 1650	2.28	87.9
CZ3	1650 – 1930	$4.37\ \text{x}10^{-3}$	19.1
CZ2	1930 - 2600	$3.18\ \text{x}10^{-2}$	6.90
CZ1	2600 - 2915	$7.37\ \text{x}\ 10^{-3}$	6.50

* values for 1495 to 1540 ft bls used for entire zone.

Solute Transport Modeling

The purpose of the modeling is to investigate the potential for the injected cooling water from Turkey Points Units 6 & 7 migrating upwards and reaching the base of the USDW. Two sources of water will be use for cooling water, treated municipal wastewater (reclaimed), which will be the primary source, and seawater obtained from Biscayne Bay using horizontal collector wells. The injected water flow when reclaimed water is used for cooling is projected to be 18.6 million gallons per day (MGD). A TDS of 2,721 mg/L was used for the injected water, based upon Table 4.6-2 of the Site Certification Application. Much greater injected water flows (84.8 MGD) will occur when seawater is used for cooling. However, the density of the waste stream when seawater is used for cooling will be greater than that of the Boulder Zone water and, as a result, the waste stream will have a tendency to sink rather than rise towards the USDW.

The primary variables controlling the vertical migration of injected fluids from the Boulder Zone are:

- The vertical hydraulic conductivity of the confining strata
- The density of the injected water, which controls buoyancy induced flow

Secondary variables that can also impact the rate of vertical migration are:

- The pressure increase in the Boulder Zone during injection, which is a function of the injection rate and the local transmissivity of the Boulder Zone.
- The effective porosity of the confining strata
- The presence of horizontal flow zones, which favors lateral flow

Groundwater modeling was performed to determine the amount of vertical migration of the injected water that might occur over the potential 60-year operation life of Units 6 & 7. The simulations also included a subsequent 40-year period without injection for a total simulation duration of 100 years.

The groundwater modeling was performed using SEAWAT (Guo and Langevin, 2002), a density-dependent, solute-transport code that was developed by the United States Geological Survey for the simulation of water flow and solute transport in aquifers with significant salinity (and thus density) differences. SEAWAT was used because it is an open-source code that was specifically designed for the modeling of the flow of groundwaters with different salinities and it has undergone extensive peer review. Version 4 of SEAWAT was used in this investigation, because it incorporates temperature effects on buoyancy.

The model has 23 layers and 150 rows and columns, whose width vary between 200 ft and 1000 ft. The total model domain is 12 miles by 12 miles. Typical default longitudinal, horizontal transverse, and vertical transverse dispersivity values of 30 ft, 3 ft, and 3 ft, respectively, were used in the baseline (most likely conditions) scenario. An effective porosity of 0.2 was used in the baseline simulation, which is a hydrogeological reasonable default value for the limestone and dolomitic limestone that constitute the confining strata encountered in EW-1, and is within the range of values measured for the Floridan Aquifer System. All layers were assigned uniform thicknesses and hydraulic properties.

The Boulder Zone was conservatively assumed to have a transmissivity of 51,000 ft^2/day, which was calculated from the specific capacity data from the testing of well EW-1, as documented in the well completion report. This value is likely much too low as EW-1 entered, but did not fully penetrate the Boulder Zone. Typical transmissivity values for the Boulder Zone are 1,000,000 ft^2/day or greater (Meyer, 1989). The use of a relatively low transmissivity value for the Boulder Zone would increase the simulated pressure in the Boulder Zone during injection, which would tend to result in more rapid simulated vertical migration rates.

Hydraulic conductivity data were obtained from the analysis of the core and geophysical log data from EW-1 (discussed above). The model layers and assigned properties and initial salinities are summarized in Table 2.

The baseline model simulation used a native groundwater temperature of 50°F (estimated from Meyer, 1989) and an injected water temperature of 64.4°F (18°C; low seasonal estimate from Site Certification Application). Both of these values may be too low. However, the temperature differential between the injection water and native groundwater (the key variable effecting density-dependent flow) is still a reasonable estimate. An extreme differential (50°F) was used in the sensitivity analysis to evaluate the impact of uncertainty in temperature values on model results.

The result of the baseline (most likely scenario) simulation (Run #1) is provided in Figure 4. The simulation was simplified by having all injection occur in only two wells located near the center of the planned injection wellfield. This assumption is conservative in that concentrating injection in one area would favor greater simulated vertical fluid migration. In reality, based on communication with FPL staff, injection would be rotated between all the planned injection wells. The modeling results indicate that after 100 years, the injected water will still be contained within the injection zone and zone CZ1. The top of the injected water will still be over 1150 feet below the base of the USDW.

Table 2: Model Summary							
Model layer	Confining zone	Elevations (ft bls) Top	Bottom	Thickness (ft)	Total dissolved solids (mg/L)	Vertical hydraulic conductivity (ft/d)	Horizontal hydraulic conductivity (ft/d)
1	CZ6	1350	1450	100	5,700	31.0	310.0
Base of the USDW							
2	CZ5	1450	1495	45	13,890	0.0012	18.6
3		1495	1540	45	13,890	0.0012	18.6
4	CZ4	1540	1595	55	20,927	45.29	77.0
5		1595	1650	55	27,963	1.177	98.86
6	CZ3	1650	1706	56	35,000	0.0048	15.85
7		1706	1762	56	35,000	0.0091	17.48
8		1762	1818	56	35,000	0.0035	45.48
9		1818	1874	56	35,000	0.0019	10.23
10		1874	1930	56	35,000	0.7926	6.61
11	CZ2	1930	2064	134	35,000	0.0076	11.84
12		2064	2198	134	35,000	0.1678	8.39
13		2198	2332	134	35,000	0.1051	2.37
14		2332	2466	134	35,000	0.1811	5.06
15		2466	2600	134	35,000	0.2144	6.85
16	CZ1	2600	2631	31	35,000	0.0490	9.47
17		2631	2676	45	35,000	0.0171	11.30
18		2676	2721	45	35,000	0.0297	0.23
19		2721	2766	45	35,000	0.0037	26.88
20		2766	2811	45	35,000	0.0105	0.207
21		2811	2856	45	35,000	0.0026	0.109
22		2856	2915	59	35,000	0.0142	0.206
23	Injection zone	2915	3175	260	35,000	20.0	196.2

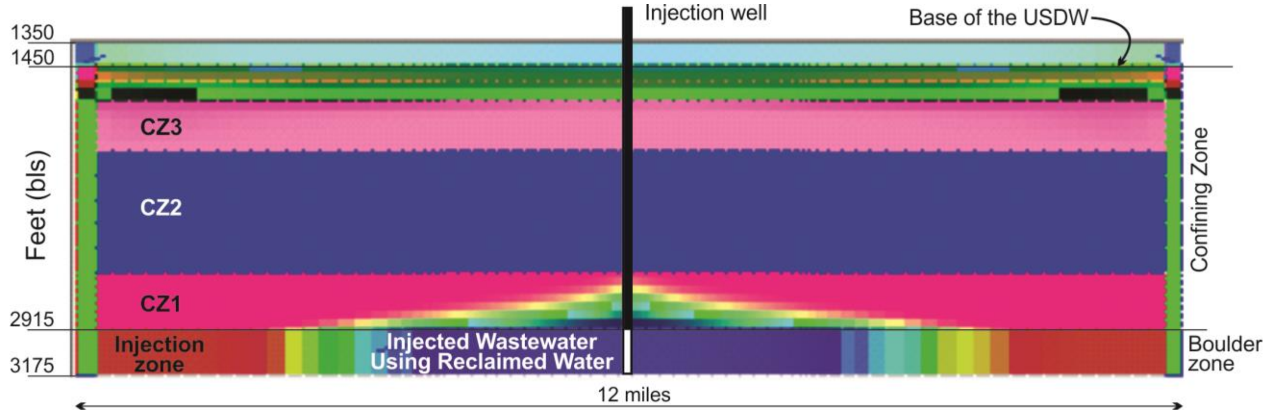


Figure 4. Cross-section diagram through the center of the injection wellfield after 100 years (Run #1). The confining zones are shaded different colors for identification purposes. The injected, low-salinity reclaimed water is shaded dark blue and native seawater-salinity groundwater is shaded in red in the injection zone. Mixtures of reclaimed water and native groundwater are shaded intermediate colors (with decreasing salinity from light blue to green to yellow to orange). Injection well is not to scale. Deep monitoring zone is at the base of confining zone CZ3

Sensitivity runs were performed to evaluate the degree to which model results are affected by variations in the values of key parameters. Parameters were adjusted in the direction that would result in greater simulated upward migration (with exception of transmissivity). The sensitivity analysis runs are as follows:

- Run 0: No injection
- Run 2: Effective porosity reduced to 0.1
- Run 3: Longitudinal, horizontal transverse, and vertical transverse dispersivity values increased to 100 ft, 10 ft, and 10 ft, respectively.
- Run 4: Injection zone transmissivity increased by a factor of 10
- Run 5: Vertical hydraulic conductivity of confining zone strata increased by a factor of 2
- Run 6: Greater injected water temperature (50°F differential between injected water and native groundwater)

The results of the sensitivity analysis simulations (Figure 5) indicate that the top of zone of injected reclaimed water will remain over 1,000 feet below the base of the USDW.

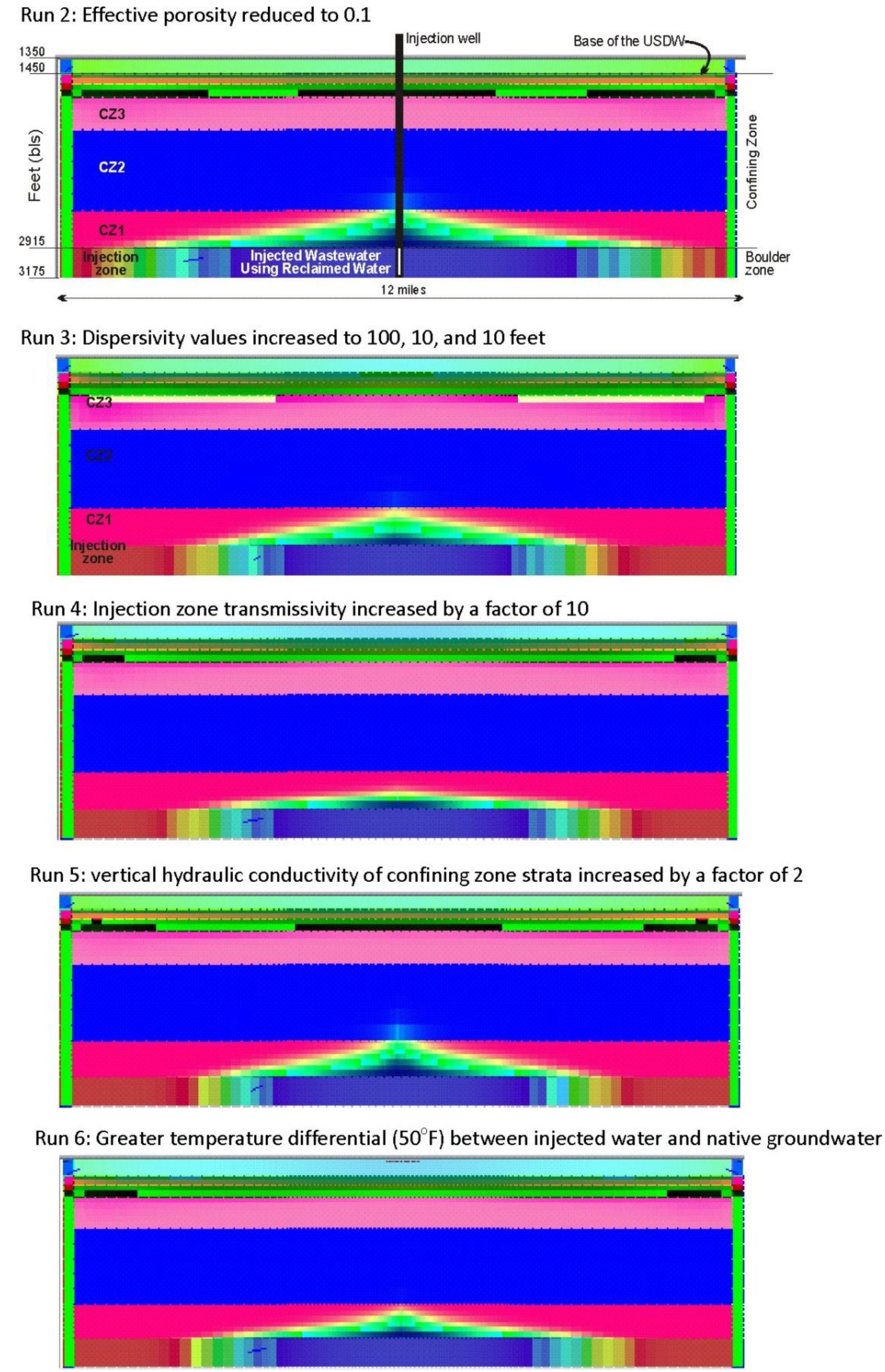


Figure 5. Sensitivity analysis results. All runs show that the injected reclaimed water will remain over 1,000 feet below the base of the USDW after 100 years

Area of Review Investigation

The simulated horizontal radial extent of the injected water after 100 years is approximately 4 miles including an approximately 1.7 mile wide mixing zone. However, the model tends to overestimate mixing due to its coarse cell size and resulting numerical dispersion. Dispersion is not considered in calculating the horizontal extent of injected water bodies using the standard method employed for Underground Injection Control permitting in Florida. An area of review investigation (well inventory) was performed for the Turkey Point site using a 5-mile radius (Figure 6).

The only wells within the 5-mile radius AOR that reach the Floridan Aquifer System were constructed by FPL. The well data are summarized in Table 3 and the locations of the wells are plotted on Figure 6. Only one well (S-3001) other than EW-1 and DZMW-1 is completed below the base of the USDW and partially penetrates the confining zone. No wells were identified within the 5-mile radial area of review that could serve as a conduit for the upward migration of injected fluids from the Boulder Zone.

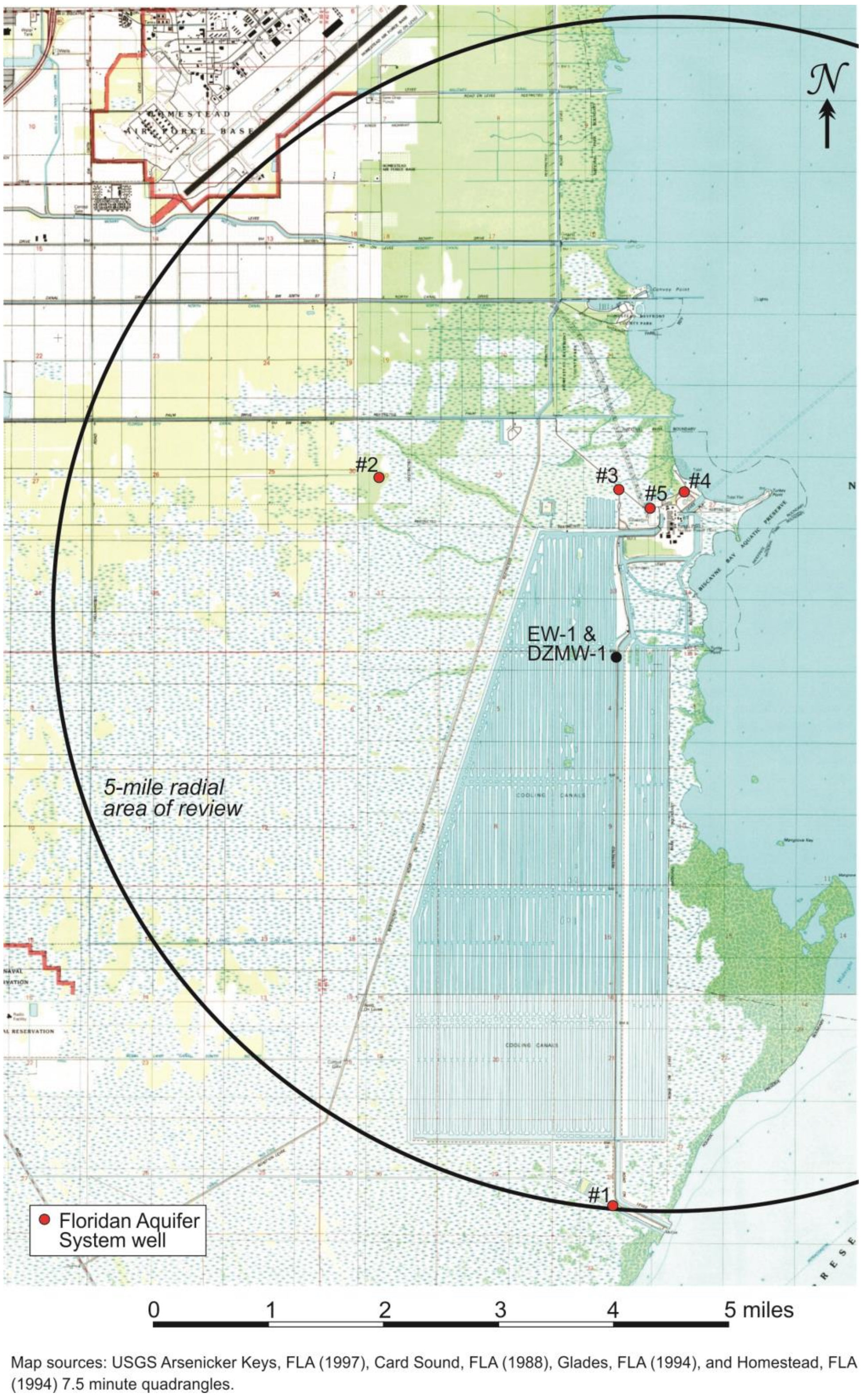
Table 3. Wells that reach the Floridan Aquifer System within a 5-mile radius AOR.

Map No.	Well No.	Name	Depth (feet)	Latitude	Longitude	Source
1	S-3001*	FPL test well	2,000	25°20’58”N	80°20’25”W	1, 4
2	GB-1**	FPL MW	1,225	25°26’26”	80°22’20”	1, 2
	16890**	FPL MW	1,225	25°26’18”	80°22’55”	4
	GB-1**	FPL MW	1,225	25°26’27”	80°22’19”	5
3	PW-1	FPL production well	1,242	25°26’22.2”	80°20’17.7”	7
4	PW-3	FPL production well	1,246	25°26’21.6”	80°19’43.7”	7
5	PW-4	FPL production well	1,243	25°26’12.6”	80°20’02.4”	7
EW-1	EW-1	FPL exploratory well	3,230	25°25’2.9”	80°20’19.7”	7
DZMW-1	DZMW-1	FPL MW	1,905	25°25’2.1”	80°20’19.7”	7

Notes:
* Well S-3001 was abandoned based on discussions with FPL staff.
** Well GB-1/16890 has different coordinates in the USGS, FGS, and SFWMD DBHYDRO systems. The DBHYDRO coordinates are used in Figure 6.
Date sources: (1) Reese (1994), (2) Reese and Richardson (2007), (3) Florida Geological Survey oil and gas maps, (4) Florida Geological Survey well database, (5) SFWMD DBHYDRO database, (6) SFWMD permitting database, (7) FPL (well completion reports).

Conclusions

The results of density-dependent groundwater modeling using site-specific hydrogeological data collected from exploratory well EW-1 and FKAA injection well IW-1 indicate that the confining strata present at Turkey Point will be effective in preventing endangerment of USDW aquifers over the 100 year study period. Simulation results show that, after 100 years, the injected water remains over 1,000 feet below the base of the USDW.



Map sources: USGS Arsenicker Keys, FLA (1997), Card Sound, FLA (1988), Glades, FLA (1994), and Homestead, FLA (1994) 7.5 minute quadrangles.

Figure 6. Map showing the locations of Floridan Aquifer System wells within a 5-mile radius area of review.

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GLOSSARY OF TERMS

Dispersion - is the mechanic mixing and spreading of waters that occurs when some of the water molecules and solute molecules travel more rapidly than the average linear velocity and some travel more slowly; spreading of the solute in the direction of the bulk flow (after Freeze and Cherry, 1979). Dispersion occurs parallel (longitudinal), lateral, and transverse (vertically) to the direction of groundwater flow.

Dispersivity – is technically defined as "A geometric property of a porous medium (e.g., rock or sediment) which determines the dispersion characteristics of the medium by relating the components of pore velocity to the dispersion coefficient." In practice, dispersivity values, in units of length, quantify the mechanical dispersion in a system. For a given flow velocity, higher dispersivity values mean that there will be a greater amount of mechanical mixing and spreading of the water.

Effective porosity - is the ratio usually expressed as a percentage of the total volume of voids available for fluid transmission to the total volume of the porous medium.

Hydraulic Conductivity - is a measure of the ease through which water will flow through a rock. Technically it is defined a proportionality constant that relates groundwater flow rate (volume/time) to the hydraulic gradient. The vertical hydraulic conductivity of rock controls the rate water will move vertically under a given hydraulic gradient.

Hydraulic gradient – is the rate of change of pressure head per unit of distance of flow at a given point and in a given direction.

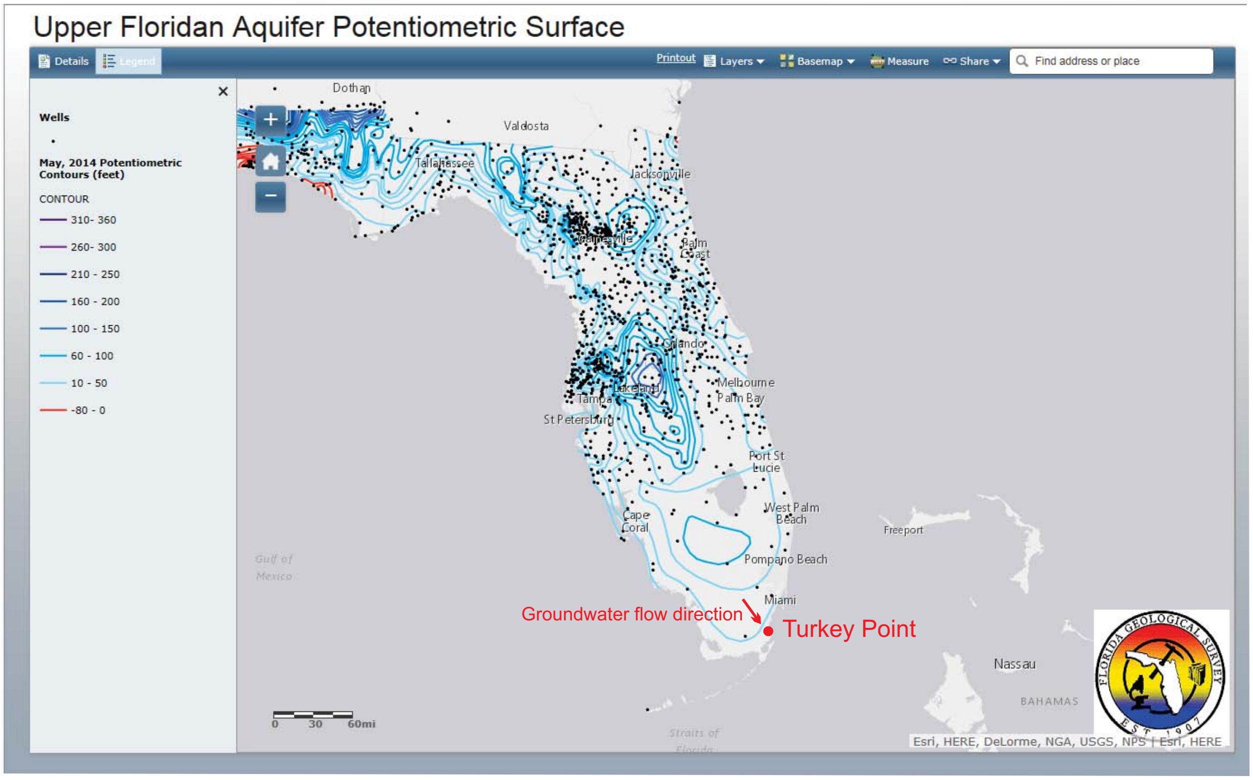
Sonic transit time – amount of time (in microseconds) for a compressional sound water to travel 1 foot through the tested formation as measured using a borehole sonic logging tool. Sonic transit time is inversely related to porosity (i.e., high porosity intervals tend to have long transit times).

Total porosity - is the ratio, usually expressed as a percentage, of the total volume of voids of a given porous medium (i.e., rock) to the total volume of the porous medium

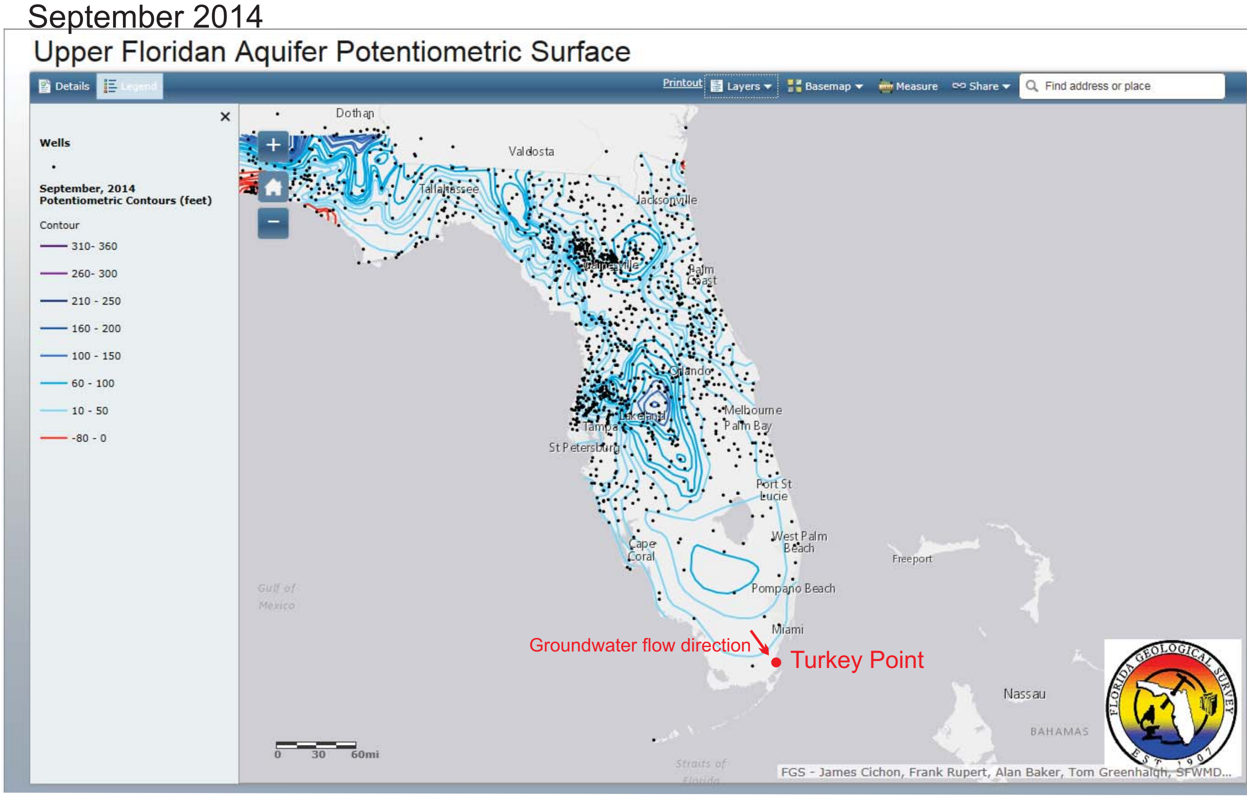
Transmissivity - is a measure of the ease through which water will flow through an aquifer. Technically it is defined as the rate at which water is transmitted through a unit width of the aquifer under a unit hydraulic gradient. Transmissivity is equal to the product of the average hydraulic conductivity of an aquifer and its saturated thickness.

ATTACHMENT 6

May 2014



September 2014



Contour interval = 10 ft

ATTACHMENT 6

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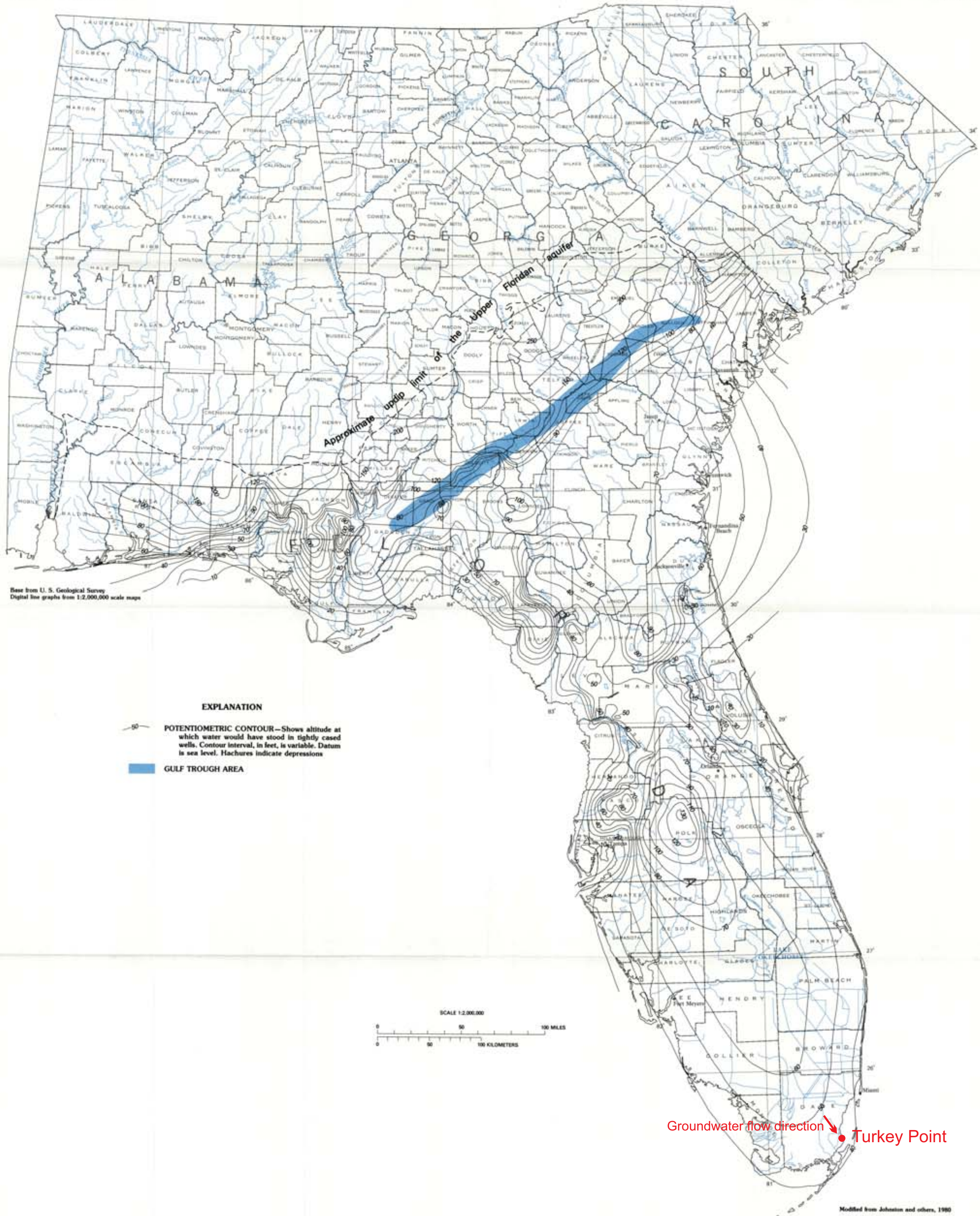


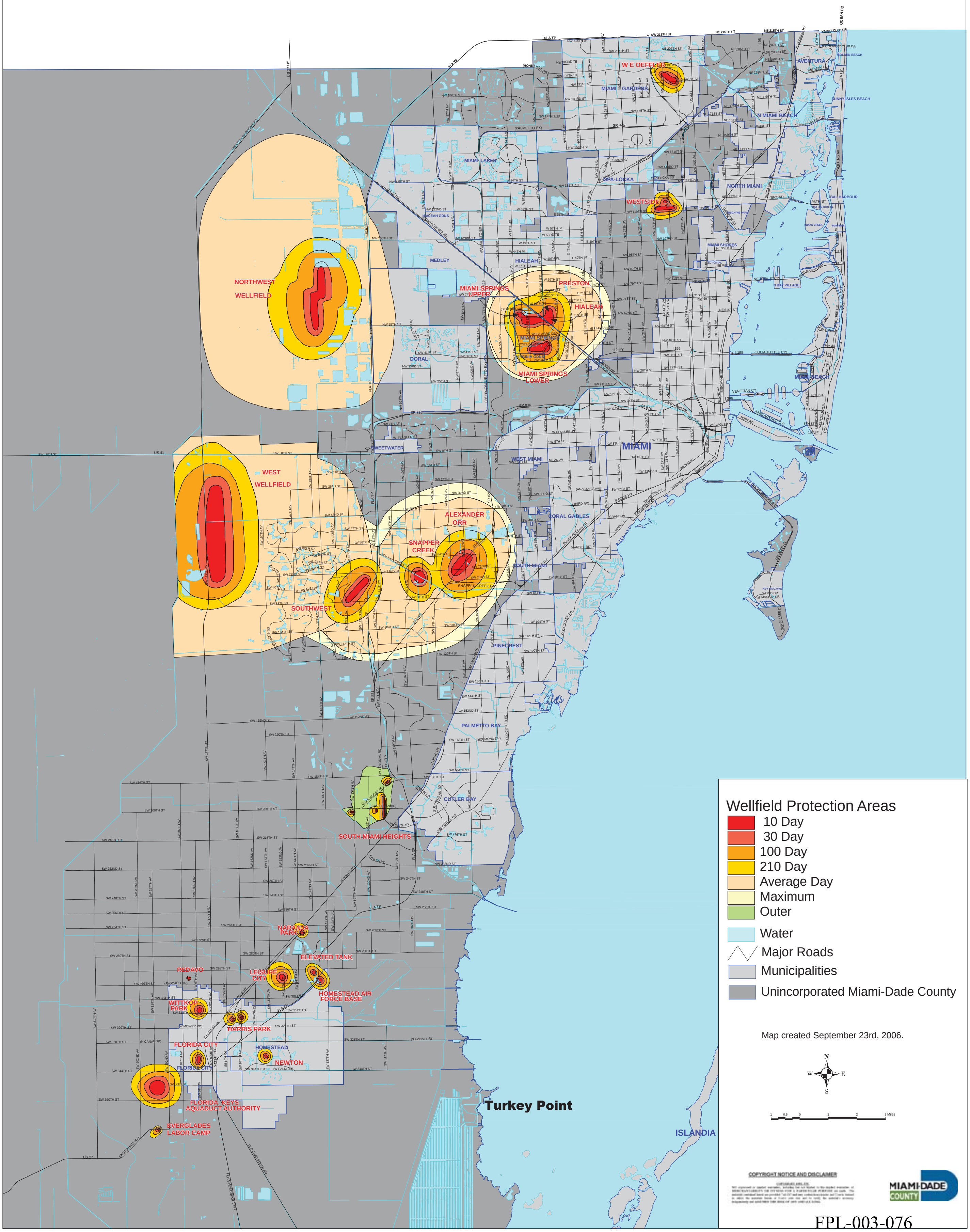
ESTIMATED PREDEVELOPMENT POTENTIOMETRIC SURFACE OF THE UPPER FLORIDAN AQUIFER

Source: Bush and Johnston (1988)

ATTACHMENT 7

Miami-Dade County

Wellfield Protection Areas



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ATTACHMENT 8