

PMTurkeyCOLPEm Resource

From: Franzone, Steve <Steve.Franzone@fpl.com>
Sent: Thursday, July 07, 2016 10:25 AM
To: Comar, Manny
Cc: TurkeyCOL Resource; Maher, William
Subject: [External_Sender] Previous presentation on Hydrogeological Site Features
Attachments: 2_Hydrogeology Site Features Turkey Point Units 6 and 7 (2).pdf

Manny

I have attached a presentation from a pre-submittal meeting we had with the staff back in 2009. It gives general information on the boulder zone and the region.

Let me know if you have any questions.

Thanks

Steve Franzone

NNP Licensing Manager - COLA

"A little more persistence, a little more effort, and what seemed hopeless failure may turn to glorious success." ~ Elbert Hubbard

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Recipients:
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Hydrogeological Site Features Turkey Point Units 6 & 7

Stewart Taylor

Technology Manager, Bechtel Corporation

March 26, 2009

**The information provided in the following
presentation is of a preliminary nature
and is considered DRAFT**

Presentation Overview

- **Data Sources**
- **Regional Hydrostratigraphic Units**
- **Floridan Aquifer System**
 - Upper Floridan aquifer
 - Middle confining unit
 - Lower Floridan aquifer (Boulder zone)
- **Boulder Zone**
 - Hydraulic and geochemical properties
 - Deep well injection
- **Regional Groundwater Flow**
- **Fate and Transport of Injectate**

Data Sources

- Bush, P. and Johnston, R., *Groundwater Hydraulics, Regional Flow and Groundwater Development of the Floridan Aquifer System in Florida and in parts of Georgia, South Carolina and Alabama*, Professional Paper 1403-C, U.S. Geological Survey, 1988.
- Maliva, R.G., and Walker, C.W., Hydrogeology of Deep-Well Disposal of Liquid Wastes in Southwestern Florida, USA, *Hydrogeology Journal*, 6: 538-548, 1998.
- Maliva, R.G., Guo, W., and Missimer, T., Vertical Migration of Municipal Wastes in Deep Injection Well Systems, South Florida, USA, *Hydrogeology Journal*, 7: 1387-1396, 2007.
- Meyer, F., *Hydrogeology, Ground-water Movement, and Subsurface Storage in the Florida Aquifer System in Southern Florida, Regional Aquifer-System Analysis-Floridan Aquifer System*, Professional Paper 1403-G, U.S. Geological Survey, 1989.
- Miller, J.A., *Hydrologic Framework of the Floridan Aquifer System in Florida and in Parts of Georgia, Alabama, and South Carolina*, Professional Paper 1403-B, U.S. Geological Survey, 1986.
- Miller, J.A., *Ground Water Atlas of the United States, Alabama, Florida, Georgia, and South Carolina*, Hydrologic Atlas 730-G, U.S. Geological Survey, 1990.
- Reese, R., *Hydrogeology and the Distribution and Origin of Salinity in the Floridan Aquifer System, Southeastern Florida*, Water-Resources Investigations Report 94-4010, U.S. Geological Survey, 1994.
- Reese, R., and Richardson, E., *Synthesis of the Hydrogeologic Framework of the Floridan Aquifer System and Delineation of a Major Avon Park Permeable Zone in Central and Southern Florida*, Scientific Investigations Report 2007-5207, U.S. Geological Survey, 2008.

Regional Hydrostratigraphic Units

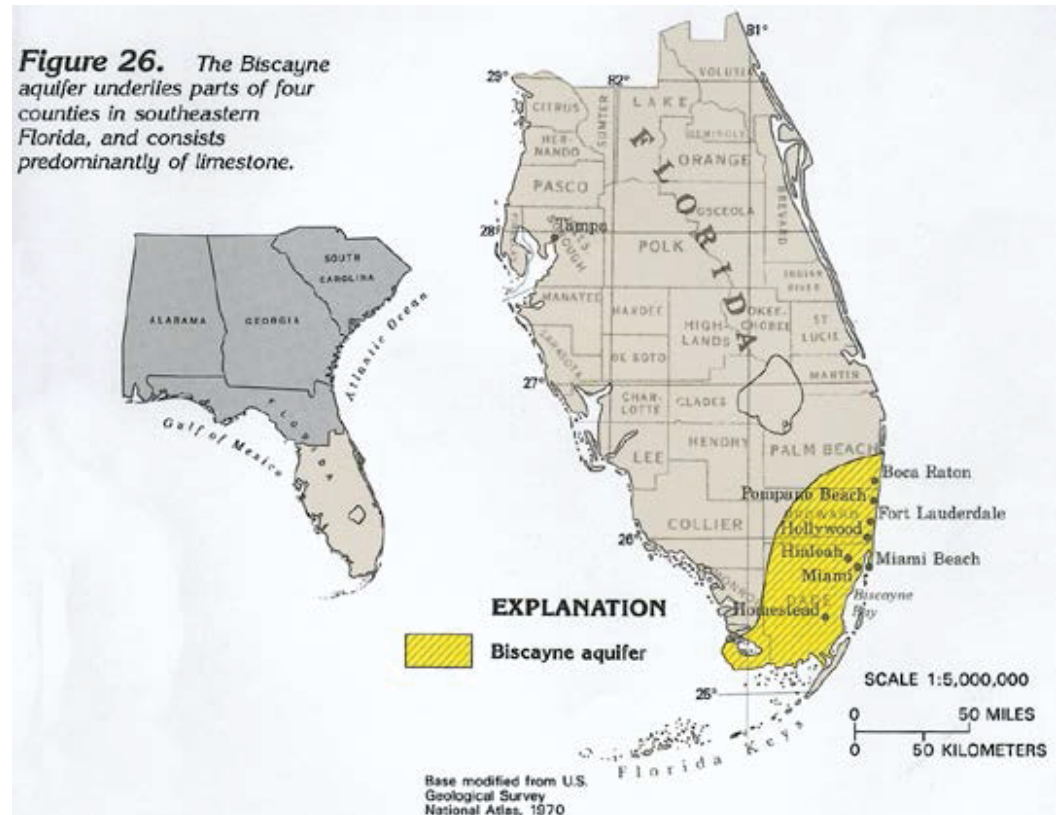
Series		Geologic unit	Marker units and horizons	Lithology	Hydrogeologic unit	Approximate thickness (feet)	EXPLANATION * Geologic unit(s) missing in some areas APPZ Avon Park permeable zone BZ Boulder Zone LHMU Lower Hawthorn marker unit PZ1, PZ2, PZ3 Permeable zones in west-central Florida MAP Middle Avon Park marker horizon GLAUC Glauconite marker horizon PLEISTOCENE-AGED FORMATIONS IN SOUTHEASTERN FLORIDA: Satilla Formation (formerly Pamlico Sand) Miami Limestone Fort Thompson Formation Anastasia Formation Key Largo Limestone			
HOLOCENE and PLEISTOCENE		Undifferentiated and various Pleistocene-aged formations		Quartz sand; silt; clay; shell; limestone; sandy shelly limestone	SURFICIAL AQUIFER SYSTEM	WATER-TABLE / BISCAYNE AQUIFER		20-400		
PLIOCENE		TAMIAMI FORMATION		Silt; sandy clay; sandy, shelly limestone; calcareous sandstone; and quartz sand		CONFINING BEDS LOWER TAMIAMI AQUIFER				
MIOCENE AND LATE OLIGOCENE		HAWTHORN GROUP	PEACE RIVER FORMATION	Interbedded sand, silt, gravel, clay, carbonate, and phosphatic sand	INTERMEDIATE AQUIFER SYSTEM OR CONFINING UNIT	CONFINING UNIT SANDSTONE AQUIFER OR PZ1(?)		0-900		
			ARCADIA FORMATION	Sandy micritic limestone; marlstone; shell beds; dolomite; phosphatic sand and carbonate; sand; silt; and clay		CONFINING UNIT MID-HAWTHORN AQUIFER OR PZ2				
						CONFINING UNIT				
						CONFINING UNIT				
EARLY OLIGOCENE		SUWANNEE LIMESTONE *		Fossiliferous, calcarenitic limestone	SYSTEM AQUIFER	LOWER HAWTHORN PRODUCING ZONE PZ3		0-300	GLAUC Glauconite marker horizon	
						UPPER FLORIDAN AQUIFER (UF)		100-800		
EOCENE	LATE	OCALA LIMESTONE *		Chalky to fossiliferous, mud-rich to calcarenitic limestone		AQUIFER		MIDDLE CONFINING UNIT (MC1) APPZ		500-1,500
	MIDDLE	AVON PARK FORMATION		Fine-grained, micritic to fossiliferous limestone; dolomitic limestone; and dolostone. Also contains in the lower part anhydrite/ gypsum as bedded deposits, or more commonly as pore filling material. Glauconitic limestone near top of Oldsmar Formation in some areas				MIDDLE CONFINING UNIT (MC2)		0-600
	EARLY	OLDSMAR FORMATION						LOWER FLORIDAN AQUIFER BZ		0-1,800 0-700
PALEOCENE		CEDAR KEYS FORMATION		Dolomite and dolomitic limestone	FLORIDAN AQUIFER					
				Massive anhydrite beds		SUB-FLORIDAN CONFINING UNIT	1,200?			

Source: Reese and Richardson (2008)

Regional Hydrostratigraphic Units

Surficial Aquifer System

- “The permeable hydrogeologic unit contiguous with the land surface that is comprised principally of unconsolidated to poorly indurated, siliciclastic deposits.”
- Includes Biscayne aquifer
- 20-400 ft thick

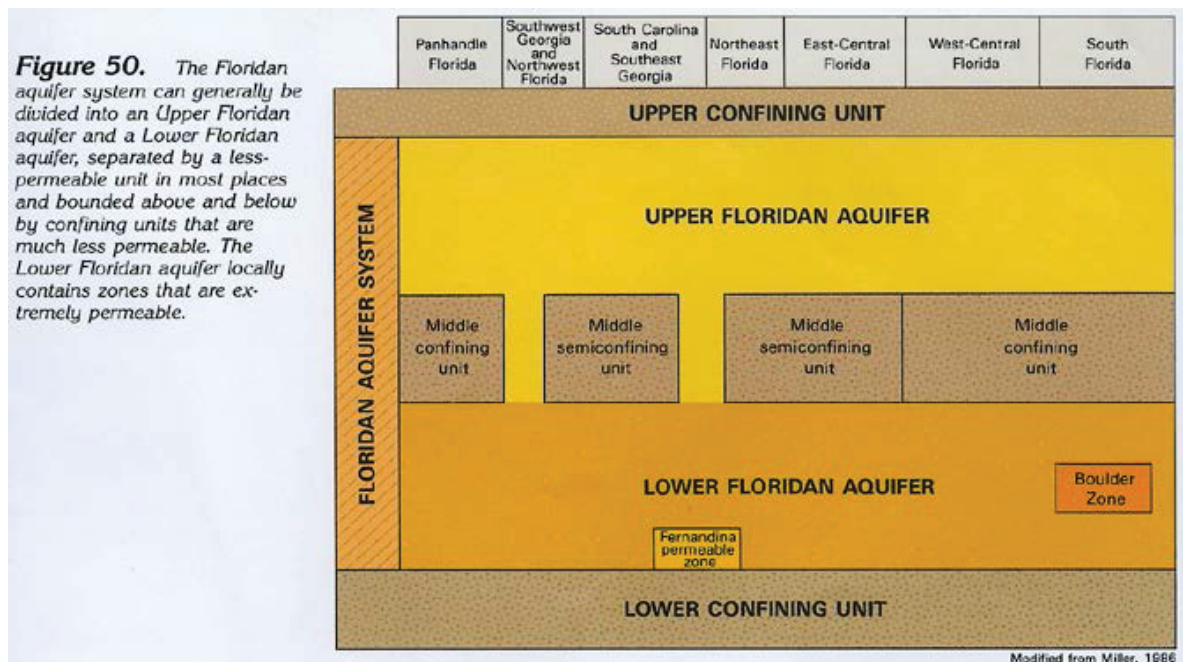


Source: Miller (1990)

Regional Hydrostratigraphic Units

Intermediate Aquifer System / Confining Unit

- “All rocks that lie between and collectively retard the exchange of water between the overlying surficial aquifer system and the underlying Floridan aquifer system”
- Interlayered aquifer/aquitard system comprised of Hawthorn Group sediments
- Up to 900 ft thick
- Brackish water quality

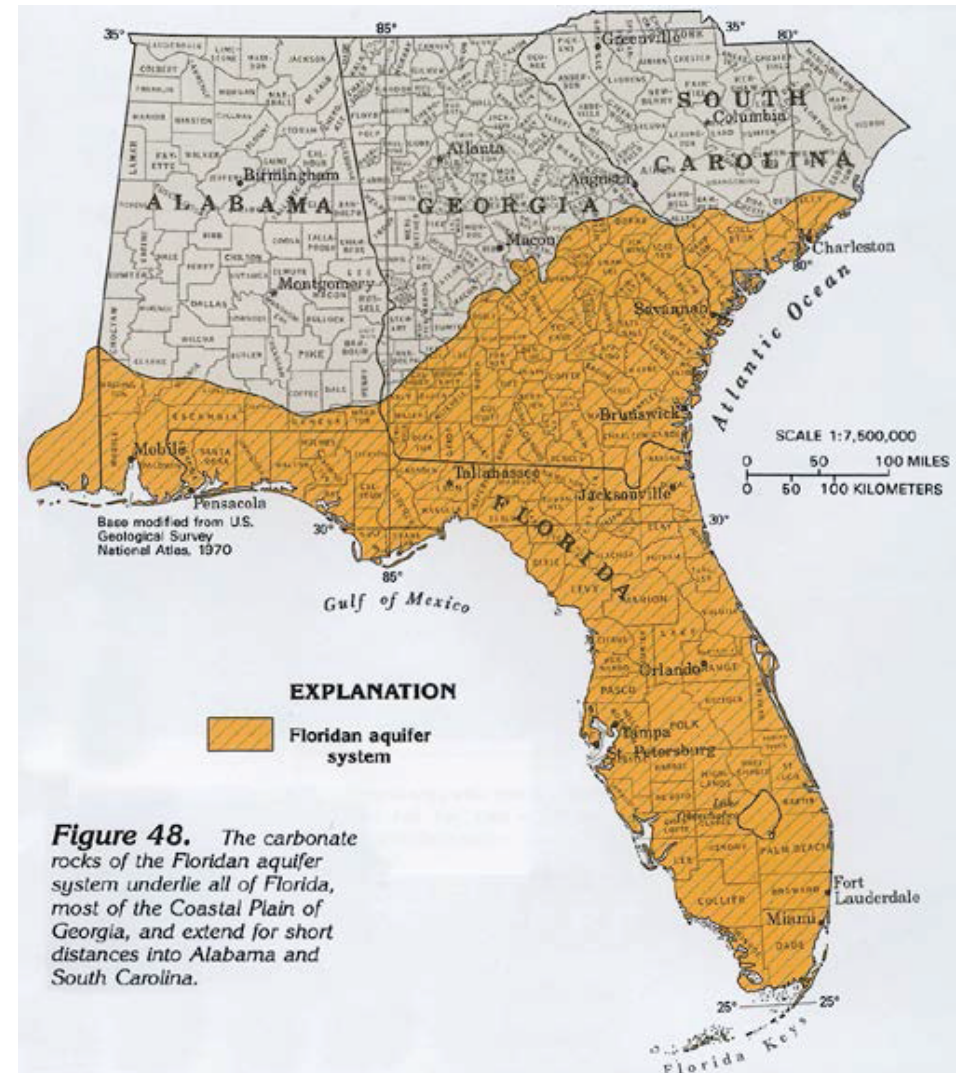


Source: Miller (1990)

Regional Hydrostratigraphic Units

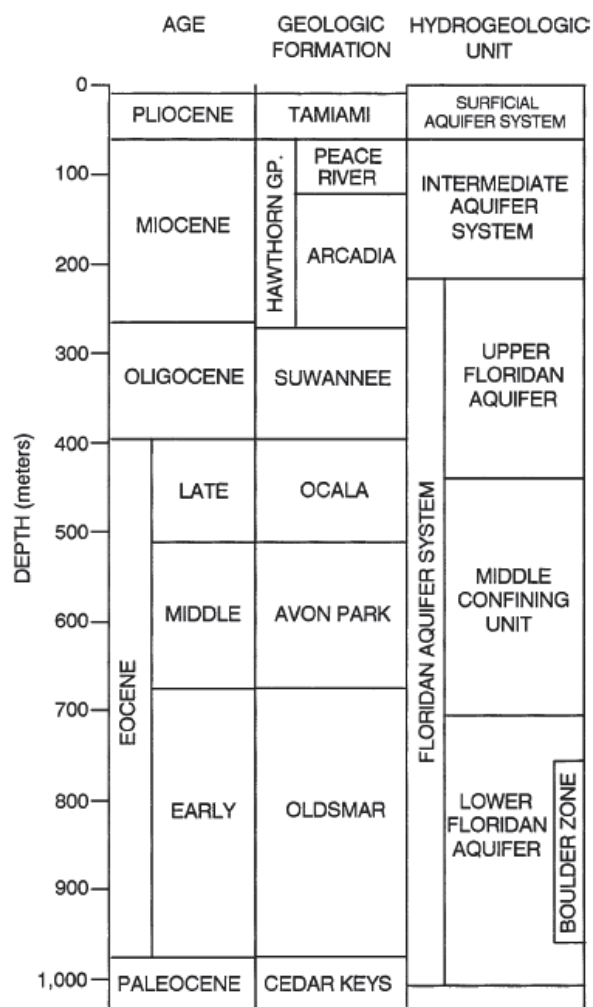
Floridan Aquifer System

- “Vertically continuous sequence of interbedded carbonate rocks of Tertiary age that are hydraulically interconnected by varying degrees and with permeabilities several orders of magnitude greater than the hydrogeologic systems above and below.”
- Comprised of shallow-water limestone and dolomite beds
- 2300 to 2400 ft thick in southern Florida
- Brackish to marine water quality



Source: Miller (1990)

Floridan Aquifer System



Upper Floridan Aquifer

- Porous limestones / dolomites
- 100 to 400 ft in thickness
- Transmissivities of 10,000 to 60,000 ft²/d
- Brackish water quality

Middle Confining Unit

- Interbedded, low permeability dolomites and limestones
- About 900 ft thick in SE Dade County
- Vertical hydraulic conductivities of 10⁻⁷ to 10⁻¹ ft/d (10⁻¹⁰ to 10⁻² cm/s)

Lower Floridan Aquifer

- Permeable dolostones separated by less permeable limestones
- Up to 2000 ft in thickness
- Lower dolostone termed “Boulder Zone” and highly transmissive
- Marine water quality

Source: Maliva and Walker (1998)

Boulder Zone

Geology

- Intervals of cavernous and fractured dolomites in the Early Eocene Oldsmar Formation
- Occurs at a depth of about 2900 ft near site

Transmissivity

- 3,200,000 to 24,600,000 ft²/d

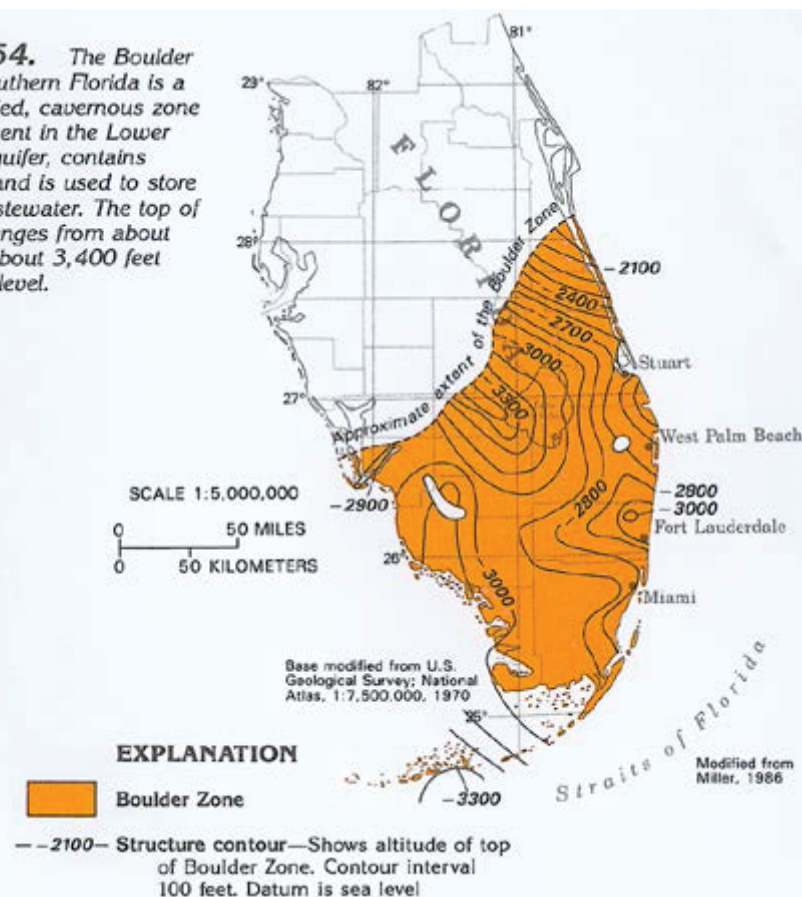
Water Quality

- Geochemically similar to modern seawater (35,000 mg/L TDS)
- Anomalous water temperature (nominally 50°F near coast)

Use

- Wastewater disposal by deep well injection
- Oil field brines, municipal and industrial wastewater

Figure 54. The Boulder Zone of southern Florida is a deeply buried, cavernous zone that is present in the Lower Floridan aquifer, contains saltwater, and is used to store treated wastewater. The top of the zone ranges from about 2,000 to about 3,400 feet below sea level.

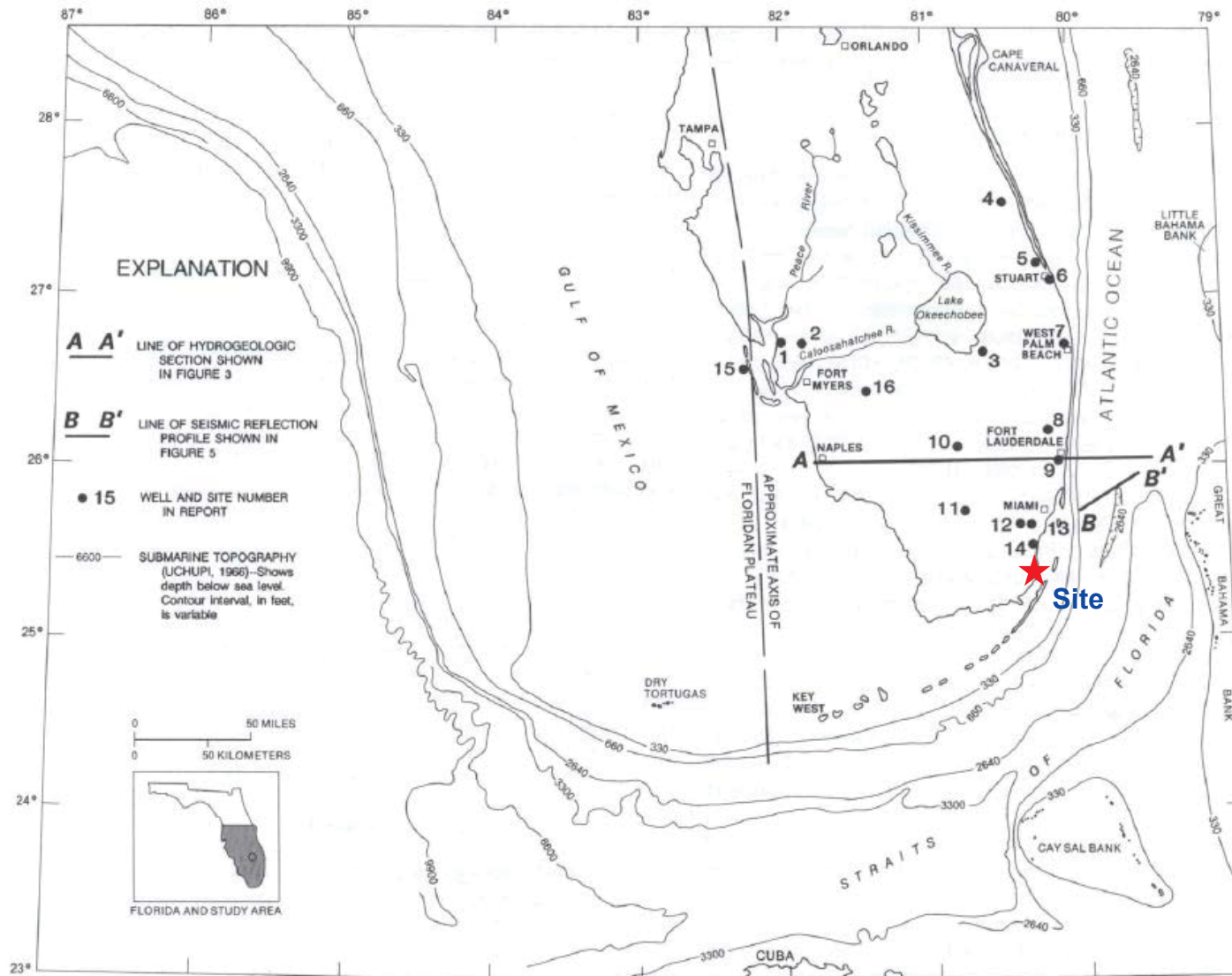


Source: Miller (1990)

Regional Groundwater Flow

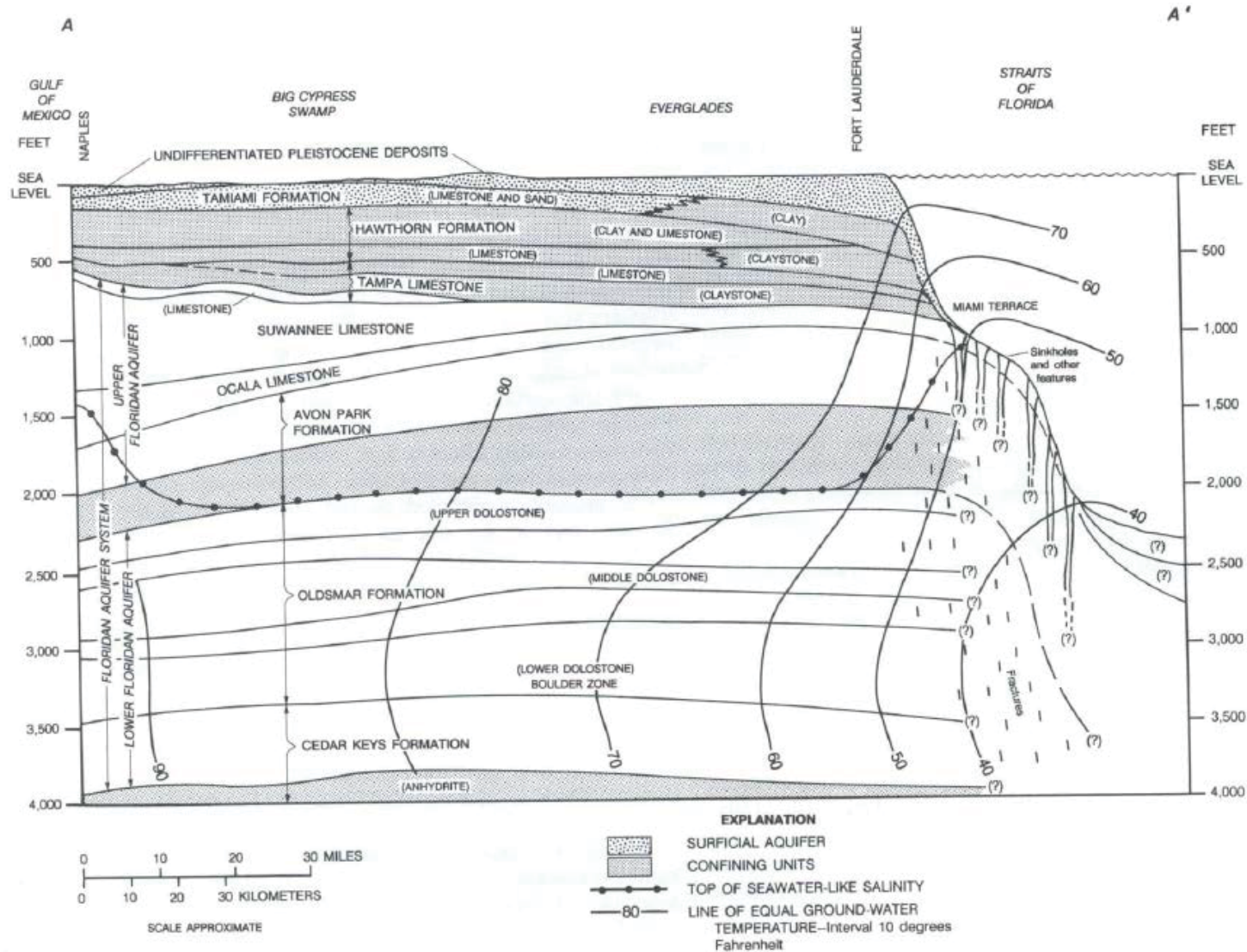
- **“Variations in water quality, hydraulic head, and water temperature within the carbonate rocks that make up the Floridan aquifer system in southern Florida suggest that the flow system is complex.” (Meyer, 1989)**
- **Regional flow in Boulder Zone difficult to assess due to:**
 - Limited number of hydraulic head observations
 - Very high transmissivities \Rightarrow very low hydraulic gradients
 - Transitory effects of tides (ocean and atmospheric)
- **USGS (Meyer, 1989) determined regional flow patterns from**
 - Temperature data
 - Water quality data
 - Groundwater age dating
 - Hydraulic head data

South Floridan Plateau



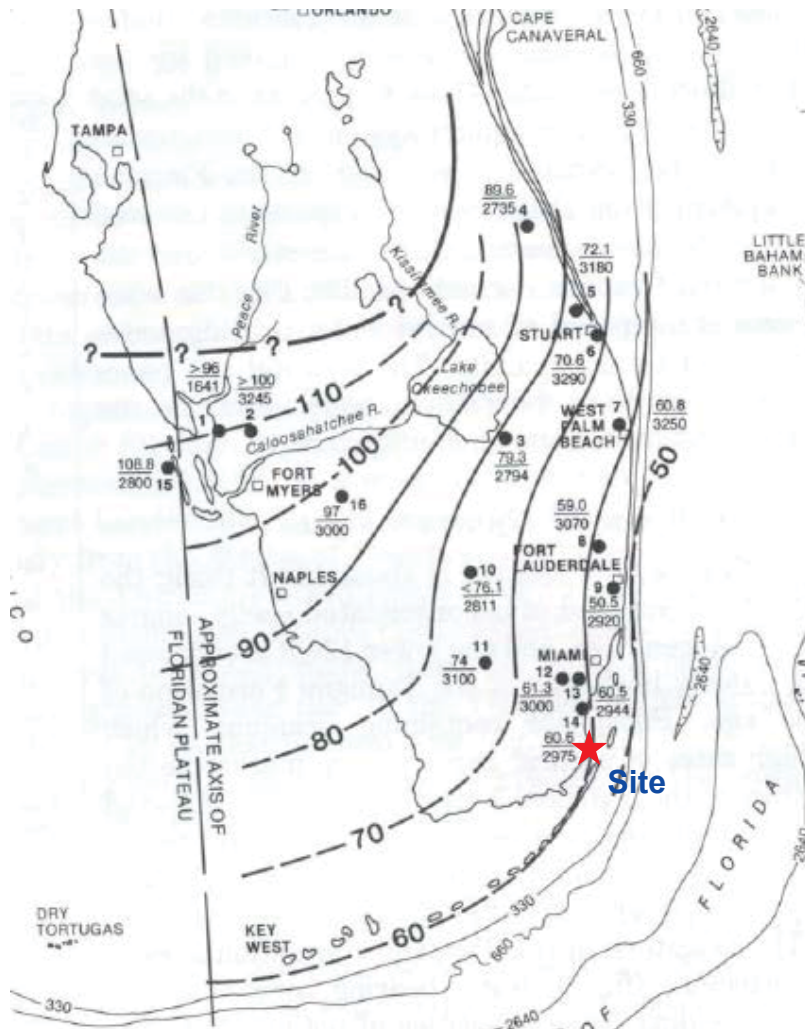
Source: Meyer (1989)

Generalized Hydrogeologic Section

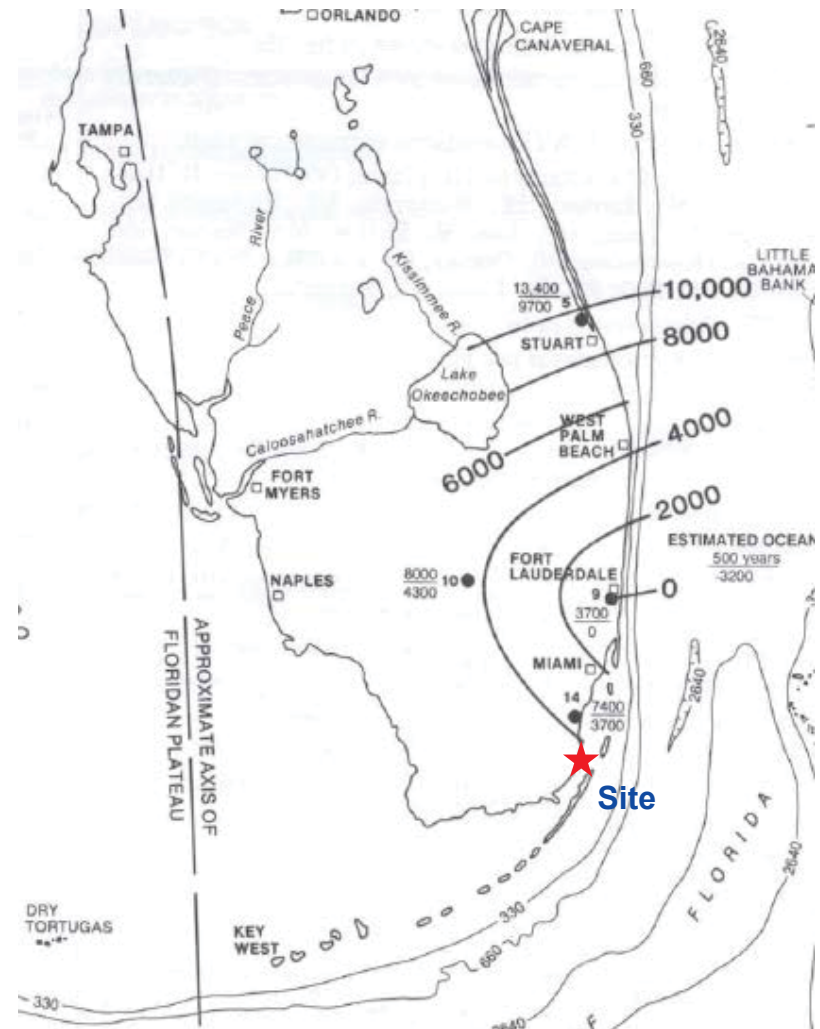


Source: Meyer (1989)

Groundwater Temperature (°F)

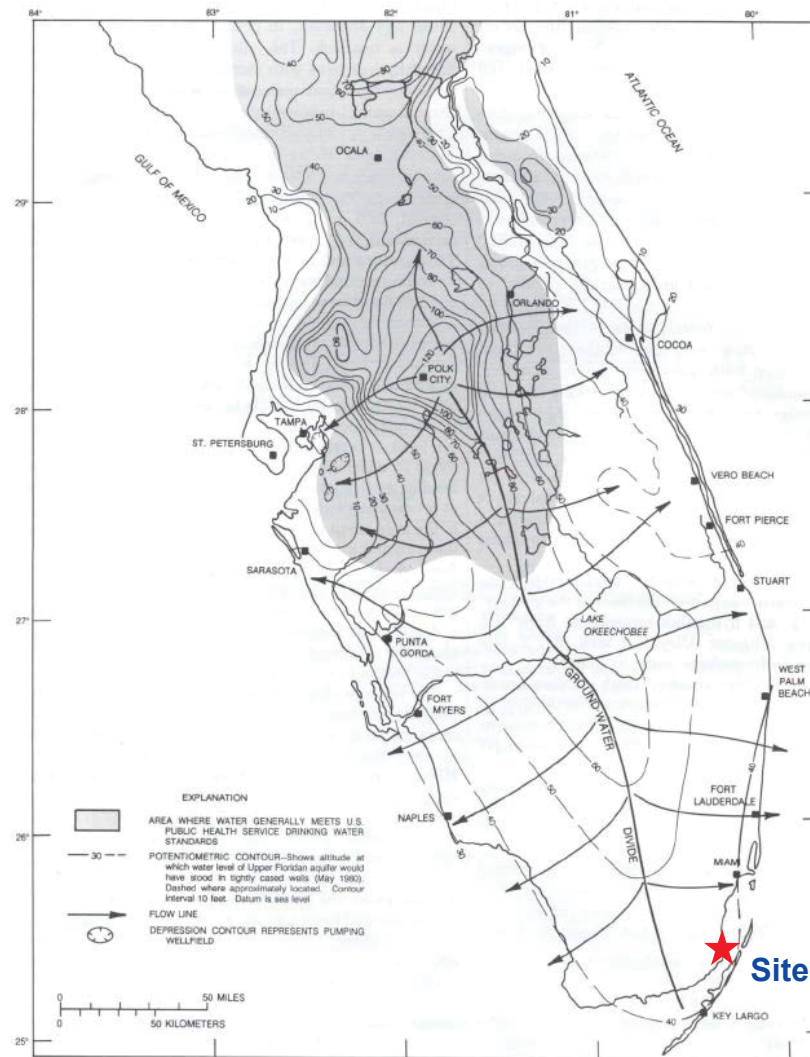


Relative Age (y) in Boulder Zone



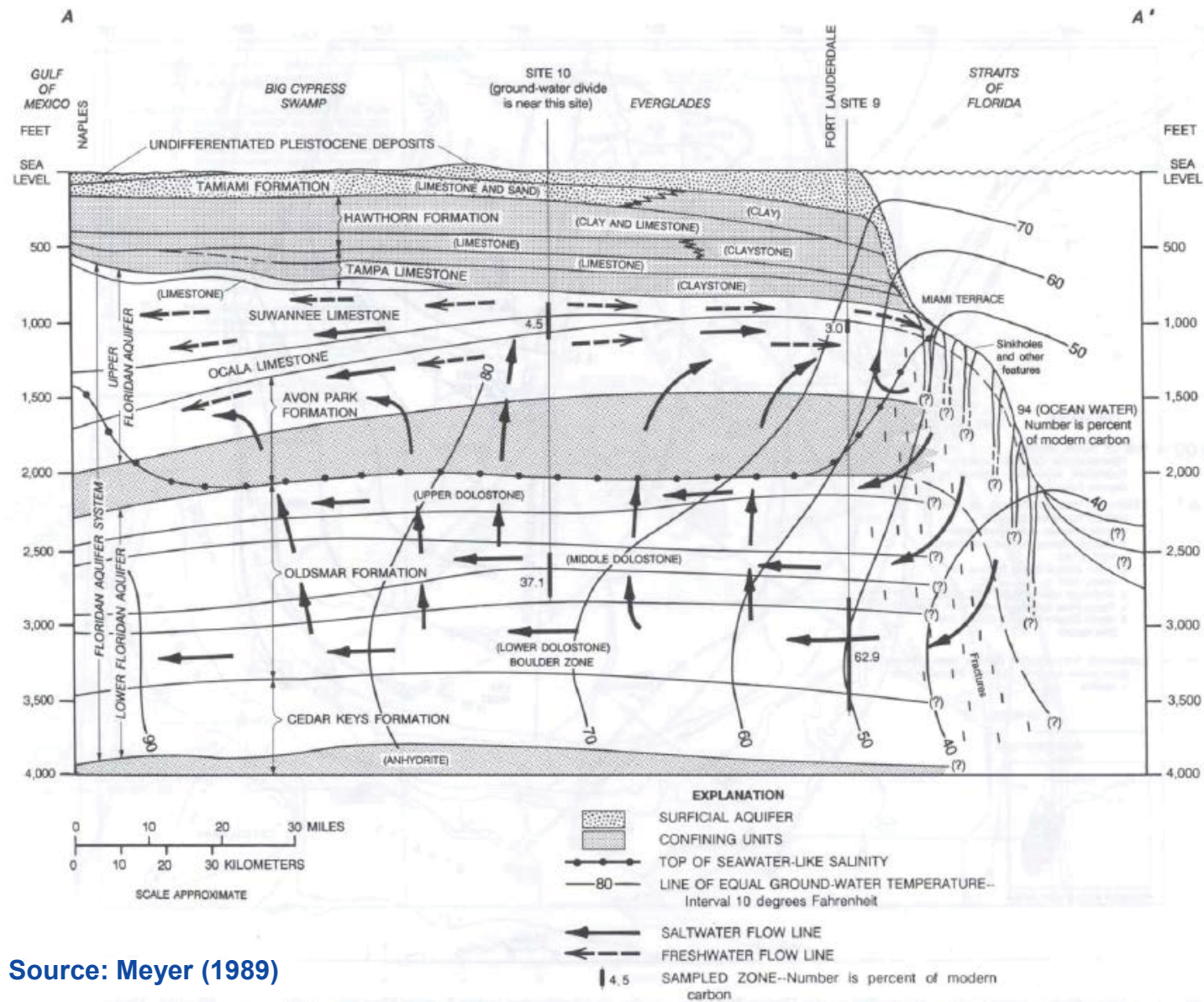
Source: Meyer (1989)

Potentiometric Surface Upper Floridan Aquifer



Source: Meyer (1989)

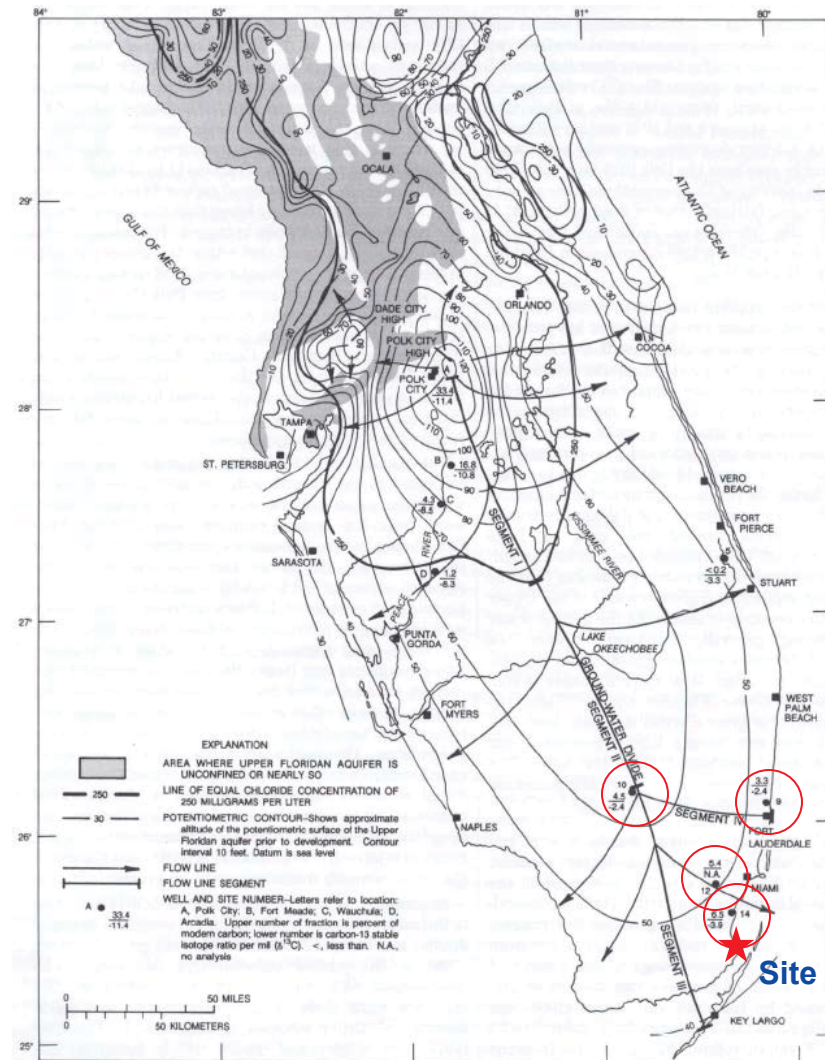
Regional Groundwater Circulation



Source: Meyer (1989)

Time Scales for Groundwater Circulation

- Measureable C-14 activity in Upper Floridan aquifer suggests source younger than 40,000 years
- Transit times from aquifer recharge areas >> 40,000 years
- C-14 attributed to upwelling from Lower Floridan aquifer
- Percent Modern Carbon (PMC) in Upper Floridan aquifer
 - $3.3\% \leq \text{PMC} \leq 6.5\%$
- Apparent age (before 1950)
 - $\text{Age} = -8033 \ln (\text{PMC} \times 10^{-2})$
 - $22,000 \text{ y} \leq \text{Age} \leq 27,000 \text{ y}$



Source: Meyer (1989)



Injectate Characteristics

- **Injection Rates**

- Cooling tower blowdown
 - 12,500 gpm for reclaimed water source (COC = 4)
 - 58,000 gpm for marine water source (COC = 1.5)
- Normal plant releases
 - 3 gpm

- **Physical Characteristics**

- Reclaimed water source
 - Salinity = $4 \times 1,000 \text{ mg/l} = \sim 4,000 \text{ mg/L TDS}$
 - Temperature = $92^{\circ}\text{F} = 33.2^{\circ}\text{C}$
 - Density = 997.607 kg/m^3
- Marine water source
 - Salinity = $1.5 \times 35,000 \text{ mg/l} = \sim 52,500 \text{ mg/l TDS}$
 - Temperature = $92^{\circ}\text{F} = 33.2^{\circ}\text{C}$
 - Density = 1033.721 kg/m^3

Injectate Characteristics

- **Ambient Boulder Zone Water**

Salinity = 35,000 mg/l TDS

Temperature = 60°F = 15.6°C

Density = 1025.866 kg/m³

- **Density Differences**

- Reclaimed water source

- Injectate (997.607 kg/m³) < groundwater (1025.866 kg/m³)

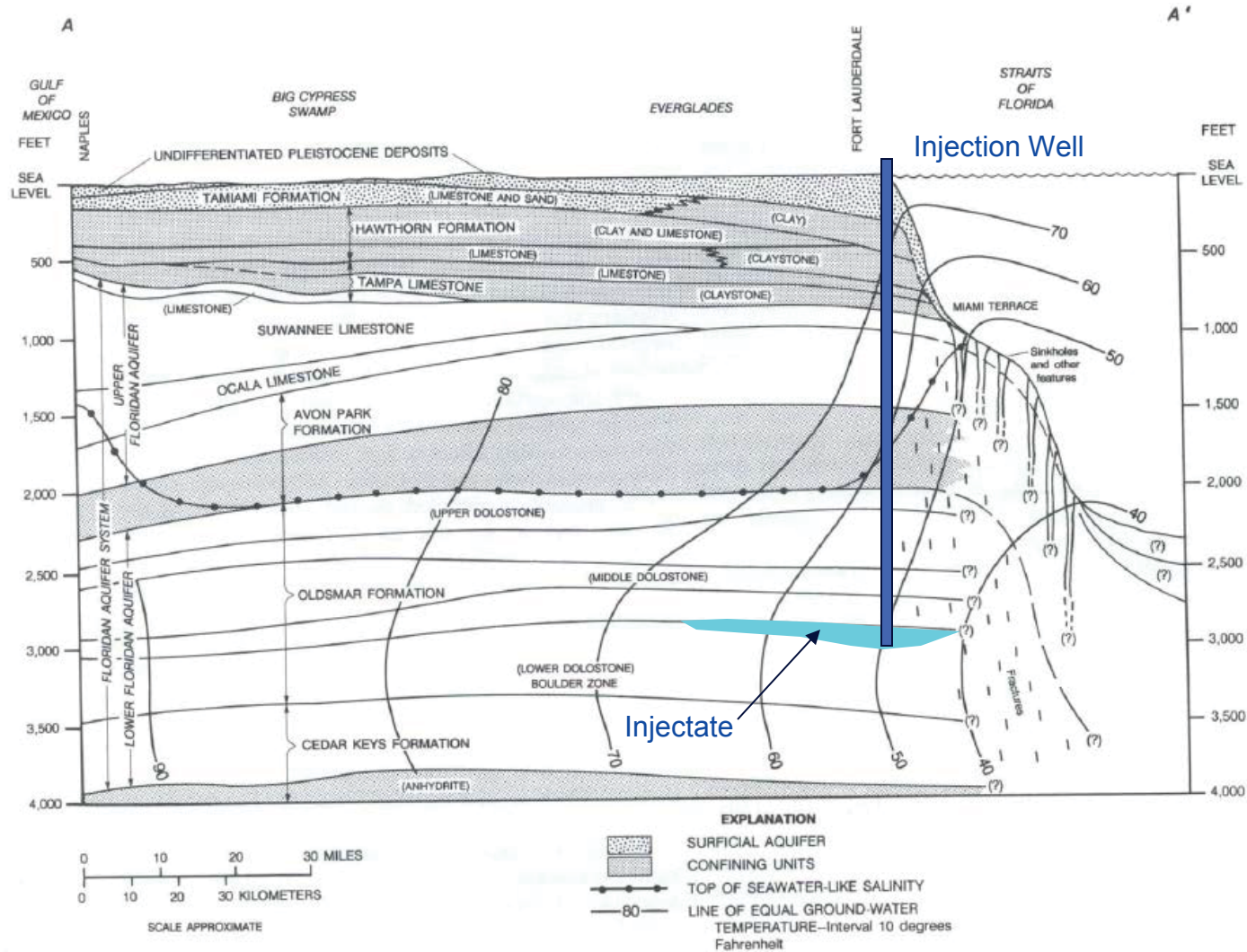
- Positively buoyant

- Marine water source

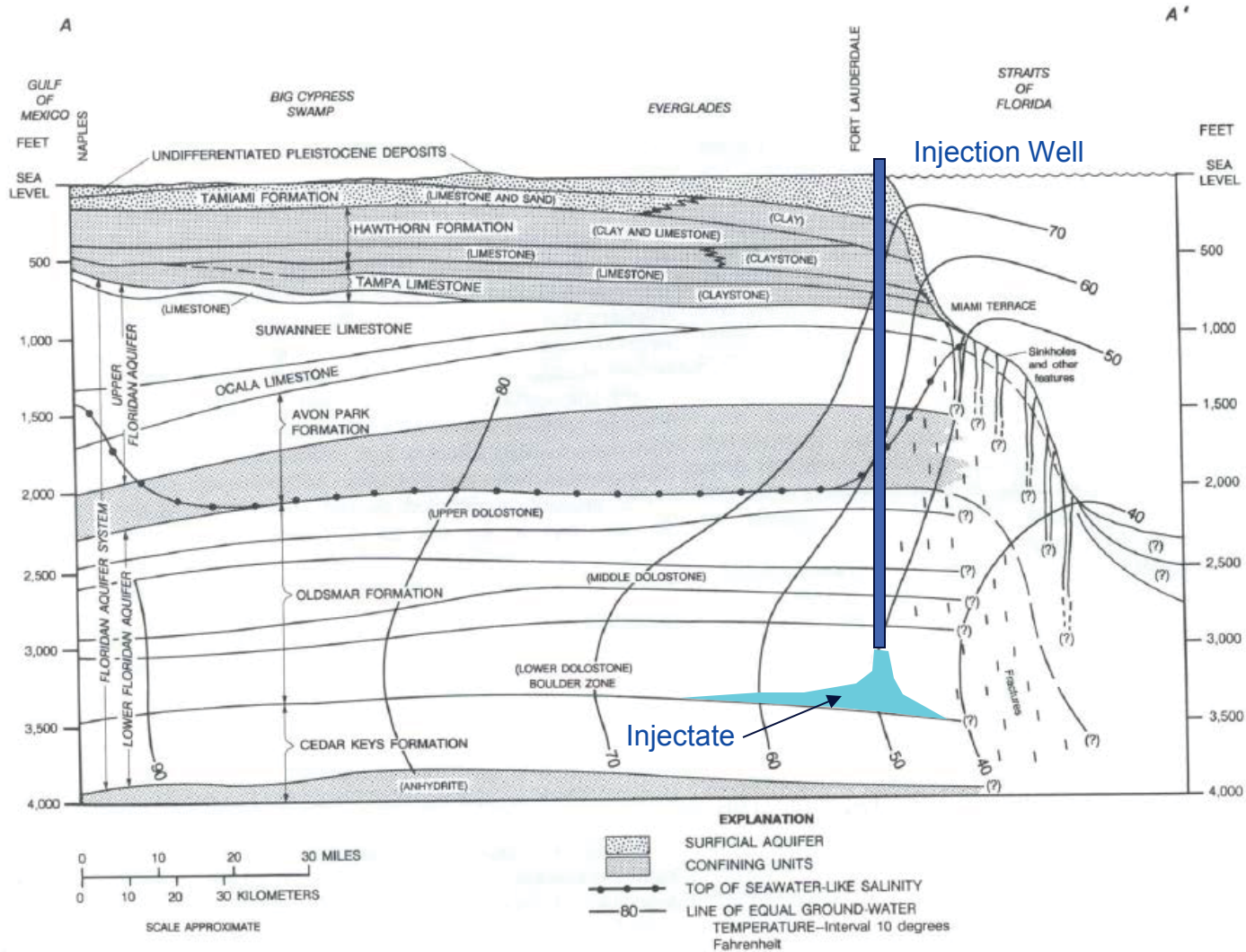
- Injectate (1033.721 kg/m³) > groundwater (1025.866 kg/m³)

- Negatively buoyant

Injectate Transport – Reclaimed Water Source



Injectate Transport – Marine Water Source



Postulated Injectate Fate and Transport

- **Initial spreading of injectate “bubble” governed by buoyancy-driven flow and geologic structure**
- **Dissolution of injectate into ambient groundwater with subsequent advective transport along ambient groundwater pathways and attenuation due to:**
 - Hydrodynamic dispersion
 - Retardation
 - Radioactive decay
- **Plausible groundwater pathways could:**
 - Be confined to the saline, Lower Floridan aquifer
 - No potential exposure
 - Include upwelling to the brackish, Upper Floridan aquifer
 - Travel times > 10,000 y