



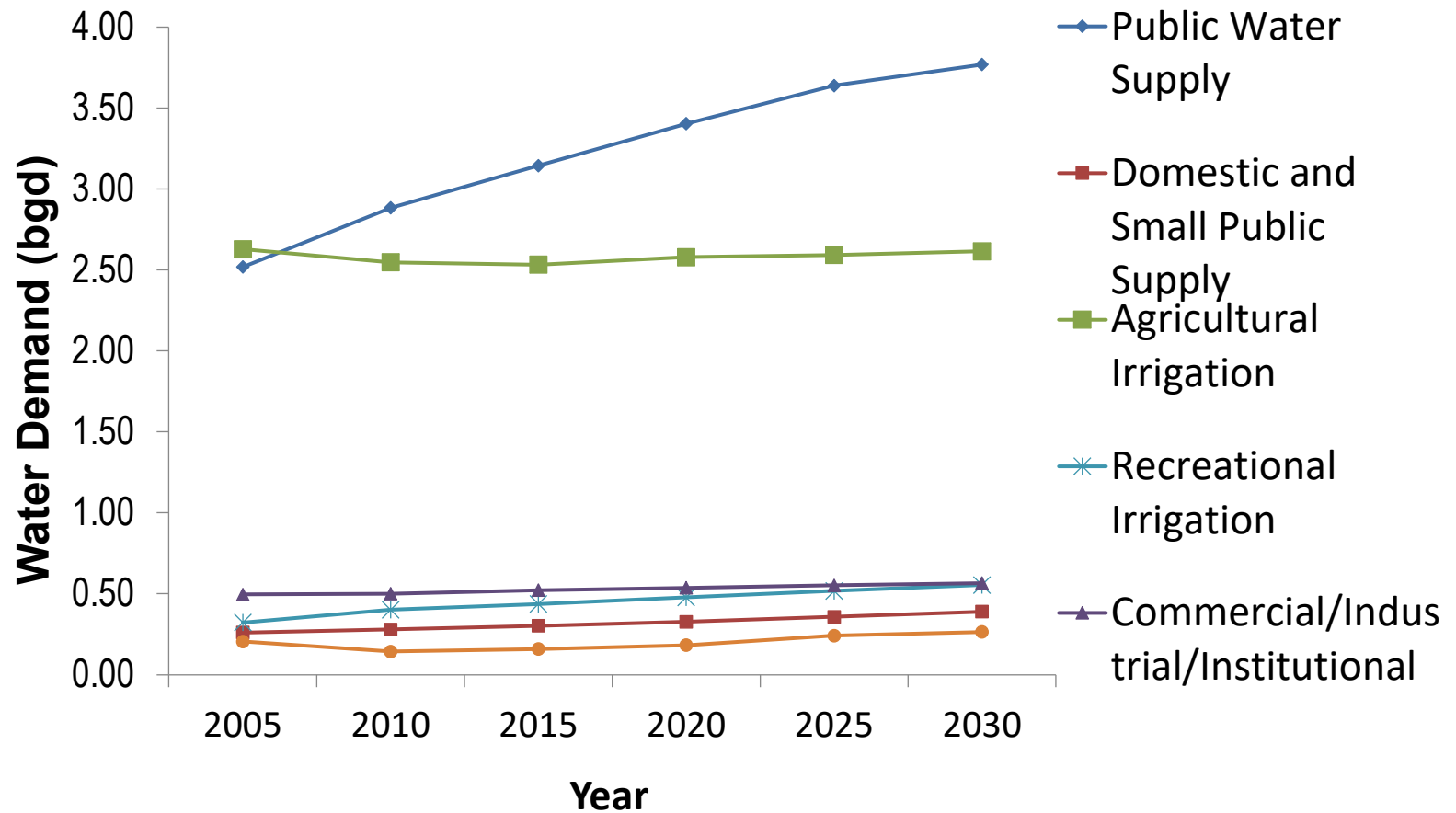
Aquifer Storage and Recovery & Aquifer Recharge in Florida

August 2020

**Division of Water Resource Management
Aquifer Protection Program**



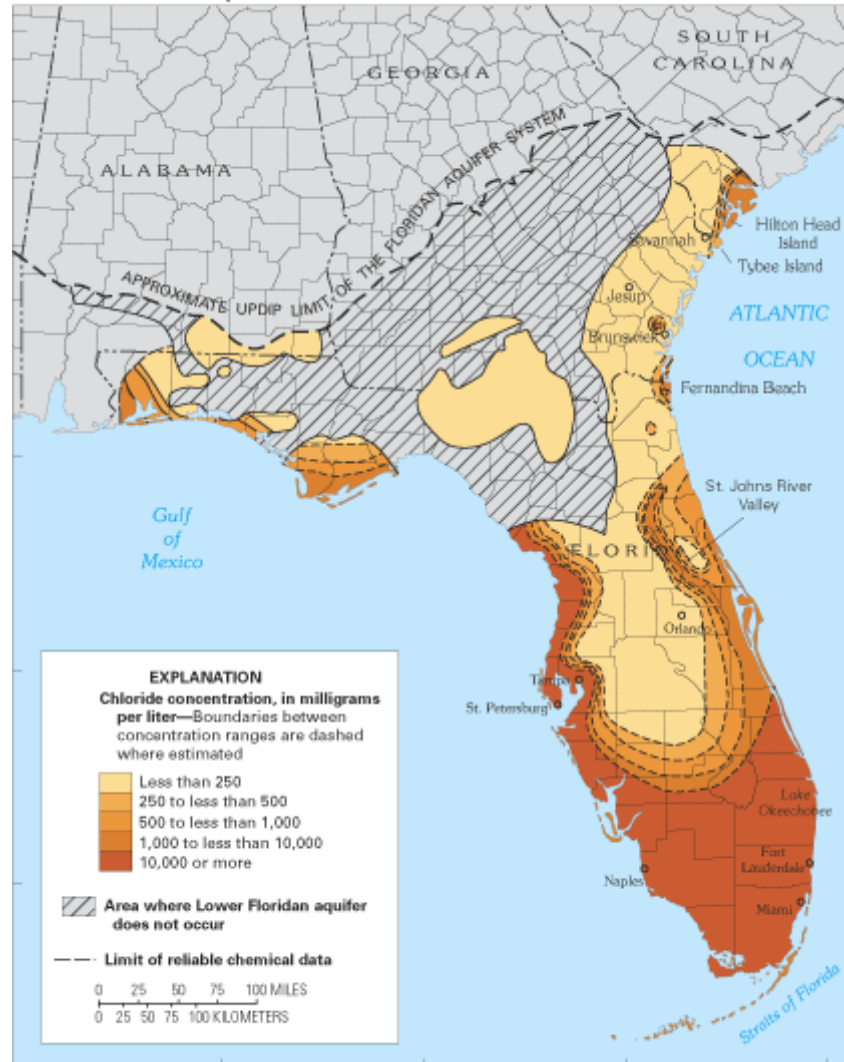
Florida Fresh Water Demand and Use





Floridan Aquifer Salinity

B. Lower Floridan Aquifer

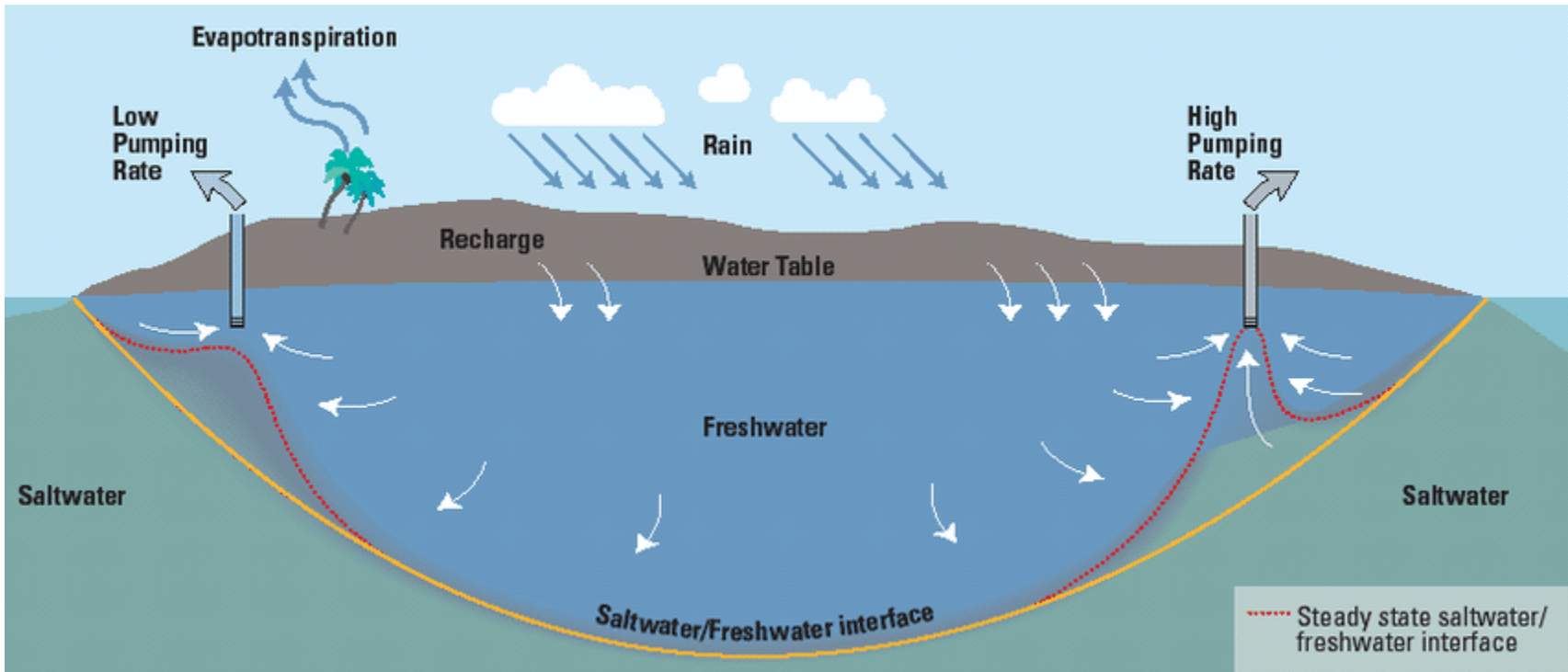


Modified from Sprinkle (1989)



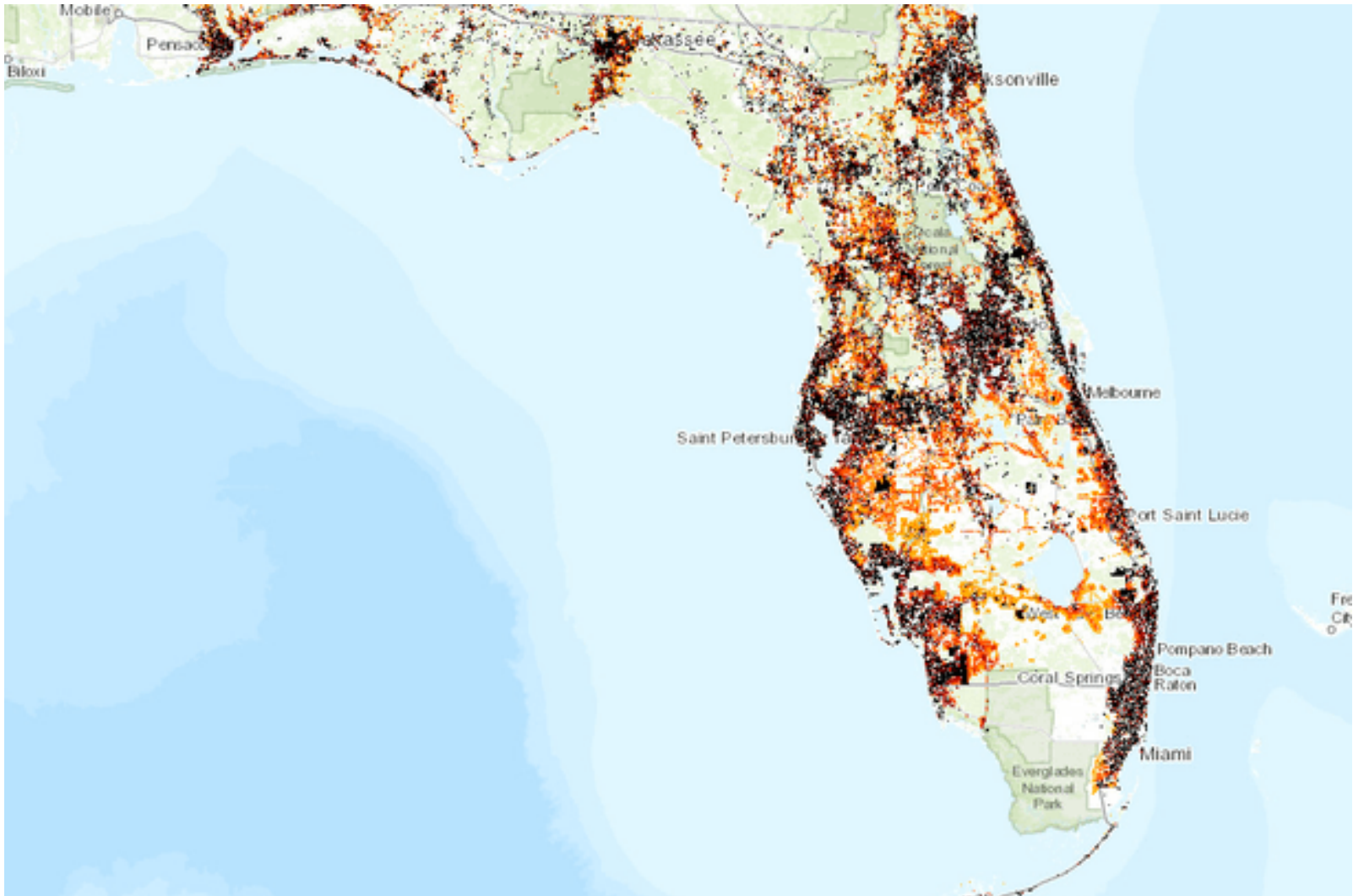
Peninsular Florida

General setting





Florida Population





Groundwater Use Restrictions

- **Water management districts (WMDs) regulate the use of water in Florida**
- **WMDs have restricted new water use permits as well as increased pumpage under existing permits**
- **To meet water needs for the future, non-traditional projects to store or reuse water are being implemented**



Florida Hydrogeology

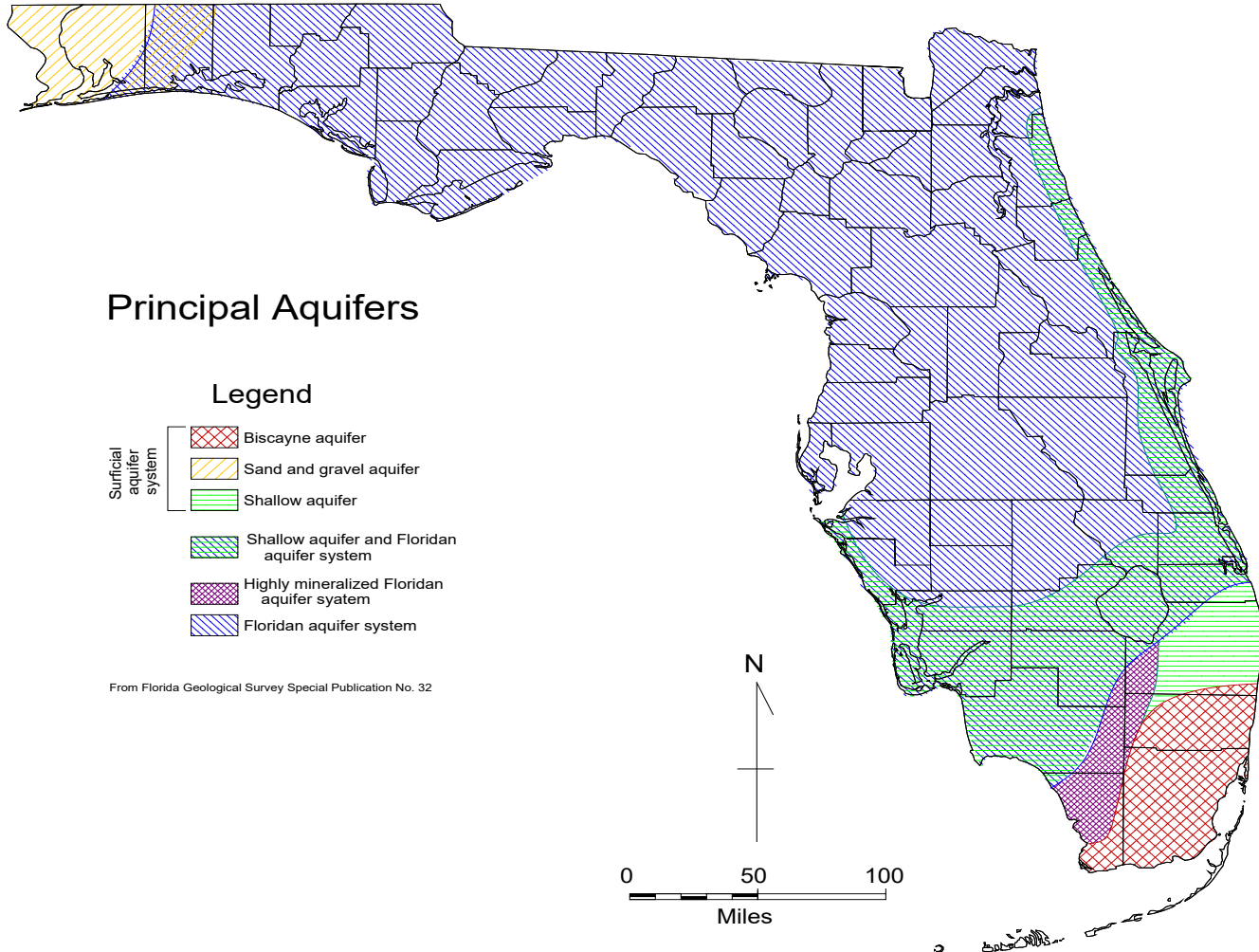
Tertiary stratigraphy

		UNIT	UNIT
Miocene		Hawthorn Group	Upper Confining Aquifer
Lower Oligocene		Suwannee Limestone	Upper Floridan Aquifer
Eocene	Late	Ocala Limestone	
	Middle	Avon Park Formation	Middle Confining Unit
	Early	Oldsmar Formation	Lower Floridan Aquifer
Paleocene		Cedar Keys	Lower Confining



Florida Hydrogeology

Aquifers



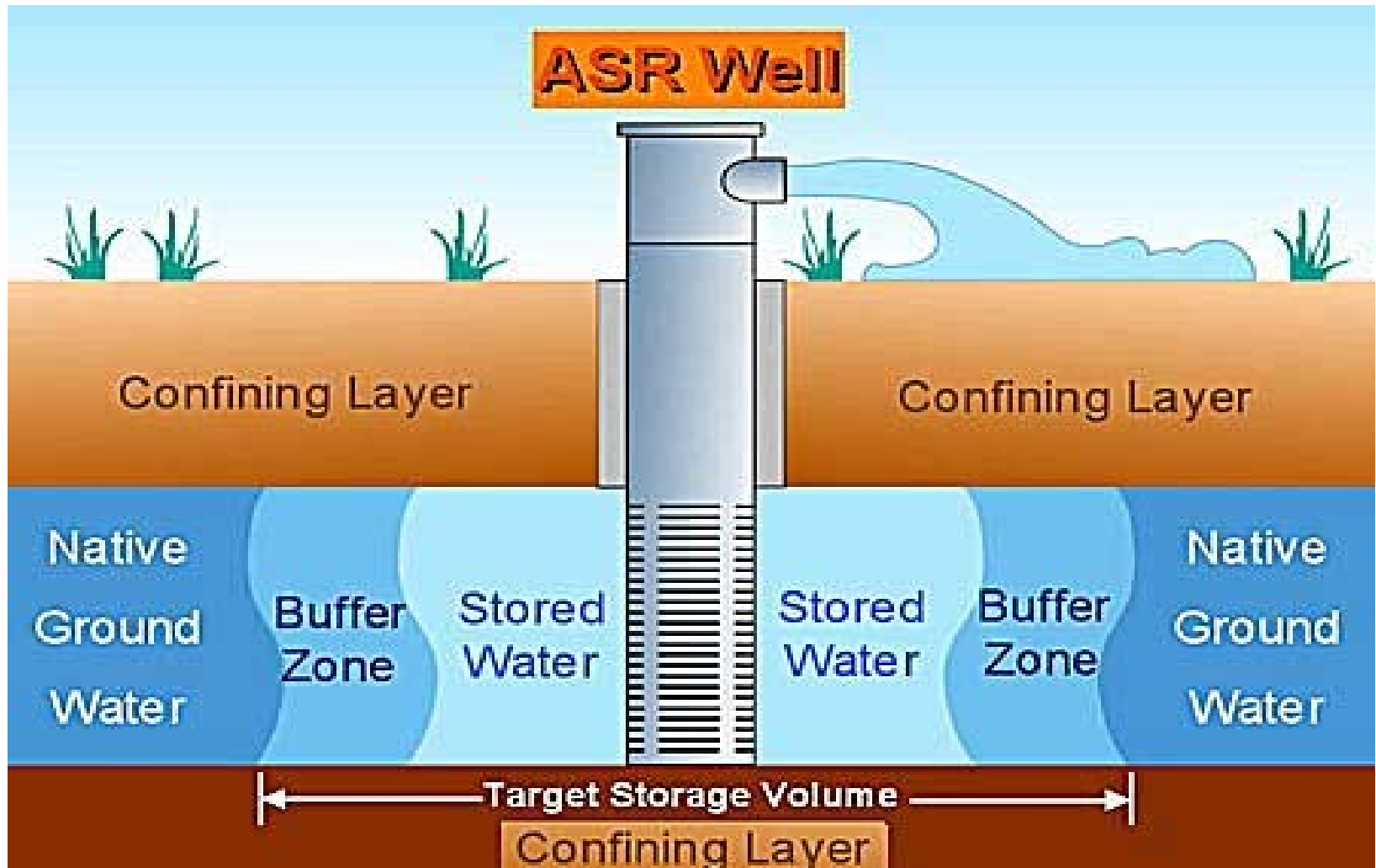


What is Aquifer Storage and Recovery (ASR)?

- **ASR uses an aquifer for underground storage, recovering water as needed in the future**
- **ASR generally stores and recovers the same water**
- **ASR wellfields may include one or multiple wells**



ASR Well in Subsurface





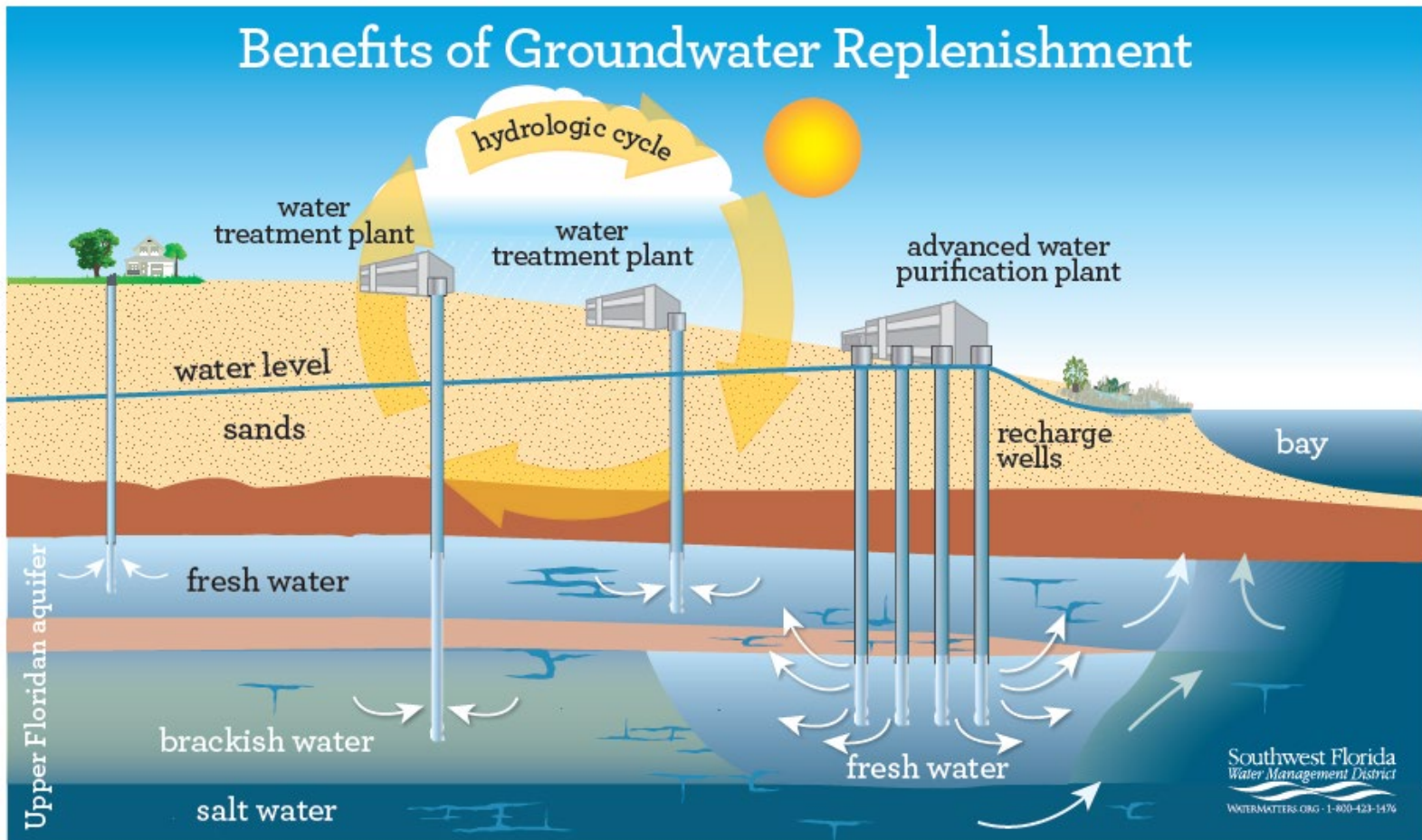
What is Aquifer Recharge?

- **Aquifer recharge using wells is a method of replenishing an aquifer that is impaired due to overuse or water quality deterioration**
- **Aquifer recharge generally does not involve the recovery of recharged water**
- **Recharge wellfields may include one or multiple wells**



Aquifer Recharge

City of Clearwater

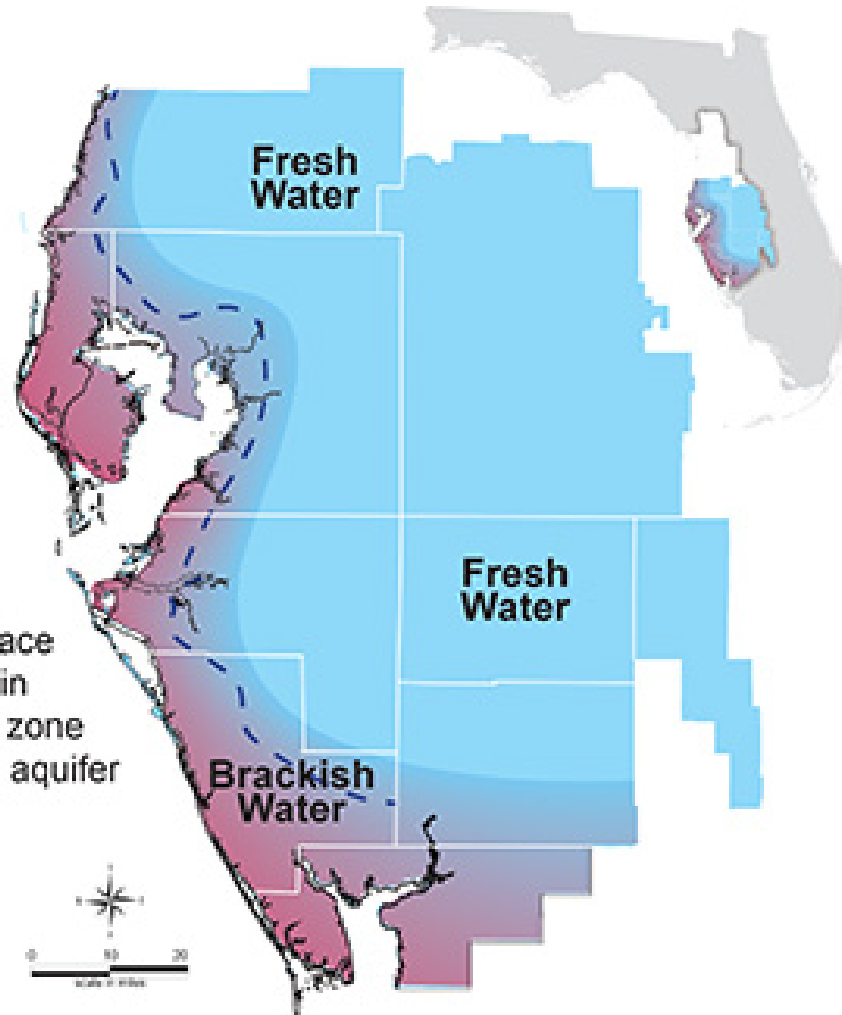




SW Florida Saltwater Intrusion

Brackish Groundwater Resources

- - Approximate location of the saltwater interface (1,000 mg/l chloride) in the high-permeability zone of the Upper Floridan aquifer





ASR Topics

- **Purposes of ASR**
- **How ASR works**
- **Regulatory aspects**
- **Types of fluids stored**
- **Potential problems**
 - **Water quality**



ASR Topics – 2

- **Cycle testing**
- **Monitoring**
- **Interpretation of ASR data**
- **What makes for a successful project?**



Purposes of ASR in Florida

- **Store water in subsurface for future use**
- **Extend/augment existing freshwater supplies**
- **Reduce use of groundwater and the number of new wells**
- **Drought protection**

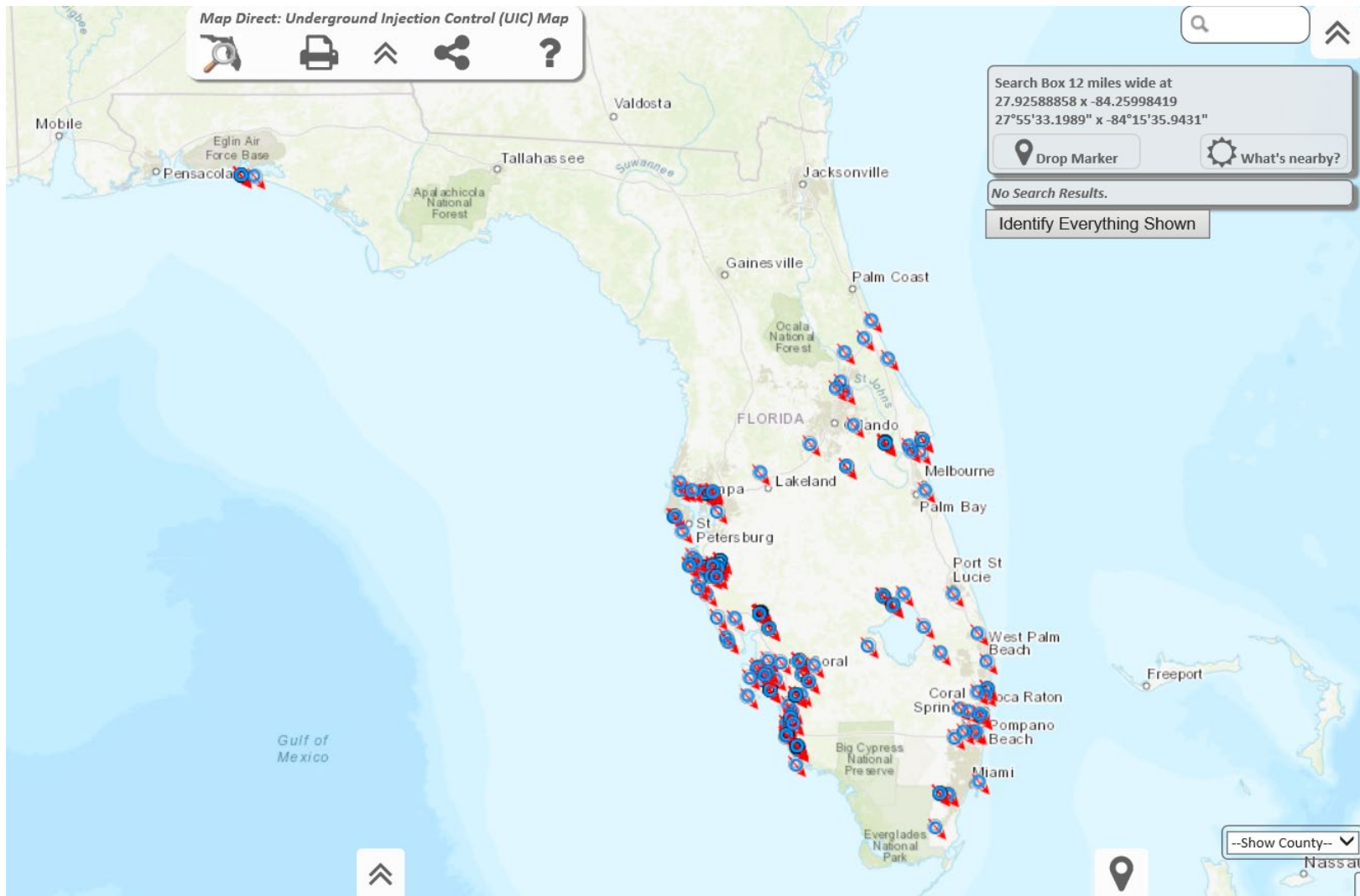


Drought Protection



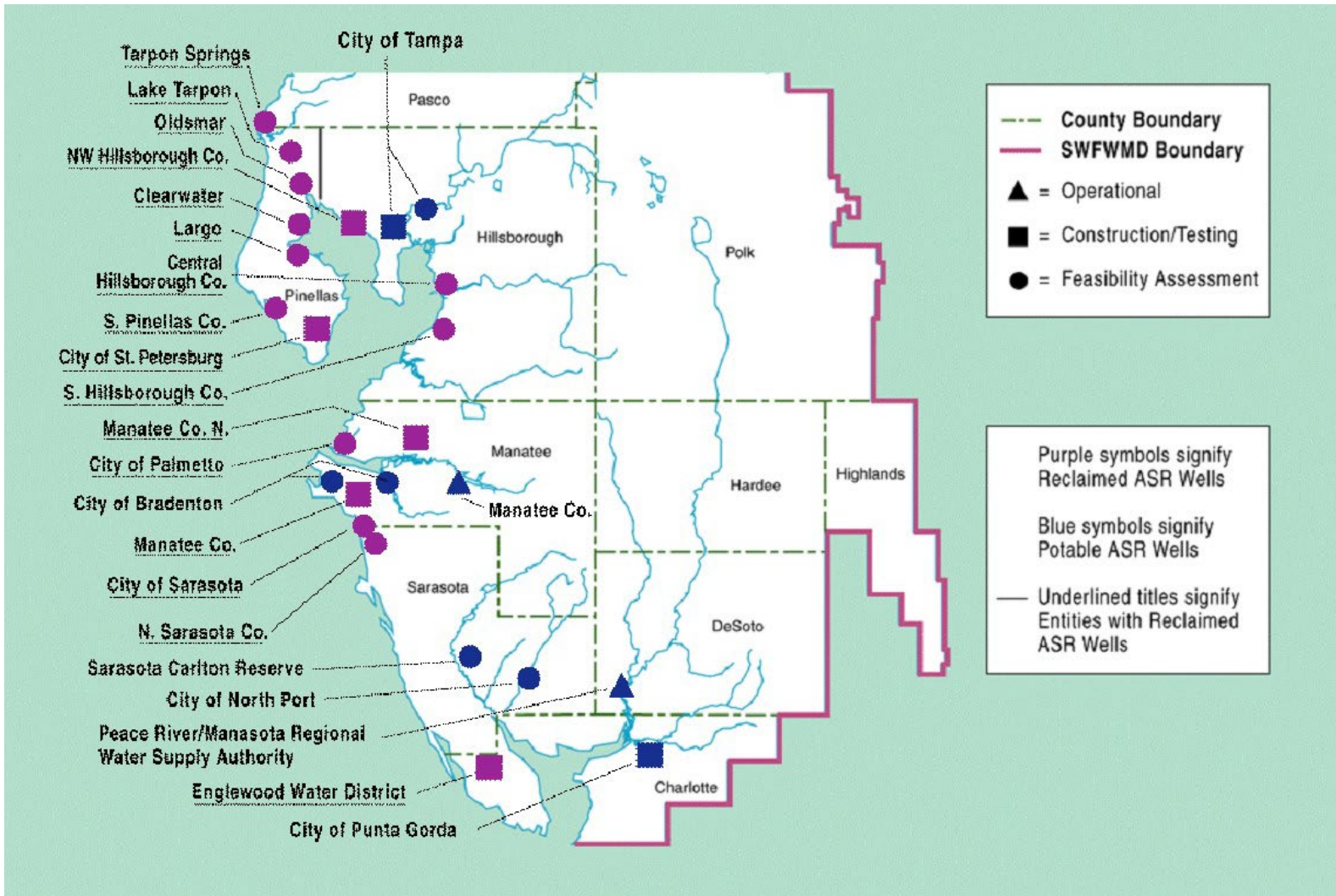


ASR Project Locations



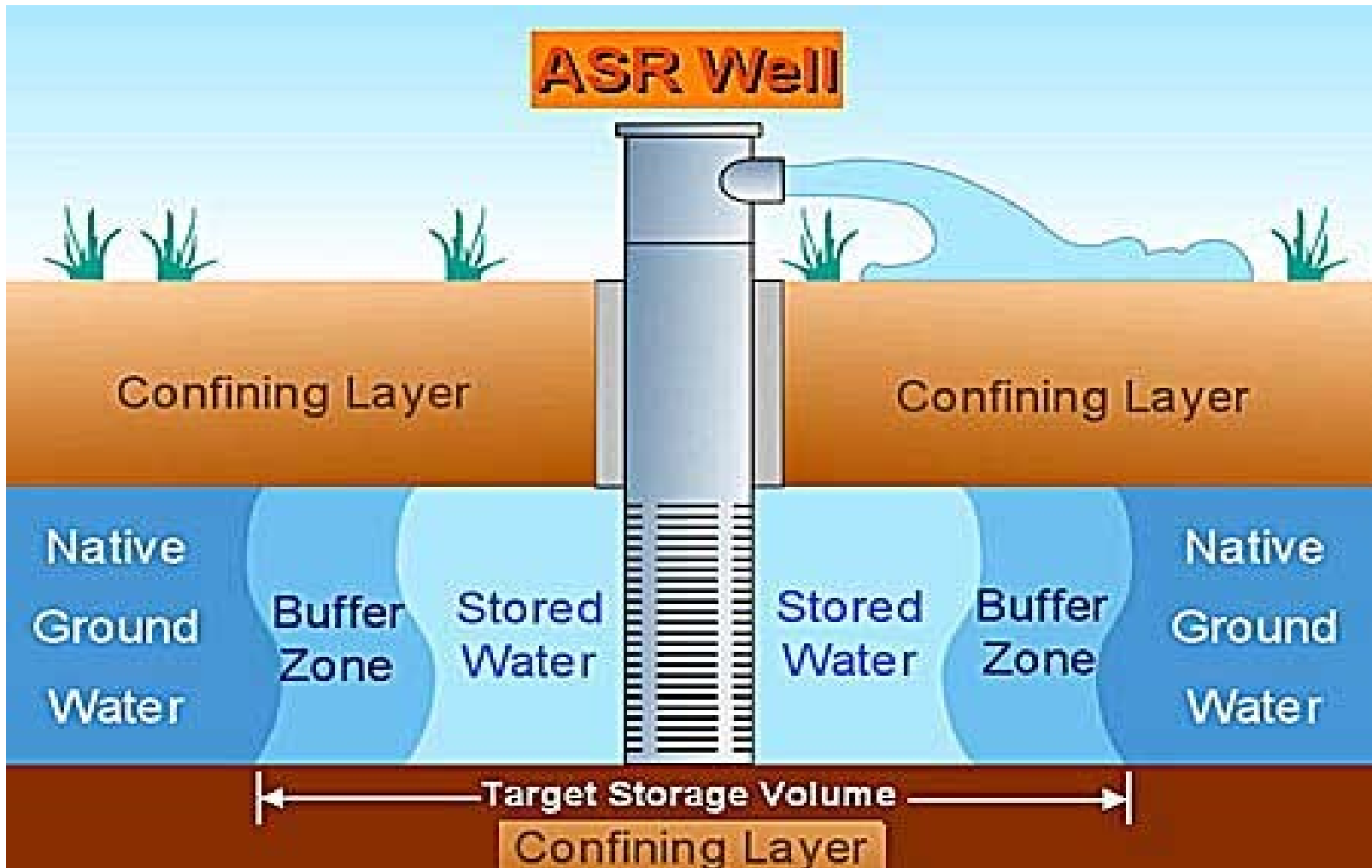


ASR Wells in the SWFMD



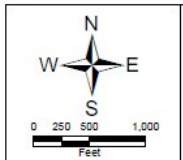
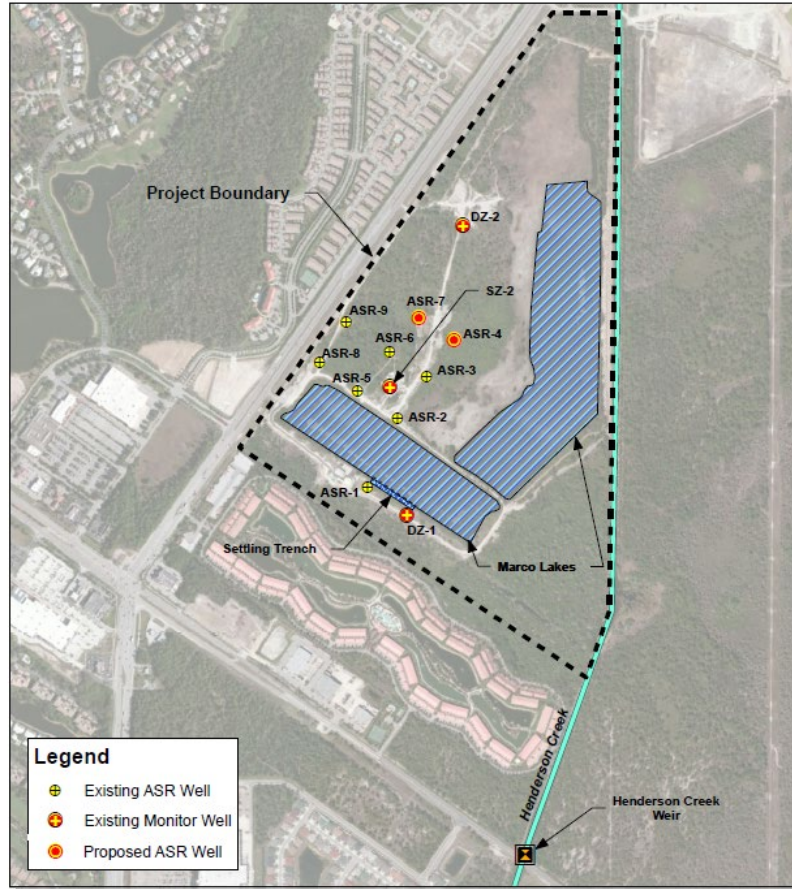


How ASR Works





Marco Lakes ASR



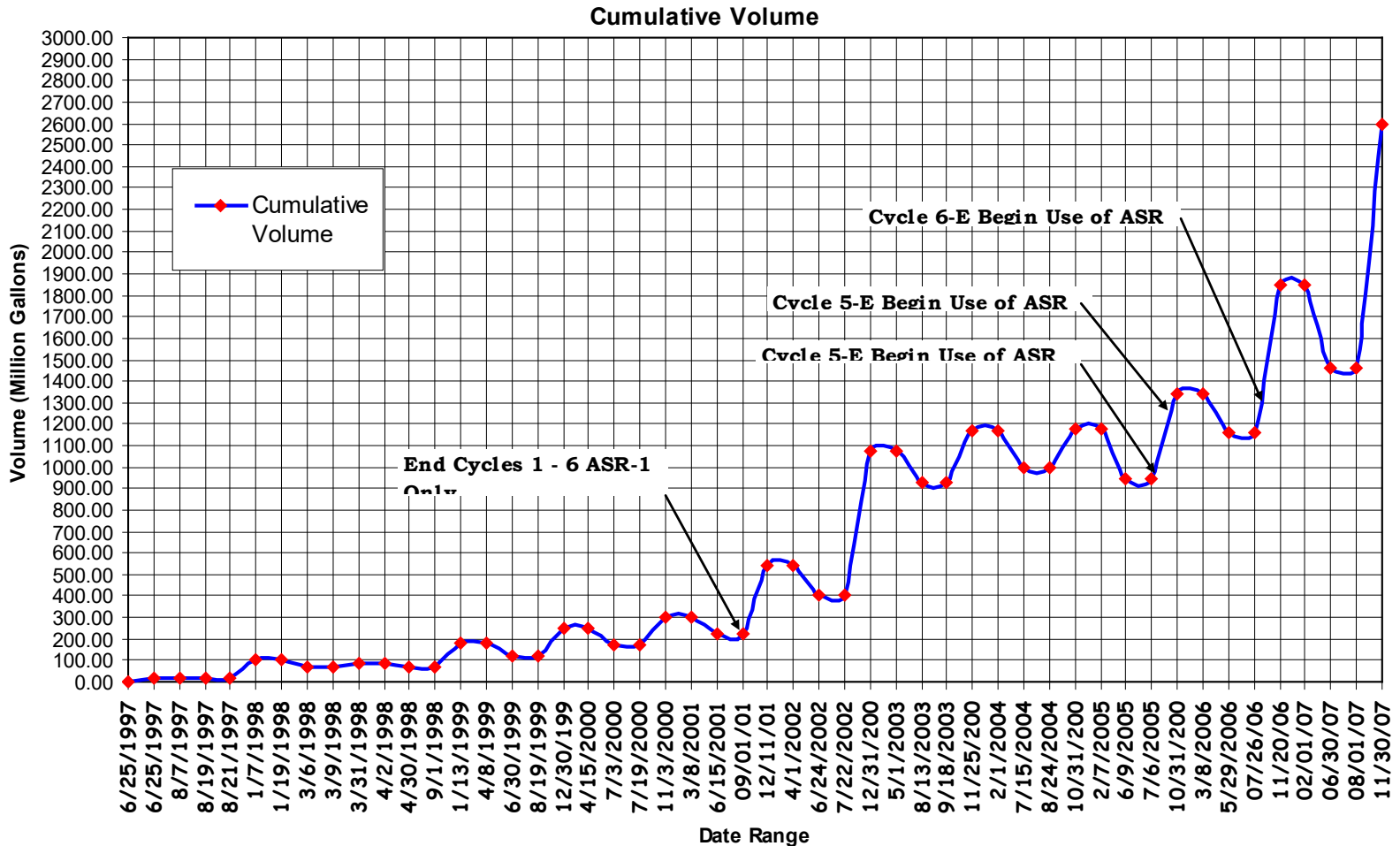
Pertinent Features of the Project Site
 City of Marco Island: Marco Lakes ASR

Project #: 1510614100
 Drawn By: JWE | Date: 03/11/15
Figure 1-2



Water In, Water Out

Marco Lakes ASR, Collier County





Class V Injection Wells

Permitting

- **ASR and aquifer recharge wells are Class V injection wells**
- **All Class V wells first used after April 1, 1982 require UIC permits**
- **UIC rule can require up to Class I standards for well construction and operation**



Other DEP Rules

- **62-520 – Groundwater**
- **62-532 – Water Well Construction**
- **62-550 – Drinking Water**
- **62-600, 601 – Domestic Wastewater**
- **62-610 – Reuse of Reclaimed Water**



Groundwater Quality

Classification of Groundwater G-II

Rule 62-520.410

Class G-II

- **Potable water use, groundwater in aquifers with a total dissolved solids content of less than 10,000 mg/L, unless otherwise classified by the Commission**
- **Injection of fluid into G-II groundwater (USDW) must meet the primary and secondary drinking water standards**



ASR Fluids Stored

- **Drinking Water (potable)**
- **Reclaimed Water**
 - **Reclaimed water meets treatment requirements of Florida's reuse rule, Chapter 62-610, F.A.C.**
 - **Higher treatment levels if warranted or if desired by utility**



ASR Fluids Stored – 2

- **Groundwater**
- **Surface Water**
 - **May need treatment or other measures to protect groundwater**



Potable Water ASR

- **Potable water treated at a permitted water treatment plant**
- **Meets all drinking water standards for recharge**
- **Recovered water is sent back to WTP for re-treatment prior to distribution**
 - **Normally blended with non-ASR source water at WTP**



Reclaimed Water ASR

- **Reclaimed (reuse) water quality**
- **Meets most drinking water standards for UIC recharge, but some secondary standards may not be met without extra treatment**



Reclaimed Water ASR - 2

- **Florida domestic wastewater program has rules on the recharge of this water**
- **Recovered water used only for reuse supply**
- **Blended with other reclaimed water**



Groundwater ASR

- **Groundwater is the source water**
- **These ASR projects are for augmenting drinking water supplies in the dry season**
- **Meets most drinking water standards for UIC recharge, but some secondary standards may not be met without extra treatment (iron, color)**
- **Recovered water sent to WTP**



Surface Water ASR

- **Surface water is the source water**
- **Water quality more variable**
- **Treatment prior to injection is more likely to be needed**



ASR Projects

- **Large volume can be stored**
- **Little land area needed**
- **No evaporation losses**
- **Cost savings**
- **Contaminants may be introduced during injection**
- **Reactions may occur between injected fluid and aquifer material/formation fluids**



Addressing Exceedance of Drinking Water Standards

- **Point of Injection Treatment**
 - Treatment of the injectate to reduce concentrations may be feasible for some systems
- **Point of Recovery Treatment**
 - Treatment used to render waters with high TDS levels potable will reduce other concentrations
 - Treatment includes blending and re-treating at WTP



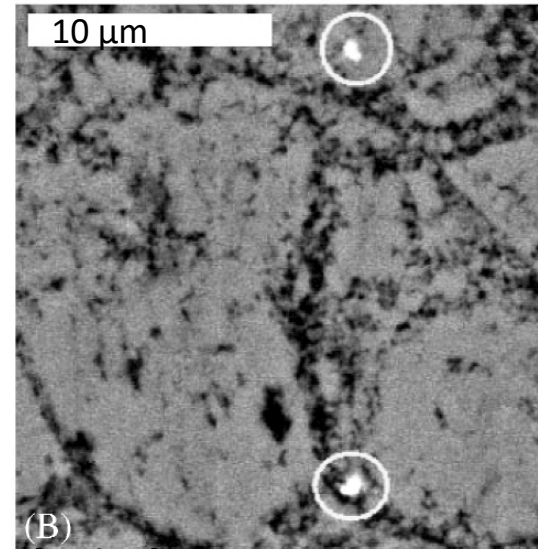
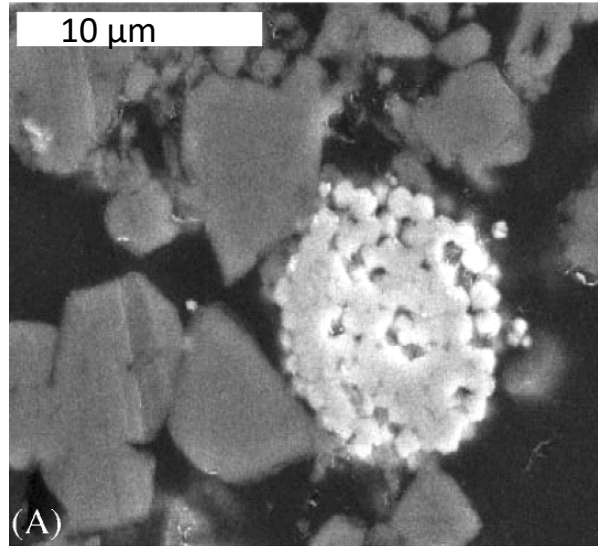
Pyrite Crystals

Source of Arsenic

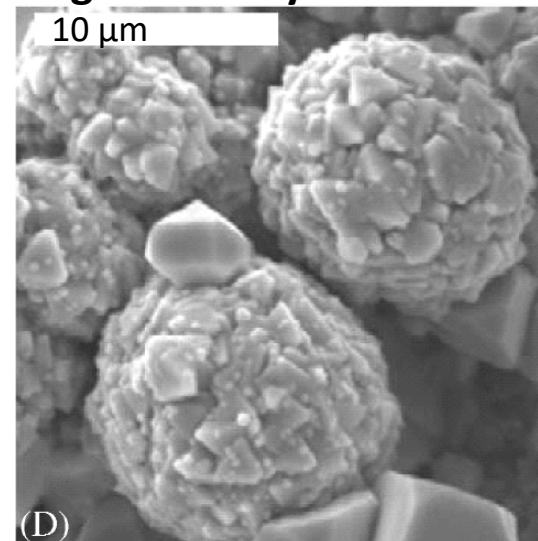
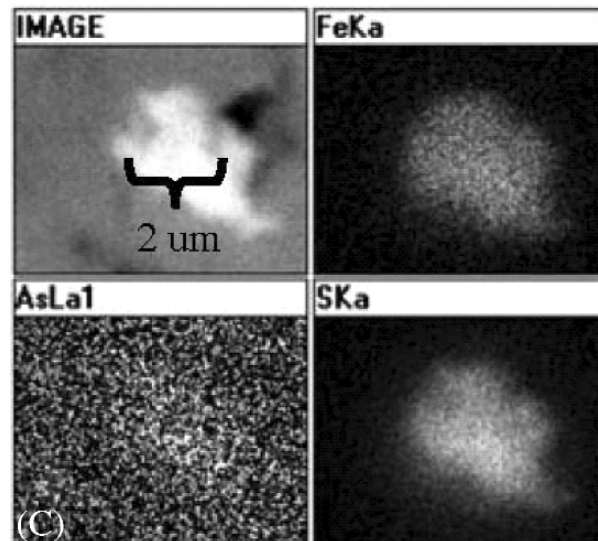




Pyrite Crystals - 2



Photos from FL Geological Survey





Treatment Prior to Injection

Arsenic Mobilization Reduction

- **Dissolved oxygen removal – Degasification**
 - **Membranes**
 - **Oxygen stripping towers**
- **Chemical treatment – Sodium bisulfide or sodium hydrosulfide**



Treatment Prior to Injection – 2

Disinfection

- **Chlorine or chloramine**
- **Disinfection byproduct considerations**
- **Alternative disinfection for surface water**
 - **Ultraviolet (UV) light; color and suspended solids considerations**
 - **Ozone**



Other Contaminants of Concern

- **Coliform bacteria (surface water)**
- **Disinfection byproducts (reclaimed water)**
 - **Total trihalomethanes, 80 $\mu\text{g}/\text{L}$ maximum**
 - **Total haloacetic acids, 60 $\mu\text{g}/\text{L}$ maximum**
- **Secondary drinking water standards**
 - **Color, odor, iron**



ASR – Other Concerns

- **Poor recovery**
 - **ASR zone too saline**
 - **ASR zone permeability not conducive to recovery**
- **Poor economics, poor investment, poor project management**



Operation Practices

- **Injection pressure, flow rates, volumes recharged and recovered monitored continuously**
- **Report total volume in storage for wellfield**
- **Water samples of water recharged and recovered**



Operation Practices - 2

- **Monitor wells for water quality sampling, water levels**
- **Monthly operation reports are required with all required data, lab sheets**
- **The permit contains the facility requirements**



Operational Limits

- **Recharge volume limits**
 - **May be written per well or per wellfield**
- **Injection pressure**
 - **Limitations may be needed to prevent upward movement**



Operational Limits - 2

- **Water quality criteria**
 - **Injectate to meet groundwater standards**
- **Aquifer appropriateness**
 - **Use and type of aquifer, confinement**



ASR Cycle Testing

- **Cycles comprised of recharge, storage, recovery; multiple cycles run**
- **DEP requires a cycle testing plan**
- **Permittee evaluates results of each cycle**
- **Changes are allowed for cycles to improve performance or adjust to water supply situation**



ASR Cycle Testing - 2

- **Purpose is to demonstrate water recovery and repeatability**
- **Increase recovery percentage with successive cycles by “conditioning” the aquifer and creating a “bubble” of stored water**



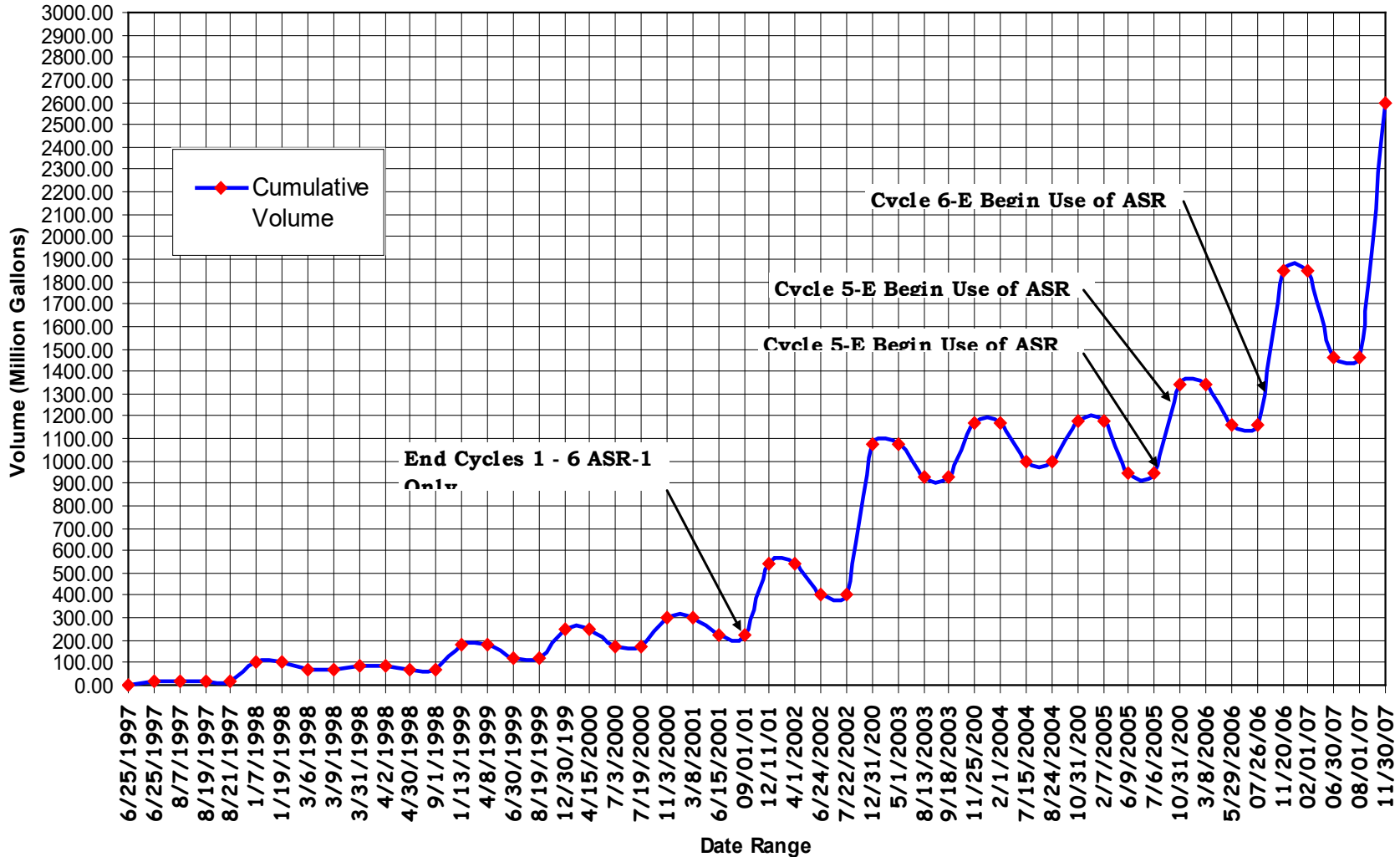
Orange County ASR Cycle Testing Plan

Cycle	Recharge		Storage		Recovery		Buffer Volume
	Days	Volume (MG)	Days	Volume (G)	Days	Volume (MG)	(MG)
Pre-Cycle Injection	60	180	0	180	0	0	180
1	10	30	14	210	10	30	180
2	35	105	40	315	10	30	255
3	90	270	45	555	90	270	255
4	60-120	225	45	480	60-120	225	255
5	60-120	225	120	480	60-120	164	316
6	30-90	90-215	20	406-531	30-90	90-215	316-441
7	30-90	60-90	20-60	502-532	60-120	100-150	352-432



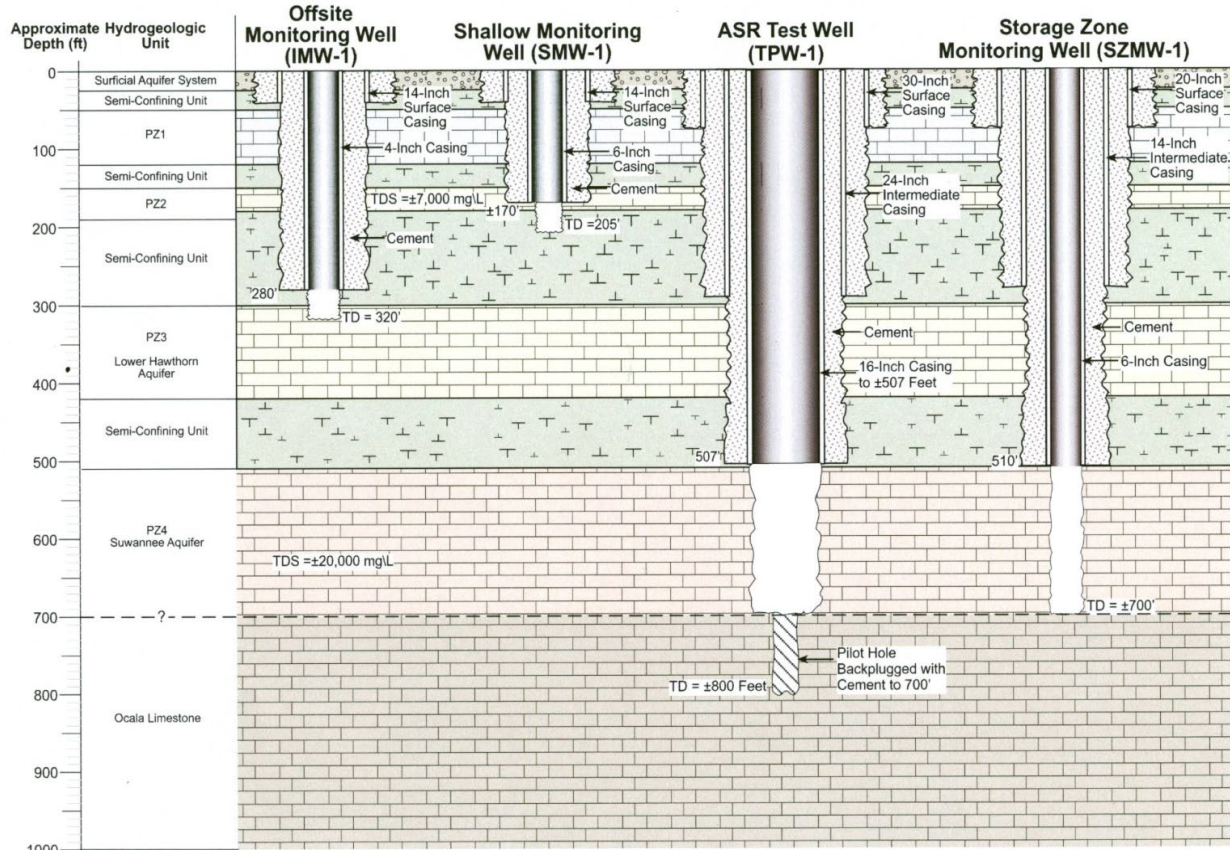
Cycle Testing - Marco Lakes ASR

Cumulative Volume





ASR Monitoring Plan



(Source: CH2M HILL, March 2004)



FIGURE 2-3
ASR System Well Construction Details





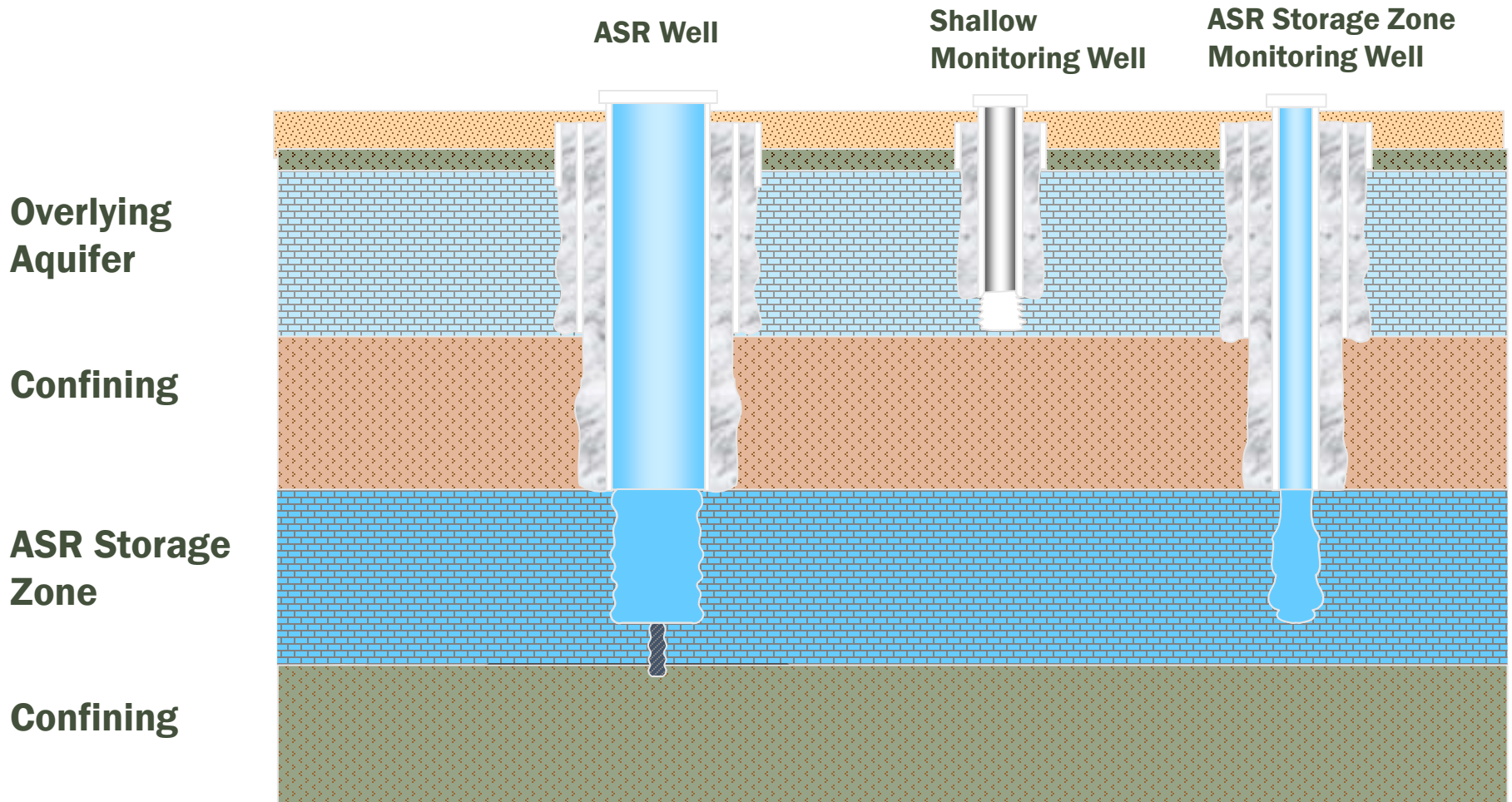
ASR Monitoring

Monitor points

- **Injected water**
- **Recovered water**
- **Monitor wells in ASR zone**
- **Monitor wells above ASR zone**
- **Annual full wastestream analyses**



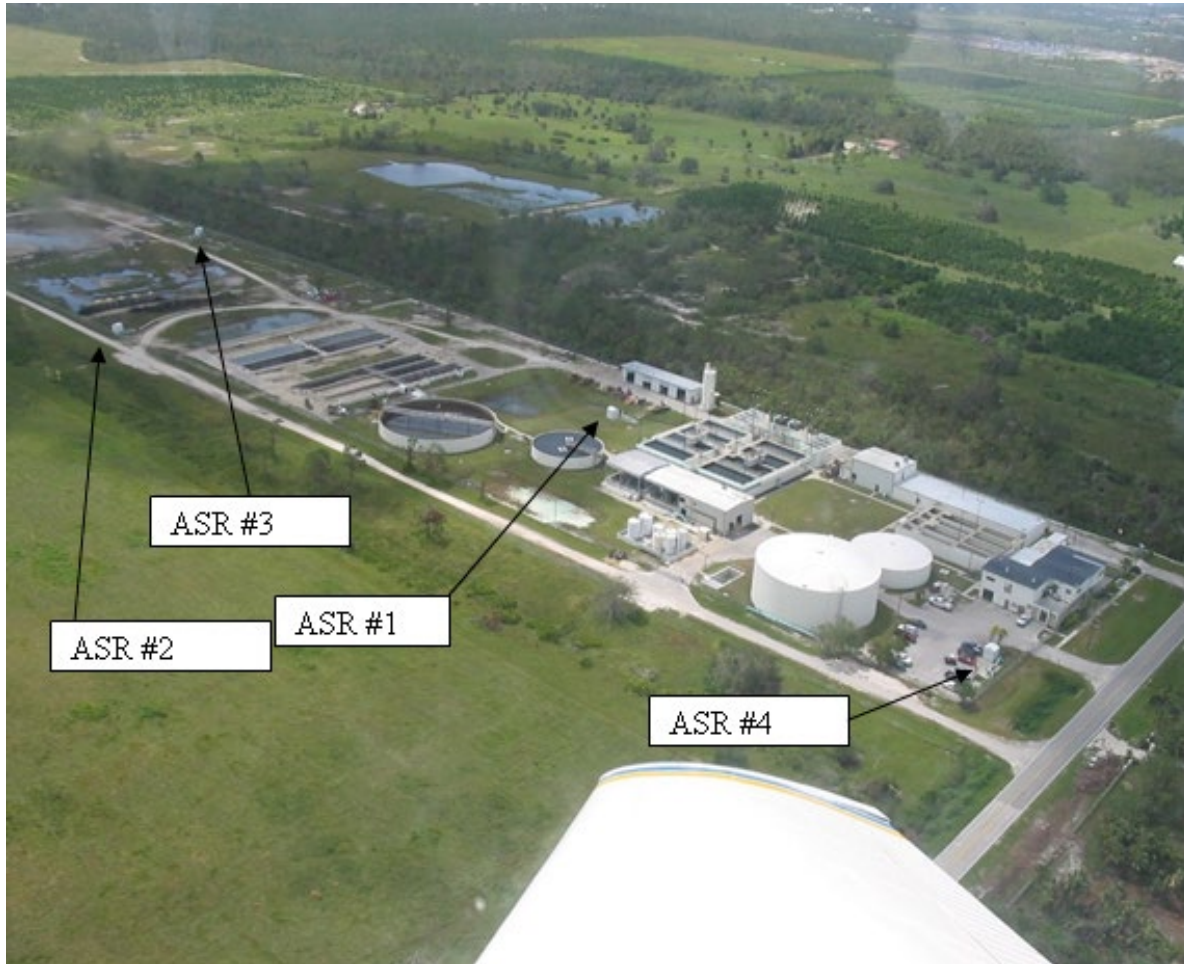
ASR Cross Section View





Punta Gorda ASR

Potable Water ASR



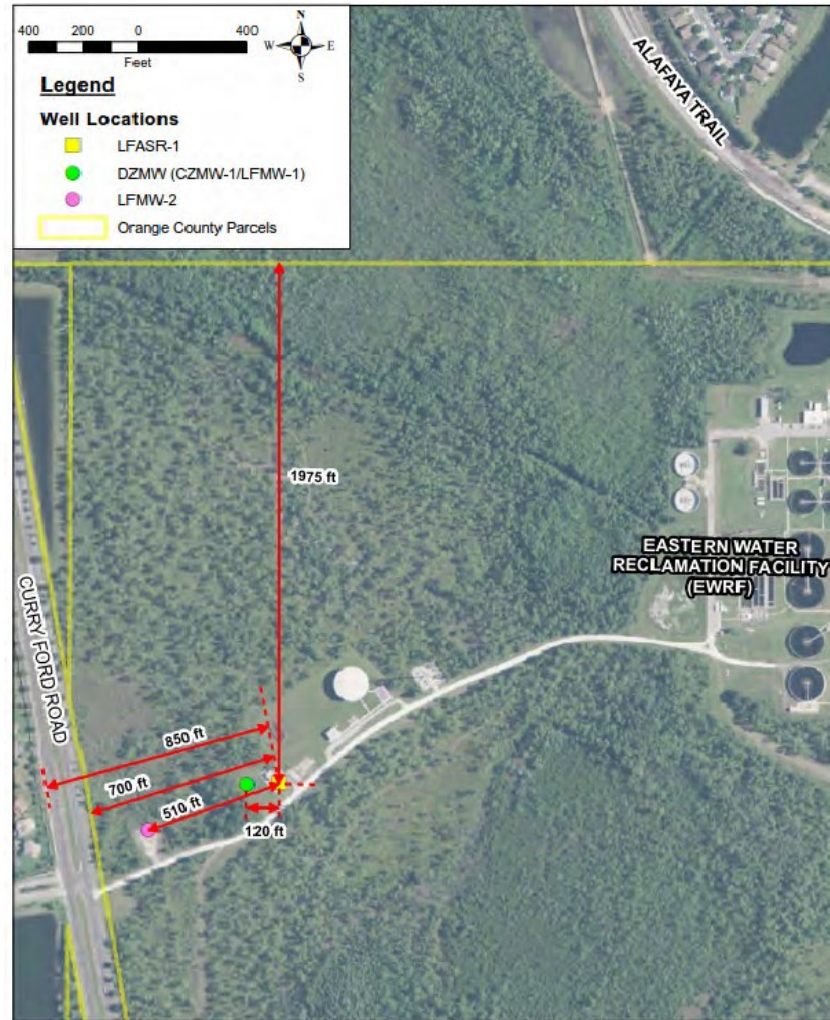


ASR Data Interpretation

- **Interpretation is best done with graphs of the collected data**
- **Identify the periods of recharge, storage, and recovery**
- **Compare with cumulative water volumes in storage**

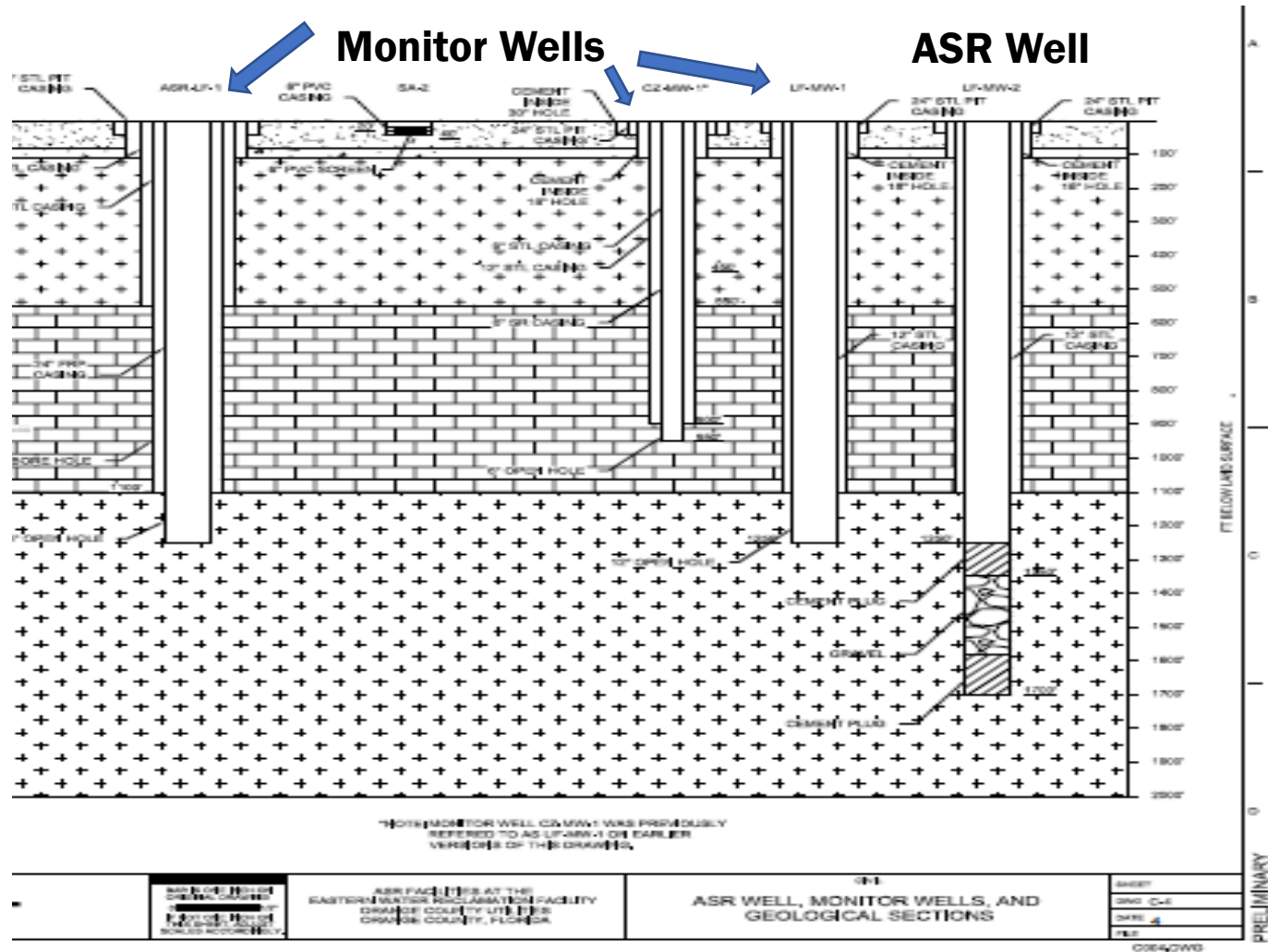


Orange County ASR





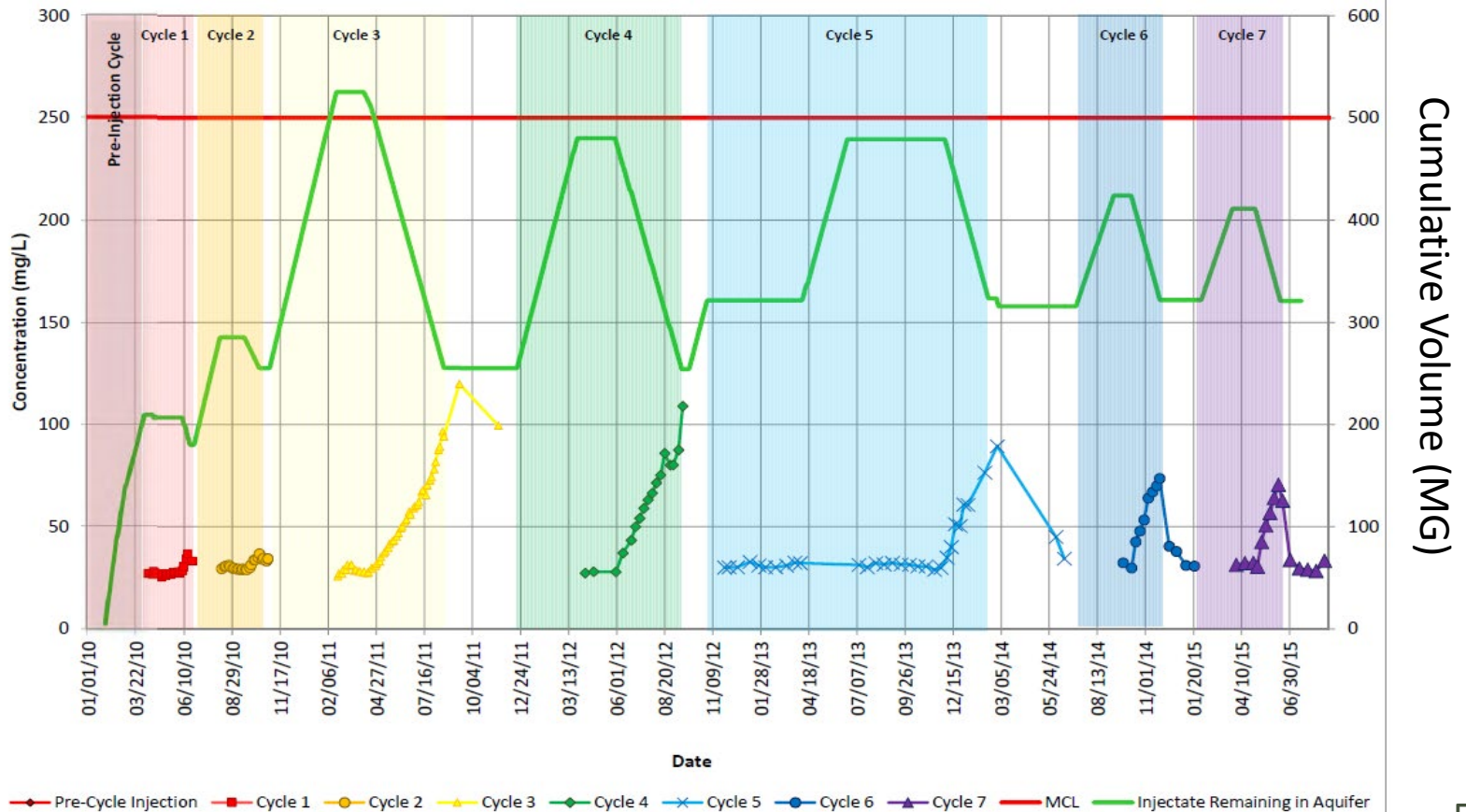
Orange County ASR - 2





Orange County ASR Well Chloride

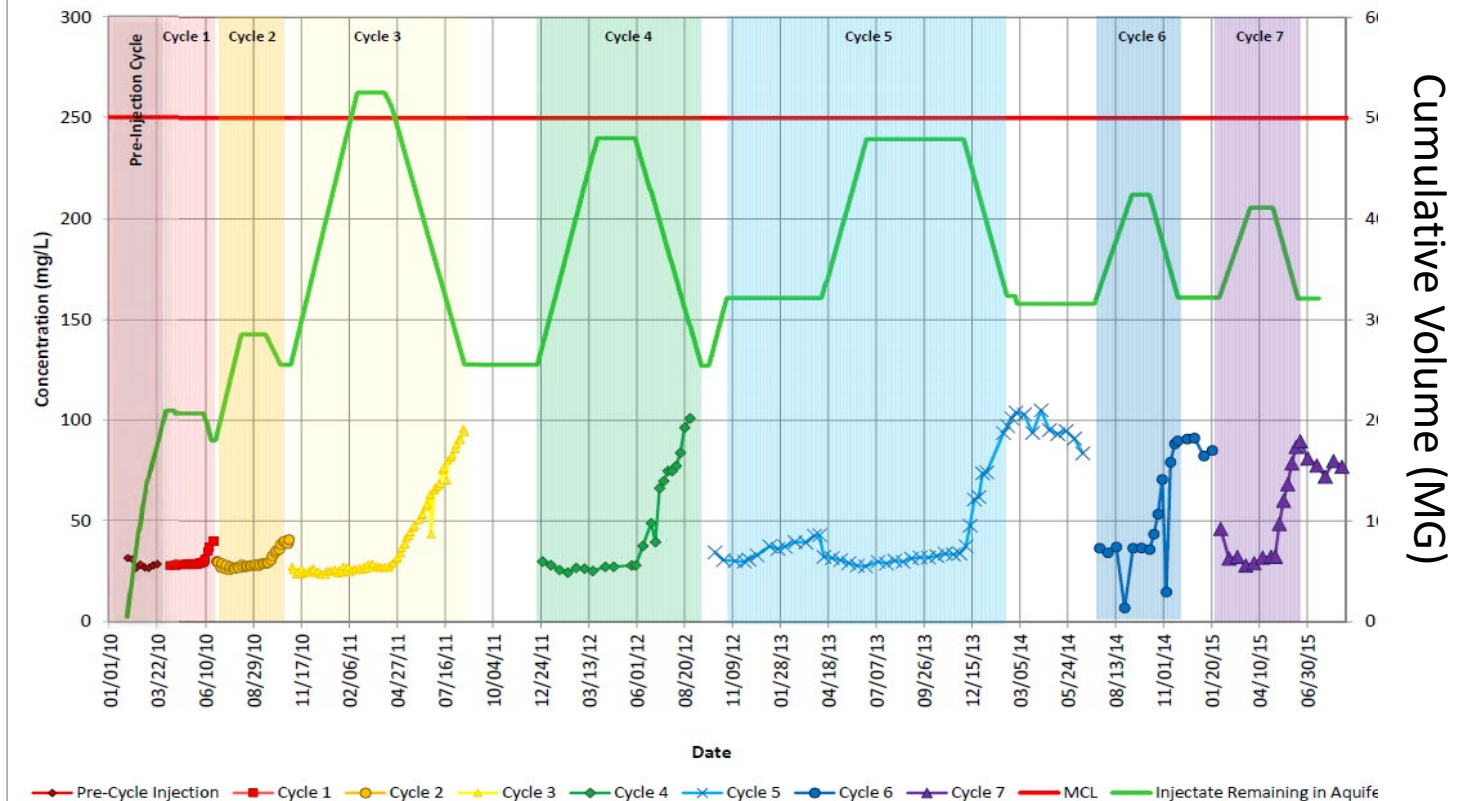
Figure 2.4.1. Chloride Concentration LFASR-1





Orange County, Nearby SZMW, Chloride

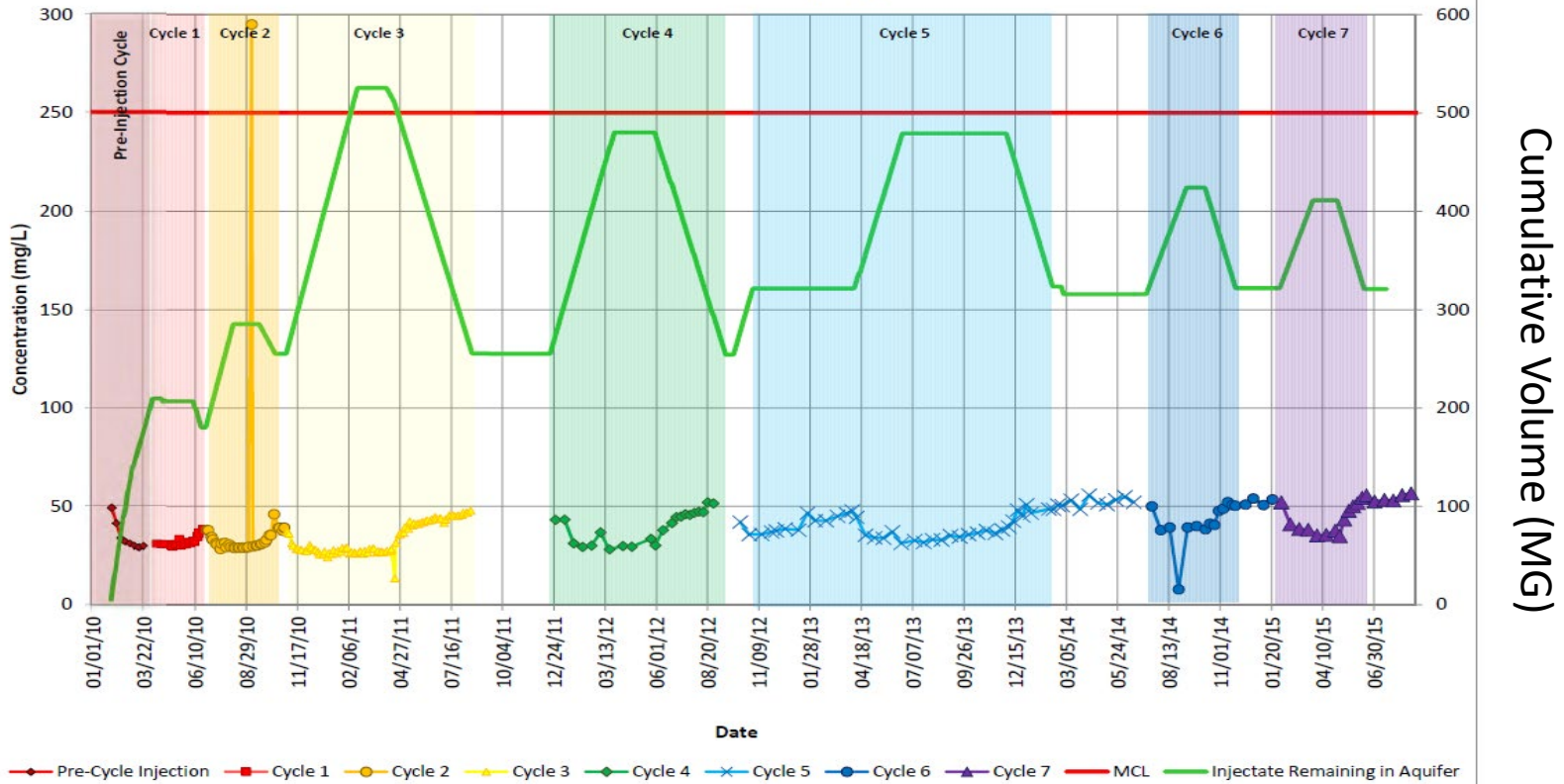
Figure 2.4.3. Chloride Concentration
LFMW-1 (Near)





Orange County, Distant SZMW, Chloride

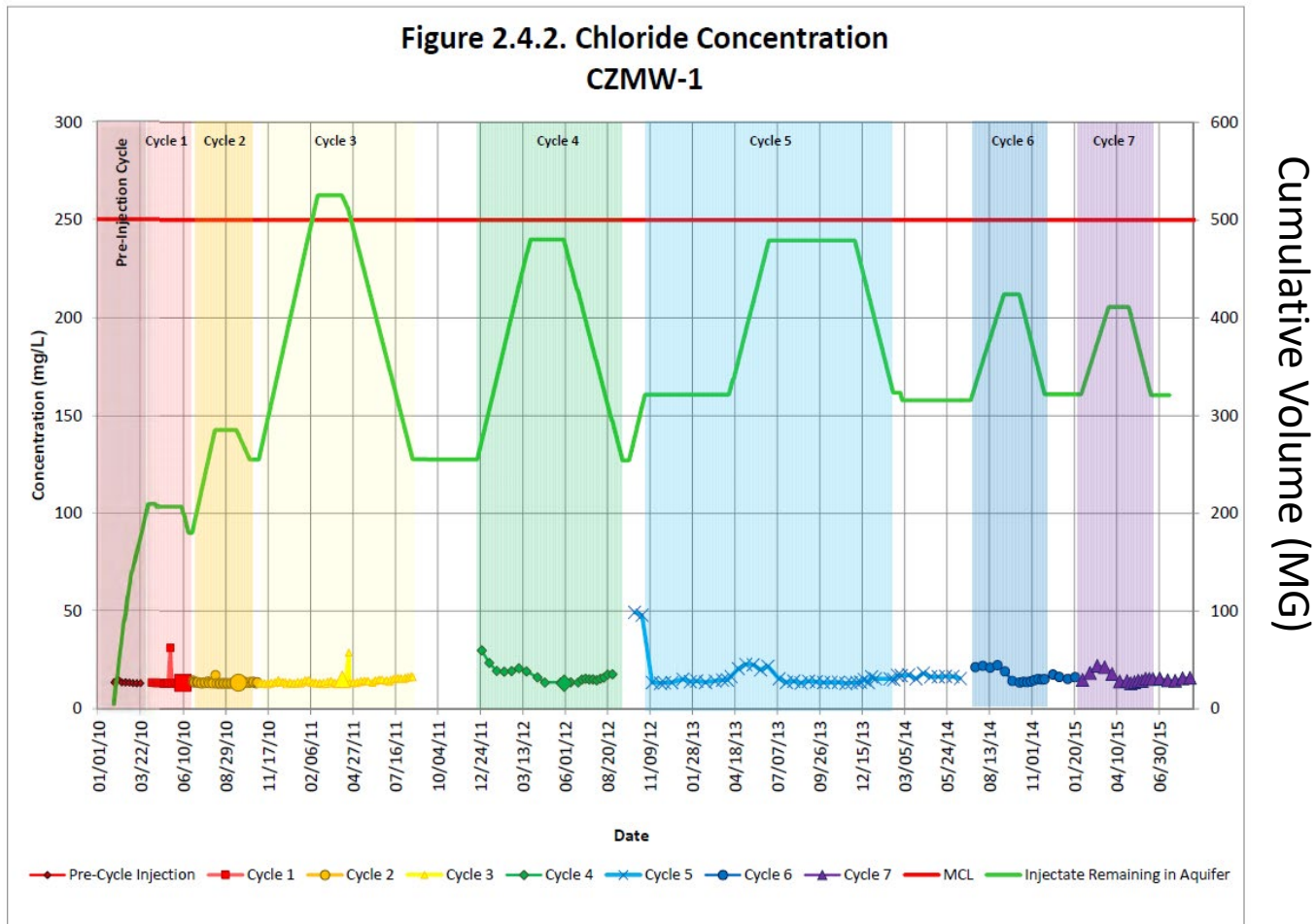
Figure 2.4.4. Chloride Concentration
LMFW-2 (Far)





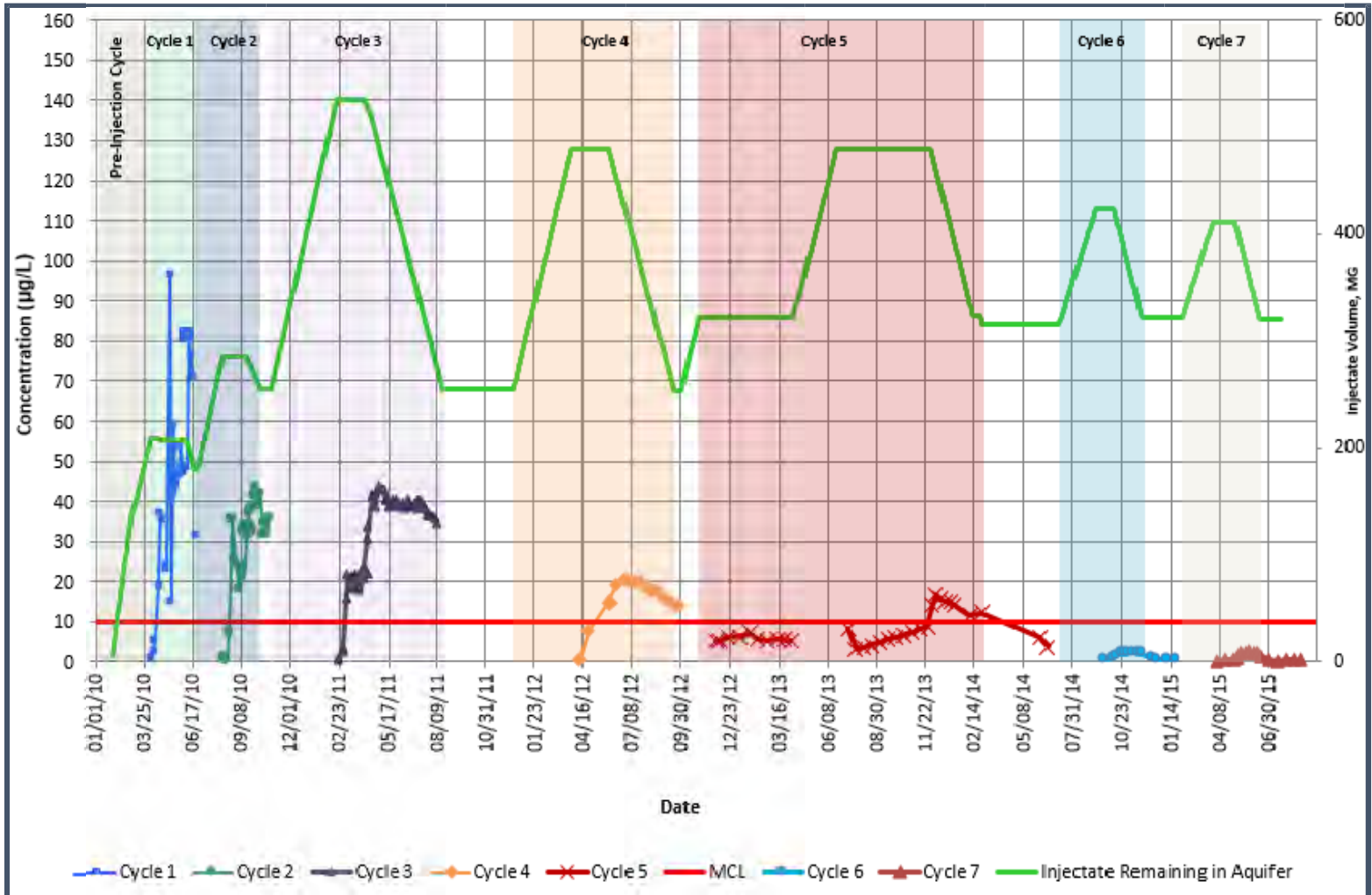
Orange County, Overlying MW, Chloride

Figure 2.4.2. Chloride Concentration
CZMW-1





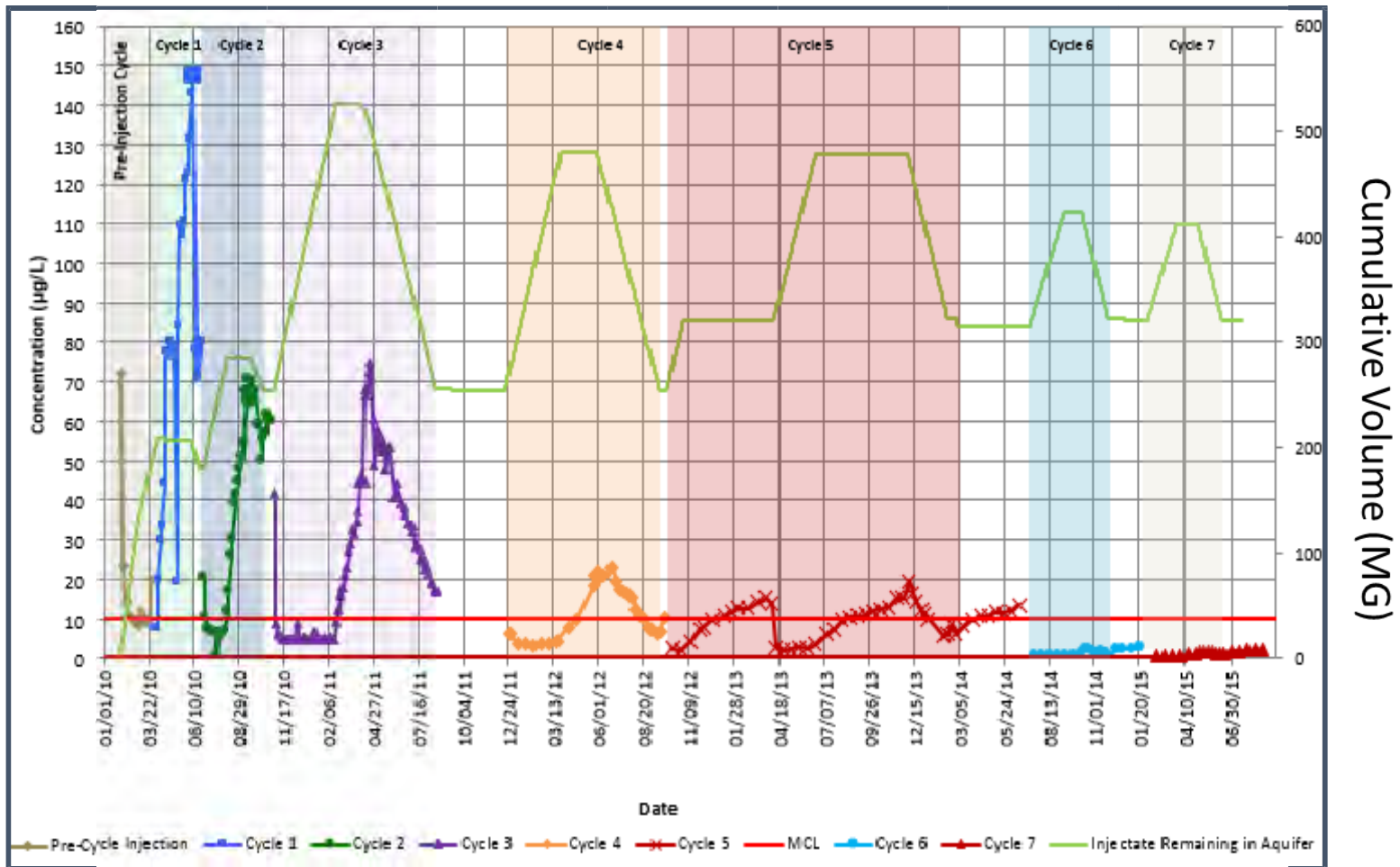
Orange County ASR Well Arsenic



Cumulative Volume (MG)

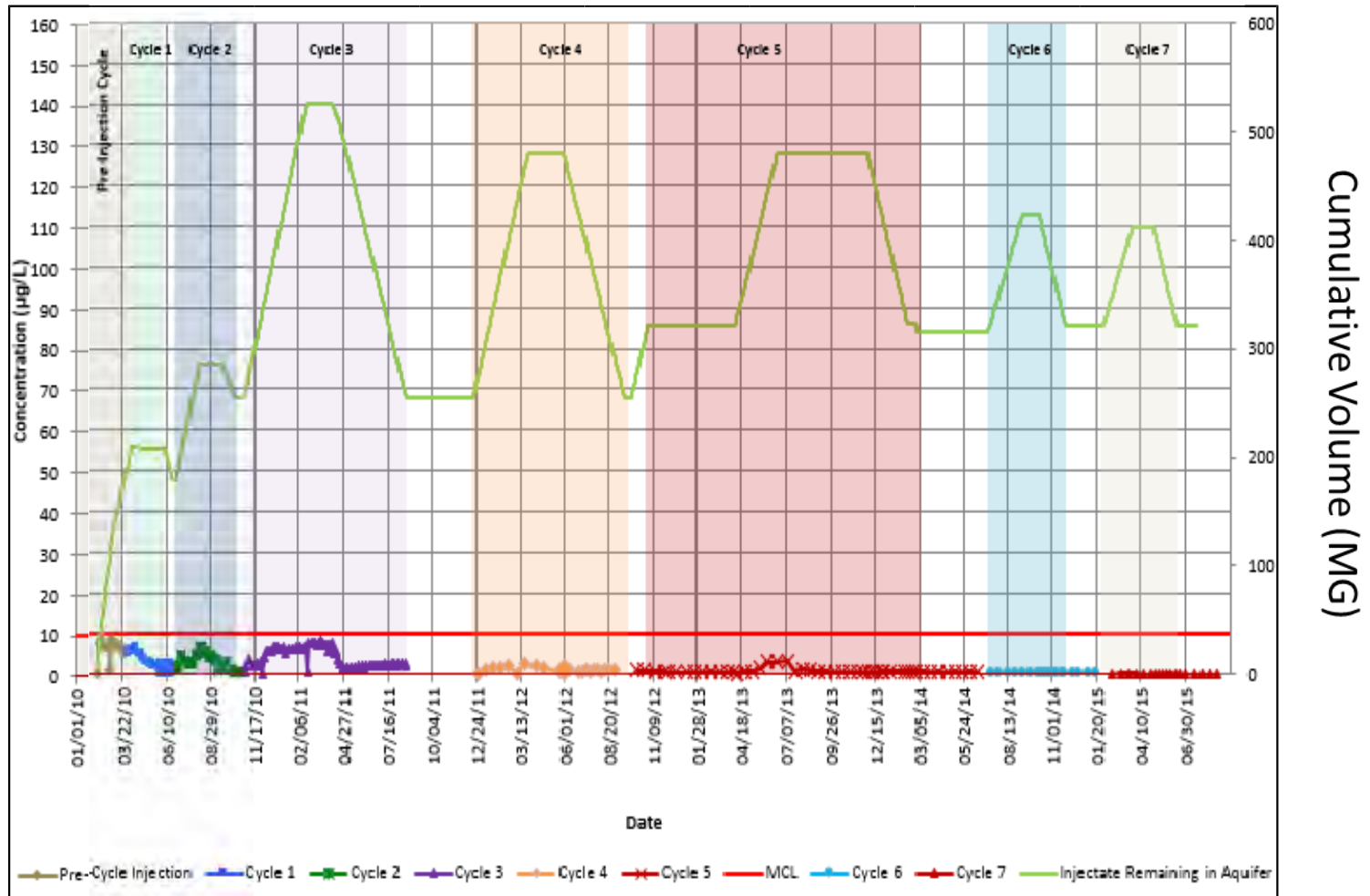


Orange County, Nearby SZMW, Arsenic



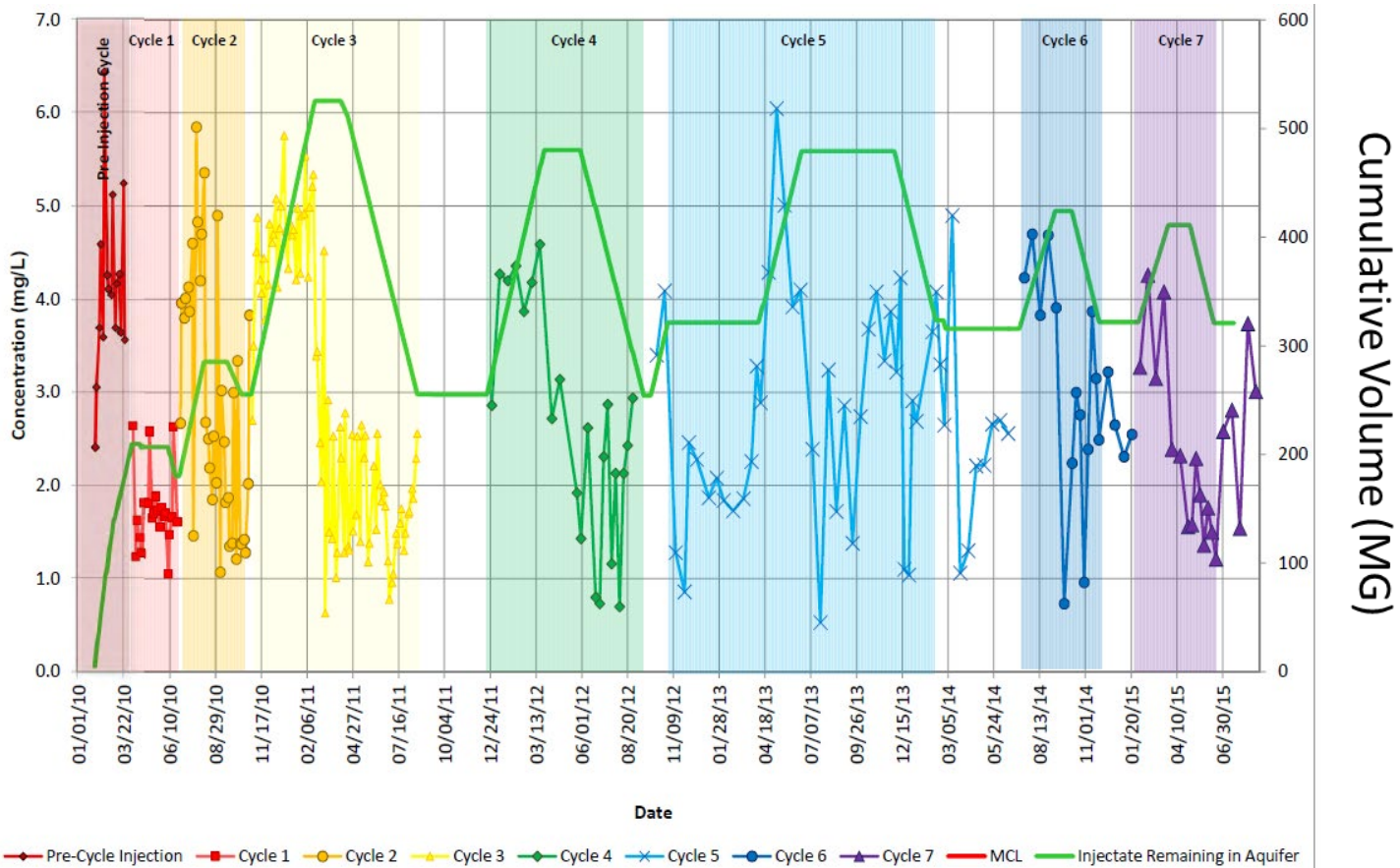


Orange County, Distant SZMW, Arsenic



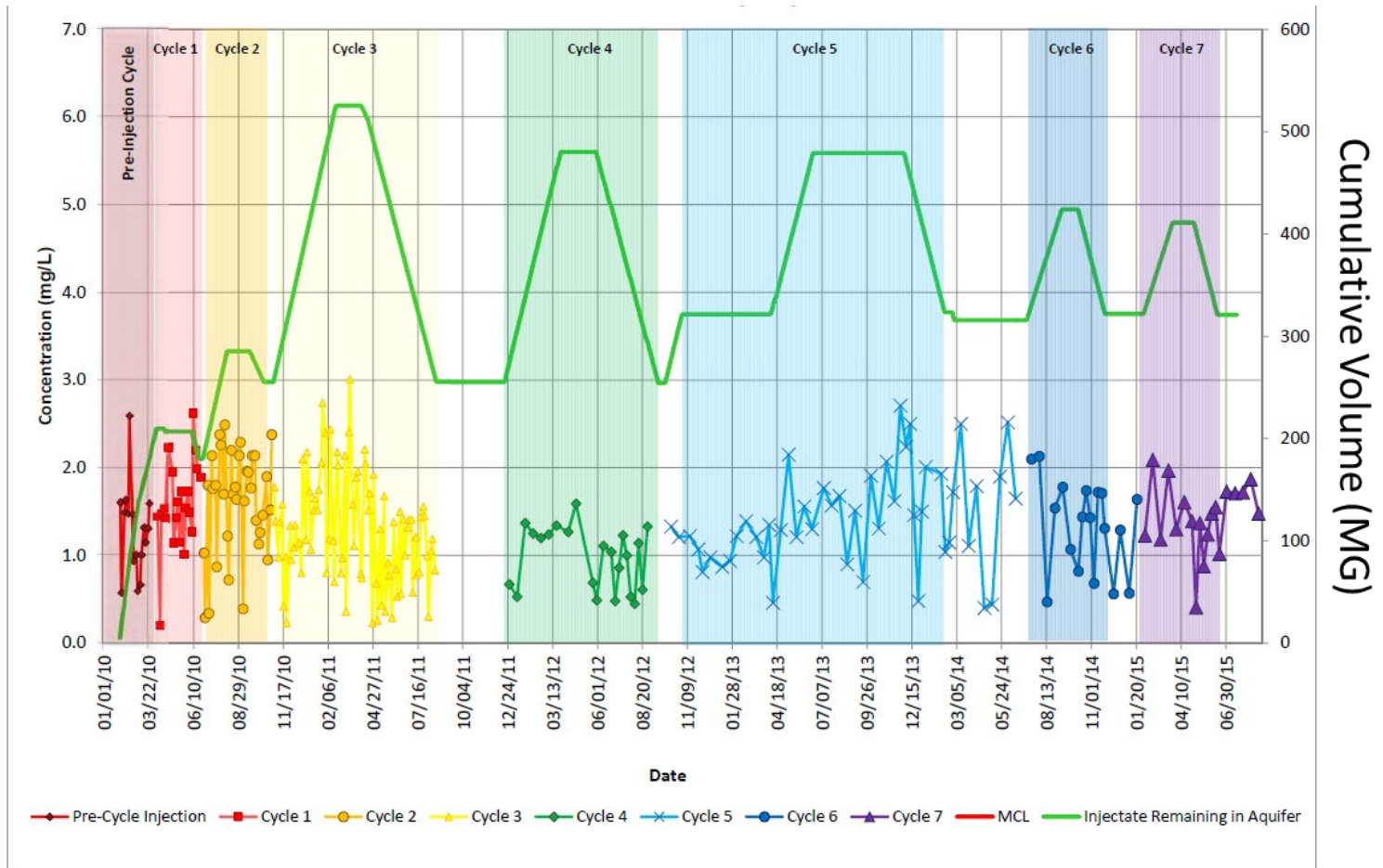


Orange County, Nearby SZMW, Dissolved Oxygen



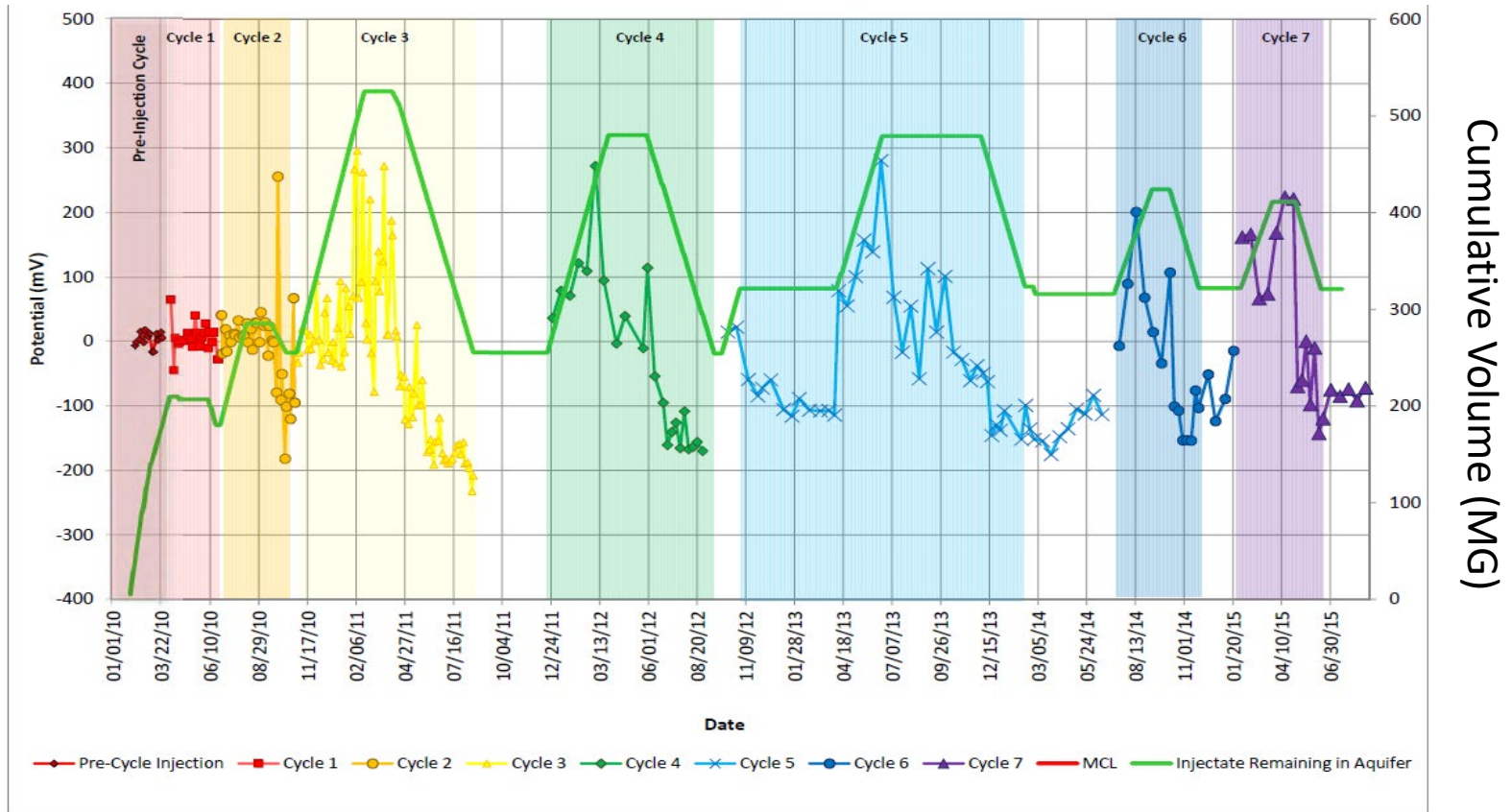


Orange County, Distant SZMW, Dissolved Oxygen



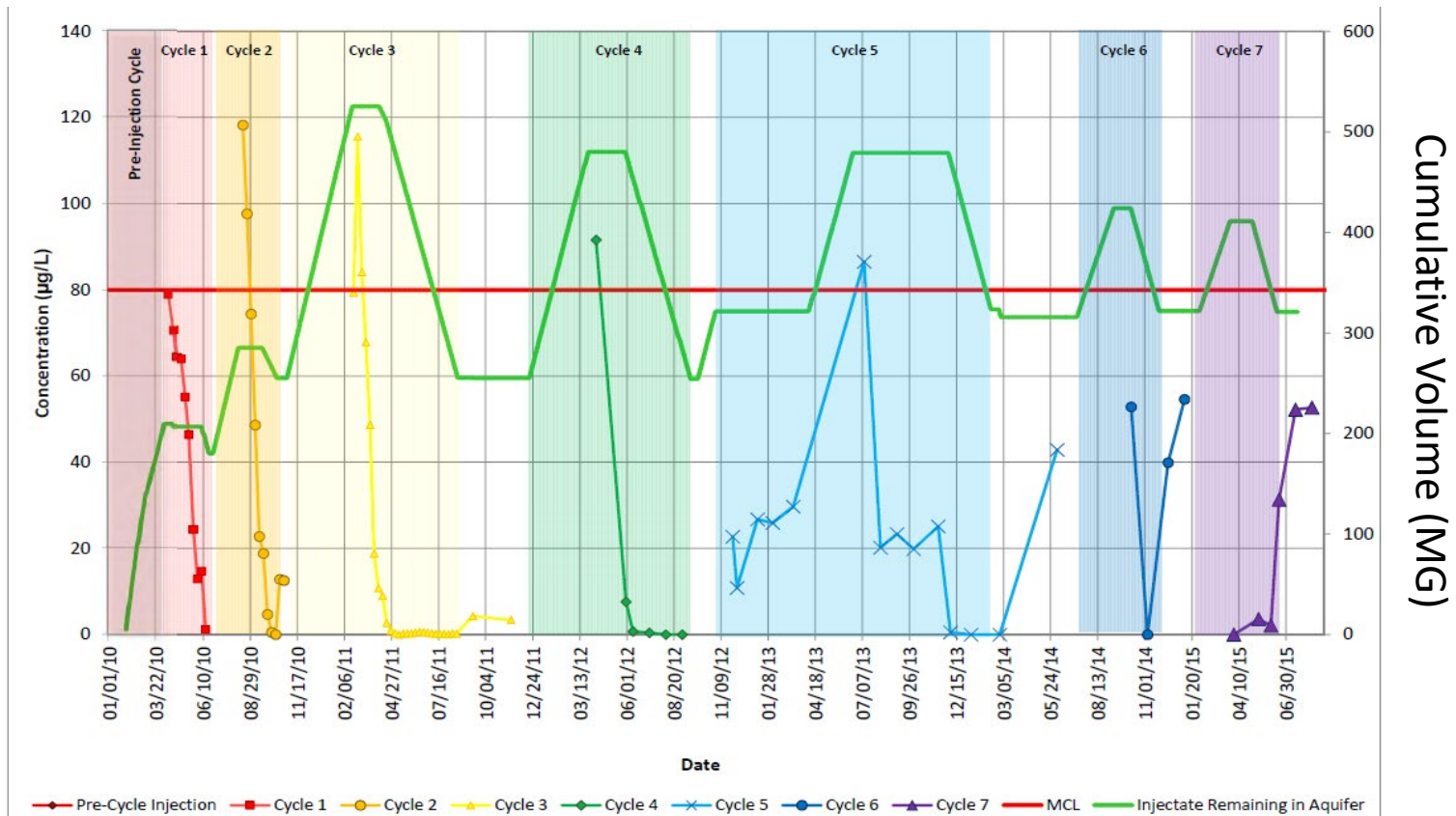


Orange County, Nearby SZMW Oxidation Reduction Potential (ORP)





Orange County, ASR Well Total Trihalomethanes (TTHM)





Regulatory Hurdles for ASR

- **Arsenic mobilization**
- **Coliform bacteria, trihalomethanes**
- **Movement of water off-site, with or without contaminants**
- **Public perception**



What Makes a Successful ASR Project?

- **Does not endanger water resources, does not pose health risks**
- **Meets applicable water quality standards**
- **Is financially viable for the owner**
- **Meets goals of water supply planning**
 - **Recovery efficiency**



Cocoa Beach ASR Recovery Efficiencies

Table 7-2- ASR System Cycle Test Volumes

Cycle No.	Recharge Period	Recharge Volume (MG)	Storage Period (Days)	Recovery Period	Recovery Volume (MG)	Recovery Efficiency (%)	Chloride Conc. (mg/L)
1	09/09/2014 to 10/09/2014	44.6	18	10/28/2014	0.024	< 1	12,400
2	01/04/2015 to 04/09/2015	143.7	60	06/09/2015	0.021	<1	11,500
3	10/04/2015 to 03/16/2016	240	58	05/25/2016	0.018	<1	13,500

Note: Recovery Efficiency calculated based on volume pumped where recovered water quality exceeded a chloride concentration of 1,500 mg/L.



Well Spacing Tampa Tippin WTP



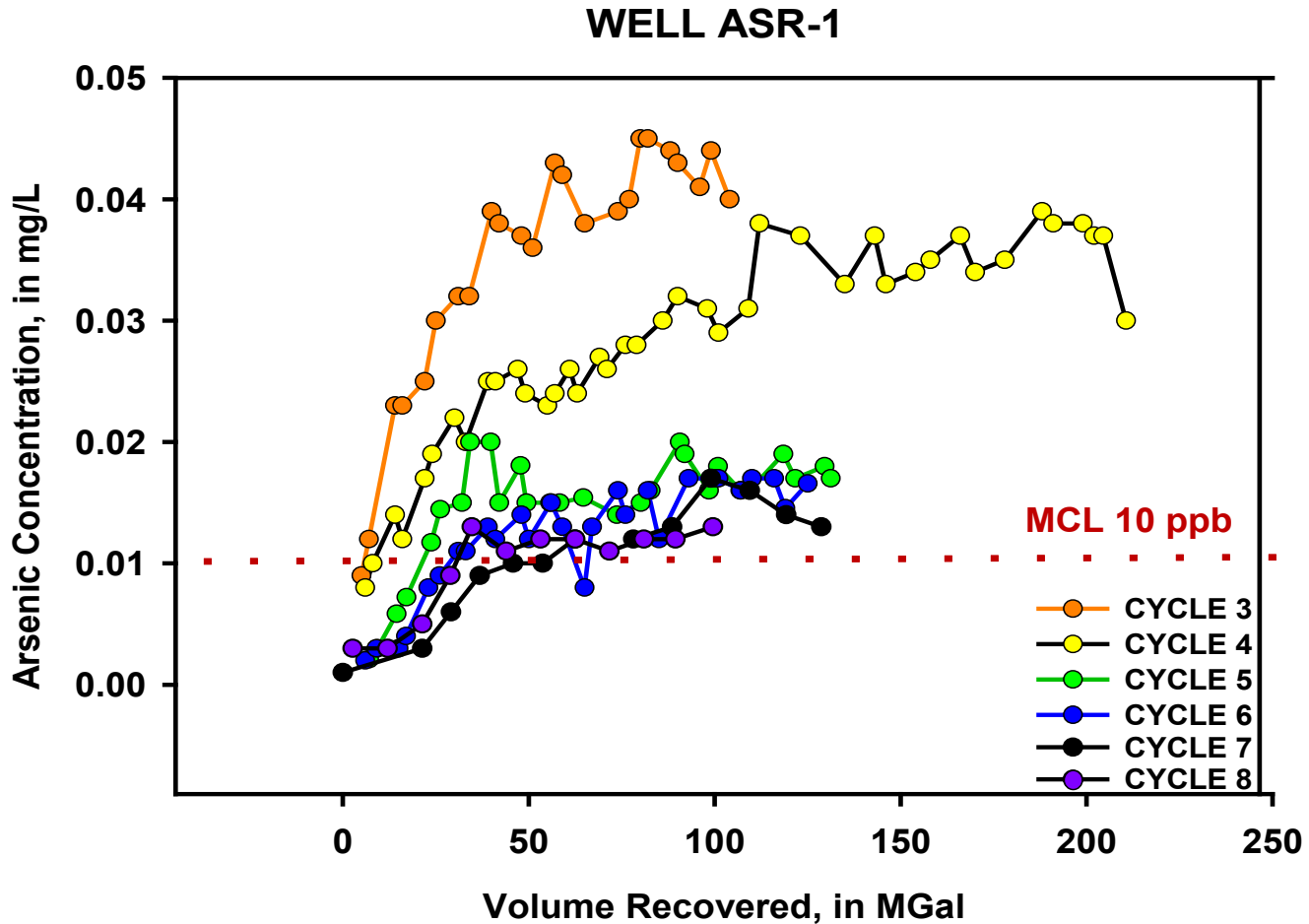
Scale in Feet
0 150 300

● Monitoring Well
■ ASR Well

FIGURE 1-4
ASR-B and Monitoring Wells Site Map
Well Completion Report for the DLT WTF ASR System
Monitoring Wells APMW-5 and SZMW-2 **CH2MHILL**

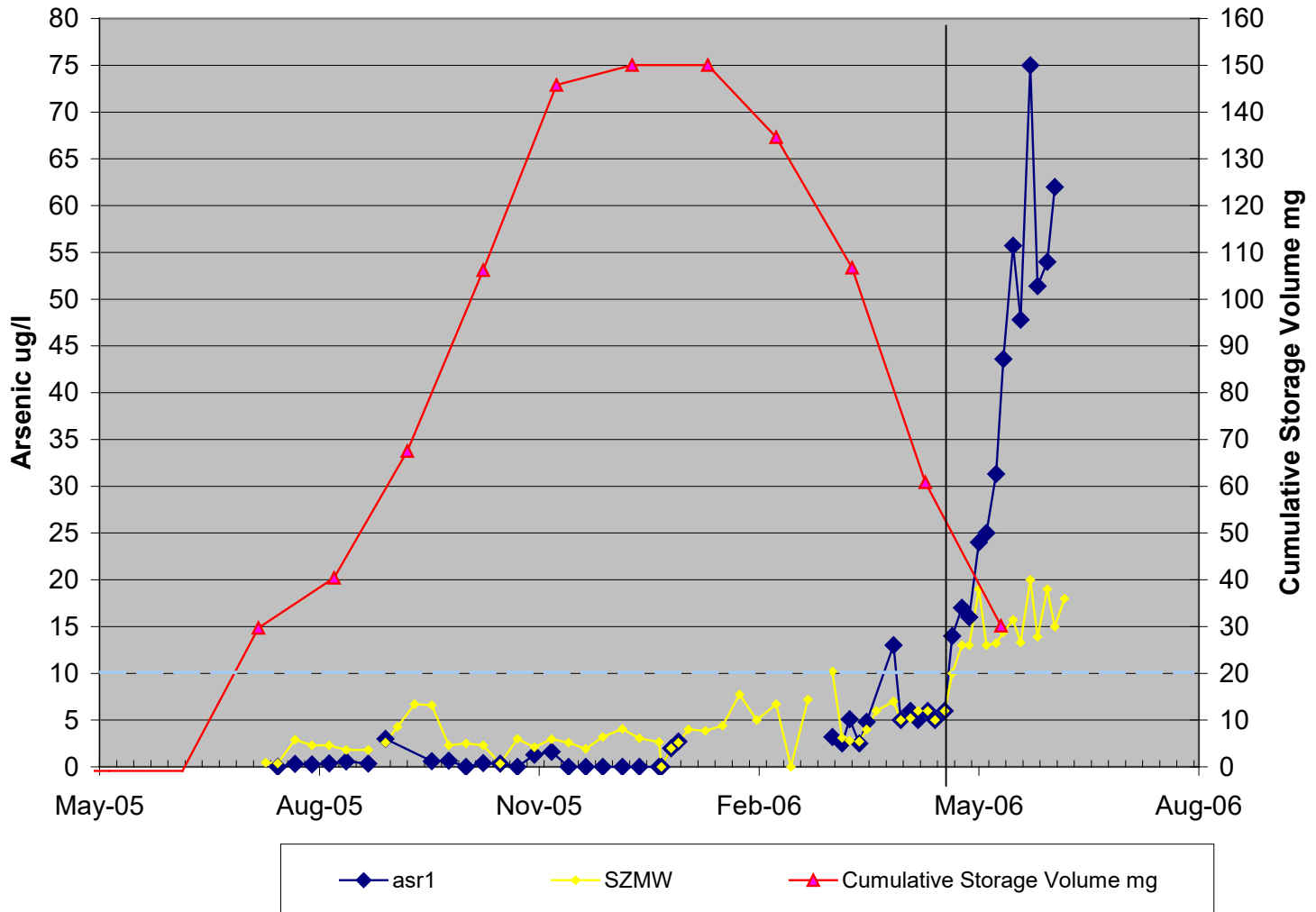


Tampa Rome Ave. ASR





Bradenton ASR





Peace River ASR Site Map





Peace River ASR Well





Lee County Corkscrew ASR

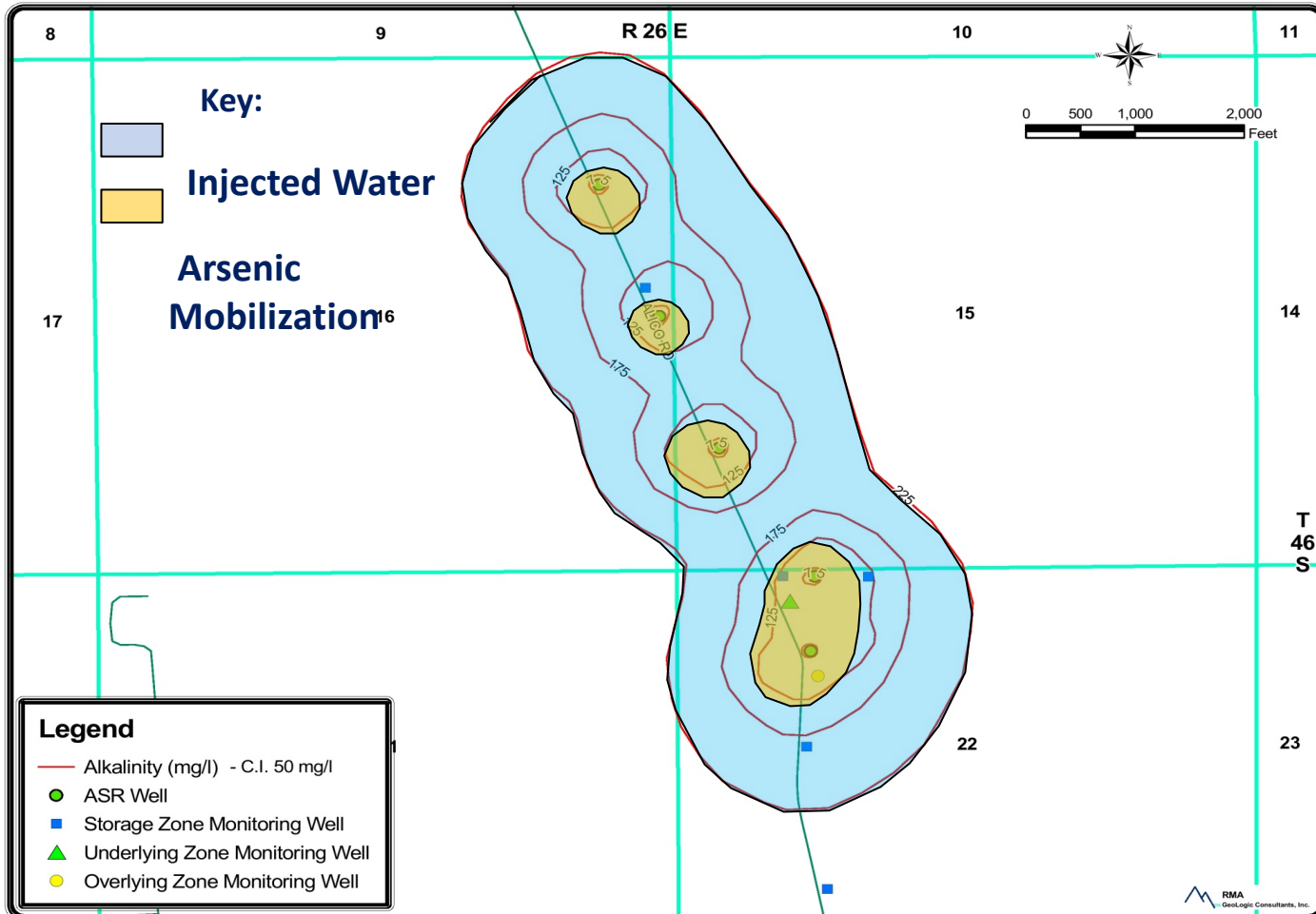


FIGURE 5-20. MAP SHOWING LOCATION OF SIMULATED ASR INJECTED WATER AT THE END OF INJECTION OF CYCLE 9.



Aquifer Recharge Topics

- **Purposes of AR**
- **Comparison with ASR**
- **Potential problems**
- **Monitoring**
- **Class V wells under the UIC rule, Chapter 62-528, F.A.C.**



Aquifer Recharge Goals in Florida

- **Extend/augment existing freshwater supplies**
- **Reduce use of groundwater and the number of new wells**
- **Restore aquifer water levels to offset drawdowns**
- **Help offset effects of over-pumping near coasts and saltwater intrusion**
- **In Miami-Dade and Broward counties, Aquifer Recharge can help replace ocean outfall**



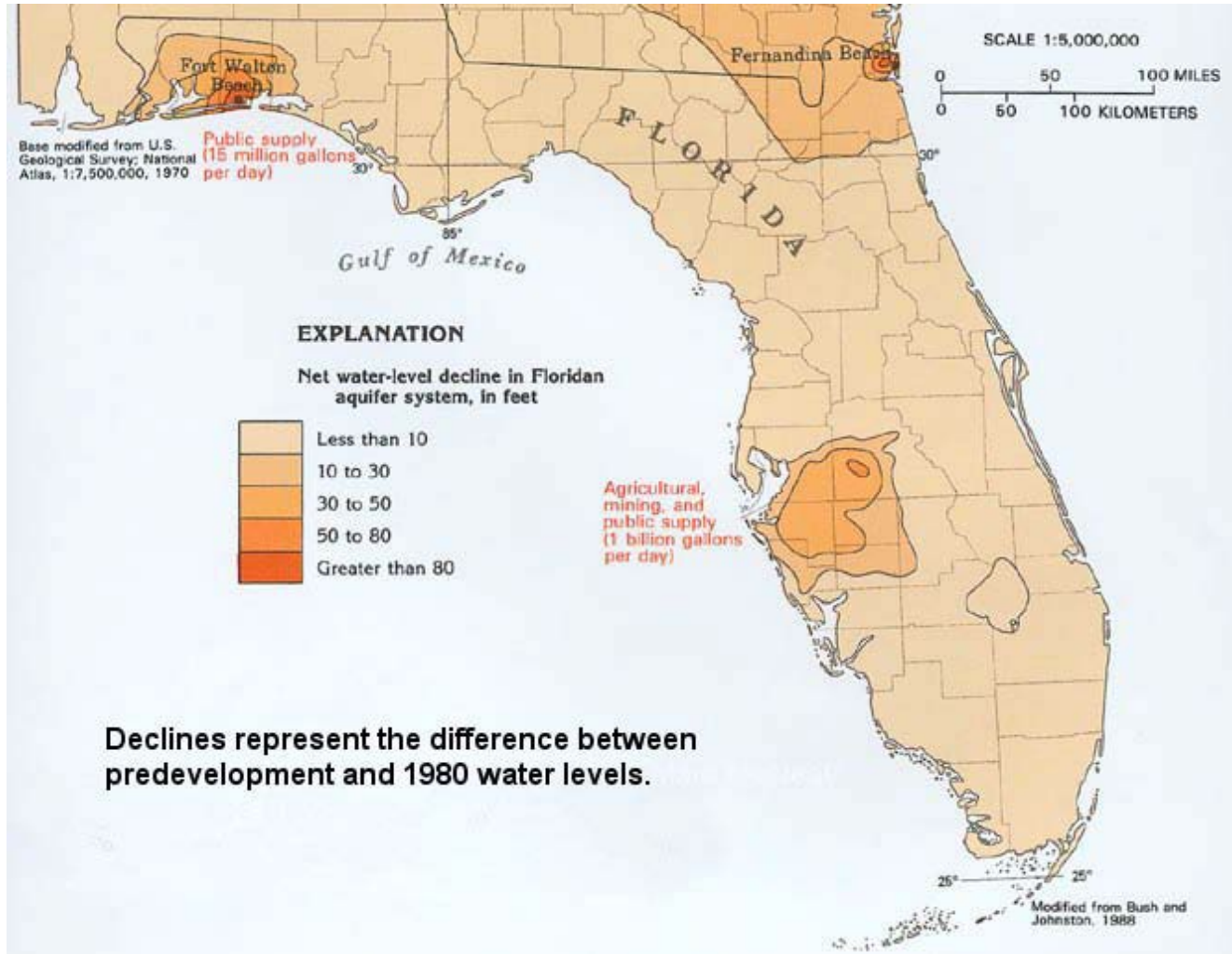
Waters Used for Aquifer Recharge

Fluids permitted

- Reclaimed water
- Surface water
- Groundwater

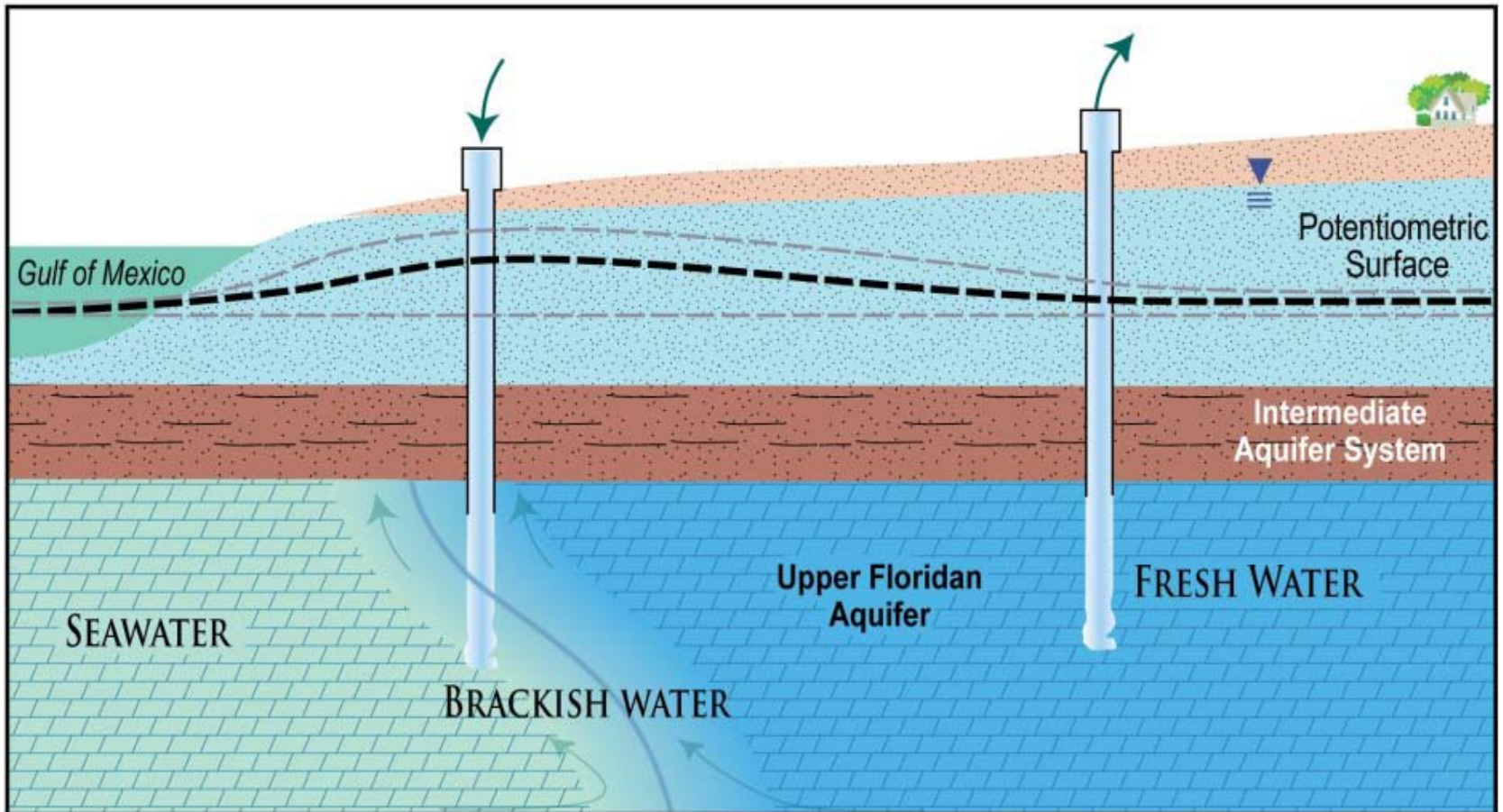


Water Level Declines



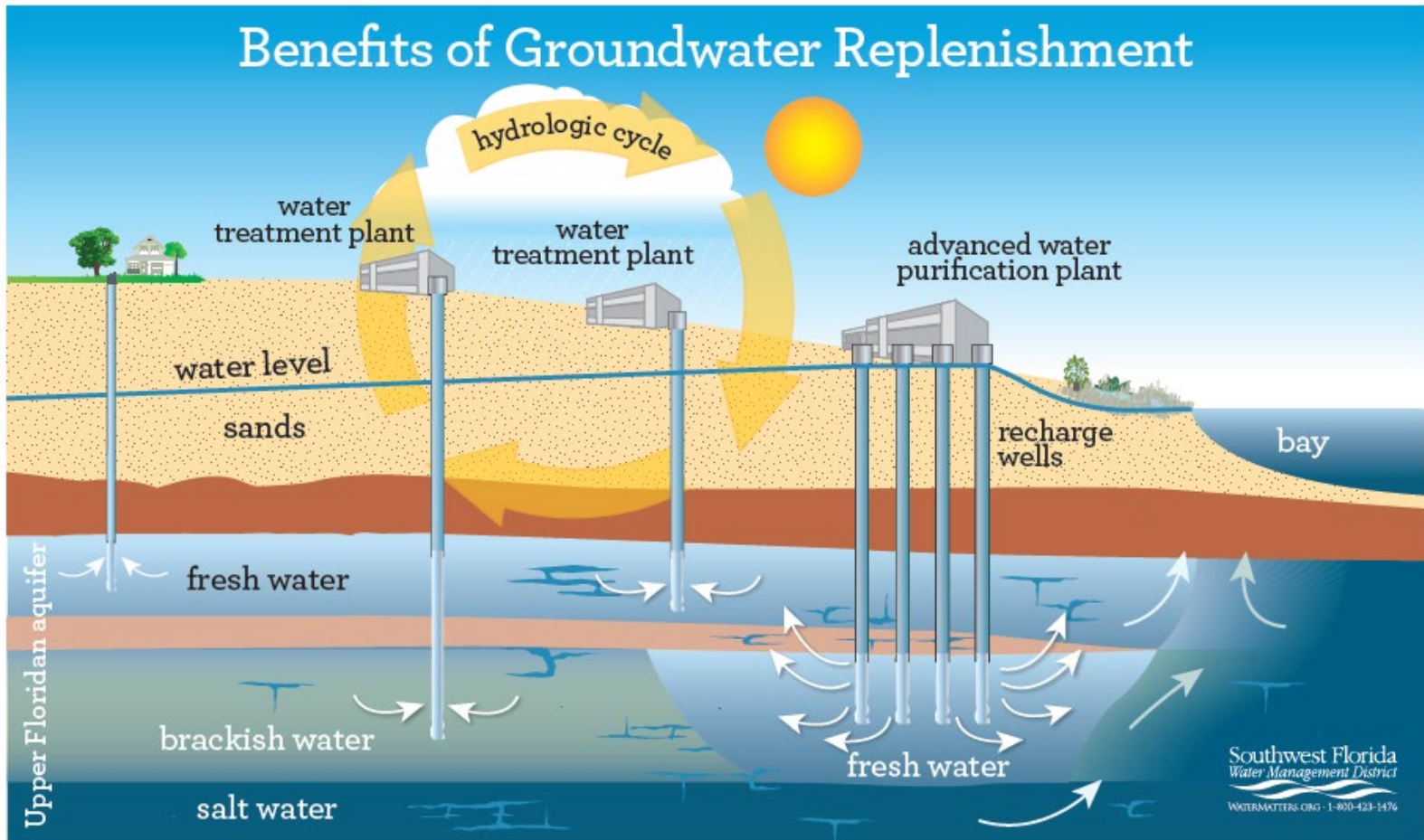


Hillsborough County Aquifer Recharge





City of Clearwater Aquifer Recharge





Regulatory Hurdles for Aquifer Recharge

- **Arsenic mobilization**
- **Coliform bacteria, disinfection byproducts**
- **Movement of water off-site, with or without contaminants**
- **Public perception**



Reclaimed Water Aquifer Recharge Projects

- **Requires full treatment & disinfection for aquifer recharge in G-II aquifer < 3000 mg/L TDS**
- **Total organic carbon and total organic halogen limitations**
- **Other requirements**



Aquifer Recharge Monitoring

- **Monitor wells in the recharge zone at greater distance than for ASR wells**
- **Monitor wells in overlying aquifer within 150 feet of recharge well**
- **Recharge water and monitor well sampling**
- **Pressure/water level and injected volume monitoring**



Aquifer Recharge

Potential Problems

- **Contaminants introduced during injection**
- **Reactions between injected fluid and aquifer material/formation fluids**
- **Well location not effective to recharge aquifer**
- **Recharge zone too deep or shallow**
- **May adversely affect springs**
- **Poor economics, poor investment**



Potable Reuse and Aquifer Recharge

- **Recharge aquifer with treated domestic wastewater**
 - **Levels of treatment – reclaimed vs. “purified”**
 - **Recharged water may be a portion of water produced by public supply wells**



Potable Reuse and Aquifer Recharge - 2

- **Indirect potable reuse**
 - Treated water is blended or has intermediate steps before it goes to WTP
- **Direct potable reuse**
 - Treated water is sent directly to WTP or potable distribution system
- **Demonstration projects have not involved recharge wells**



Overlap With Other DEP Programs

ASR and Aquifer Recharge

- **Domestic Wastewater – ASR, aquifer recharge**
- **Drinking Water – ASR**
- **Groundwater Programs (springs) – aquifer recharge**



Working With Other Agencies

ASR and Aquifer Recharge

- **U.S. Environmental Protection Agency**
- **Florida's Water Management Districts**
- **Florida Department of Health**
- **Florida Department of Transportation**
- **U.S. Geological Survey**
- **Local Governments**



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