SOUTH FLORIDA WATER MANAGEMENT DISTRICT

Aquifer Storage and Recovery (ASR) 2020 Science Plan Public Workshop

December 8, 2020

sfwmd.gov

Welcome/Meeting Purpose

- Welcome/Meeting Purpose and Objectives
- Module 1: Background
  - Comprehensive Everglades Restoration Plan (CERP) Pilot Projects
  - Aquifer Storage and Recovery (ASR) Regional Study
- Module 2: Lake Okeechobee Watershed Restoration Project (LOWRP) and ASR Well Program
- Module 3: 2020 ASR Science Plan
  - National Research Council Review
  - 2020 ASR Science Plan Report/Future Studies
- Public Comment

Module 1

CERP Pilot Projects
ASR Regional Study

ASR in the CERP

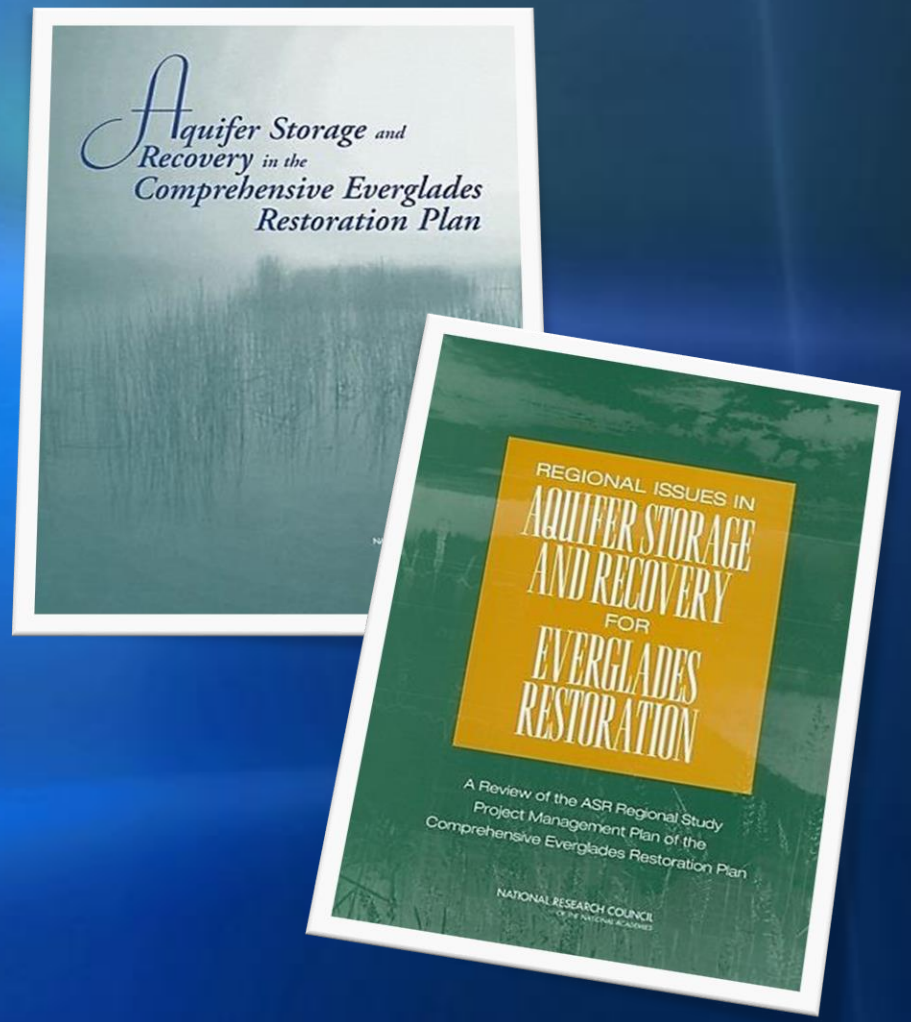
- Augments the use of surface reservoirs
- 333 5-million gallons per day (mgd) wells
  - 200 wells with Lake Okeechobee
  - 44 wells in Caloosahatchee Basin
  - 89 wells in Lower East Coast
- Unprecedented scale
- Authorized pilot projects

1999 South Florida Ecosystem Restoration Issue Team: 7 Essential Questions for ASR

- Characterize the source waters
- Characterize the hydrogeology
- Analyze for potential fracturing
- Analyze for changes in groundwater flow patterns and rates
- Analyze for water quality changes during storage
- Test for potential for mercury accumulation
- Determine the relationship between recovery and aquifer properties

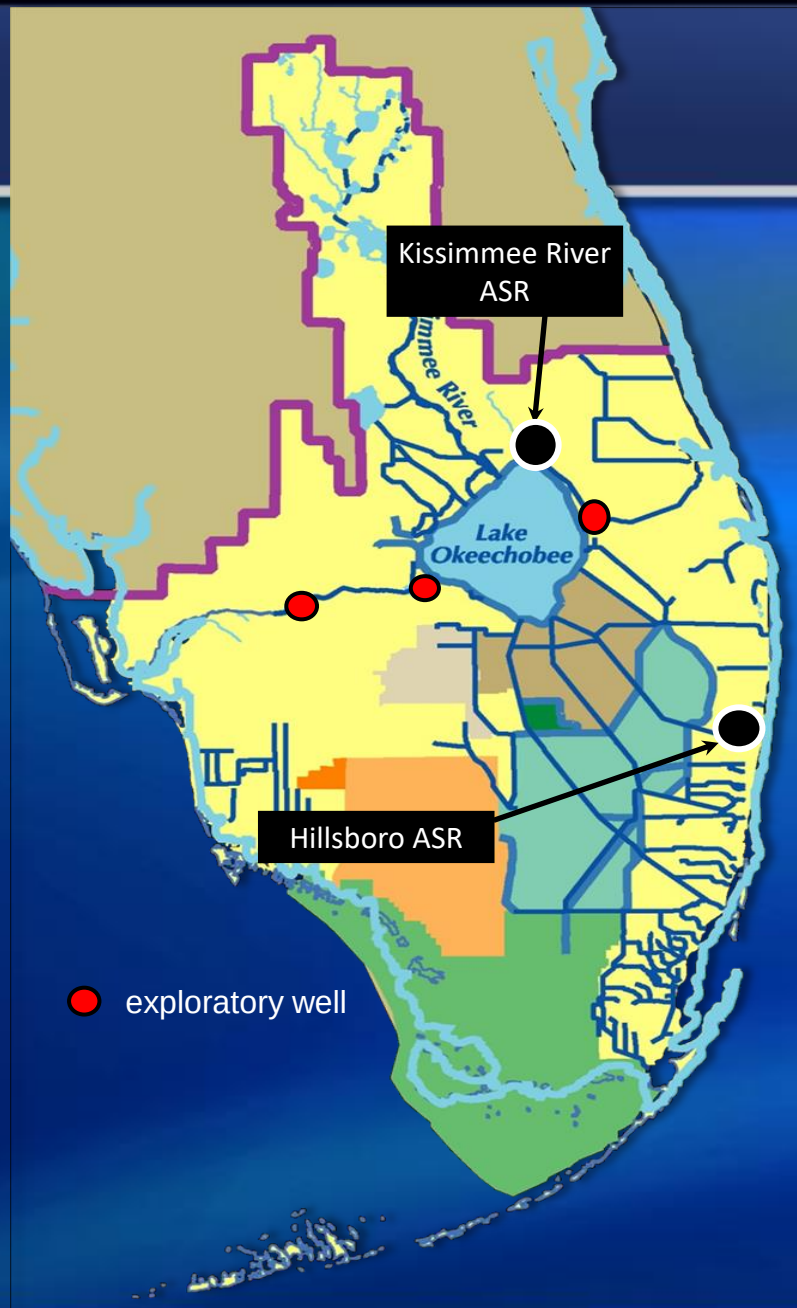
Early National Research Council Reviews

- Pilot Project Plans
- 1st National Research Council (NRC) review (2001)
- The two-pronged approach
- Regional Study Plan
- 2nd NRC review (2002)
- Need for regional analysis

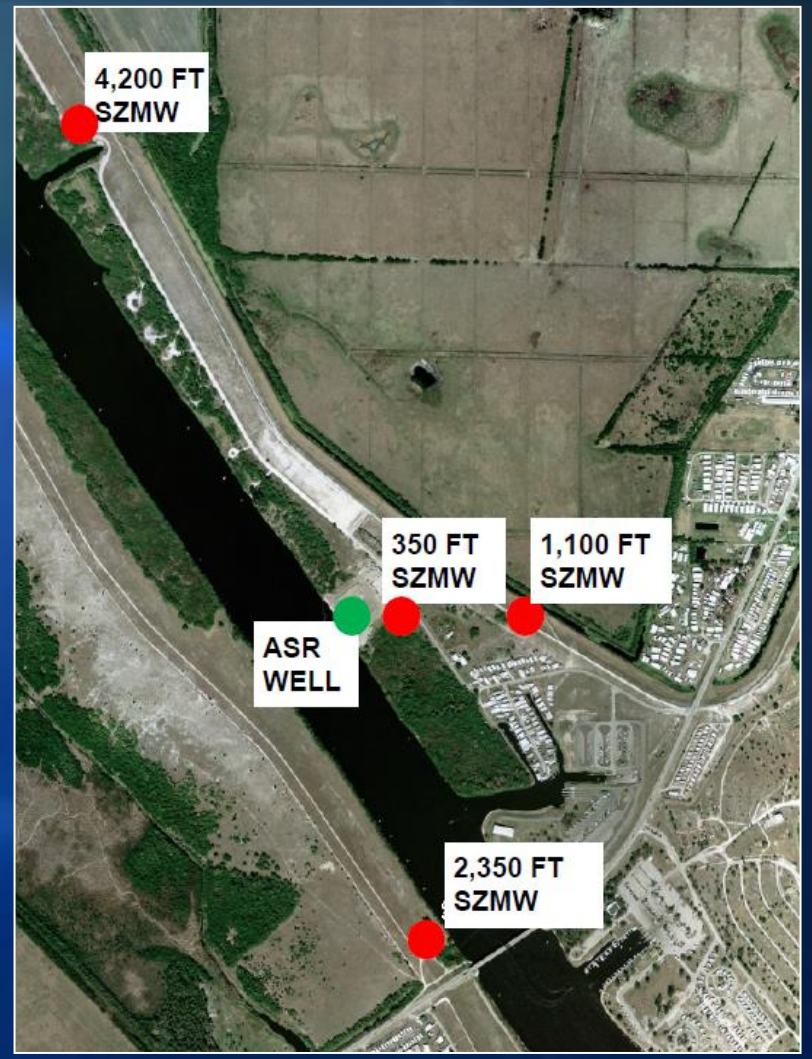


Implementation Strategy

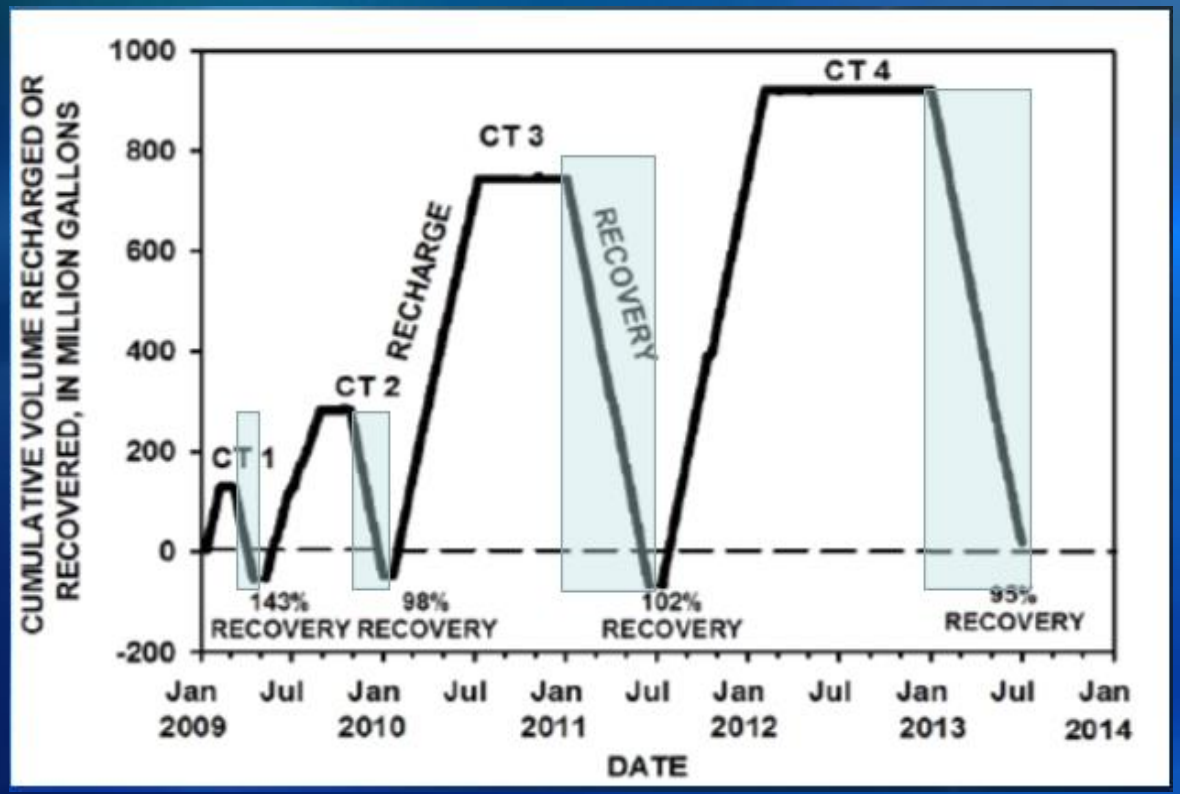
ASR Pilot Projects



Kissimmee River ASR (KRASR) Pilot Project

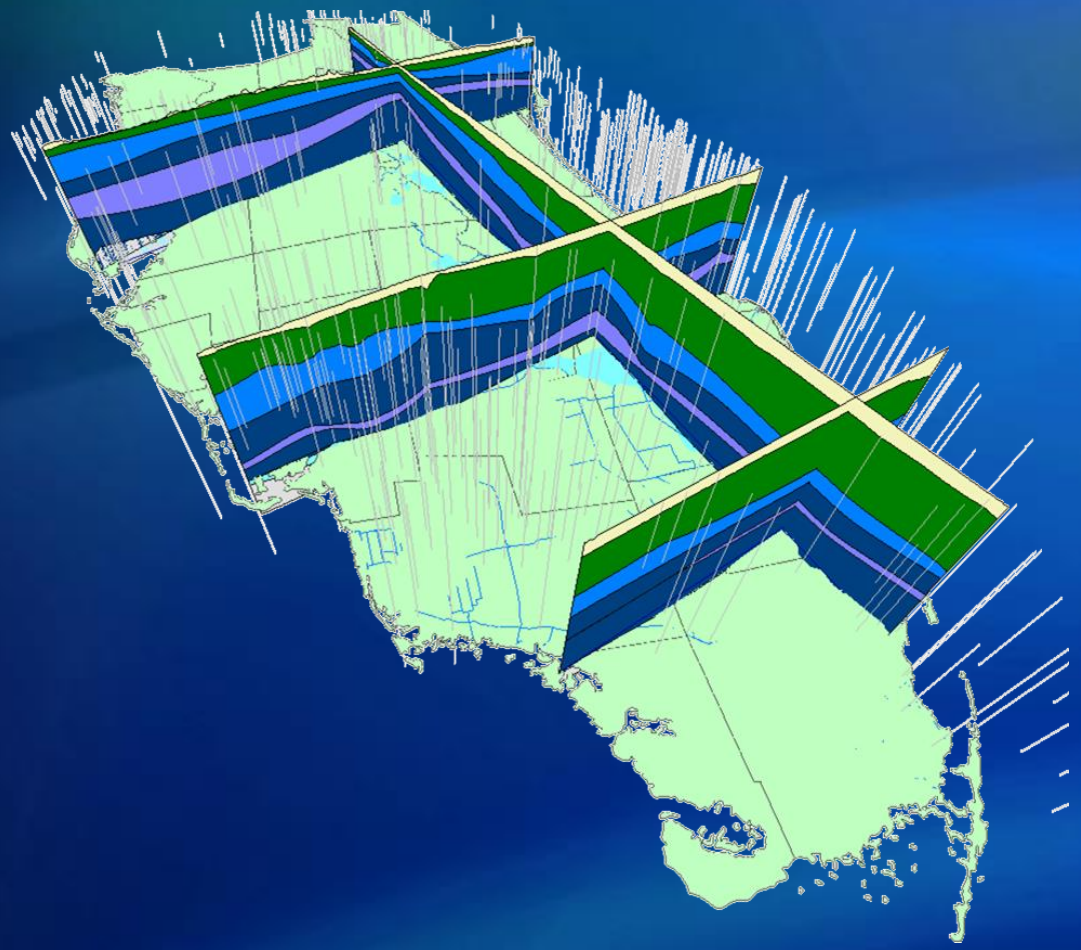


KRASR Pilot Project (cont.)



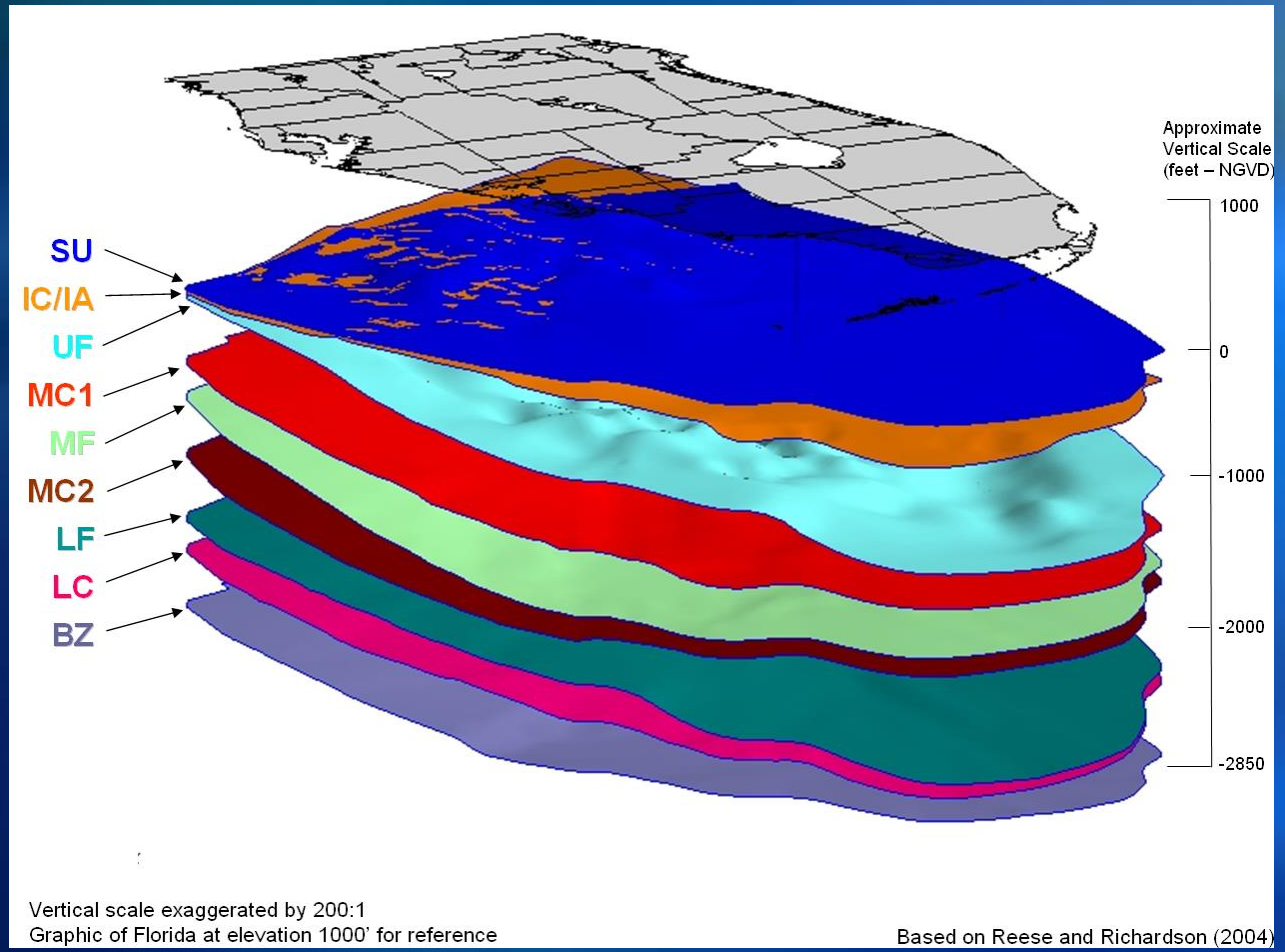
- Four consecutive recharge/recovery cycles (at 5 mgd) of increasing volume
- High recovery efficiencies due to fresh native groundwater in Upper Floridan Aquifer (UFA)
- Cycle test 4 was the largest volume recharge/recovery cycle from a single well in FL at the time

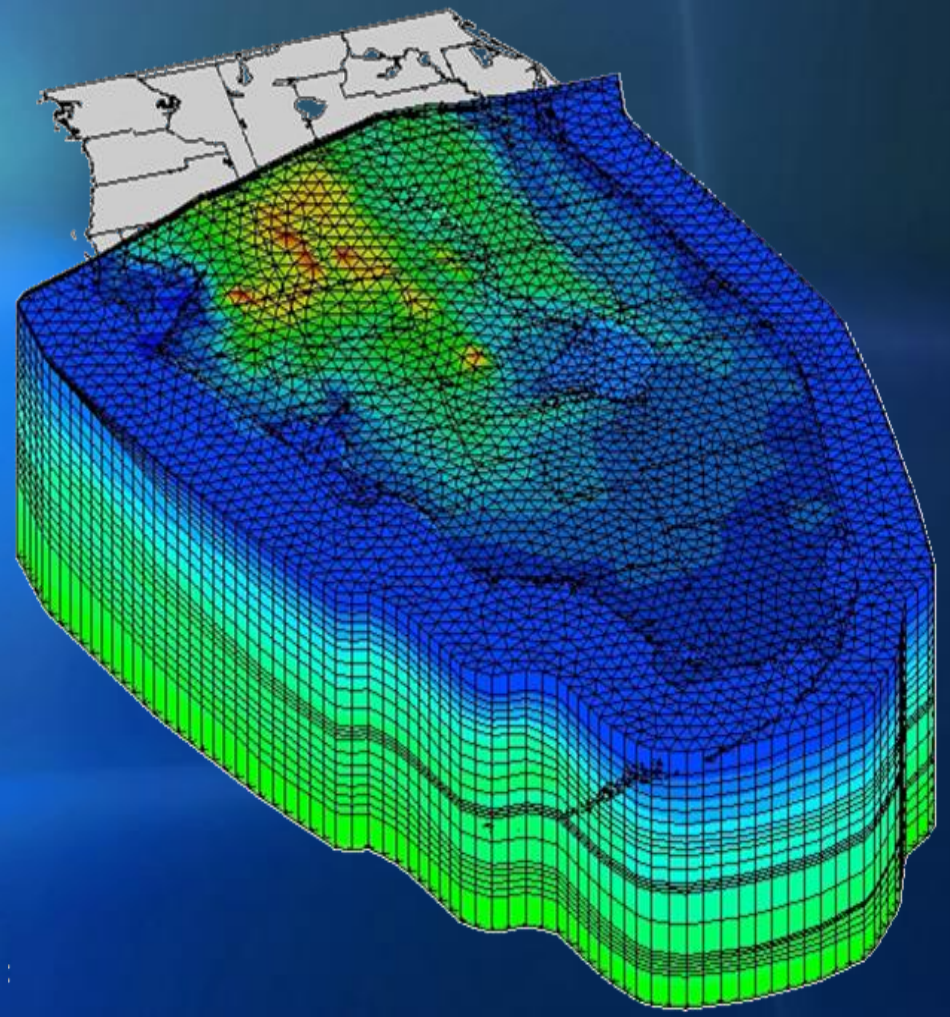
CERP ASR Regional Study



- To address regional considerations beyond the pilot projects associated with full-scale ASR implementation
- Groundwater model and ecological risk assessment
- Simulations tied to pilot project cycle testing data

Synthesis of Geologic Structure and Stratigraphy





Groundwater Model Analysis

- A total of 140 ASR wells are possible – not 333
  - About 80 wells associated with Lake O is reasonable
- Simulations assumed wells distributed in locations as originally envisioned in CERP
- Placed all ASR wells on properties in ownership by the SFWMD Rights-of-Way/State ownership
- Simulations took into account potential for:
  - Rock fracturing
  - Injection pressure (less than 100 psi)
  - Saltwater intrusion
  - Impacts to nearby artesian users
  - Areas designated for reduced thresholds

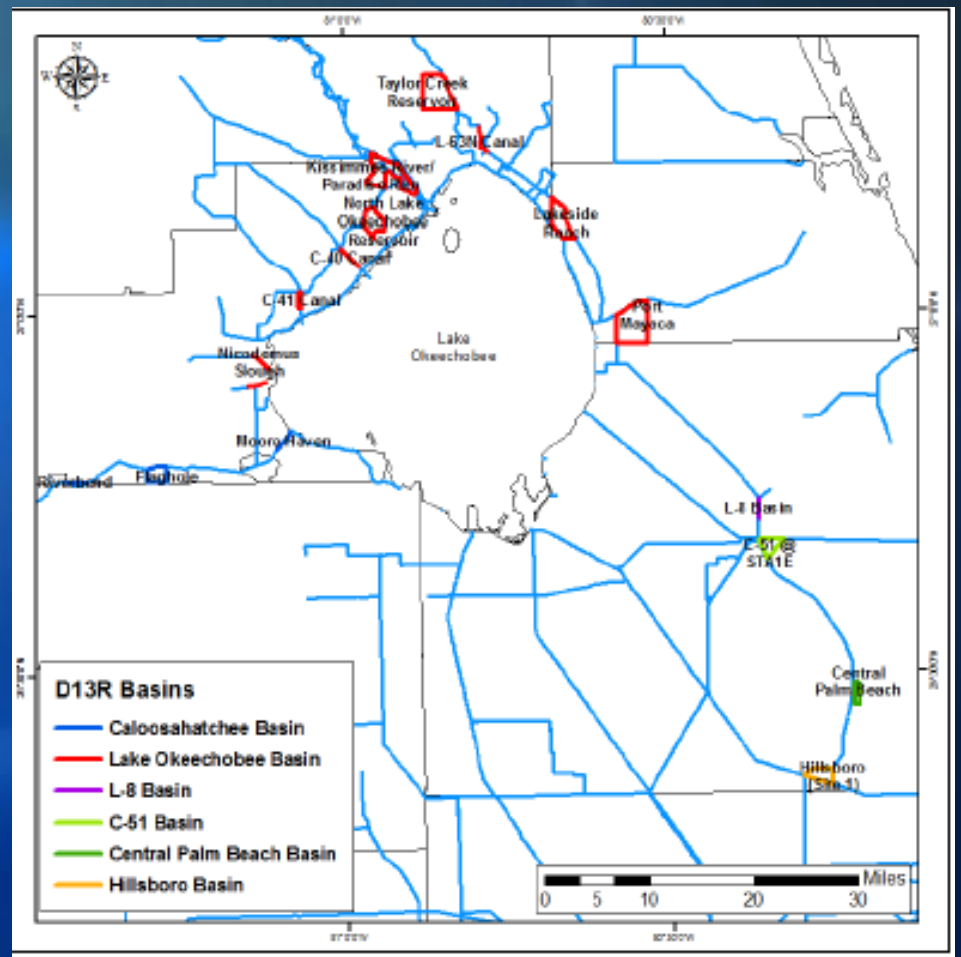


Figure 7-18 -- Proposed ASR Locations in D13R Basins.

Ecological Risk Assessment Summary

- Likelihood of ecological harm to Lake Okeechobee and the Everglades is low
- Risk to fishery is considered low, with low to moderate uncertainty
- Larval fish and/or entrainment risk is moderate to high, with some uncertainty
- ASR systems should be constructed where sufficient dilution can occur, but further investigation is warranted to confirm results
- ASR is viable, but implementation should be incremental and geographically dispersed

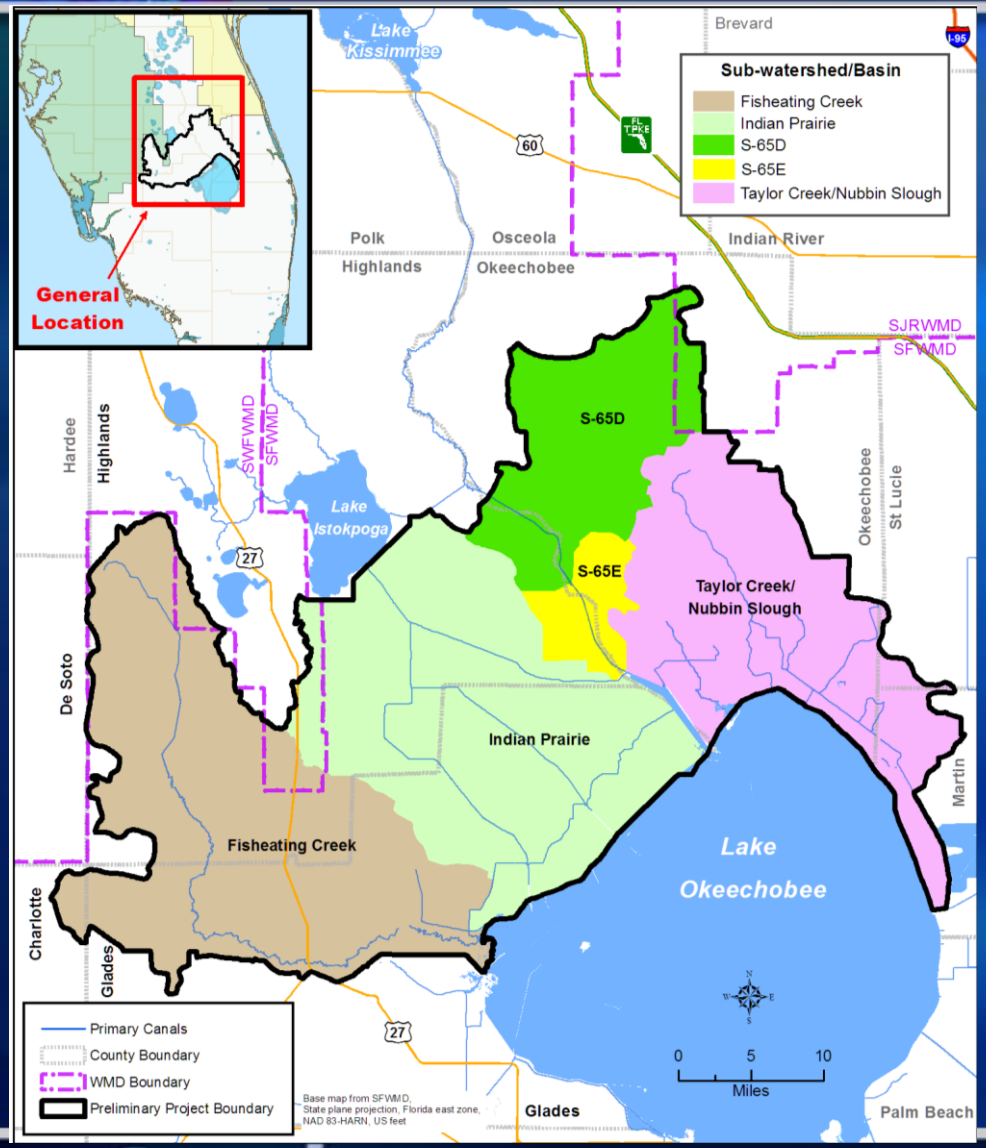
Essential Findings from the CERP ASR Studies

- No “fatal flaws” were uncovered
- Large capacity (5 mgd) ASR wells can be built; however, variability in hydrogeology makes it prudent to do exploratory programs first
- Water recovered from the ASR did not show persistent acute or chronic toxicological effects on test species.
- The potential for mercury methylation is low, but sulfate in recovered water should be monitored.
- Further implementation of CERP ASR should proceed in a phased approach.

Module 2

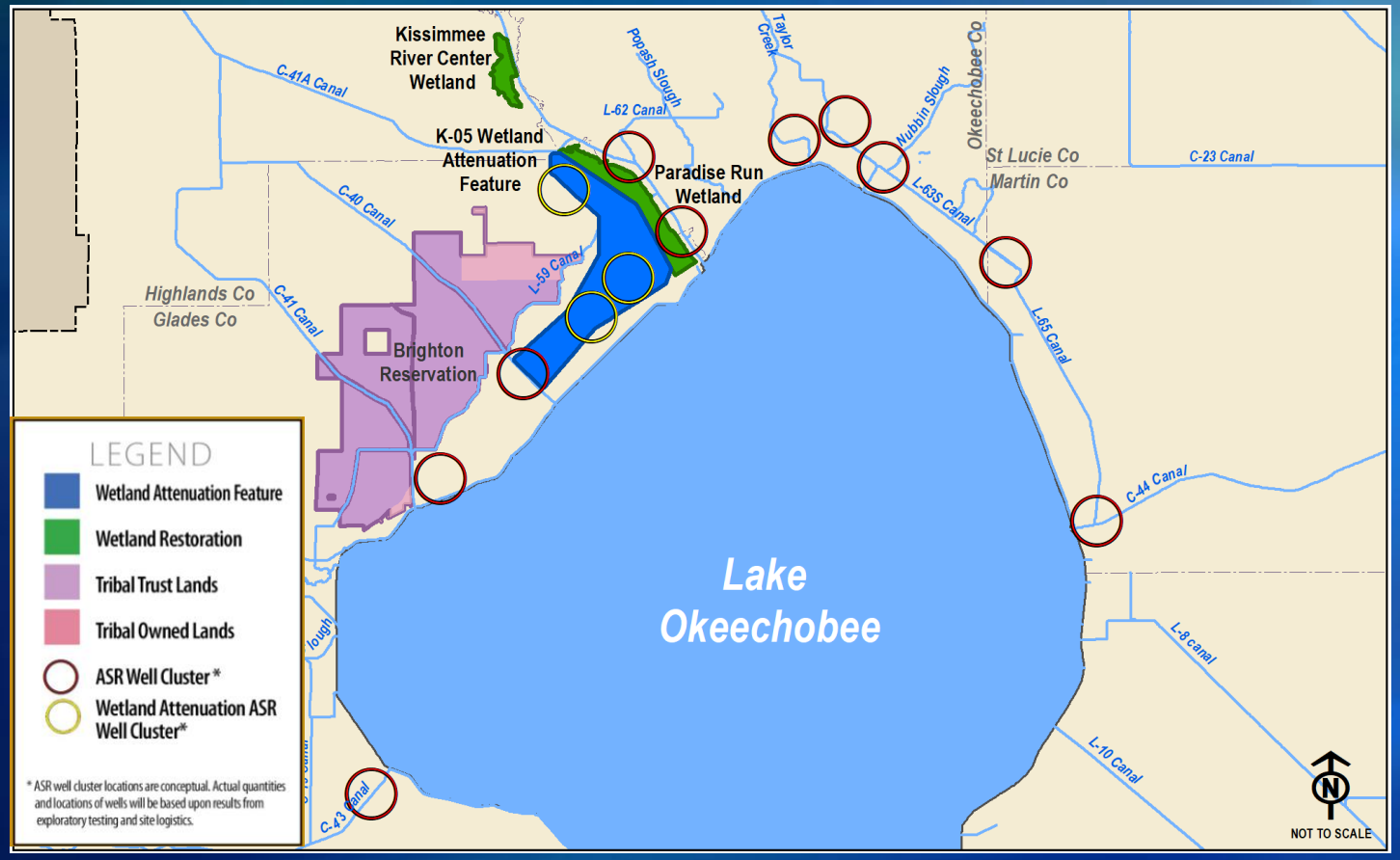
Lake Okeechobee Watershed Restoration Project
ASR Well Program

LOWRP Planning Area



- Planning area ~920,000 acres
- Focus on storage north of Lake Okeechobee
- Watershed historically dominated by prairies and wetlands
- Current land use includes:
  - Agriculture
  - Natural/Open land and water
  - Urban/Infrastructure

LOWRP Recommended Plan: $1.96B



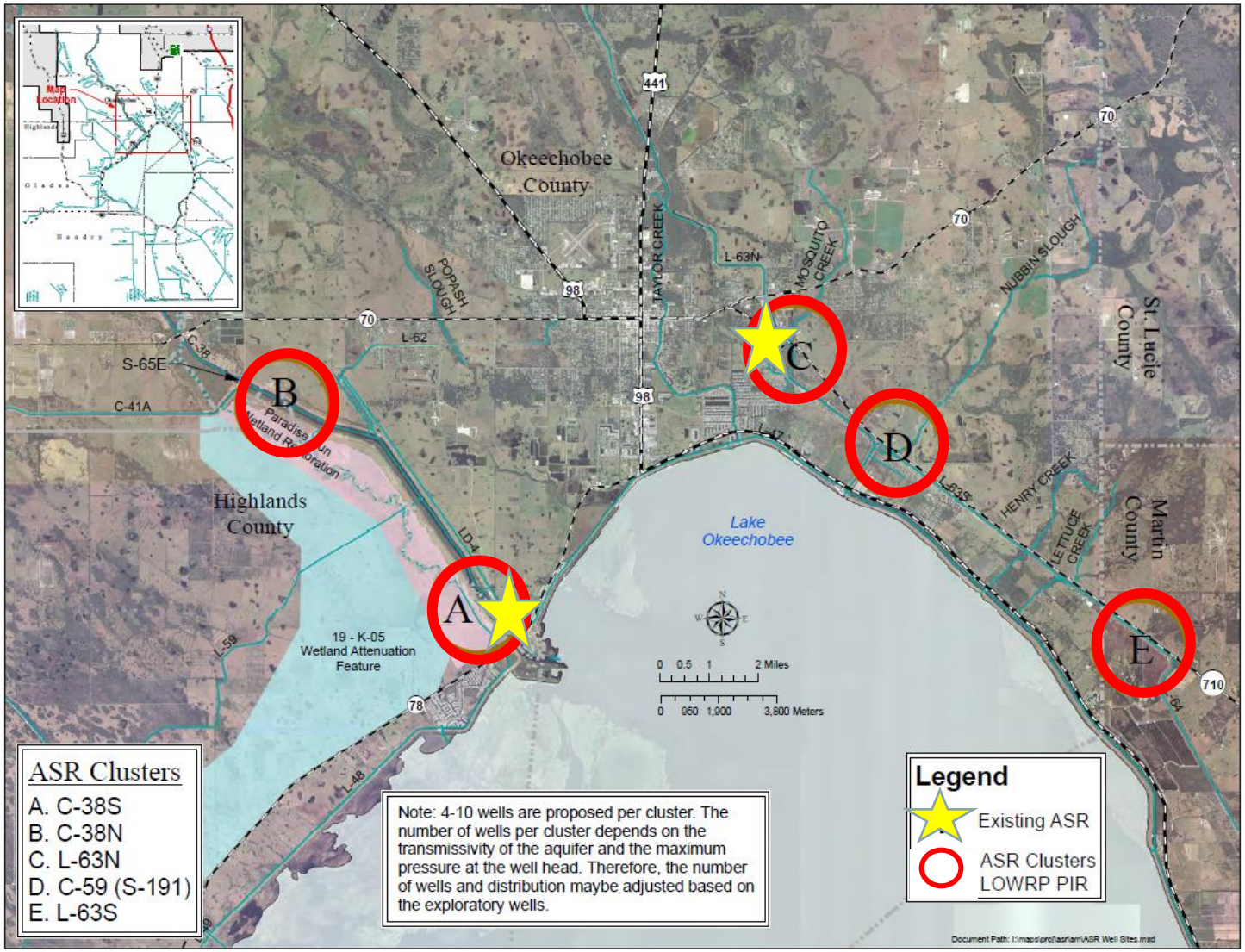
Recommended Plan components:

- **Shallow aboveground storage**
  - Wetland Attenuation Feature (WAF)
  - ~ 13,600 acres
  - 46,000 ac-ft storage
- **Aquifer storage and recovery**
  - **80 ASR wells**
  - 448,000 ac-ft of storage per year (400 MG/day)
- **Wetland restoration**
  - Paradise Run ~ 3,600 acres
  - Kissimmee River – Center ~ 1,200 acres

LOWRP ASR Well Program

- State Appropriations
  - Received $50M in FY19-20
  - Additional $50M in FY20-21
- "Design, engineering, and construction of specific project components designed to achieve greatest reductions in harmful discharges to the Caloosahatchee and St. Lucie Estuaries" (Specific Appropriation 1642A)
- Incremental, phased approach being implemented in the Program and the specific watershed ASR projects prioritized for these State Appropriations

ASR Cluster Evaluation: Phased Approach

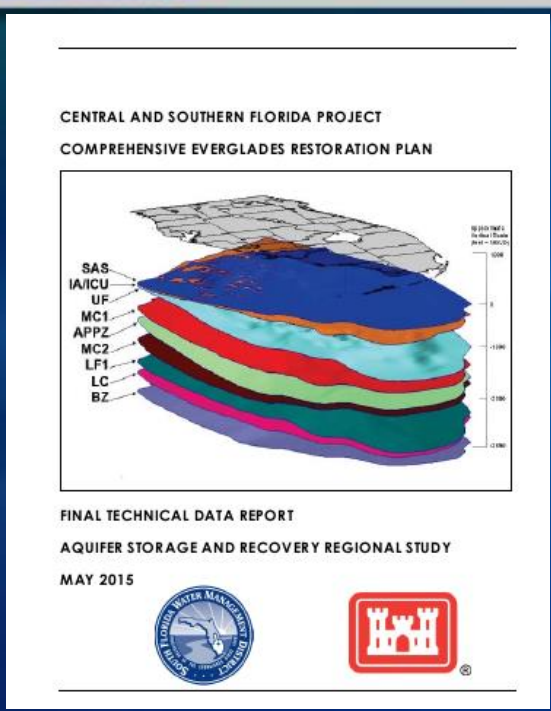


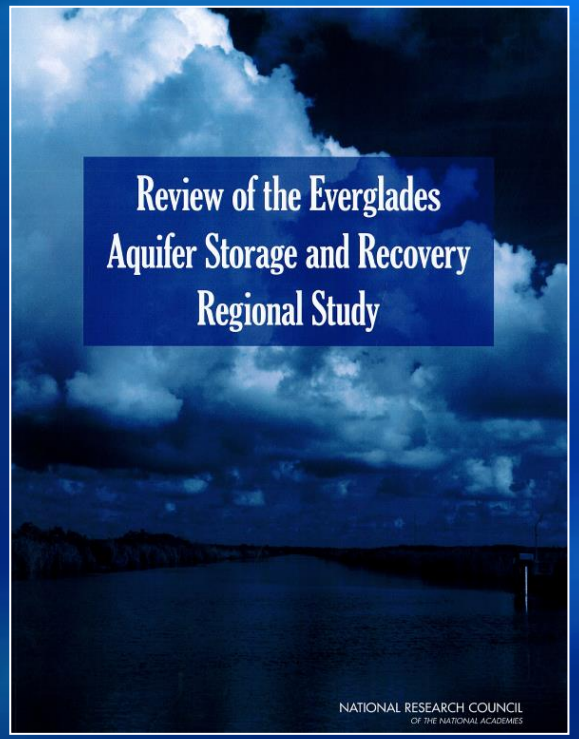
- Reactivate existing ASR wells
- Continuous cores
- Exploratory/test wells
- Treatment technology evaluation
  - Screening
  - Media filtration
  - UV
  - Ion exchange
  - Coagulation
  - Nanofiltration
  - Ultrafiltration

Module 3

2020 ASR Science Plan

NRC Review of ASR Regional Study





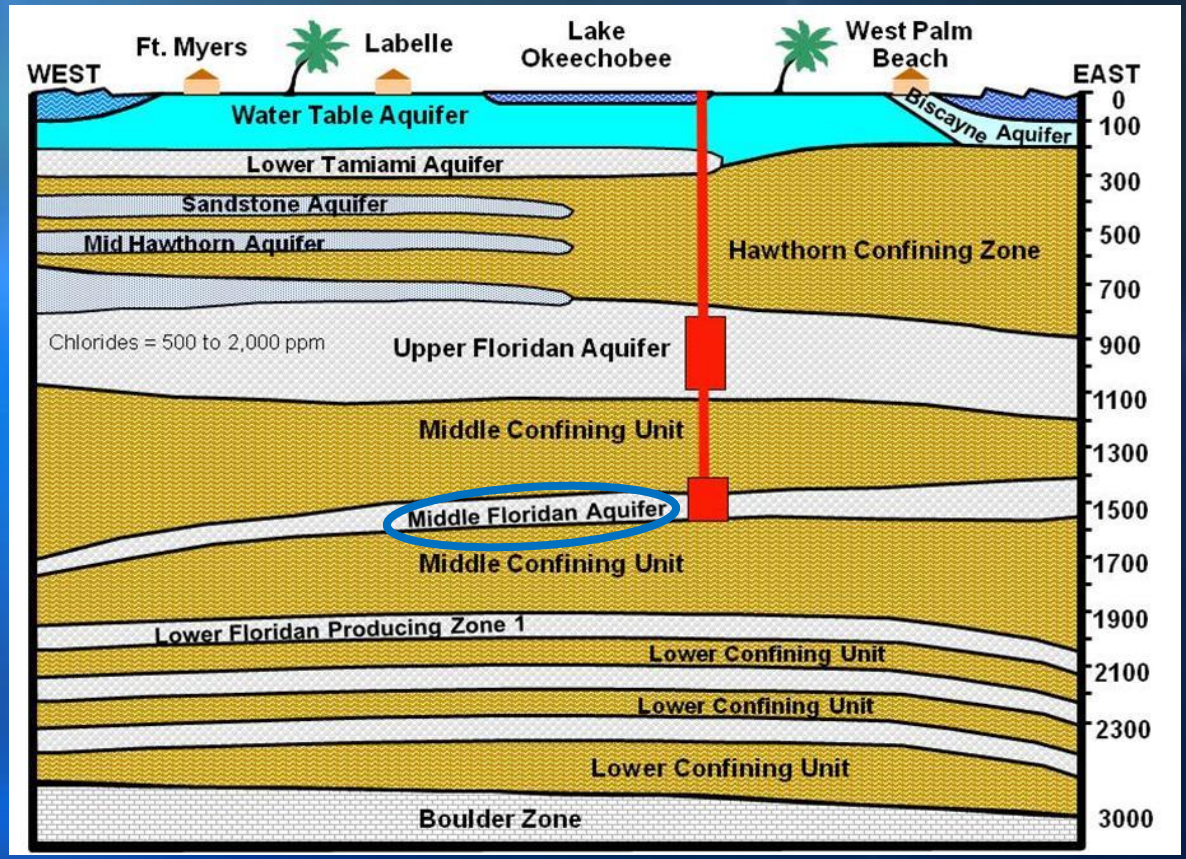
- No “fatal flaws” preclude the use of ASR in CERP
- An incremental approach may involve phased clusters of ASR wells while providing some early benefits
- 6 Topics of Remaining Uncertainty
  - Future Construction and Testing
  - Understanding Phosphorus Reduction Potential
  - Operations to Maximize Recovery
  - Disinfection/Treatment Technology
  - Ecotoxicology and Ecological Risk Assessment
  - Water Quality

ASR Peer Review Panel

- Recognized, independent south Florida experts to assist in addressing remaining ASR uncertainties
  - Dr. Jon Arthur, FGS
  - Dr. Tom Missimer, FGCU
  - Dr. Rene Price, FIU
  - Reid Hyle, FFWCC Research Institute
  - Dr. Sam Upchurch, retired USF
- Workshops during July and November
  - Reviewed the results of previous ASR studies
  - Provided a report containing suggestions for addressing the NRC recommendations

Future Construction and Testing

- More local scale information is needed on the attributes of the Avon Park Permeable Zone
  - Reactivate the L63N ASR well
    - Mechanical integrity test (2020)
    - Cycle testing (2023-2024)
  - Continuous cores at new locations (2021-2022)
    - Drilled to 2,000 feet bls
    - Water sampling at 30-foot intervals
    - Mineralogy, porosity, geotechnical and hydraulic properties
    - Geochemical modeling
    - Slabbed, described and stored by the USGS in Davie



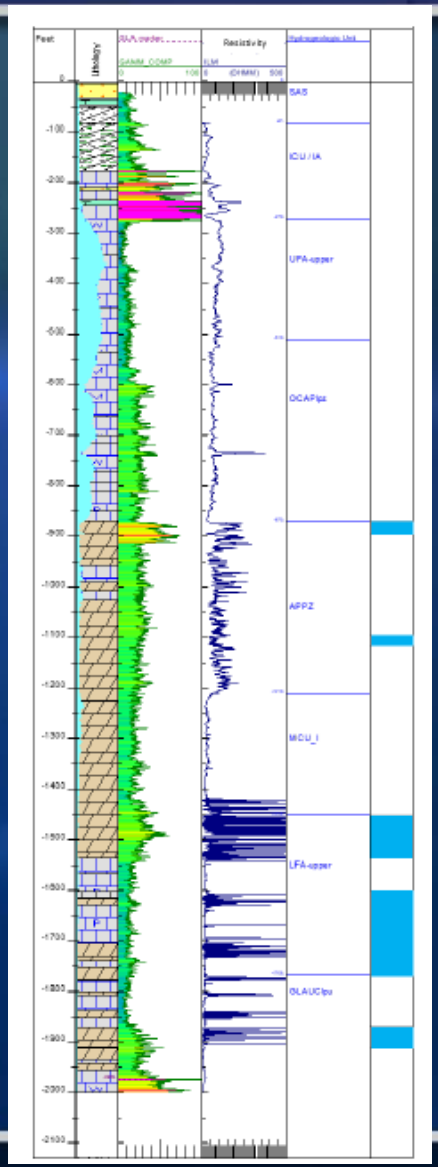
L63N ASR: Completed in the APPZ

Figure 5. Blockage at 1,570 ft bpl with partial cavern floor.

Figure 6. Recovered XY caliper tool cable.

Figure 9. Clean and clear open hole at 1,568 ft bpl.

Future Construction and Testing Continuous Cores

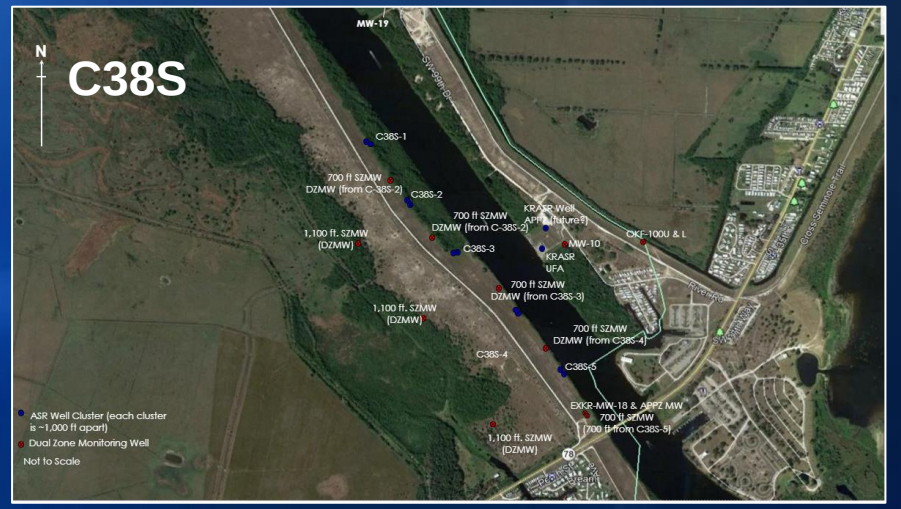


Future Construction and Testing
Water Quality Sampling

- Every 30 feet interval (beginning at 500 ft bls)
  - Chloride
  - Alkalinity
  - Arsenic
  - Calcium
  - Potassium
  - Magnesium
  - Sodium
  - Silica
  - Sulfate
  - Total dissolved solids (TDS)
  - Strontium
- At discrete intervals (potential storage zones)
  - Total suspended solids
  - Color
  - Fluoride
  - Carbonate alkalinity
  - Bicarbonate alkalinity
  - Iron
  - Aluminum
  - Copper
  - Manganese
  - Zinc
  - Cadmium
  - Selenium
  - Total hardness
  - Calcium hardness
  - Nitrate
  - Phosphate
  - Ammonia
  - Hydrogen sulfide
  - Total organic carbon
  - Specific gravity or fluid density
  - Total coliform
  - Chloroform
  - Bromodichloromethane
  - Dibromochloromethane
  - Bromoform
  - Total trihalomethane

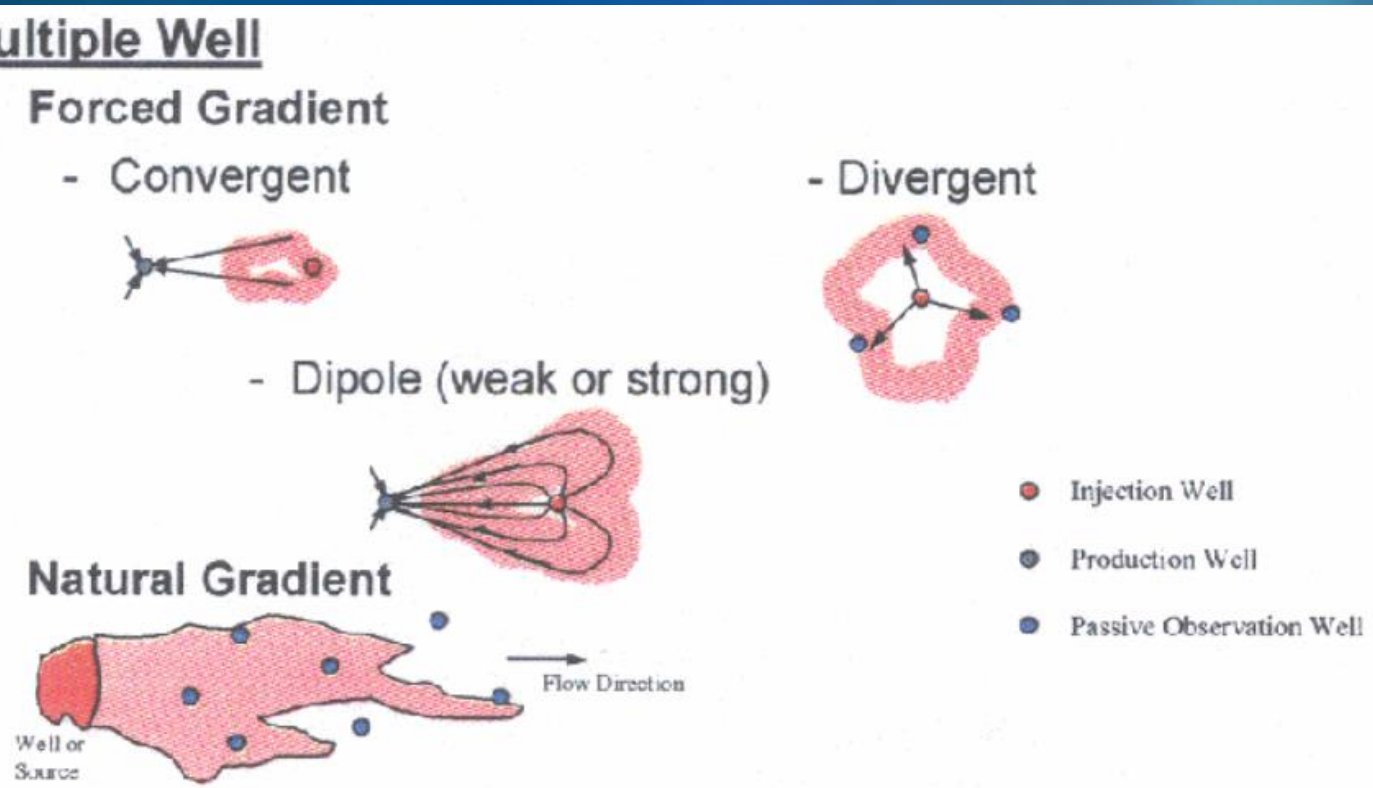
Future Construction and Testing Exploratory/Test Wells

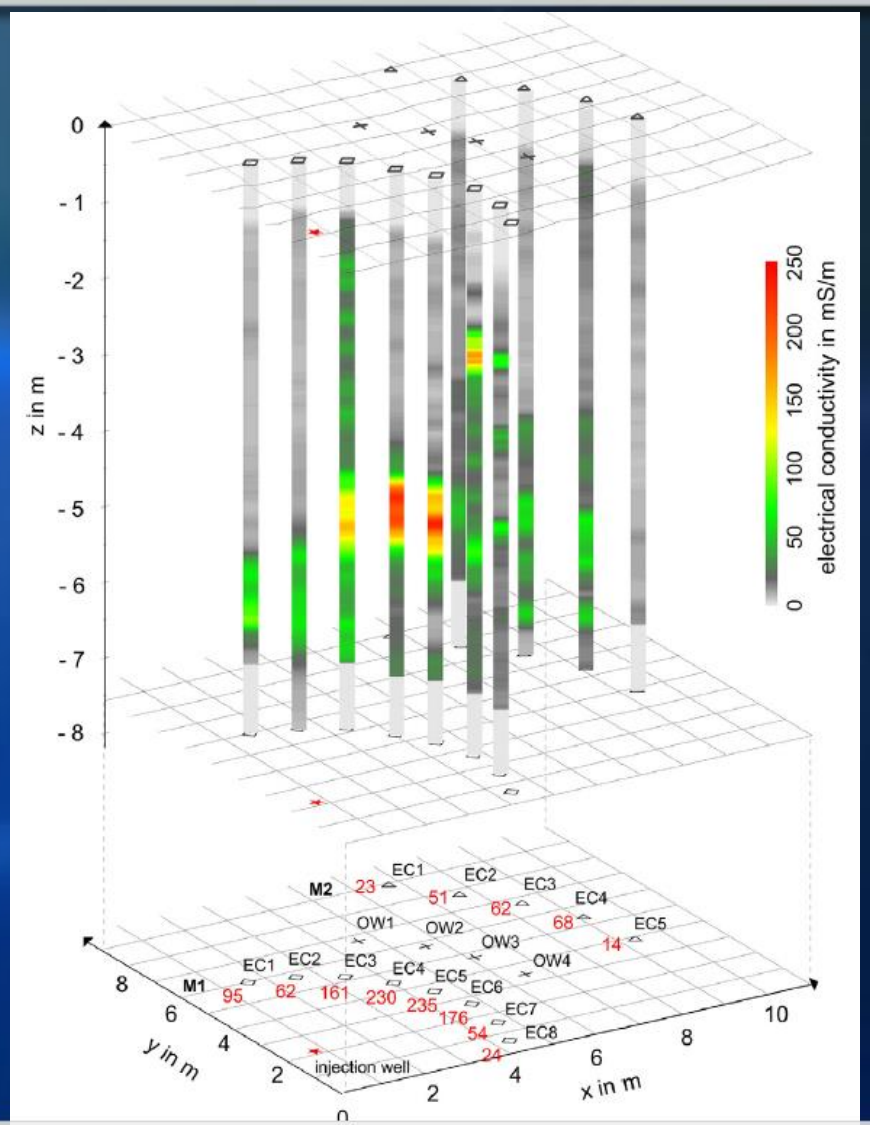
- Analyze optimal wellfield cluster configurations and consider orienting wells to maximize recovery and monitoring
- Use groundwater models, geophysics, and tracer tests to anticipate heterogeneity, anisotropy, and travel times
  - Constructing multi-level, nested exploratory test wells at two locations along C38 canal (2021-2022)
  - Monitoring wells
  - Pumping (withdrawal) and tracer (injection) tests (2022)
  - Wellfield-scale groundwater models (2022)



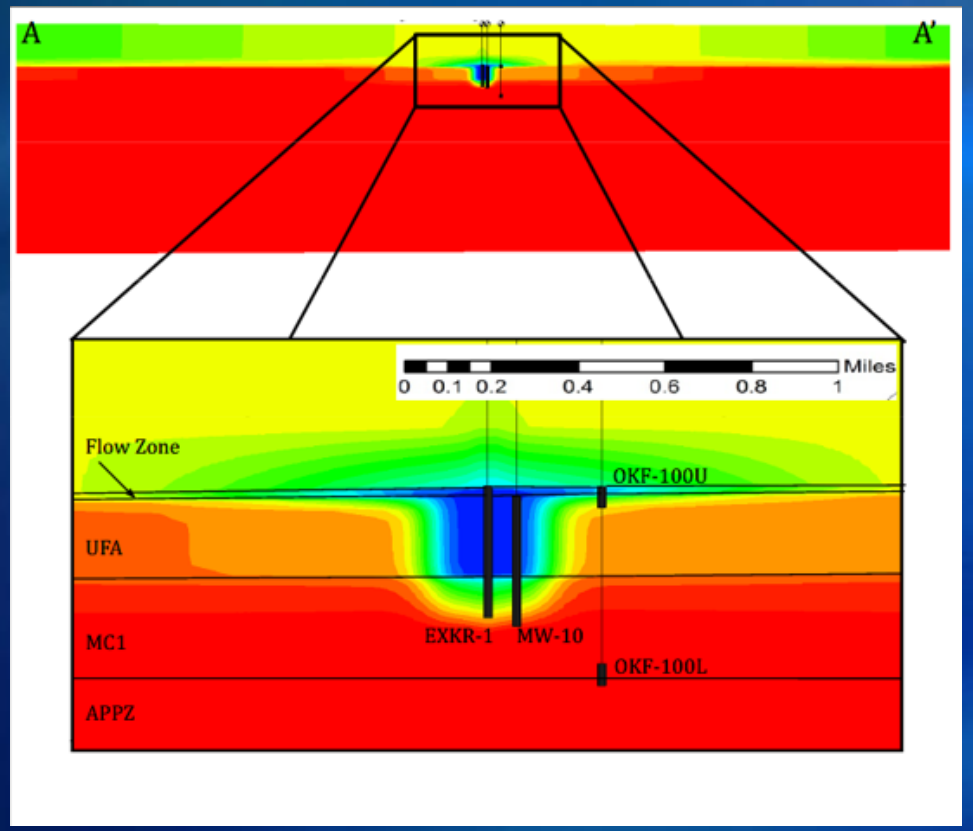
Future Construction and Testing
Tracer Studies

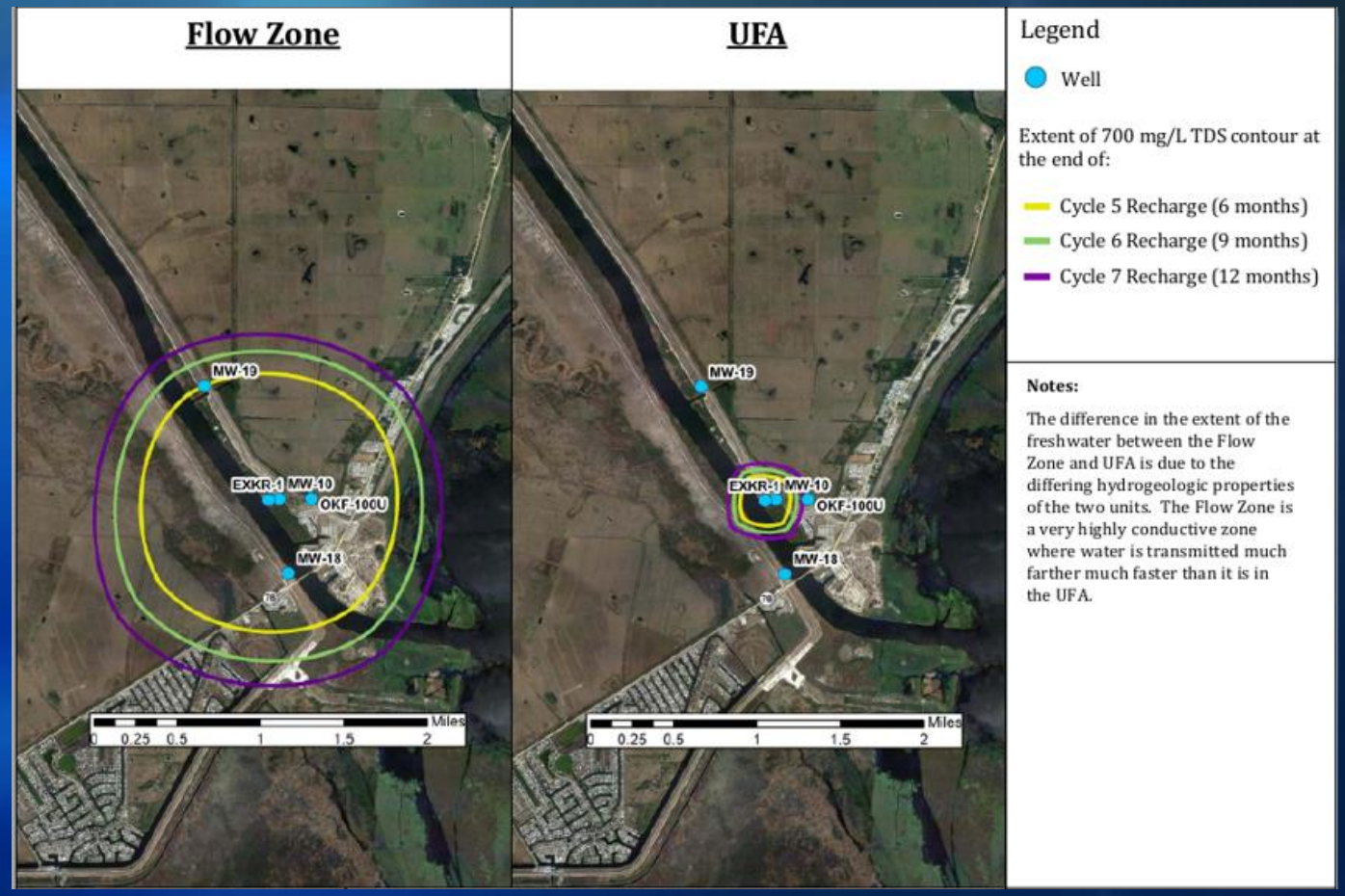
- **Multiple Well**
  - Forced Gradient
    - Convergent
    - Divergent
    - Dipole (weak or strong)
  - Natural Gradient





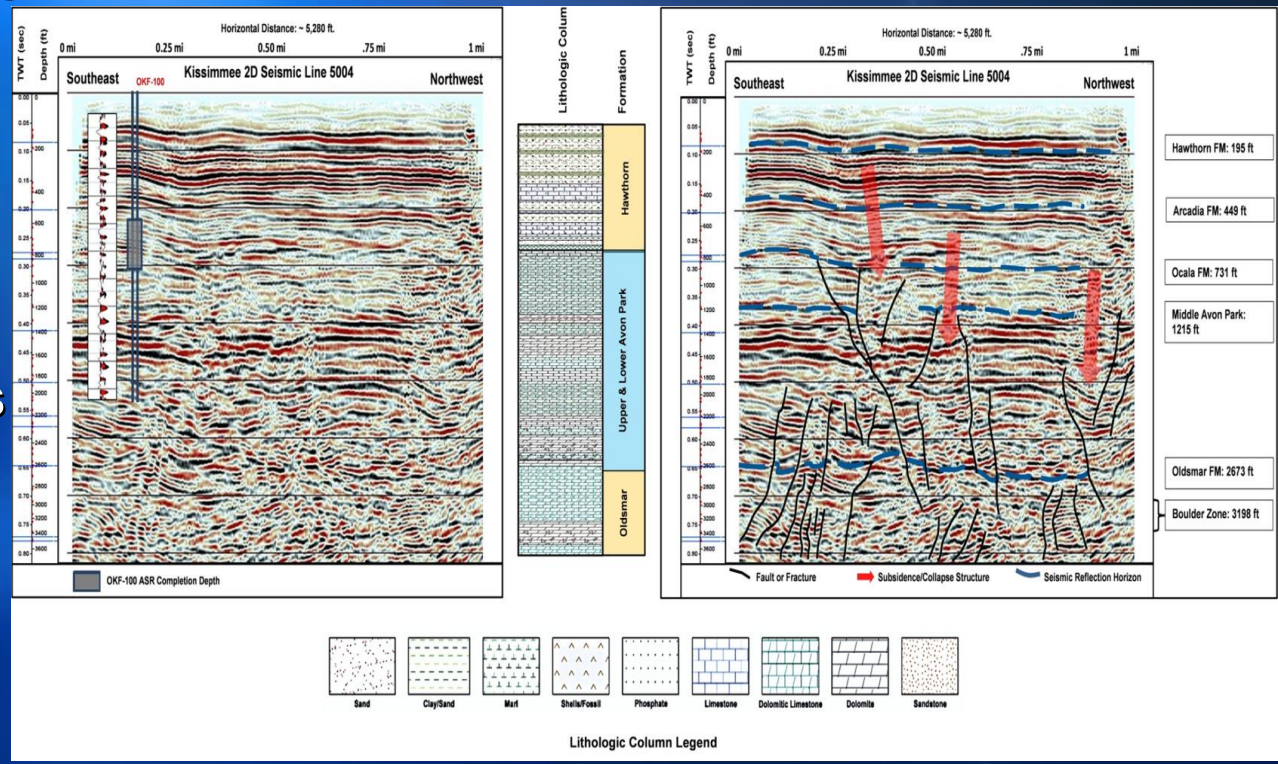
Future Construction and Testing Wellfield-Scale Groundwater Modeling





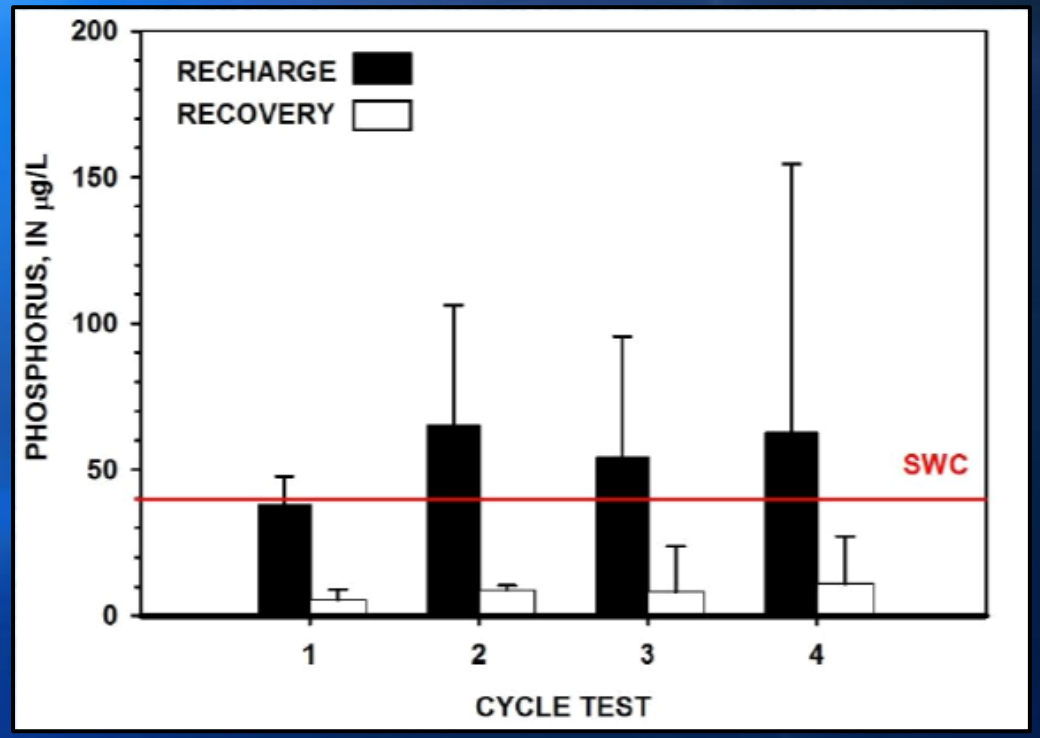
Future Construction and Testing Geophysical Surveys

- Consider cross-well tomography and seismic evaluations to determine effects of faults on well location and performance
- Verify that injection pressures will not fracture formations
  - Evaluating the following technologies
    - Time domain electromagnetic induction
    - Electrical resistivity
    - Vertical seismic profiling
    - Cross-well tomography
    - Controlled source audio magnetotellurics
    - 2-dimensional seismic survey
    - 3-dimensional imaging
    - Passive micro-seismic monitoring



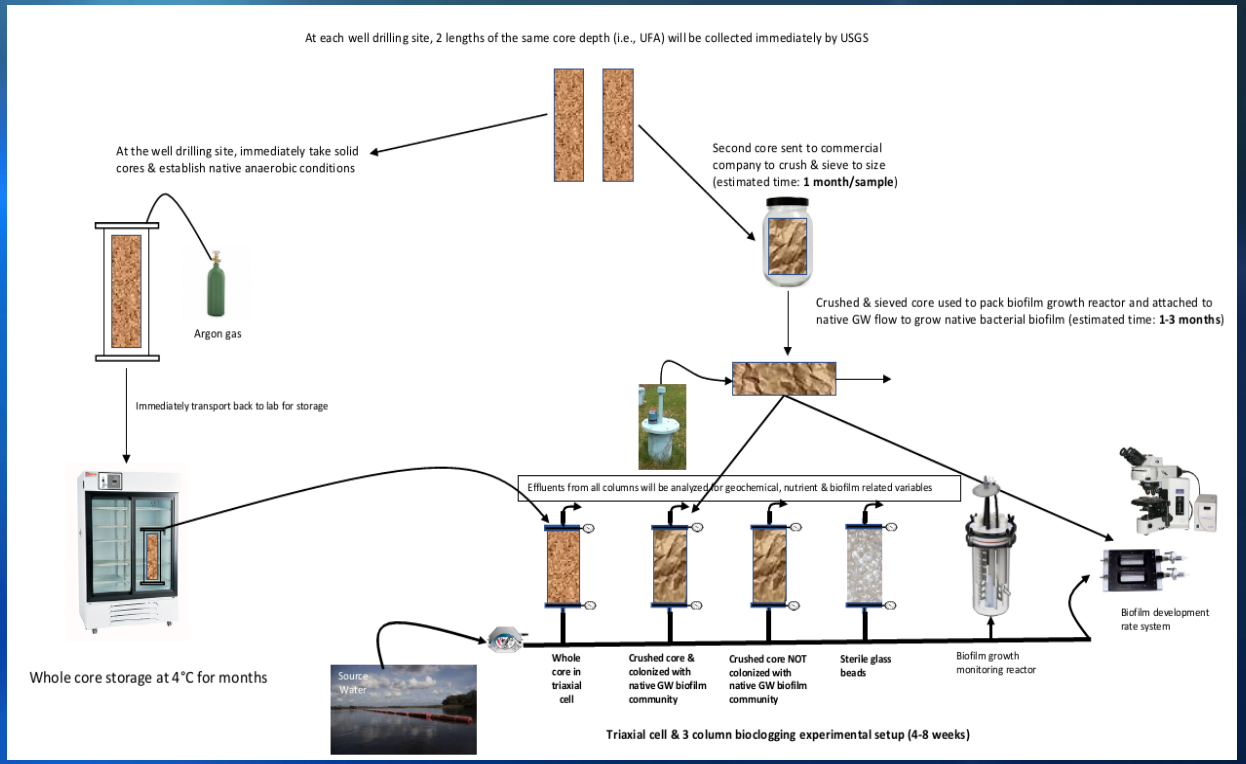
Understanding Phosphorous Reduction

- More research into the long-term nutrient removal mechanisms and rates should be undertaken
  - USGS to develop low-through column experiments using continuous cores (2021)
  - Geochemical modeling from continuous core water quality data
  - Enhanced monitoring P and N species when Kissimmee and L63N systems are back up and running (2023)
  - Revision of the SFWMD Phosphorus Load Simulation Model



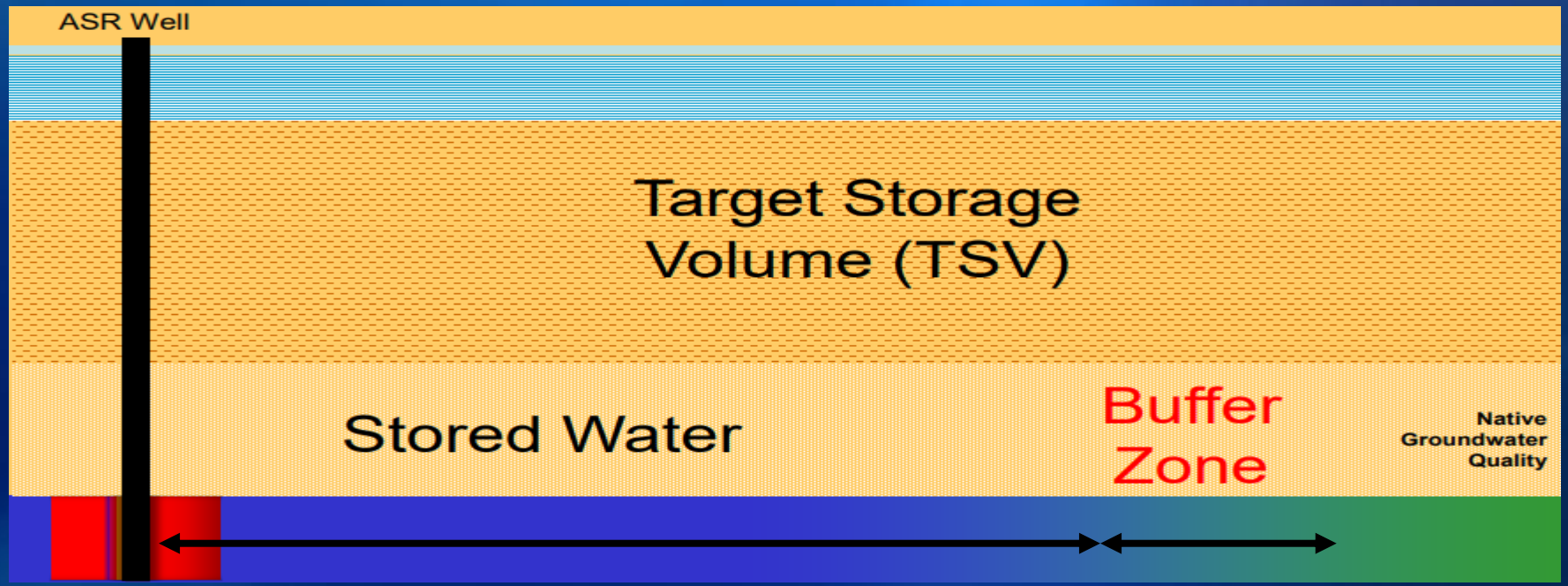
Understanding Phosphorous Reduction Column Studies

- **USGS flow-through column analyses**
  - Microscopic visualization of progression
  - Biofilm production rates
  - Organic carbon characterization
  - Microbial community biomass turnover
  - Biogenic gas production
  - Microbial community diversity and function
  - Calcium carbonate geochemical modeling
  - Mineralogic analysis
  - Geochemical analysis of output water
  - Particle size analysis
  - Zeta potential



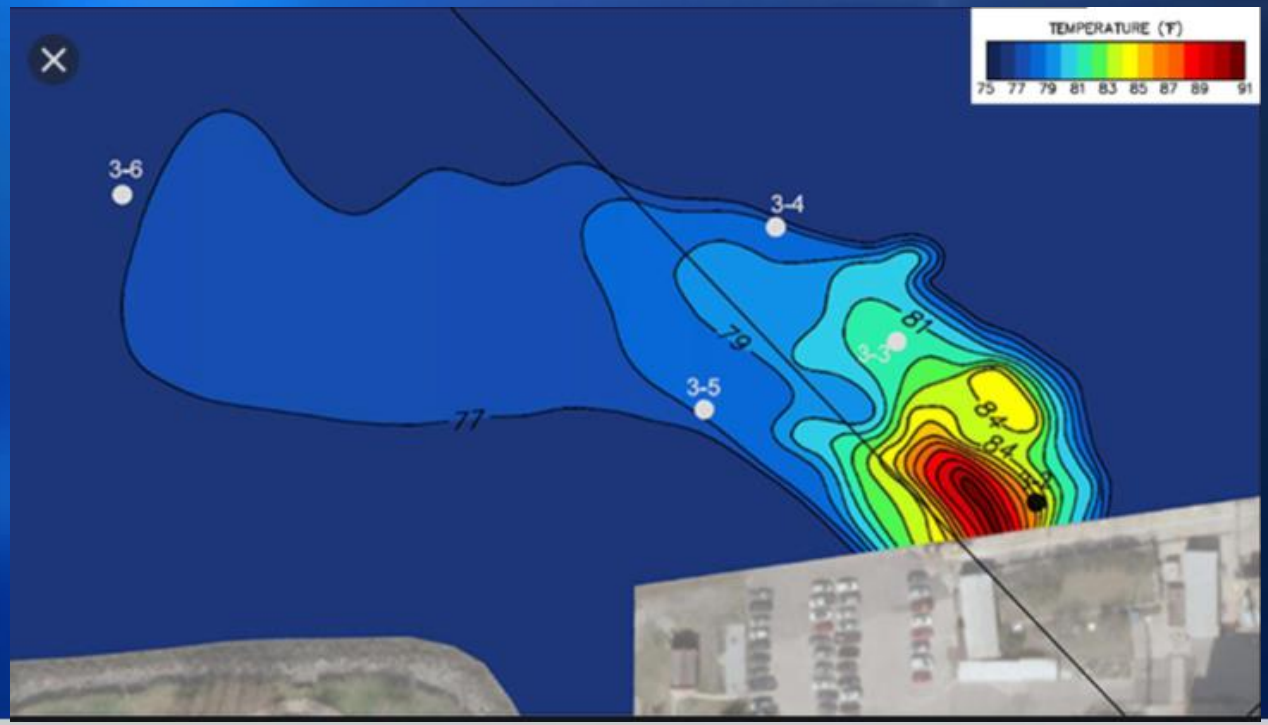
Operations to Maximize Recovery
Buffer Zone Creation

- Establish and maintain a Buffer Zone (TSV) during cycle testing
  - Invest in an initial volume of water to condition aquifer prior to cycle testing
  - Don't withdraw all recharged water during cycle testing to maintain a boundary



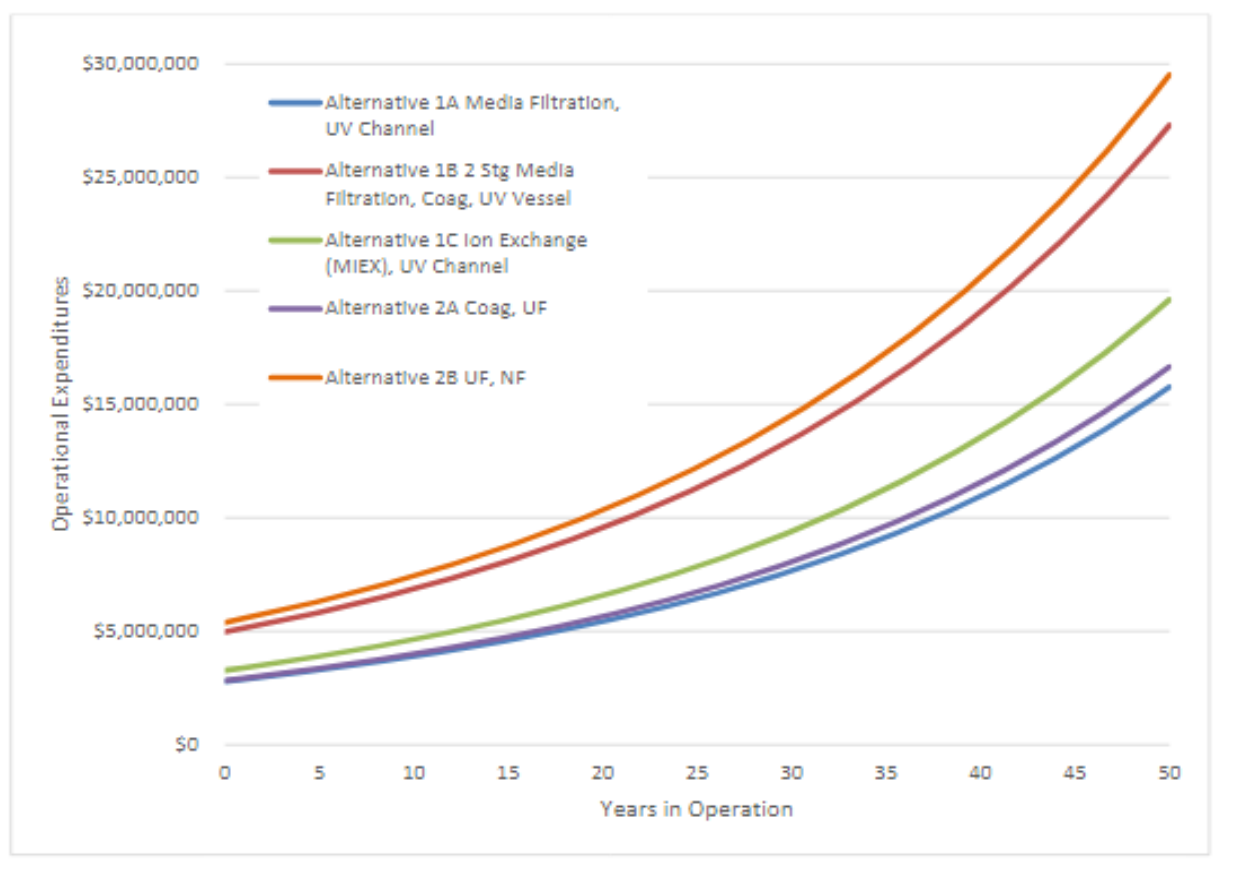
Operations to Maximize Recovery
Mixing Models

- Locate ASR systems adjacent to large water bodies to allow for adequate mixing zones
  - Perform discharge plume modeling (thermal and chemical effects)
  - Minimize effects to fish spawning, manatees
  - Integrate into the design of discharge components



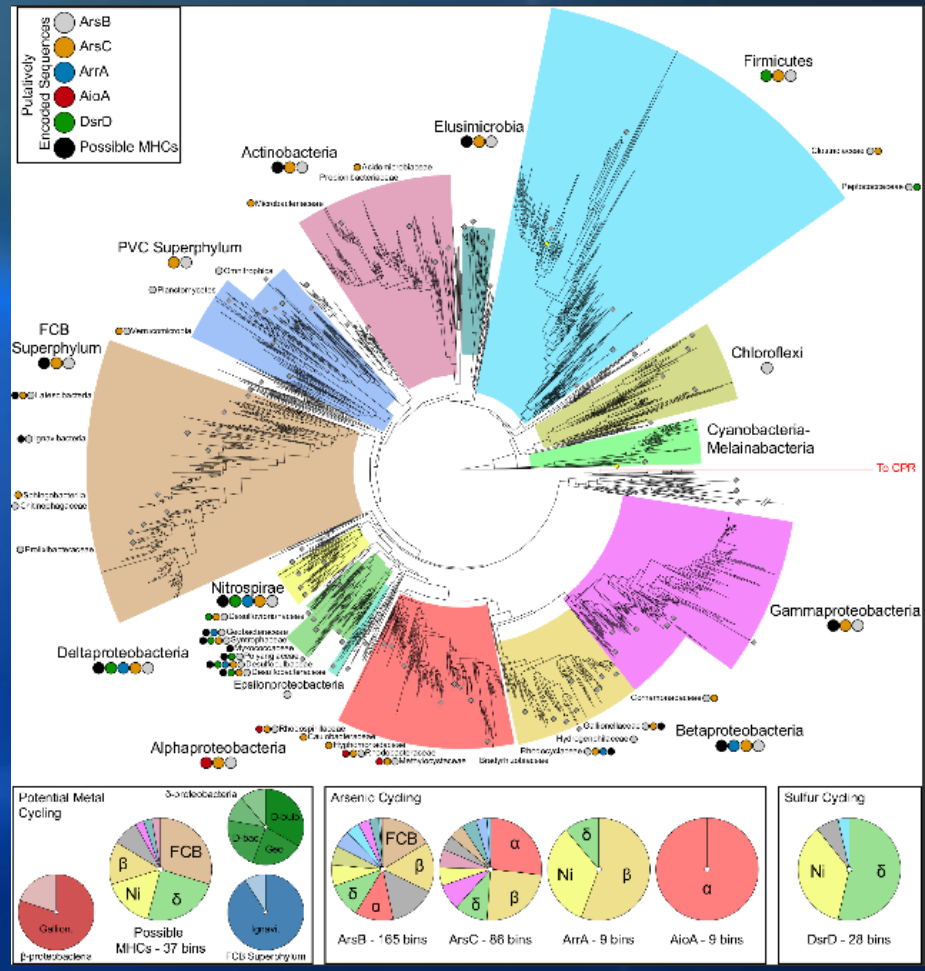
Disinfection/Treatment Technology

- Develop appropriate pretreatment strategies to consistently meet regulatory requirements
- Completed Phase 1 assessment of available processes (2020)
- Phase 2 assessment may follow an independent technical review (2021)
  - May include pilot testing of high-graded alternatives



Disinfection/Treatment Technology Benchtop Geochemical Modeling

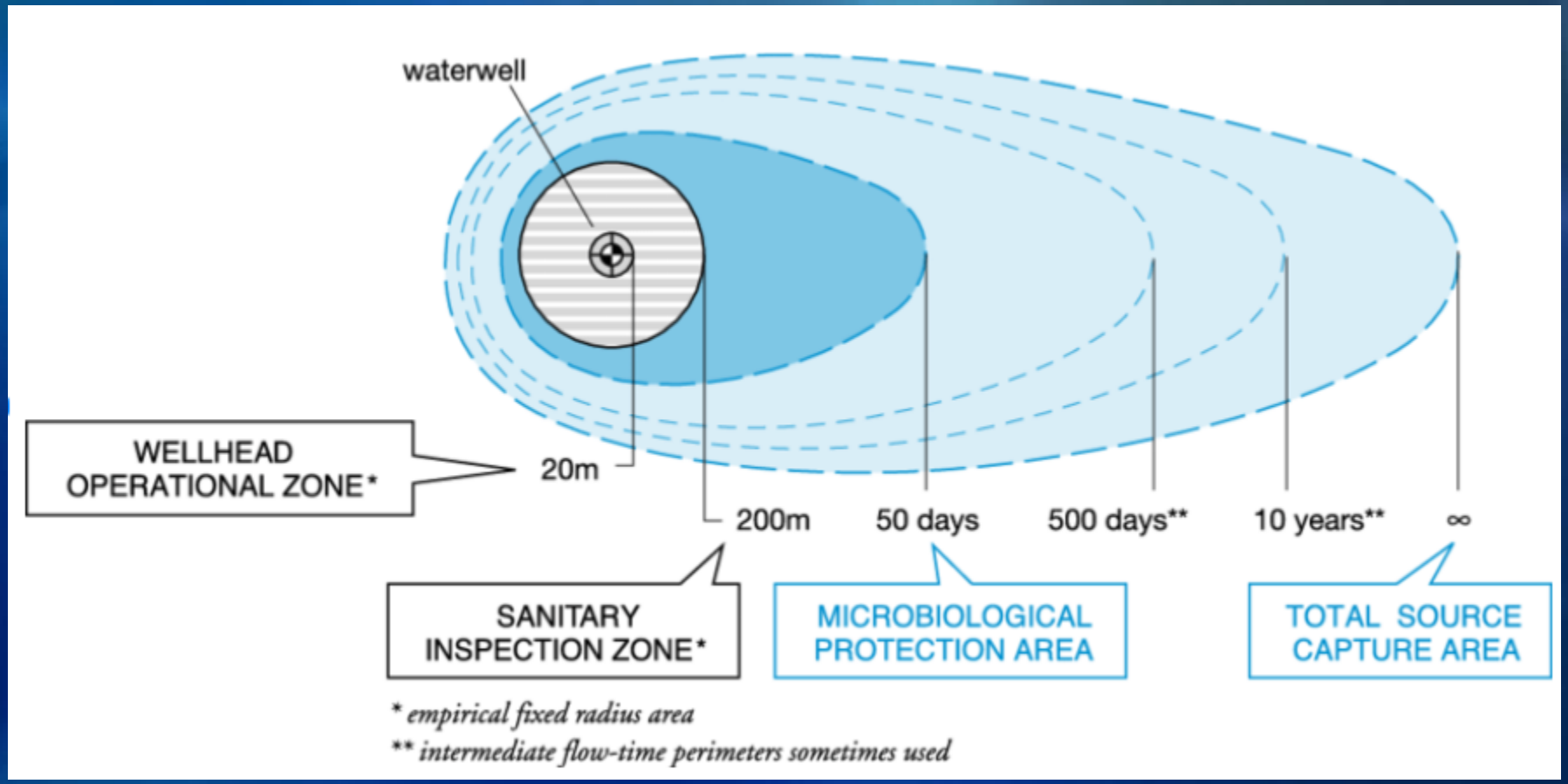
- Develop pretreatment strategies to attenuate arsenic mobilization
  - Geochemical benchtop mixing models from continuous cores
  - Phase 2 treatment technology evaluation may consider options such as:
    - Oxygen degasification, Redox adjustment
    - TSV/buffer zone maintenance



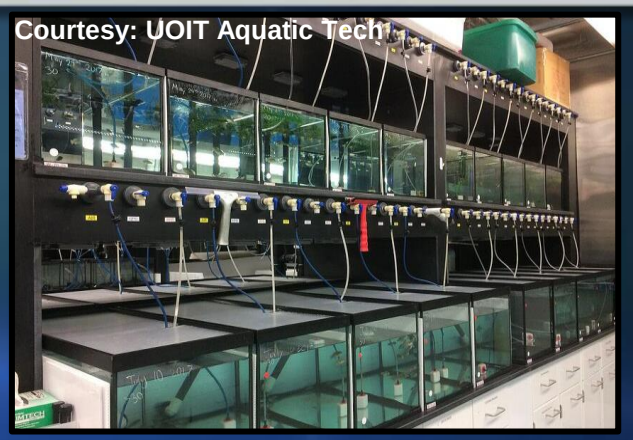
Disinfection/Treatment Technology Pathogen Inactivation

- Continue research on subsurface pathogen inactivation using a wider array of pathogens
  - Recently included *Crypotosporidium* and *Enterovirus* (2020)
    - 5-log reduction over a 60-day period
    - Supports previous estimates using *Estericia coli* and MS2 bacteriophage
- Couple pathogen inactivation studies to groundwater travel times and distances using local scale groundwater modeling
  - Will utilize tracer studies at exploratory/test wells at C38 to develop local scale groundwater model with travel times/distances (2022)

Disinfection/Treatment Technology Distance/Travel Time Modeling



Ecotoxicology and Risk Assessment
Bench-Scale Chronic Toxicity Testing

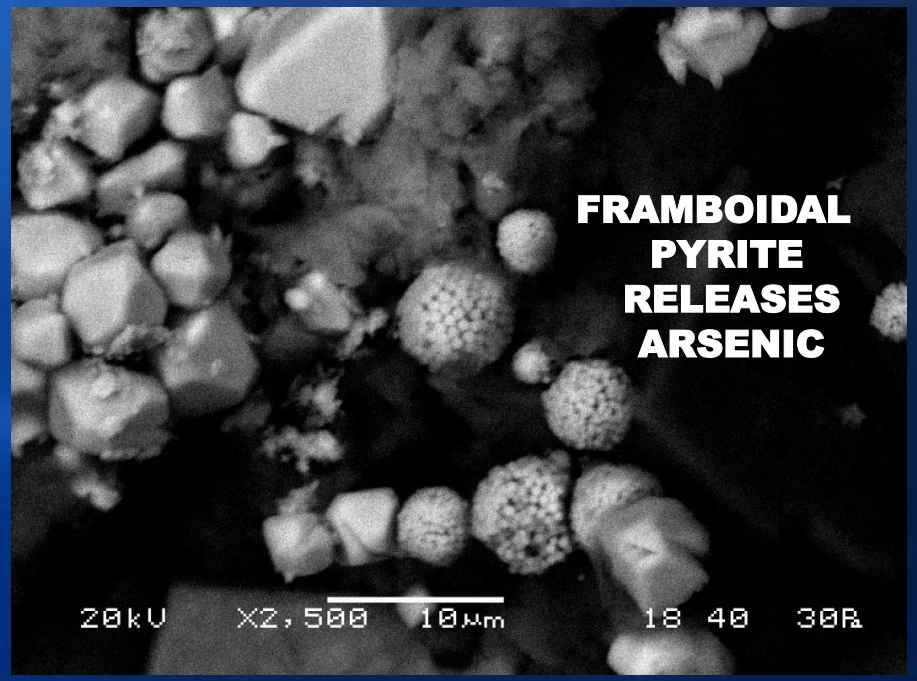


Ecotoxicology and Risk Assessment
Updated Ecological Risk Assessment

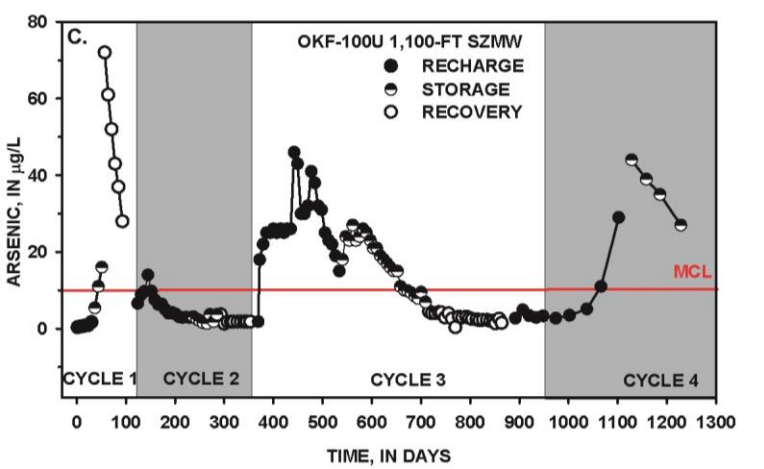
- Ecological Risk Assessment to incorporate all of the chemical, toxicity, bioaccumulation, and other data collected throughout the project into a comprehensive assessment of risks to ecological receptors based on the conditions expected in a range of ecosystems modeled using the data
- The assessment endpoints of the risk assessment will be based on receptor populations and will be both predictive and probabilistic in nature using the expected operational parameters of the wells
- Extensive coordination with stakeholders will be sought to determine which receptors, ecosystems, and population variables are most important to consider as part of assessment

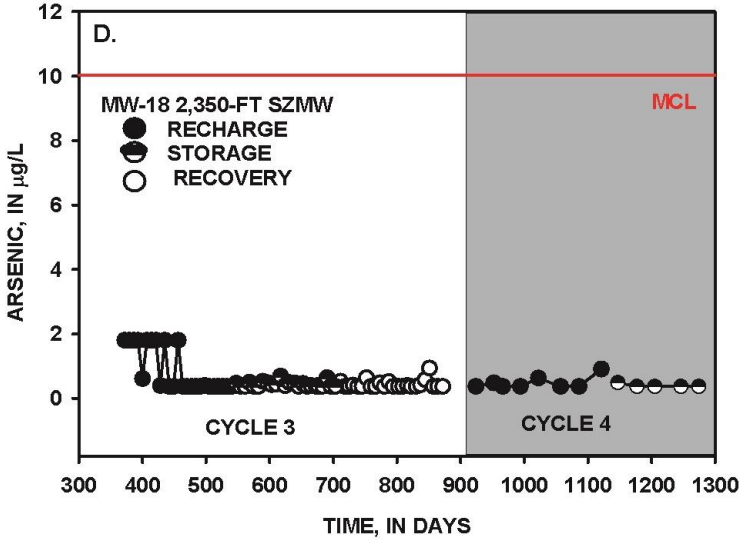
Water Quality
Metals Mobilization

- More research is needed to understand the impacts of different source water qualities on the long-term redox evolution of the aquifer and its effect on arsenic mobilization
  - Recharged surface water can interact with rocks in minerals in the Floridan Aquifer, resulting in water quality changes in recovered water
  - Compared to surface water, the following compound concentrations can change:
    - Metals, including arsenic
    - Hardness and alkalinity
    - Sulfate
    - Chloride
  - Water quality changes will be characterized in a robust sampling program



Water Quality
Metals Mobilization (cont.)

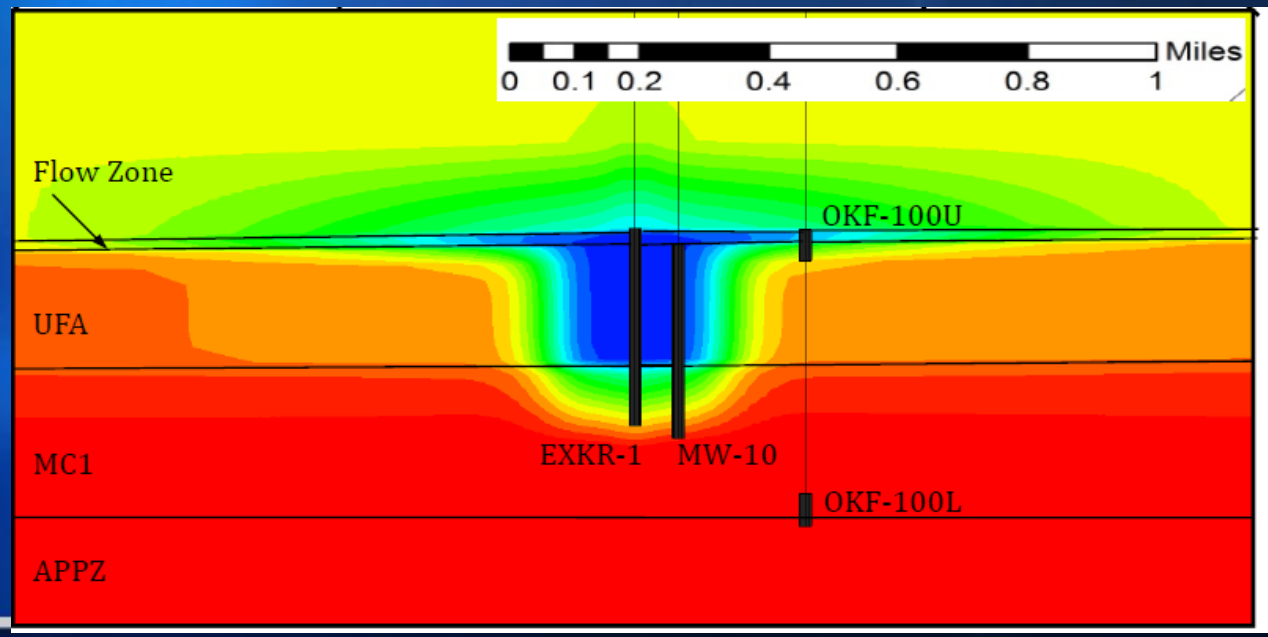




- Need to determine how far arsenic can be transported within the aquifer using extended (>1 year) cycles and development of a buffer zone
  - Arsenic mobilization examined during testing at pilot ASR systems
  - Proximal monitoring well (1,100 ft from ASR) and distal monitoring well (2,350 ft from ASR)
  - Maximum cycle test duration 6 months recharge/recovery, 1 year storage
  - Longer duration, larger volume cycles at larger capacity ASR systems are planned in LOWRP
  - Arsenic mobility and buffer zone development will be evaluated in a robust monitoring program to calibrate a groundwater model

Water Quality
Buffer Zone Improvements to Recovered Water

- Need to determine how development of a buffer zone can be utilized to reduce sulfate concentrations in recovered water or determine limits on recovery based upon sulfate concentrations
  - "Buffer Zone" is the region where recharged water mixes with native groundwater
  - Native groundwater sulfate concentrations are higher than those in surface water
  - Increased sulfate in surface water could enhance mercury methylation
  - Buffer zone development will be characterized in a robust sampling program particularly during different recharge and recovery duration operations



Water Quality
Recovered Water Modeling

- Further modeling on the fate of sulfate in recovered water should be conducted, along with additional study on the temporal and spatial variability of sulfate and methylmercury in Lake Okeechobee is warranted
  - Earlier lake water quality simulations suggested that sulfate concentrations could increase when ASR wells discharge into rivers and canals that inflow to Lake Okeechobee
  - Sulfate concentrations are below surface water quality standards, but could still impact the environment
  - Surface water modeling will provide insights and guidance on water quality changes during ASR system operations

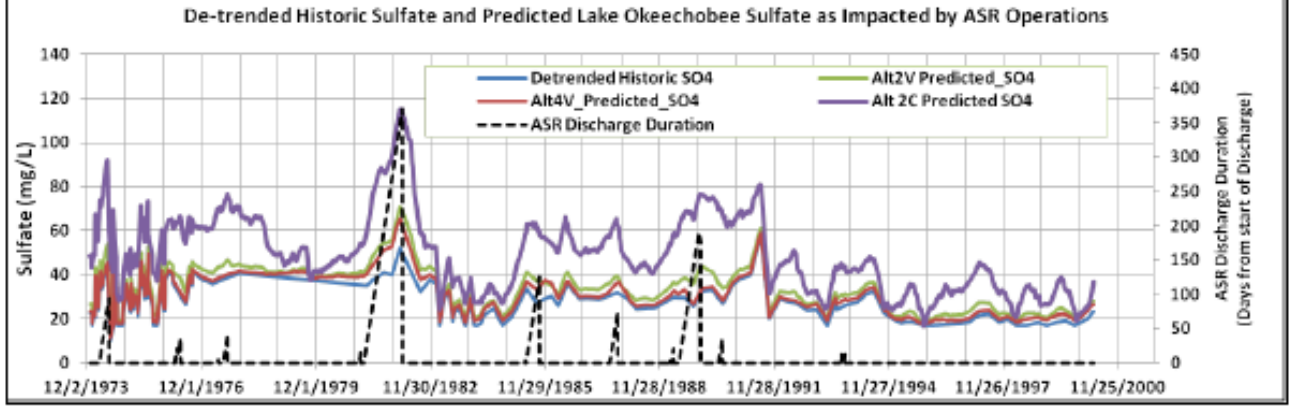


Figure 8-15 -- Predicted SO_4 concentrations in Lake Okeechobee from LOEM for the 1999-2009 period (top graph); and estimated ASR-related SO_4 concentrations during the 1974-2000 time period (bottom graph).

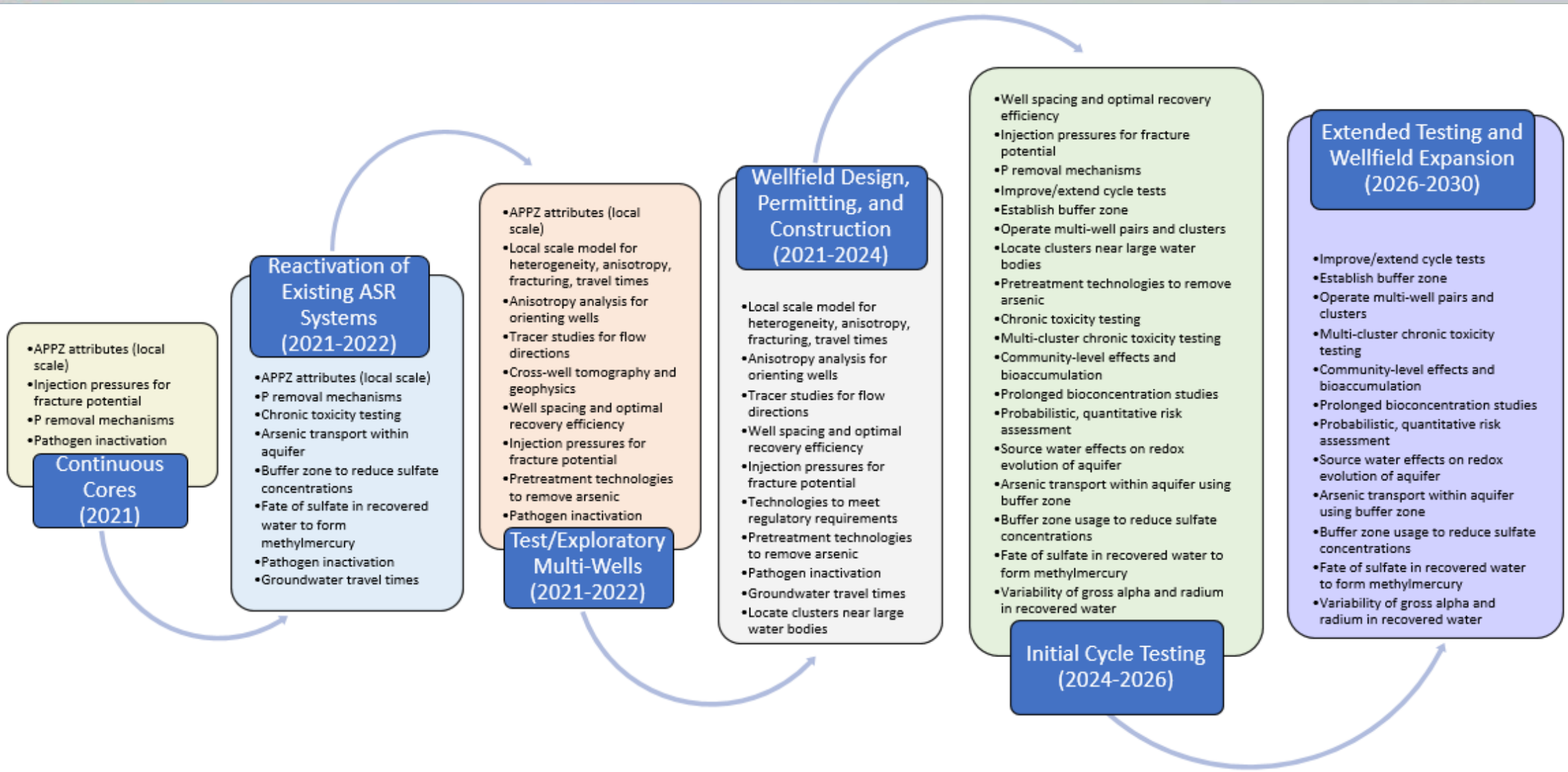
Water Quality
Isotopic Evaluations

- More understanding on the spatial variability of gross alpha and radium at future ASR locations should be addressed during longer term testing
  - Dissolved radium isotopes are naturally occurring in Floridan Aquifer groundwater at coastal counties of southwest Florida
  - Gross alpha is a proxy constituent to screen for radium
  - Gross alpha and radium measured at existing CERP ASR systems are below drinking water standards, but SFWMD monitoring wells in Gulf Coastal counties
  - Radium isotope activity and gross alpha concentrations will be known prior to ASR system construction. Buffer zone development will keep radium in the aquifer.

Project Sequencing and Data Management

- Phased approach; monitoring and research as construction proceeds
- Annual Science Plan workshops
- Data Management
  - Combination of data management tools
  - Data to be accessible via web browser
- Comprehensive QA/QC Plan to be developed

ASR Phased Implementation as Recommended by NRC



Science Plan Study Schedule

	2021 Continuous Cores	2021-22 Reactivation of Existing Wells	2021-22 Test/Exploratory Multiple Wells	2021-24 Design, Permitting, and Construction	2024-26 Initial Cycle Testing	2026-30 Extended Testing and Wellfield Expansion
Local scale information on APPZ attributes	■	■	■			
P removal mechanisms	■	■			■	
Pathogen inactivation	■	■		■		
Injection pressures for fracture potential	■		■	■	■	
Chronic toxicity testing		■			■	
Arsenic transport within aquifer using buffer zone		■			■	■
Buffer zone usage to reduce sulfate concentrations		■			■	■
Fate of sulfate in recovered water to form methylmercury		■			■	■
Groundwater travel times		■	■	■		
Local scale model for heterogeneity, anisotropy, fracturing, travel times		■	■	■		
Pretreatment technologies to remove arsenic		■		■	■	
Well spacing and optimal recovery efficiency			■	■	■	
Anisotropy analysis used for orienting wells			■	■		
Tracer studies for flow directions			■	■		
Cross-well tomography and geophysics			■	■		
Locate clusters near large water bodies				■	■	
Technologies to meet regulatory requirements				■		
Multi-cluster chronic toxicity testing					■	■
Community-level effects and bioaccumulation					■	■
Prolonged bioconcentration studies					■	■
Probabilistic, quantitative risk assessment					■	■
Variability of gross alpha and radium in recovered water					■	■
Source water effects on redox evolution of aquifer					■	■
Improve/extend cycle tests					■	■
Establish buffer zone					■	■
Operate multi-well pairs and clusters					■	■

Project Sequencing and Data Management
ASR Report Card

ASR Science Plan Report Card										
Date: October 2020	% Progress Towards Adressing the Topic									
	10	20	30	40	50	60	70	80	90	100
Local scale information on atributes of APPZ										
Research P removal mechanisms										
Reseach pathogen inactivation										
Anaysis of injection pressures for fracture potential										
Continue chronic toxicity testing										
Arsenic transport within aquifer using buffer zone										
Buffer zone usage to reduce sulfate concentrations										
Fate of sulftate in recovered water to form methylmercury										
Couple pathogen inactiation with groundwater travel times										
Local scale model for heterogeniety/anisotropy/fracturing/travel times										
Pretreatment technologies to remove arsenic										
Analysis of wellfield cluster for spacing and optimal recovery efficiency										
Anisotropy analysis used for orienting wells										
Tracer studies for flow directions										
Cross-well tomography and geophysics										
Locate clusters near large water bodies										
Examine technologies to meet regulatory requirements										
Multi-cluster chronic toxicity testing										
Examine community-level effects and bioaccumulation										
Prolonged bioconcentration studies										
Probabilistic, quantitative risk assessment										
Variability of gross alpha and radium in recovered water										
Examine source water effects on redox evolution of aquifer										
Improve/extend cycle tests										
Establish buffer zone										
Operate multi-well pairs and clusters										

Next Steps

- Technical review of ASR Science Plan by USACE
- Construction of continuous cores at two or more locations
- Analysis of cores for mineralogic and geotechnical properties
- Continuing the next phase of treatment technology evaluation
- USGS column studies of nutrient reduction/plugging potential
- Initiation of construction of exploratory wells at C38S and C38N locations
- Reactivation of Kissimmee ASR pilot facility
- Design evaluations for reactivation of L63N ASR system
- Early start tasks for ecological assessments
- Draft Plan will be available in early 2021

Discussion

www.sfwmd.gov/asr