Movement of recharge water from land surface to wells

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In cooperation with: The Northeastern San Joaquin Groundwater Banking Authority, Calaveras County Water District, and California Department of Water Resources
Scope of Presentation

- Overview of recharge sites
  - Morada Lane ("STK-2")
  - Stockton East ("STK-7")
- Morada Lane
  - Monitoring and sample collection
  - Flow logging and depth-dependent sampling
  - Tracer test
  - Groundwater flow simulation
- Stockton East
  - Monitoring and sample collection
  - Flow logging and depth-dependent sampling
- Conclusions
Morada Lane “STK-2”

Stockton East Water District “STK-7”
Morada Lane

- Depth to water = 50-65 ft
- Infiltrated water from Mokelumne River plus storm-flow
- 2,675 ac-ft recharge infiltrated between 2003 - 2007
- Monitoring of wells 11H4-7, 8
- Flow logging and depth-dependent sampling of 11H3
- SF$_6$ tracer test
- 2-dimensional radial flow simulation
Monitoring Site 11H4-8

- Water level hydrographs
- Downward gradient in general
- Upward gradient at depth
- Pressure responses to pumping and infiltration throughout aquifer(s)
- Dampened/delayed response at depth (>400 feet)
- Arsenic changes
**SF₆ Tracer Test**
- Non-reactive tracer
- Applied to detention basin
- Monitored 1ˢᵗ arrival times in wells

**SF₆ Arrival times**
- 119 days (2ⁿᵈ) [11H8]
- Also arrived at 11H3 (prod. well)
- 108 days (1ˢᵗ) [11H7]
- 122 days (3ʳᵈ) [11H6]
- 175 days (4ᵗʰ) [11H5]
- (very low conc.)
- ND (upward gradient at depth) [11H4]
Pressure propagation vs. physical movement of water

- Pressure responses to recharge seen up to 635 ft (11H4)
- Pressure responses and tracer travel times show relative isolation of deposits >300 ft (>11H6)
Flow contribution to well is heterogeneous

~70% of flow at:
350-365 ft
375-385 ft

~10% from deeper screens

Low arsenic concentrations

Wellbore flow, groundwater flow, and particle-tracking simulated using 2D radial flow model (AnalyzeHOLE)
Radial Flow Model

Production well 11H3
Multiple-well monitoring site
2D radially symmetric simulation

Unsaturated zone—not modeled

2N/6E-11H3
Saturated zone
194 Rows

Image: Google Earth
Simulated response to pumping in well 11H3

- Calibrated by adjusting K’s to match wellbore flow and observed drawdowns
- Simulated particle velocity = 6.2 ft/d
- $SF_6$ Tracer particle velocity = 5.5 ft/d
- Propagation of pressure head vs. physical movement of water
Stockton East Water District
Monitoring Site 3D2-5 ("STK-7")

Preliminary Findings

GOES satellite system for real-time transfer of data to the web

pmC
- 95.05 [412 ybp]
- 42.58 [6900 ybp]
- 28.52 [10100 ybp]
- 19.89 [13000 ybp]
STK-7 Hydrographs

- 3D5 (145-165)
- 3D4 (270-290)
- 3D3 (415-435)
- 3D2 (545-565)

Preliminary Findings

- Downward gradient
- Pumping responses at depth
- Maximum pumping depression = potential for upward gradient?
Production well 4G1 flow logging and sampling

- >95% flow contributed at shallower than 330’
- 30% flow contributed near top of screen (convergent?)
- Generally consistent chemistry with depth
- Elevated As at 215’-280’ (16.8 µg/L)
  Bulk = 8.9 µg/L
  3D4 = 19 µg/L (270’-290’)
  3D5 = 10.4 µg/L (145’-165’)
- High As corresponds to anoxic conditions in 3D4
- Denitrification at 270’-290’ under reducing conditions
• Local stormflow heavier than river water
• Shallowest well (11H8) is variable & reflects recharge source (stormflow vs. river)
• 11H4 & 1H5 wells similar to wells in east (tritium ND)
• 11H6 & 11H7 similar to Mokelumne (tritium present)
• Deep STK-7 wells similar to stormflow (tritium absent)
• 3D5 (Stockton East) lightest
Conclusions

• Pressure responses propagate to great depths in response to recharge.
• Pressure responses are dampened with depth (in time and magnitude).
• Deeper water relatively isolated based on isotopic and age data, but tracer studies indicate physical movement of water to depth.
• Aquifer system is heterogeneous with highly permeable deposits accounting for majority of water produced from production wells.
• Artificial recharge is an effective method to recharge aquifers, however:
  • High groundwater velocities may be of concern in areas with residence time requirements.
  • Artificial recharge may result in changes in redox chemistry with negative implications for water quality (e.g., arsenic).
• Quantitative (physical and chemical) understanding of the effects of aquifer heterogeneity on recharge, storage, and recovery is one of the most effective tools available to understand the physical movement of recharge water.
Questions?
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<td>Assigned hydraulic conductivities of model aquifer</td>
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Acknowledgements

San Joaquin County Public Works, California Department of Water Resources, and Lawrence Livermore National Laboratory, Northeastern San Joaquin Ground Water Banking Authority, the City of Stockton, Stockton East Water District, the California State Water Resources Control Board, and Condor Earth Technologies and other local consultants.
Radial Flow Model

Simulated and measured drawdown

**EXPLANATION**
- Measured drawdown
- Modeled drawdown with well screen encrustation in production well 11H3 screens situated deeper than 125 meters