12th Annual Groundwater Quality Workshop

4040 Paramount Boulevard
Lakewood, CA 90712

August 9, 2017 (9:30AM ~ 2:30PM)
Speaker #1

WRD Overview – August 2017

Brian Partington
Water Replenishment District
bpartington@wrd.org
Overview - August 2017

Brian Partington, PG, CHg
August 9, 2017
9:30 – 10:00
WRD Overview
Brian Partington, WRD

10:00 – 10:30
DDW Regulatory Updates
Jeff O-Keefe, SWRCB - DDW

10:30 – 11:00
Well Profiling Tool to Identify Zones of Contamination in Water Supply Wells
Noah Heller, BESST Inc.

11:00 – 11:30
Designing and Implementing a Multi-Facility SCADA System in the Age of Information
Phuong Ly, WRD; Luke Stephenson & Chris Schleich, Enterprise Automation

11:30 – 12:00
Ex-Situ Groundwater Remediation Options for Perchlorate
Steve Winners, WorleyParsons Advisian
Cathy Swanson, Evoqua Water Technologies, LLC.
**Program**

12:00 – 12:45

*Lunch provided by WorleyParsons*
12:45 – 1:15
UCMR4 Implementation Strategies for Water Systems
Rick Zimmer, Eurofins Eaton Analytical

1:15 – 1:45
Principles of Efficient Water Well Design
Kevin McGillicuddy, Roscoe Moss Company

1:45 – 2:15
Groundwater Basins Master Plan
Everett Ferguson, WRD

2:15 – 2:30
Questions and Certificates

The presentations will be emailed to the participants and/or uploaded to http://www.wrd.org
High Level Overview of WRD

- History and Mission
- Major Programs
- Resources and Online Programs
- Water Independence Now
Past History: 1900s-1950s
Pumping Double Natural Replenishment.

- Overdraft
  - Plunging Water Levels
  - Loss of Supply
  - Wells going Dry
  - Seawater Intrusion

100 foot drop in 10 years (10’/yr)
Solutions

- WRD formed in 1959 to eliminate overdraft via Managed Aquifer Recharge (MAR).
- Pumping adjudicated at 281,835 acre feet/year (AFY).
- Higher than natural recharge within the basin, but the difference is made up WRD.
GROUNDWATER BASINS IN THE WRD SERVICE AREA

SERVICE AREA = 420 SQUARE MILES

43 CITIES

POPULATION > 4 MILLION

550,000 ACRE FEET USED PER YEAR

50% GROUNDWATER FROM LOCAL WATER WELLS

50% IMPORTED WATER

WRD SUPPLEMENTS NATURAL GROUNDWATER RECHARGE

SECURING OUR WATER FUTURE TODAY

4040 Paramount Boulevard | Lakewood, California 90712

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facebook.com/waterreplenishment
youtube.com/waterreplenishment
www.wrd.org
Over 400 Wells Provide Water Supply
HOW WRD MANAGES THE BASINS

REPLENISHMENT OF GROUNDWATER

GROUNDWATER CLEAN UP

BASIN MONITORING

BASIN MODELING
LA County Public Works Recharge Facilities
Results of WRD Basin Management

Rising water levels & drought protection
Forecasted water levels during drought without recharge

- > 55 ft lower without recycled water

- **May 2011**
- **Nov 2015**

**Groundwater Elevation (ft msl)**

**Date**

Regional Groundwater Monitoring Program

Sampling

Nested Monitoring Wells

Drilling with USGS
Data Presented in Two Annual Reports

Reports are available at http://www.wrd.org
Interactive Well Search
Interactive Well Search

WRD currently updating the Interactive Well Search Tool.

Account requests at http://gis.wrd.org/wrdmap/login.asp
Well Profiling Program

Contact Charlene King at cking@wrd.org (562.275.4252)
Safe Drinking Water Program (since 1991)

- Outreach program for DACs.

Contact Charlene King at cking@wrd.org (562.275.4252)
• WRD staff track the progress of high priority environmental investigations located in the West Coast Basin and Central Basin (currently 48).
• Conduct high level reviews and when necessary provide feedback to the various regulatory agencies including EPA, DTSC, RWQCB.

WRD awarded $7.28M in Proposition 1 grant funds to cleanup a Perchlorate and VOC “hot spot” in the City of Vernon (March 30, 2017).

Contact Brian Partington at bpartington@wrd.org (562.275.4249)
A key to developing independence from imported water is the development of local recycled water sources.

PROJECTS TO:
- Capture and conserve additional stormwater
- Increase use of recycled water for groundwater replenishment
GOAL IS TO REPLACE IMPORTED WATER WITH LOCALLY AVAILABLE WATER (E.G. RECYCLED WATER) FOR AQUIFER REPLENISHMENT.

BENEFITS OF RECYCLED WATER OVER IMPORTED WATER:

- INCREASED RELIABILITY
- COST-EFFECTIVE
- LOCALLY CONTROLLED
- DROUGHT PROOF

SECURING OUR WATER FUTURE TODAY

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www.wrd.org
GROUNDWATER RELIABILITY IMPROVEMENT ADVANCED WATER TREATMENT FACILITY

GRIP IS THE CORNERSTONE OF WRD’S WIN PROGRAM

GRIP WILL PROVIDE 21,000 ACRE-FEET PER YEAR OF RECYCLED WATER IN PLACE OF EXPENSIVE IMPORTED WATER.

UPON COMPLETION, GROUNDWATER BASINS WILL BE COMPLETELY LOCALLY SUSTAINABLE
GROUNDWATER RELIABILITY IMPROVEMENT
ADVANCED WATER TREATMENT FACILITY

Operations & Learning Center

Process Facility
Thank You!

Brian Partington
bpartington@wrd.org
562.275.4249
Speaker #2

DDW Regulatory Update

Jeff O’Keefe
SWRCB - DDW
Jeff.okeefe@waterboards.ca.gov
California Drinking Water Program
Regulatory Update
WRD Groundwater Quality Workshop
August 9, 2017

Jeff O’Keefe, P.E., Chief
Southern California Coast Section
Southern California Field Operations Branch
SWRCB – Division of Drinking Water
Presentation Outline

1. 1,2,3-TCP Maximum Contaminant Level (MCL)
2. Hexavalent Chromium MCL Removal
3. Lead and Copper – Recent Developments
4. Revised Total Coliform Rule
5. Perchlorate MCL Revision
6. Potable Reuse of Recycled Water
7. ELAP Regulations
8. Cross-Connection Control regulations
California’s Division of Drinking Water

- Northern California Field Operations Branch
- Southern California Field Operations Branch
- Program Management Branch
  - Technical Operations Section
  - Environmental Laboratory Accreditation Program (ELAP)
  - Quality Assurance Section - NEW

District Offices and LPAs:
- 7500+ Water Systems
- 5 Regions
- 24 State District Offices
- 30 County Local Primacy Agencies
1,2,3-TCP Maximum Contaminant Level (1,2,3-Trichloropropane)

• Synthetic organic chemical (SOC)
  – Industrial solvent, degreaser
  – Ingredient in soil fumigants widely used for many decades

• Public Health Goal (PHG) established 2009
  – 0.7 ppt (parts per trillion)
  – Possible carcinogen

• MCL adopted by Board on July 18, 2017
  – 5 ppt (DLR also 5 ppt)

• GAC is a best available technology
1,2,3-TCP Maximum Contaminant Level

• Regulation will be effective October 2, 2017
• Initial monitoring period begins January 1, 2018
  – 4 quarterly samples
• Compliance determination
  – For PWS serving >3,300 population, compliance based on initial, confirmation sample(s), and 6 monthly samples
  – For PWS serving <3,300 population, compliance based annual average of initial, confirmation sample(s), and quarterly samples
• Grandfathering of previous monitoring
  – Results collected within two calendar years of effective date
  – Substituted for same quarter of initial period
    • 2nd quarter 2016 for 2nd quarter 2018
    – Only substitute 3 of 4 required initial samples
    – Request must be in writing to DDW
1,2,3-TCP Maximum Contaminant Level

- 2001-2015 Occurrence Data:
  - 471 wells with confirmed detections above 5 parts per trillion (ppt)
  - Range of Detections: 5 ppt to >10,000 ppt

- Vast majority of detections in groundwater
  - Most in Central Valley (Kern, Fresno, Tulare counties)
  - Riverside – 25 sources
  - San Bernardino - 31 sources
  - Los Angeles – 58 sources
### 1,2,3-TCP Occurrence Data

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Hexavalent Chromium (Cr 6)

- On May 31, 2017, the Superior Court of Sacramento County invalidated the Cr 6 MCL stating the regulator did not adequately document the economic feasibility of complying with the MCL.
- On August 1, 2017 the State Board adopted a resolution to remove the current Cr 6 MCL.
- Staff will begin the process of having the regulatory text deleted, which should take effect in late September 2017, and develop a new standard as soon as possible.
Lead and Copper Rule –
DDW Recommendations

• March 7, 2016, DDW sent a letter to all community and nontransient noncommunity water systems

• Recommendations on improving public access to Lead and Copper Rule (LCR) information

• Reminder to provide sample results to those participating in LCR tap sampling:
  – w/in 30 days of receiving the results from lab, and;
  – w/in 1-2 working days if lead and/or copper levels over the respective action levels are found

http://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/leadandcopperrule.shtml
Lead in Drinking Water

• U.S. EPA is working to issue a Revised Federal Lead & Copper Rule

• EPA Resources on its Web Site
  – Basic Information about Lead in Drinking Water
  – Lead in Drinking Water at Schools and Child Care Facilities
  – 3Ts for Reducing Lead in Drinking Water in Schools

• State Board priority regulation

• NEW Electronic submittal of lead and copper tap sample results using Lab to State Portal
  – Training for laboratories provided on 6/20/2017, check with your certified lab
Lead Sampling in Schools

• Meetings with the Governors office and Department of Education throughout 2016 resulted in the decision for DDW to issue an amended permit to all community water systems who serve a K-12 school.

• Permit requires water systems to sample at school (5 sample sites) when a school official makes a request in writing to the water system for sampling assistance.

• Permits issued January 17, 2017 along with a media release and resources on the DDW website (FAQs, details of sampling procedures, lab data submittals).

http://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/leadsamplinginschools.shtml
Lead Sampling in Schools

• Schools can request sampling assistance anytime prior to November 1, 2019.

• As of July 21, 2017, a total of 1,201 schools have provided a copy of their request letter to the Division, and 981 schools have submitted results.

• Schools will be responsible for corrective actions (removing/replacing drinking fountains, POU devices, etc.)

• Drinking Water for Schools Grant Program
  – $9.5 M available, serving small DACs
School Requests and Results Received

**Number of School Requests as of July 21, 2017**

Lead Sampling in California Schools

1,201 = Total Number of schools that have requested lead sampling

13,000 (approx.) = Total number of K-12 schools in California

**Number of Results Received as of July 21, 2017**

Lead Sampling in California Schools

981 = Number of schools for which DDW has received results via electronic data submission

13,000 (approx.) = Total number of K-12 schools in California
Lead Service Lines: Requirements of SB 1398

- All public water systems must compile an inventory of known lead service lines by July 1, 2018
- PWS must also identify areas that may have lead service lines and identify any areas where the PWS cannot identify the service line material
- By July 1, 2020, PWS will be required to propose a schedule to replace all the known lead service and service lines constructed of unknown material
- SB-427 has been introduced to change and clarify - the requirement should only apply to community water systems (bill is still in committee)
- DDW will have a web portal available in Fall 2017 to begin receiving documents for the water system’s inventory.
- FAQs, guidance and updates available on DDW website http://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/lead_service_line_inventory_pws.shtml
Revised Total Coliform Rule

• Federal RTCR effective April 1, 2016
• Interim Period before state adoption
  – All PWS must comply with existing CA rule and Federal RTCR

• CA regulation in development and anticipated in 2018
  – Draft regulation available on DDW website
Revised Total Coliform Rule

• Overall approach is to “Find and Fix” problems
• Minor changes to routine and repeat sampling
  – No changes to # of samples per week or month
  – 3 repeat samples for each TC+ routine
    • Existing location, U/S and D/S within 5 service conn.
    • PWS collecting 1 routine/month, 4 repeats still needed

• Established E.coli MCL
  – EC+ Routine, TC+ Repeat
  – TC+ Routine, EC+ Repeat
  – EC+ Routine, no repeats collected
  – TC+ Routine, fail to analyze for E.coli

• Established Coliform Treatment Technique
Revised Total Coliform Rule

Level 1 Coliform Treatment Technique

• Triggers when:
  – > 5% of samples TC+, if collecting 40 or more samples/month
  – 2 or more samples TC+, if collecting fewer than 40 samples/month
  – Failure to collect all repeats following TC+ routine

• Water system must complete Level 1 assessment and make corrective actions within 30 days

• Issue Tier 2 public notice within 30 days
  – INTERIM PERIOD ONLY
Revised Total Coliform Rule

Level 2 Coliform Treatment Technique

• Triggers when:
  – E. Coli MCL violation
  – Second Level 1 trigger within a 12-month period
• Issue Tier 1 Public Notice by end of day
• Contact DDW (or LPA) by end of day
• DDW (or LPA) staff will conduct Level 2 assessment and water system must complete and make corrective actions within 30 days
Revised Total Coliform Rule

• Failure to conduct the Level 1 or Level 2 assessments within 30 days or failure to complete corrective actions is a violation requiring a Tier 2 Public Notice

• New requirements for seasonal water systems to follow approved start-up protocol including sampling before serving water to the public

http://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/rtcr.shtml
Perchlorate MCL Revision

- Current MCL 6 ug/L is greater than revised Public Health Goal of 1 ug/L (2015).
- Current Detection Level for Reporting (DLR) is 4 ug/L.
- July 5 Board meeting decision to initiate two-step process for revising perchlorate MCL
  1. Amend Title 22 regulations to lower DLR
  2. Gather occurrence data below 4 ug/L for use in considering a revised perchlorate MCL
Potable Reuse of Recycled Water

• **Groundwater Recharge** is “the planned use of recycled water for replenishment of a groundwater basin or an aquifer that has been designated as a source of water supply for a public water system”

• **Surface Water Augmentation** is “the planned placement of recycled water into a surface water reservoir used as a source of domestic drinking water supply”

• **Direct Potable Reuse** is “the planned introduction of recycled water either directly into a public water system, as defined in Section 116275 of the Health and Safety Code, or into a raw water supply immediately upstream of a water treatment plant”
## Potable Reuse - Statutory Requirements

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<td>Adopt Surface Water Augmentation Regulations</td>
<td>Dec 31, 2016</td>
<td>Moving quickly</td>
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<td>Submit Final Report to the Legislature</td>
<td>Dec 31, 2016</td>
<td>✓</td>
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</table>
Surface Water Augmentation Regulations

• GW recharge regulations built over 38 years experience

• **Key components**
  – Pathogen reduction requirements – reclamation plant + Surface Water Treatment Plant (SWTP)
  – Reservoir criteria, meaningful environmental buffer
  – Wastewater source control
  – Full advanced treatment (RO + advanced oxidation)
  – Monitoring for regulated & unregulated chemicals

• Public Hearing Sept 7, comment period closes Sept 12, 2017

• 0 approved SWA projects in CA; 3 SWA projects in planning
Direct Potable Reuse - Feasibility

- **Public health is most important**
- Expert Panel & Advisory Group
- Research needs & knowledge gaps
- Lessons learned from other projects
- Crafting effective criteria
- Deliberate and phased approach
Environmental Laboratory Accreditation Program (ELAP)

- Preliminary draft regulations released on 7/24/2017 and six stakeholder workshops were held statewide from 7/25/2017 to 8/3/2017
- Comments can be submitted by email to elapca_comments@waterboards.ca.gov. Use subject line: ELAP Preliminary Draft Regulations Comments
- Board adoption expected in 2018
Cross-Connection Control Regulations

• Work on updating these regulations, which are currently in CCR Title 17, is anticipated to begin soon
Questions?

Jeff O’Keefe
Jeff.okeefe@waterboards.ca.gov
(818) 551-2068
Speaker #3

Well Profiling Tool to Identify Zones of Contamination in Water Supply Wells

Noah Heller
BESST Inc.
heller@besstinc.com
Selective Groundwater Extraction

Profiling Groundwater Production Wells and Temporary Long Screened Test Wells
For Zonal Flow, Zonal Water Chemistry

By

Noah Heller, MS PG (CA 5792)
President, BESST, Inc.
50 Tiburon Street, Suite 7
San Rafael, CA  94901
Office: 415.453.2501
Mobile: 415.302.7354
nheller@besstinc.com
Flow and Water Chemistry Profiling

Basic Purpose Historically: To Understand Zonal Flow and Water Chemistry into Well

Why?: Lost Production and Water Quality Problems

Historical Well Profile Frequency – Rare (1970-2006)

Why? Cost, Relatively New Idea, Not enough institutional and market sector knowledge
GOALS

• AVOID TREATMENT
• MINIMIZE TREATMENT
• UNDERSTAND STRATIFICATION OF CONTAMINANTS IN WATER RESOURCE AQUIFERS
• USE GEOCHEMICAL STRATIFICATION DATA TO SELECT TEST HOLE LOCATIONS FOR NEW WELLS
• USE IN LONG SCREENED, TEMPORARY TEST WELLS TO INCREASE DATA DENSITY (AVOID WATER QUALITY FAILURES FOR NEW WELLS)
• SUPPORT FOCUSED WELL REHABILITATION (BEFORE AND AFTER PERFORMANCE METRIC – ZONAL SPECIFIC CAPACITY)
Dr. John Izbicki
- Over 90 Peer Reviewed Articles
- Recipient of California Groundwater Resources Association Lifetime Achievement Award
- Inventor of Dye Tracer
California

• >700 Municipal Production Wells Profiled Since 2005

• Largest Stratified, Dissolved Aqueous Phase Geochemistry Data Base in California for Production Wells
How Has Miniaturization Changed Frequency of Well Profiling Groundwater Production Wells?
### Cost Comparison / Well Profiling Technologies

**Largest Tools**

- Remove Pump: $8,000 / $12,000.00
- Install and Rent Test Pump with Access Pipe: $30,000 / $80,000.00
- Perform Spinner Log Survey: $3,000 / $5,000.00
- Perform Water Sampling Survey (5 to 8 Samples): $4,000 / $6,000.00
- Reinstall Pump: $8,000 / $12,000.00
- Consulting Planning, Workplan, Field Fees: $12,000 / $20,000.00
- Consulting Fee: $10,000 / $20,000.00
- Total: $75,000 / $155,000.00

### Smallest Tools

- Remove Pump: $- / $12,000.00
- Install Straddle Packer (3 to 5 Zone Tests): $90,000 / $150,000.00
- Perform Spinner Log Survey: $0 / $0
- Perform Water Sampling Survey (5 to 6 Samples): $0 / $0
- Reinstall Pump: $8,000 / $12,000.00
- Consulting Planning, Workplan, Field Fees: $12,000 / $20,000.00
- Consulting Fee: $10,000 / $20,000.00
- Total: $128,000 / $214,000.00

### Technology: Miniaturized Tracer / Water Samp.

- Remove Pump: $- / $12,000.00
- Install Straddle Packer (3 to 5 Zone Tests): $- / $-
- Perform Spinner Log Survey: $- / $-
- Perform Water Sampling Survey (5 to 6 Samples): $- / $-
- Perform Tracer / Water Sampling Survey: $25,000.00 / $35,000.00
- Reinstall Pump: $8,000.00 / $12,000.00
- Consulting Planning, Workplan, Field Fees: $5,000.00 / $10,000.00
- Consulting Fee: $5,000.00 / $10,000.00
- Total: $43,000.00 / $79,000.00

As profiling tools get smaller and wells more accessible, profiling cost decreases.
Well Access and Incrementally Tiered Access Survey
Vent Tubes, Bolt Holes, Plug Holes, Existing Sounding Pipes
Pedestal Core

First core hole attempt on north side of 20 inch well (with 14” bowls) found less than ¾” annular clearance with pump column.

Portable drill is adjustable to various angles and is mounted directly to pedestal.

Core hole was drilled at 5 Degree angle from vertical and at 1.5” in diameter.

Approximate drill time for each of the core holes (1st attempt north side of well and 2nd attempt (successful) on south side of well was 2.5 hours per hole. Coring cost was about $125 / hr. The core hole was temporarily lined with a section of PVC pipe to protect the tracer hose from scraping and tearing against any rough surfaces within the hole.

Elliptical Piece of Metal From Outer Casing generated from steep angle core hole.

Core Hole # 2 was successful and found 5+ inches of annulus on south side of well.

Pump Pedestal (Block) Coring
Lift and Shift
No Access Pipe(s)
Remove Primary Pump and Reinstall Primary Pump With Access Pipe(s)

Access Pipe Layout with Bottom End Cone Flare

Blue Pipe Requirements:

Either
1) 1.25” ID x 1.66” OD
2) 1.00” ID x 1.51” OD

And
3) Flush threaded PVC above bowls
4) Flush threaded stainless steel along bowls and extending 10’ feet past bowls
5) Pared, smoothed, rounded or bottom.

Optional:
6) Client can use galvanized steel pipe with couplings provided there is enough annular space.

Well Screen above Pump Scenario
If the primary pump and the intake are located within the well screen then alternate strategy can be taken by installing two access pipes as shown in Figure 2 below.
Remove Primary Pump and Reinstall With Test Pump and Access Pipe(s)

Access Pipe Installation
Assuming that the position of the primary pump is located above the well screen, the bottom of the access pipe should extend at least 10 feet below the pump intake and still be above the well screen. The access pipe should be secured firmly to the pump column at intervals to prevent movement of the pipe as shown in the following examples.

The access pipe should terminate above the wellhead, and should be smoothed as well to prevent snagging of tools or sampling tubing.

Figure 2: Riser bonded to pump bowls
Figure 3: Stainless Steel Pipe attached to pump
Brief Description of Conventional Technologies

Straddle Packer

Spinner
Tracer Technology
Flow and Water Chemistry Profiling are volumetric and chemical mass balance accounting systems

Think about a river with blue ping pong balls!
Explanation of Dye Injection Process For Dynamic Flow Profiling In Production Wells

Dynamic Flow Profile Under Steady State Draw-Down

Cumulative Flow Slices (CFS)

Dye Injection Shot Points

Flow From Well To Fluorometer

Flow From Fluorometer To Waste

1,900 GPM

40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380 400

Ft. Below Ground Surface
Dynamic Flow Profile Under Steady State

Draw-Down

- GPM Distribution
- No Flow Contribution
- No Flow Contribution

Cumulative Flow Can Be Defined As

\[ Q_1 = V_1 \times A_1 \]
\[ V_1 = (d_1-d_2)/(t_1-t_2) \]
\[ A_1 = \pi r^2 \]

Incremental Flow Can Be Defined As

\[ Q_1 - Q_2 \]

When we subtract \( Q_2 \) from \( Q_1 \), we get the incremental flow (IF or GPM) contribution between the two measured injection points.
Average Cumulative Contaminant Concentration Can Be Defined As

\[ Ca_1 = \frac{(Q_1C_1 - Q_2C_2)}{(Q_1 - Q_2)} \]

Incremental Average Contaminant Concentration between two imaginary flow planes within the well can be expressed...
Houston Metro Area Well

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<td>1004-1024</td>
</tr>
<tr>
<td>Perforated</td>
<td></td>
<td>14</td>
<td>1024-1042</td>
</tr>
<tr>
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<td>1042-1078</td>
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<tr>
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<td></td>
<td>14</td>
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<tr>
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<td>14</td>
<td>1136-1170</td>
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<td>14</td>
<td>1170-1194</td>
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<tr>
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<td></td>
<td>14</td>
<td>1194-1210</td>
</tr>
<tr>
<td>Blank</td>
<td></td>
<td>14</td>
<td>1210-1230</td>
</tr>
</tbody>
</table>

*At the time of testing

---

**KEY**

- Sandy Clay
- Clay
- Gray Sand
- Gray Sand
- Loose Sand
- Blue Clay

**Zonal Flow Contribution**
Total Flow: 1000 GPM

**Zonal Percent Flow Contribution**
Total Flow: 1000 GPM

**Depth Interval (Ft. BGS)**

- **730-740**: 13 GPM (2.3%)
- **740-760**: 20 GPM (2.3%)
- **760-780**: 5 GPM (0.5%)
- **780-800**: 10 GPM (1.0%)
- **800-850**: 0 GPM (0.0%)
- **850-855**: 5 GPM (0.5%)
- **855-858**: 0 GPM (0.0%)
- **908-915**: 32 GPM (3.2%)
- **916-966**: 5 GPM (0.5%)
- **966-972**: 1 GPM (0.1%)
- **972-980**: 5 GPM (0.5%)
- **980-1004**: 8 GPM (0.8%)
- **1004-1024**: 0 GPM (0.0%)
- **1024-1042**: 104 GPM (10.4%)
- **1042-1044**: 209 GPM (20.9%)
- **1042-1078**: 0 GPM (0.0%)
- **1078-1110**: 0 GPM (0.0%)
- **1110-1136**: 0 GPM (0.0%)
- **1136-1170**: 0 GPM (0.0%)
- **1170-1194**: 0 GPM (0.0%)
- **1194-1210**: 0 GPM (0.0%)
- **1210-1230**: 0 GPM (0.0%)
Gross Alpha

Well Head Average: 8.6 pCi/L
Total Flow: 1000 GPM

Depth Interval (Ft. BGS)

- Gross Alpha
- Zonal Flow Graph
City Yard
Well Information and Lithology Log

Well Information
- Old (outside) well casing diameter: 20" -> 14"
- Outside screened intervals (ft. bgs): (290-330), (390-410), (480-570), (560-720), (780-830), (880-970), (1000-1020), (1070-1190)
- New well casing diameter: 16" -> 12" -> 10"
  - New well casing is constructed with all stainless steel wire wrap
- New pump column diameter (in): 10" (16" casing)
- Cross sectional area of new well casing:
  - From 0'-282': 1.40 sq ft
  - From 282'-288': 1.79 sq ft
  - From 288'-320': 2.55 sq ft
- Reported new well bottom: 1190 ft bgs
- Pump Intake Depth: 730 ft bgs
- Pumping water level: 143 ft bgs
- Flow rate: 1860 USG min⁻¹

Dynamic Flow Profile
1860 gpm 11/19/13

Zonal Flow Contribution (GPM)

0.00  50.00  100.00  150.00  200.00  250.00  300.00


Dye Injection Tubing
Wire Wrap
Screen
Clay
Sand
Silt
Gravel Fill

Lithologic Log (1950)
2 Field Days
To collect data
Chemistry Profile
1860 gpm 11/20/13
Average Sulfate Well Head Concentration: 43 mg/L
Chemistry Profile

1860 gpm 11/20/13

Average TDS Well Head Concentration: 270 mg/L

Well Zonal Production %
TDS Concentration mg/l
MCL 1000. mg/l

Zonal Production GPM
TDS Concentration mg/l
MCL 1000. mg/l
Chemistry Profile
1860 gpm 11/20/13

Average Arsenic Well Head Concentration: **12.5 µg/L**

**Well Zonal Production % (Green)**
**Arsenic Concentration µg/l (Blue)**

- **MCL 10. µg/l**

- **Zonal Production GPM (Green)**
**Arsenic Concentration µg/l (Blue)**

- **MCL 10 µg/l**
**Chemistry Profile**

1860 gpm 11/20/13

**Average Iron Well Head Concentration:** 145 μg/L

---

### Well Zonal Production % Iron Concentration ug/l

<table>
<thead>
<tr>
<th>Depth</th>
<th>Production %</th>
<th>Iron Concentration ug/l</th>
</tr>
</thead>
<tbody>
<tr>
<td>290-330</td>
<td>15.08</td>
<td>205.29</td>
</tr>
<tr>
<td>390-410</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>480-540</td>
<td>6.74</td>
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<tr>
<td>540-570</td>
<td>5.46</td>
<td>549.43</td>
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<tr>
<td>620-660</td>
<td>12.00</td>
<td></td>
</tr>
<tr>
<td>660-700</td>
<td>15.24</td>
<td></td>
</tr>
<tr>
<td>700-720</td>
<td>1.96</td>
<td></td>
</tr>
<tr>
<td>770-810</td>
<td>18.57</td>
<td></td>
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<tr>
<td>810-830</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>880-920</td>
<td>0.83</td>
<td>666.36</td>
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<tr>
<td>920-970</td>
<td>15.20</td>
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<tr>
<td>1000-1020</td>
<td>1.62</td>
<td></td>
</tr>
<tr>
<td>1070-1100</td>
<td>8.72</td>
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</tr>
<tr>
<td>1100-1140</td>
<td>2.23</td>
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</tr>
<tr>
<td>1140-1190</td>
<td>4.99</td>
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### Zonal Production GPM Iron Concentration ug/l

<table>
<thead>
<tr>
<th>Depth</th>
<th>Production GPM</th>
<th>Iron Concentration ug/l</th>
</tr>
</thead>
<tbody>
<tr>
<td>290-330</td>
<td>0.00</td>
<td>260.58</td>
</tr>
<tr>
<td>390-410</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>480-540</td>
<td>24.05</td>
<td>125.40</td>
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<tr>
<td>540-570</td>
<td>10.18</td>
<td>549.43</td>
</tr>
<tr>
<td>620-660</td>
<td>12.00</td>
<td>223.15</td>
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<tr>
<td>660-700</td>
<td>12.00</td>
<td>283.38</td>
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<tr>
<td>700-720</td>
<td>32.82</td>
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<tr>
<td>770-810</td>
<td>82.57</td>
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<tr>
<td>810-830</td>
<td>0.00</td>
<td>20.33</td>
</tr>
<tr>
<td>880-920</td>
<td>11.80</td>
<td>666.36</td>
</tr>
<tr>
<td>920-970</td>
<td>14.00</td>
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<td>1000-1020</td>
<td>30.20</td>
<td>238.18</td>
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<tr>
<td>1070-1100</td>
<td>113.41</td>
<td>162.2</td>
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<tr>
<td>1100-1140</td>
<td>41.59</td>
<td>172.34</td>
</tr>
<tr>
<td>1140-1190</td>
<td>92.87</td>
<td>140.00</td>
</tr>
</tbody>
</table>
Chemistry Profile
1860 gpm 11/20/13
Average Manganese Well Head Concentration: 64 µg/L
Well Reconstruction / Re-Engineering

How Do We Hydraulically Manipulate Groundwater Production Wells?

- **Change Pumping Rate**
  - Higher Pumping Rate Vertically Shifts Flow Contribution Downward Inside Well – Away From Pump Intake
  - Lower Pumping Rate Vertically Shifts Flow Contribution Upward Inside Well – Towards Pump Intake

- **Change Pump Intake Location and/or Diameter**
  - Lower or Raise Pump (Intake)
  - Attach Suction Pipe To Bottom of Pump

- **Packers, Sleeves and Engineered Suctions**

- **Focused Well Rehabilitation**
  - Remove Mineral Encrustations and Bio-film on Inside and Outside of Well Screen
Comparison of BESST Dynamic Tracer Pulse Flow Survey with Spinner Log Flow Meter Survey:
Performed At Different Pumping Rates and At Different Times

<table>
<thead>
<tr>
<th>Flow Rate Difference</th>
<th>Between Surveys:</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,166 GPM Spinner</td>
<td>1,200 GPM Dye</td>
</tr>
<tr>
<td>966 GPM</td>
<td></td>
</tr>
</tbody>
</table>

**Dynamic Tracer Pulse Flow Meter Survey @ 1,200 GPM / 11/08/07**

<table>
<thead>
<tr>
<th>Flow Rate</th>
<th>Percentage</th>
<th>GPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>175-190</td>
<td>71.9%</td>
<td>863.16 gpm</td>
</tr>
<tr>
<td>190-210</td>
<td>8.3%</td>
<td>99.81 gpm</td>
</tr>
<tr>
<td>210-230</td>
<td>5.7%</td>
<td>68.62 gpm</td>
</tr>
<tr>
<td>230-250</td>
<td>5.8%</td>
<td>69.96 gpm</td>
</tr>
<tr>
<td>250-270</td>
<td>3.5%</td>
<td>42.32 gpm</td>
</tr>
<tr>
<td>270-290</td>
<td>3.6%</td>
<td>43.29 gpm</td>
</tr>
<tr>
<td>290-310</td>
<td>0.8%</td>
<td>9.45 gpm</td>
</tr>
<tr>
<td>310-330</td>
<td>0.3%</td>
<td>3.40 gpm</td>
</tr>
</tbody>
</table>

**Dynamic Spinner Log Flow Meter Survey @ 2,166 GPM / 04/29/05**

**Flow Rate Between Surveys:**
- 2,166 GPM Spinner
- 1,200 GPM Dye
- 966 GPM
Comparison of BESST Dynamic Tracer Pulse Flow Survey with Spinner Log Flow Meter Survey: Performed At Different Pumping Rates and At Different Times

<table>
<thead>
<tr>
<th>Pump Column</th>
<th>Screen Intervals</th>
</tr>
</thead>
<tbody>
<tr>
<td>483.5 ft</td>
<td>483.5 - 510 ft</td>
</tr>
<tr>
<td></td>
<td>510 - 530 ft</td>
</tr>
<tr>
<td></td>
<td>530 - 560 ft</td>
</tr>
<tr>
<td></td>
<td>560 - 591.5 ft</td>
</tr>
<tr>
<td></td>
<td>591.6 ft - 679 ft</td>
</tr>
<tr>
<td></td>
<td>679 - 697.5 ft</td>
</tr>
<tr>
<td></td>
<td>697.5 ft - 889 ft</td>
</tr>
<tr>
<td></td>
<td>889 - 997.7 ft</td>
</tr>
<tr>
<td></td>
<td>997.7 ft - 1009.7ft</td>
</tr>
<tr>
<td></td>
<td>1009.7 ft - 1249.9 ft</td>
</tr>
</tbody>
</table>

### BESST Dynamic Tracer Pulse Flow Survey

<table>
<thead>
<tr>
<th>Percent of Total (%)</th>
<th>10%</th>
<th>20%</th>
<th>30%</th>
<th>40%</th>
<th>50%</th>
</tr>
</thead>
<tbody>
<tr>
<td>483.5 - 510 ft</td>
<td>1.10%</td>
<td>(20.68 gpm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>510 - 530 ft</td>
<td>19.2%</td>
<td>(361.37 gpm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>530 - 560 ft</td>
<td>7.01%</td>
<td>(133.14 gpm)</td>
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<td></td>
</tr>
<tr>
<td>560 - 591.5 ft</td>
<td>2.38%</td>
<td>(44.87 gpm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>591.6 ft - 679 ft</td>
<td>4.47%</td>
<td>(84.94 gpm)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>679 - 697.5 ft</td>
<td>1.14%</td>
<td>(21.63 gpm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>697.5 ft - 889 ft</td>
<td>1.97%</td>
<td>(33.37 gpm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>889 - 997.7 ft</td>
<td>11.66%</td>
<td>(221.45 gpm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>997.7 ft - 1009.7 ft</td>
<td>27.24%</td>
<td>(517.63 gpm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1009.7 ft - 1249.9 ft</td>
<td>23.50%</td>
<td>(446.58 gpm)</td>
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<td></td>
</tr>
</tbody>
</table>

### Spinner Log Dynamic Flow Meter Survey

<table>
<thead>
<tr>
<th>Percent of Total (%)</th>
<th>10%</th>
<th>20%</th>
<th>70%</th>
</tr>
</thead>
<tbody>
<tr>
<td>483.5 - 591.6 ft</td>
<td>8.8%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>591.6 ft - 679 ft</td>
<td>3.1%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>679 - 697.5 ft</td>
<td>17.6%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>697.5 ft - 889 ft</td>
<td>70.5%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>889 - 997.7 ft</td>
<td>70.5%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>997.7 ft - 1009.7 ft</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1009.7 ft - 1249.9 ft</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Flow Rate Difference Between Surveys:**
- **3,500 GPM Spinner**
- **-1,900 GPM Dye**
- **992 GPM**
**Dynamic Tracer Pulse Flow Meter**
Survey @ 2,600 GPM / 04/24/08

**Dynamic Spinner Log Flow Meter**
Survey @ 3,004 GPM / 04/18/06

**Flow Rate Difference Between Surveys:**
- 3,004 GPM Spinner
- 2,600 GPM Dye
- 404 GPM
- Change Pump Intake Location
- Change Pump Intake Diameter
Pump Depth Location From Top Of 16” Well Screen

32.25 feet
Below Top Of Well Screen

43.75 feet
Below Top Of Well Screen
Lowest Entrance Velocities
Least Drawdown (Head Loss)

67.85 feet
Below Top of Well Screen
Packers, Sleeves and Engineered Suctions
Packer Case History

Well #26 Geologic Log and BESST Dynamic Flow Contribution Profile

(2/11/2010)

BESST Dynamic Flow Profile

Pumping Rate: 849 GPM  Pumping Water Level: 340’
Screen Interval: 655-715, 745-785, 825-870, 890-920, 960-1010, 1075-1190

Percent of Total (%)

<table>
<thead>
<tr>
<th>Depth Interval</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>655-715’</td>
<td>11.4%</td>
</tr>
<tr>
<td>745-785’</td>
<td>22.1%</td>
</tr>
<tr>
<td>825-870’</td>
<td>31.6%</td>
</tr>
<tr>
<td>890-920’</td>
<td>11.4%</td>
</tr>
<tr>
<td>960-1010’</td>
<td>21.8%</td>
</tr>
<tr>
<td>1075-1190’</td>
<td>10.9%</td>
</tr>
</tbody>
</table>

Calculated percent of flow distribution from intervals. Average pumping rate: 849 gpm (2/11/10)
### Chemical Mass Balance Analysis: Arsenic

<table>
<thead>
<tr>
<th>Sample Depth (ft bgs)</th>
<th>Screen Interval (ft bgs)</th>
<th>Cumulative Flow Per Screen Interval (GPM)</th>
<th>As Measured Concentration (From Lab)</th>
<th>Incremental Flow Per Screen Interval</th>
<th>Incremental Flow</th>
<th>As Measured Concentration</th>
<th>Mass Balance As Incremental Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>600-655-715</td>
<td></td>
<td>849.00</td>
<td>97.00</td>
<td>19.50</td>
<td>16555.5</td>
<td>11.5</td>
<td>97.00</td>
</tr>
<tr>
<td>730-745-785</td>
<td></td>
<td>752.00</td>
<td>188.00</td>
<td>22.00</td>
<td>16544.0</td>
<td>188.00</td>
<td>188.00</td>
</tr>
<tr>
<td>805-825-870</td>
<td></td>
<td>564.00</td>
<td>268.00</td>
<td>26.00</td>
<td>14664.0</td>
<td>7856</td>
<td>268.00</td>
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<tr>
<td>880-890-920</td>
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<td>296.00</td>
<td>14.00</td>
<td>23.00</td>
<td>6808.0</td>
<td>322.0</td>
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</tr>
<tr>
<td>940-960-1010</td>
<td></td>
<td>282.00</td>
<td>97.00</td>
<td>23.00</td>
<td>6486.0</td>
<td>4266.0</td>
<td>97.00</td>
</tr>
<tr>
<td>1055-1075-1190</td>
<td></td>
<td>185.00</td>
<td>185.00</td>
<td>12.00</td>
<td>2220.0</td>
<td>185.00</td>
<td>185.00</td>
</tr>
</tbody>
</table>

#### Dynamic Chemical Profile: Well 26

2/11/10 849 GPM

**Arsenic**

<table>
<thead>
<tr>
<th>Sampling Intervals (ft bgs)</th>
<th>Concentration (µg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>655-715</td>
<td>97.03</td>
</tr>
<tr>
<td>745-785</td>
<td>187.99</td>
</tr>
<tr>
<td>825-870</td>
<td>268.26</td>
</tr>
<tr>
<td>890-920</td>
<td>13.73</td>
</tr>
<tr>
<td>960-1010</td>
<td>44.10</td>
</tr>
<tr>
<td>1075-1125</td>
<td>114.48</td>
</tr>
</tbody>
</table>
### Well 26: Estimated Arsenic Distribution By Screen Interval
Blocking Off 3rd, 4th and 5th Screen From Top Of Well

<table>
<thead>
<tr>
<th>Sample Depth</th>
<th>Screen Interval</th>
<th>Cumulative Flow (GPM)</th>
<th>Incremental Flow (GPM)</th>
<th>Measured Concentration (From Lab)</th>
<th>CnQn</th>
<th>CnQn- Cn+1Qn+1</th>
<th>Incremental Flow</th>
<th>Mass Balance Incremental Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>605-655-715</td>
<td>470.00</td>
<td>97.00</td>
<td>19.50</td>
<td>16555.5</td>
<td>11.5</td>
<td>97.00</td>
<td>0.12</td>
<td>11.5</td>
</tr>
<tr>
<td>730-745-785</td>
<td>373.00</td>
<td>188.00</td>
<td>22.00</td>
<td>16544.0</td>
<td>1880.0</td>
<td>188.00</td>
<td>10.00</td>
<td>0</td>
</tr>
<tr>
<td>805-825-870</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>14664.0</td>
<td>7856.0</td>
<td>0.00</td>
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<td>0</td>
</tr>
<tr>
<td>880-890-920</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>6808.0</td>
<td>322.0</td>
<td>0.00</td>
<td>0.00</td>
<td>0</td>
</tr>
<tr>
<td>940-960-1010</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>6486.0</td>
<td>4266.0</td>
<td>0.00</td>
<td>0.00</td>
<td>0</td>
</tr>
<tr>
<td>1055-1075-1190</td>
<td>185.00</td>
<td>185.00</td>
<td>12.00</td>
<td>2220.0</td>
<td>2220.0</td>
<td>185.00</td>
<td>12.00</td>
<td>2220</td>
</tr>
</tbody>
</table>

**Spigot 1** Cumulative Flow: 470.00 8.75
**Spigot 2** Cumulative Flow: 470.00 8.75

The hypothetical scenario presented represents a worse case scenario in terms of estimated maximum production loss from well. Feasibility testing is recommended to determine hydraulic compensation yield from unblocked zones.

### Dynamic Arsenic Profile: Well 26

849 GPM

- **Screen Interval** (ft. bgs)
  - 655-715: 0.17
  - 745-785: 10.00
  - 825-870: 0.00
  - 890-920: 0.00
  - 960-1010: 0.00
  - 1075-1190: 12.00

- **As ug/l**
  - 655-715: 97.00
  - 745-785: 188.00
  - 825-870: 0.00
  - 890-920: 0.00
  - 960-1010: 0.00
  - 1075-1190: 185.00

- **4111.5 8.75**
Potential Strategies for a Feasibility Test:
Goal: To Produce Less Arsenic at Discharge and Hydraulically Compensate for Groundwater Production Lost From Blocked Zones (red)
Solution For “Synergistic Well Modification”

Before Modification

US EPA MCL = 10 ug/l

Side Stream Treatment

50%/50%

12 ug/l As

ND As

Treatment

6 ug/l As

Distribution

Well #26: Arsenic Reduction Profile
Tools of the Trade: Swage

Drive Swage

Hydraulic Swage

Hydraulic Swage, ready for use
Casing Patch
Swaging & Patching

Hydraulic Swage ready to set a casing patch

Hydraulic Swage
Focused Well Rehabilitation
Wide Spread Encrustations as indicated by video survey – No to Little Production

Predominantly Clay Matrix – No to Little Production

Total GPM = 950

- < 1%: 23.5%
- 17.0%
- 7.1%
- 51.5%
BEFORE AND AFTER REHAB WELL PROFILING

One of the least used performance metrics
Before and After Well Profiling

Rehab Performance Metrics

Pre-Rehabilitation
S.C. 17.4
Q  700 gpm
Eff. 62%
Mn  75 ug/L

Zone of High Manganese Production

Post-Rehabilitation
S.C. 22.6
Q  850 gpm
Eff. 72%
Mn  < 20 ug/L

Cement/Bentonite Cap
Gravel Fill Material
Zonal Profiling During or After Pump Tests

Rules, Recommendations and Insights:

1. Zonal flow profiling assumes dynamic steady state condition.
2. Can be performed during or following pump test.
3. If performed following pump test, then dynamic profile must be performed at same pumping rate as pump test.
4. Use of zonal profiling during or following pump test provides estimate of hydraulic conductivity.
5. Can be performed with primary pump or test pump.
6. Recommend that pump intake depths are the same when dynamic zonal test is performed following pump test.
7. Estimates may be skewed in wells lacking recent rehab; however data may still be very useful on a relative basis and provide clues concerning sections of gravel pack clogging.
Using Pump Test and Zonal Flow Results To Calculate Estimated Zonal Hydraulic Conductivity From Production Wells

\[ K_{FM,i} = \frac{\triangle Q_i / Q_p}{\triangle b_i / B} \]

Molz et. al 1989 and 1994

\[ \bar{K} = \text{Average hydraulic conductivity from well pump test} \]
\[ Q_p = \text{Average pumping rate from well} \]
\[ B = \text{Screened thickness of aquifer} \]
\[ \triangle Q_i = \text{Discharge measured within the i-th sampling interval of vertical thickness } \triangle b_i \]
\[ K_{FM,i} = \text{Estimated value for the hydraulic conductivity representative of the } i-th \text{ vertical interval} \]
Compelling Application:

Well Field Design, Expansion, Management
Standard Exploration Test Method Options

Method 1
- Drill Stem Test Well

Method 2
- PVC Test Well

1. **Drill Rig Can Never Leave Site**
2. Expensive: funding typically enough for ONLY 3 to 5 zones
3. More time and difficult to develop
4. More time and costly to abandon
5. Drill String could become buried (method 1)
6. Bentonite seal may leak
Expensive Data Deficiencies

Zone Testing 6 to 24 Hours Per Zone Using Sequential Backfill Method
Determine Pumping Rate For Each Test?
Zone Selections are COARSIFIED!!

Leakage
Thin Clay or Grout Seals
Profiling Temporary Long Screened Wells with BESST Tracer Technology

Multiple Pump Intake Locations: Each pump intake depth – pumped at dynamic, steady state conditions

Legend:
- Injection Point
- 50 ml Rhodamine Red FWT 50
- Groundwater Sampling Location

- Steady State Profile #1
- Steady State Profile #2
- Steady State Profile #3
Long Screened Test Well

Advance Borehole and Log Cuttings

Run Geophysics

- Spontaneous Potential (SP) (eV)
- Resistivity (Ohm m)

Identify Injection and Sampling Depths

Construct Long Screened Well Build Well Screen Intervals
Construct Long Screened Well Gravel Pack and Seals (tremmied)

Drilling Rig Demobs From Site

Pump Rig Mobs Onto Site

Develop Well: Remove Mud Cake and Drilling Fluid w/ Electric Submersible Pump

GOAL = 10 NTUs

Pump Development Location 1

Pump Development Location 2

Pump Development Location 3

Development
Zonal Flow Profile with Miniaturized USGS/BESST Tooling Of Long Screened Test Well

6 to 8 Inch Inside Diameter / 15 to 20 cm

- All Injections are performed one depth at a time
- All Tracer injection return times monitored with ground surface fluorometer connected to line tap
- All Injections are sideways to obtain most accurate flow rate inside long screened well
- Injections performed until no return from furthest tracer release depth
- Then, pump is raised to just below the furthest tracer return depth from pump depth location #1
- Packer below pump is inflated
- The second velocity, zonal flow profile is now performed from pump depth location #2
Speaker #4

Designing and Implementing a Multi-Facility SCADA System in the Age of Information

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Designing & Implementing a Multi-Facility SCADA System in the Age of Information

WRD Groundwater Quality Workshop
August 9, 2017
Agenda

• Purpose of the WRD SCADA Master Plan
• SCADA Master Plan Development
• Key WRD SCADA Projects
• Partnering with the Right Integrator
• Benefits of executing the WRD SCADA Master Plan
• Road Map to Success
A SCADA System Master Plan was completed in May 2016

Some key components:

- Support the design of future facilities
- Integration with existing facilities, including communications back to a centralized SCADA system
- Network design and cybersecurity program
- Develop & implement stds for software, hardware, graphics, programming, etc.

Major challenges:

- WRD is not an operating agency
- Facilities constructed at different times with no standards in place
- Construction projects in progress
- Lack of internal staff with expertise
Key Objectives of SCADA Master Plan

- Build consensus & determine future direction
- Prioritize SCADA projects with useable budgets
- Maximize investment in control system equipment
- Retain SCADA system integrator (Enterprise Automation) to assist with integration of key WRD projects
SCADA Master Plan Dvlpt

Phase I: Project Initiation/Identify Goals and Metrics
- Task 1 – Project Initiation
- Task 2 – Visioning Workshop

Phase II: Baseline Assessment
- Task 3 – Perform Baseline Assessment

Phase III: Evaluate Alternatives & Recommend Actions
- Task 4 – Perform Requirements Definition
- Task 5 – Evaluate SMP Alternatives and Recommend Initiatives

Phase IV – Development of Draft Technology Master Plan
- Task 6 – Draft SCADA Master Plan

Phase V: Development and Delivery of Final Technology Master Plan
- Task 7 – Finalize SCADA Master Plan

Evaluate Alternatives & Recommend Actions
Final SCADA Master Plan
- CSIA Certified Integrator (1 of 3 in SoCal)
- Schneider Electric’s #1 Integrator in U.S.
  - SCADA Certified Alliance I.P. (1 of 1 in U.S.)
  - PlantStruxure Certified Alliance I.P. (1 of 1 in CA)
- Wonderware System Platform Certified (1 of 3 in SoCal)
WRD System Overview
The CIS is being established at WRD’s headquarters

The CIS will be able to view, and eventually operate, all of WRD’s facilities
By Summer 2018, the GRIP AWTF will be completed and have the ability to produce up to 21,000 AFY of advanced treated recycled water for recharge at the Montebello Forebay Spreading Grounds.

The current design requires coordination with the SCADA Master Plan.
ENTERPRISE ASSET MANAGEMENT SYSTEM

Development & Implementation

Centralized SCADA System (CIS)

Multiple Information Sources (CMMS, Document Mngt System, etc.)

- SCADA LVL AWTF
- SCADA Goldsworthy Desalter
- SCADA Turnout Structures
- SCADA GRIP AWTF
- Groundwater Monitoring Wells
The Right Integration Partner

- Long-term captive integrator (3+ years)
- Qualified, based on the needs of the Master Plan
- Partnership, behaves like an extension of staff
- Participation, seeks to engage with you
Winning Formula

Right Plan + Right Partner = Incredible Value

Long-term, qualified partner who wants to collaborate
Introduction
World Class SCADA Benefits

Consistency
Consistency

Installed 2008

Installed 2012
2009 - Filters System

2017 - HydroElec System
World Class SCADA Benefits

Consistency

Predictable
Predictable

Unreliable & Unvalid

Unreliable, But Valid

Reliable, Not Valid

Both Reliable & Valid
World Class SCADA Benefits

Consistency

Predictable

Documented / Traceable
World Class SCADA Benefits

- Consistency
- Predictable
- Documented / Traceable
- Secure
Skeptical? Good!
Client Involvement, both client and integrator need to be working together
1. Client Involvement - Workshops

Non-PTW individual startup sequence

- Permissives (SDF-7 only)
  - pump + valve in remote & SCADA Auto + in service
  - no device alarms
  - value closed (SDF-7 only)

Initiation
- Start-up button (Plant config screen) + Remote (Well LCP)
- Start button + tank switch (Well LCP)
- Non-PTW group startup sequence start command

PTW Shutdown

Initiation
- Shutdown button (Plant config screen) + Remote (Well LCP)
- Stop button + Local (Well LCP)
- Shutdown alarms

Sequence
1. EF ptw enable/open-waste valve to initial pos SP
2. Call pump, wait for pump until valve fully open
3. Enable PTW FC loop
4. Start PTW timer
5. Wait for timer to expire + PTW button
6. EF in local, wait until process else shutdown
7. Open production valve, wait for full open (SDF-7 only)
8. Disable waste FC loop
9. Close waste valve
10. Close waste valve

PTW enable/disable
Flow to plant enable/disable
PTW timer
TDS
Chloride
Sulfate
Phosphate (SDF-7)
PTW not required timer

Initial waste valve position SP
Client Involvement, both client and integrator need to be working in concert.

Document decisions and standards, otherwise things will change.
Standards

“The way we do things around here…”
Client Involvement, both client and integrator need to be working in concert

Document decisions and standards, otherwise things will change

Both sides need a champion, enforcement of decisions is key
3. Champions

How standards proliferate:
(See: A/C chargers, character encodings, instant messaging, etc)

Situation:
There are 14 competing standards.

14?! Ridiculous! We need to develop one universal standard that covers everyone's use cases. Yeah!

Soon:

Situation:
There are 15 competing standards.
Client Involvement, both client and integrator need to be working in concert

Document decisions and standards, otherwise things will change

Both sides need a champion, enforcement of decisions is key

Project execution
- Defined and Clear Estimate/Scope
- Written Specifications
- QC / Testing
- Real Project Management
- Early Planning
Thank You

For more information visit

www.wrd.org

www.EAintegrator.com
Ex-Situ Groundwater Remediation Options for Perchlorate

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Cathy Swanson
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EX-SITU GROUNDWATER REMEDIATION OPTIONS FOR PERCHLORATE

Water Replenishment District of Southern California

2017 Annual Groundwater Quality Workshop

August 9, 2017
SPEAKERS

Cathy Swanson, Evoqua
Ms. Swanson received her BS in Chemical Engineering from Northwestern University. Her experience includes, lab technician, facilities engineering, operations, technical service, marketing, account management, and most recently business development. She has spent the past 10 years focused on groundwater cleanup of inorganic constituents especially for drinking water.

Steve Winners, PE, WorleyParsons
Mr. Winners received his BS in Agricultural Engineering from Cal Poly San Luis Obispo. He is a Professional Civil Engineer in the State of California with 20+ years of environmental engineering experience working for two firms in Southern California. He has held both management and technical roles. He has assembled and participated in multi-disciplinary teams of geologists, hydrogeologists, geochemists, toxicologists, and engineers conducting assessment, remediation and management of chemical releases to groundwater.
AGENDA

PART 1
1. Perchlorate Chemistry
2. Natural Sources of Perchlorate
3. Perchlorate Use
4. Perchlorate In The Environment
5. Drinking Water Contaminant History
6. Human Health Considerations
7. Regulatory Update

PART 2
1. Technology Selection Factors
2. Information Needed To Design A System
3. Treatment Technologies
   Not Applicable to Perchlorate
4. Treatment Technologies
   Applicable to Perchlorate
5. Ion Exchange
6. Biological
PERCHLORATE CHEMISTRY

- Fundamental physical and chemical nature complicates treatment.
- Perchlorate tetrahedron structure of four oxygen atoms surrounding the central chlorine atom.
- Effectively blocks reductants from directly attacking the chlorine.
- Thermodynamically a strong oxidizing agent but kinetically a sluggish species, such that its reduction is generally very slow, rendering common reductants ineffective.

Source: US EPA
NATURAL SOURCES OF PERCHLORATE

• Chilean nitrate deposits
  • Chief source of nitrogen for explosives, fertilizer, and chemical industries from the 1830s to the 1930s.
  • Only significant source of iodine from the 1870s (replacing seaweed) until the mid-20th century (when iodine began to be extracted from oilfield brines).
• New Mexico potash
• Canada potash
• California hanksite
• Bolivian playa (evaporative) crusts
PERCHLORATE USE

- Solid propellant for rockets, missiles, for the defense and aerospace industries.
- Primary oxidizer in matches, road flares, air bag initiators for vehicles, pyrotechnics, ordnance, and explosives.

Source: Water Research Foundation
PERCHLORATE IN THE ENVIRONMENT

- Soluble and very mobile in water systems.
- Resistance to reactions with other available water constituents.
- Can persist in the environment for many decades under typical groundwater and surface water conditions.

Source: US EPA
DRINKING WATER CONTAMINANT HISTORY

- Perchlorate was found to be a contaminant in drinking water supplies for the Western United States in 1997. The issue was triggered when elevated levels of perchlorate were discovered in California drinking water supplies using a new, more sensitive analytical method (US EPA Method 314.0 Determination of Perchlorate in Drinking Water Using Ion Chromatography).

- More recent occurrence studies have found perchlorate contamination in both groundwater and surface waters serving as drinking water sources for more than 16 million people in at least 26 states nationwide, though most often in the southwest.

### Drinking water sources with perchlorate detections.

<table>
<thead>
<tr>
<th>County</th>
<th>Year initially detected</th>
<th>Total No. of Sources</th>
<th>Peak level (μg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Los Angeles</td>
<td>54 31 21 13 8 24 7 12 7 177 159</td>
<td></td>
<td></td>
</tr>
<tr>
<td>San Bernardino</td>
<td>31 1 1 8 34 8 3 4 5 95 820</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Riverside</td>
<td>14 5 5 11 16 19 10 3 1 84 73</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Orange</td>
<td>- 20 - - - 1 9 7 - - 37 11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sacramento</td>
<td>10 2 - 1 - 1 - 1 - 1 9 24 400</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tulare</td>
<td>- - - - - 2 11 1 - - - 14 24</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Santa Clara</td>
<td>- - - - - 1 2 - 2 - - - 10 8.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>San Diego</td>
<td>- - - - - - 1 - - - - 4 - 5 7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ventura</td>
<td>- - - - - - - - - 2 - - 4 20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Imperial</td>
<td>- - - - - - - - - 3 - 1 - - - 4 6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sonoma</td>
<td>- - - - - - - - - - - - - - - - 1 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stanislaus</td>
<td>- - - - - - - - - - 1 - - - - 1 3.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>109 60 29 38 75 65 31 26 23 456 -</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: State of California
HUMAN HEALTH CONSIDERATIONS

• Perchlorate is classified as a goitrogen by the United States Environmental Protection Agency (US EPA), because at high levels it can interfere with the thyroid’s ability to uptake iodide and thus affect hormone production.

• Thyroid hormones play a vital role in the growth and development of the central nervous system of fetuses and infants.

• According to the National Research Council, pregnant women, infants, children, and people with iodine-deficient diets or preexisting thyroid deficiencies may be more sensitive to perchlorate than the general population.

Source: Water Research Foundation
REGULATORY UPDATE

• **US EPA** anticipated proposing an MCL but does not currently regulate perchlorate in drinking water.

• **California** and Massachusetts currently regulate Perchlorate in drinking water with maximum contaminant levels (MCLs) at 6 μg/L and 1 μg/L.

• California established an MCL for perchlorate 2007 based on a Public Health Goal (PHG) of 6 μg/L.

• California reduced the PHG from 6 μg/L to 1 μg/L in 2015.

• **California** previously set the detection limit for purposes of reporting (DLR) at 4 μg/L, and in July 2017 recommended reducing the DLR to a level closer to, equal to, or less than the PHG of 1 μg/L.

• If supported by new data at a lower DLR, California may lower the MCL to as close to the 1 μg/L PHG as is technologically and economically feasible.
PART 2
TECHNOLOGY SELECTION FACTORS

• Water Quality Factors
  – Perchlorate and co-contaminant concentrations
  – Geochemical and other water quality parameters
  – Indigenous Perchlorate-Reducing Microbes (PRM) and substances that inhibit PRM.

• Water Quantity Factors
  – Groundwater Remediation (10-100 gpm)
  – Groundwater Production (1,000-10,000 gpm)

• Waste Disposition Considerations
  – Brine discharge pipelines and permit
  – Liability of generator

• End Use Considerations
  – Direct domestic use
  – Groundwater recharge
  – Recycled water use
  – Storm drain or surface water discharge
  – Publicly owned treatment works (POTW) discharge

Source: Ground-Water Remediation Technologies Analysis Center
# INFORMATION NEEDED TO DESIGN A SYSTEM

<table>
<thead>
<tr>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operational Flow Rate</td>
</tr>
<tr>
<td>Operational Schedule</td>
</tr>
<tr>
<td>Daily Volume (average)</td>
</tr>
<tr>
<td>Perchlorate</td>
</tr>
<tr>
<td>Chloride</td>
</tr>
<tr>
<td>Nitrate (as NO3)</td>
</tr>
<tr>
<td>Sulfate</td>
</tr>
<tr>
<td>Alkalinity (as CaCO3)</td>
</tr>
<tr>
<td>pH</td>
</tr>
<tr>
<td>TDS</td>
</tr>
</tbody>
</table>
TREATMENT TECHNOLOGIES
NOT APPLICABLE TO PERCHLORATE

• Standard Granular Activated Carbon (GAC)
  – Designed to sorb contaminant to a solid
  – Perchlorate has a high solubility and low affinity for sorption to solids

• Air Stripping
  – Designed to partition the contaminant from water to air phase
  – Perchlorate is non-volatile

• Precipitation
  – Perchlorate will not precipitate at any pH

• Chemical Reduction
  – Add a reagent to enhance contaminant degradation
  – Structure blocks reductants from directly attacking the chlorine.

Source: US EPA
TREATMENT TECHNOLOGIES

Most Common Approaches:

- Ion Exchange
  - Single-Pass
  - Regenerable
- Biological Reduction
  - Fluidized Bed Reactors
  - Fixed Bed Reactor
  - Continuously Stirred Reactor
  - Post-treatment required

Not Generally Used:

- Membrane Filtration
  - Reverse Osmosis – 25% waste stream to dispose of
- Tailored GAC
  - More expensive than resins
- Chemical Reduction
  - “Expensive and slow”
- Electrochemical Reduction
  - “Slow process”
- Electrodialysis

Source: US EPA
**PRINCIPLES OF ION EXCHANGE**

- Ion Exchange, or IX, is based on the principle of exchanging a harmless ion for the contaminant.

- A reversible exchange of ions between a solid and a liquid in which there is no substantial change in the structure of the solid - the solid being the ion exchange resin.

- Example: \[ R-\text{Cl} + \text{NH}_4\text{ClO}_4 \rightleftharpoons R-\text{ClO}_4 + \text{NH}_4\text{Cl} \]
ANION ION EXCHANGE – SELECTIVITY FOR A PERCHLORATE RESIN

Least Selective

SiO₂ - Silicate
OH - Hydroxide
F - Fluoride
HCO₃ – Bicarbonate
CL - Chloride
SO₄ – Sulfate
NO₃ – Nitrate / Cr₂O₄ - Chromate
UO₂(CO₃)₂ – Uranium
ClO₄ – Perchlorate
PFCs

Most Selective

Many of the anions in ground water, also call Total Dissolved Solids or TDS
REGENERABLE ION EXCHANGE

• Produces concentrated perchlorate waste brine which generally cannot go to sewer
• Perchlorate is not destroyed, so liability is not severed for the generator
SINGLE PASS ION EXCHANGE

• Most common treatment
• DDW listed best available technology
• Low carbon footprint
• Simple operations – generally runs 6 to 9 months until spent
• Perchlorate is destroyed if resin goes to Waste-to-Energy Facility for incineration where a Certificate of Destruction ends generator liability
SINGLE PASS RESIN SITE CONSIDERATIONS

• Compact design: Treat up to 2000 gpm in 420 sq ft (vessels only)
• Systems run in lead/lag because perchlorate is considered an acute toxin
• Prefiltration is recommended
BIOLOGICAL TREATMENT

- Types:
  - Fixed Bed Reactor
  - Fluidized Bed Reactor
  - Biocatalyst
  - Continuously Stirred Reactor

- Excellent choice when paired with high nitrate levels. Also, chrome VI, selenium

- Requires chemical feeds

- Must meet surface water treatment regulations with post filtration

- Limited number of drinking water applications in US as technology is just starting to gain acceptance
SOURCES OF INFORMATION

• National Sources
  • United States Environmental Protection Agency (US EPA)
  • American Water Works Association Research Foundation (AWWARF)
  • Water Research Foundation (WRF)
  • Ground-Water Remediation Technologies Analysis Center (GWTRAC)
  • Interstate Technology & Regulatory Council (ITRC)

• State Sources
  • California Environmental Protection Agency (Cal-EPA)
  • California State Water Resources Control Board (SRWCB)
THANK YOU!

QUESTIONS?

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562-217-0419

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Steve.Winners@Advisian.com
714-920-8836
Speaker #6

UCMR4 Implementation Strategies for Water Systems

Rick Zimmer
Eurofins Eaton Analytical
RickZimmer@eurofinsUS.com
UCMR4
Implications & Strategies for water systems

August 9, 2017
Purpose of the UCMR

- Draft CCL
  - Final CCL
  - Draft UCMR
    - Final UCMR
      - UCMR Monitoring Results
      - No further action if make decision to not to regulate (may develop health advisory).

- Preliminary Regulatory Determinations
  - Final Regulatory Determinations
    - Proposed Rule (NPDWR)
      - Final Rule (NPDWR)
        - Six Year Review of Existing NPDWRs

- Public review and comment
UCMR History
# UCMR4 Schedule

<table>
<thead>
<tr>
<th></th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
</tr>
</thead>
<tbody>
<tr>
<td>After final rule publication: EPA/state primacy authorities (1) develop SMPs (including the nationally representative sample); (2) inform PWSs/ establish monitoring plans; and (3) continuation of laboratory approval</td>
<td></td>
<td></td>
<td></td>
<td>Assessment Monitoring</td>
<td>Complete reporting and analysis of data</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>List 1 Contaminants</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><em>All large systems serving more than 10,000 people;</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><em>800 small systems serving 10,000 or fewer people for cyanotoxins;</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><em>800 small systems serving 10,000 or fewer people for the 20 additional contaminants.</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Reporting and analysis of data</td>
</tr>
</tbody>
</table>
# UCMR4 Monitoring Requirements

<table>
<thead>
<tr>
<th>UCMR4 Requirement</th>
<th>Groundwater Systems</th>
<th>Surface Water and GWUDI Systems</th>
<th>Sample Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metals (2)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pesticides (9)</td>
<td>Two Times in 12-Month Period 5-7 Months Apart</td>
<td>Four Times in 12-Month Period 3 Months Apart</td>
<td>EPTDS</td>
</tr>
<tr>
<td>Alcohols (3)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Semivolatiles (3)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brominated HAA groups (3)</td>
<td>Only Required if conducting DBP Stage 2 Monitoring</td>
<td></td>
<td>DBP Stage 2 HAA Compliance Point</td>
</tr>
<tr>
<td>DBP Indicators - TOC, Bromide (2)</td>
<td></td>
<td></td>
<td>Source Water</td>
</tr>
<tr>
<td>Total Microcystins (1)</td>
<td>Not Required</td>
<td>8 times (2 weeks apart) in 4-Month Period March - November</td>
<td>EPTDS</td>
</tr>
<tr>
<td>Microcystins, Nodularin (7)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anatoxin-a, Cylindrospermopsin (2)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**DBP Stage 2 Exemption = No DBPs or source monitoring**

**Consecutive Systems = No source monitoring**
UCMR4 Sample Locations

SOURCE

40CFR141.132 or 40CFR141.703

EPTDS

STAGE 2 DBP SITES
# UCMR4 Sample Locations - DBPs

<table>
<thead>
<tr>
<th>Contaminant/Disinfectant</th>
<th>Coverage</th>
<th>Stage 2 DBPR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Source Water</td>
<td>Population</td>
</tr>
<tr>
<td>TTHM/HAA5</td>
<td>SW and GWUDI (Subpart H)</td>
<td>&lt; 500</td>
</tr>
<tr>
<td></td>
<td></td>
<td>500 - 3,300</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3,301 - 9,999</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10,000 - 49,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>50,000 - 249,999</td>
</tr>
<tr>
<td></td>
<td></td>
<td>250,000 - 999,999</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1,000,000 - 4,999,999</td>
</tr>
<tr>
<td></td>
<td></td>
<td>≥ 5,000,000</td>
</tr>
<tr>
<td>Ground water</td>
<td>&lt; 500</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>500-9,999</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>10,000-99,999</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>100,000-499,999</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>≥ 5,000,000</td>
<td>8</td>
</tr>
</tbody>
</table>
# UCMR4 Chemistry Analytes

## Metals: EPA Method 200.8, ASTM D5673-10, SM 3125

<table>
<thead>
<tr>
<th>Contaminant</th>
<th>MRL (μg/L)</th>
<th>Additional Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>germanium</td>
<td>0.3</td>
<td>Naturally-occurring element;</td>
</tr>
<tr>
<td>manganese</td>
<td>0.4</td>
<td>Naturally-occurring element;</td>
</tr>
</tbody>
</table>

## Pesticides and a Pesticide Manufacturing Byproduct: EPA Method 525.3

<table>
<thead>
<tr>
<th>Contaminant</th>
<th>MRL (μg/L)</th>
<th>Additional Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>alpha-hexachlorocyclohexane</td>
<td>0.01</td>
<td>Component of benzene hexachloride (BHC); formerly used as an insecticide</td>
</tr>
<tr>
<td>chlorpyrifos</td>
<td>0.03</td>
<td>Organophosphate; used as an insecticide, acaricide and miticide</td>
</tr>
<tr>
<td>dimethipin</td>
<td>0.2</td>
<td>Used as an herbicide and plant growth regulator</td>
</tr>
<tr>
<td>ethoprop</td>
<td>0.03</td>
<td>Used as an insecticide</td>
</tr>
<tr>
<td>oxyfluorfen</td>
<td>0.05</td>
<td>Used as an herbicide</td>
</tr>
<tr>
<td>profenofos</td>
<td>0.3</td>
<td>Used as an insecticide and acaricide</td>
</tr>
<tr>
<td>tebuconazole</td>
<td>0.2</td>
<td>Used as a fungicide</td>
</tr>
<tr>
<td>total permethrin (cis- &amp; trans-)</td>
<td>0.04</td>
<td>Used as an insecticide</td>
</tr>
<tr>
<td>tribufos</td>
<td>0.07</td>
<td>Used as an insecticide and cotton defoliant</td>
</tr>
</tbody>
</table>

## Alcohols: EPA Method 541

<table>
<thead>
<tr>
<th>Contaminant</th>
<th>MRL (μg/L)</th>
<th>Additional Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-butanol</td>
<td>2.0</td>
<td>Used as a solvent, food additive and in production of other chemicals</td>
</tr>
<tr>
<td>2-methoxyethanol</td>
<td>0.4</td>
<td>Used in a number of consumer products, such as synthetic cosmetics,</td>
</tr>
<tr>
<td>2-propan-1-ol</td>
<td>0.5</td>
<td>Used in the production flavorings, perfumes and other chemicals</td>
</tr>
</tbody>
</table>

## Semivolatile Chemicals: EPA Method 530

<table>
<thead>
<tr>
<th>Contaminant</th>
<th>MRL (μg/L)</th>
<th>Additional Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>butylated hydroxyanisole</td>
<td>0.03</td>
<td>Food Additive/Anti oxidant</td>
</tr>
<tr>
<td>o-toluidine</td>
<td>0.007</td>
<td>Production of dyes, etc.</td>
</tr>
<tr>
<td>quinoline</td>
<td>0.02</td>
<td>Pharmaceutical, flavoring agent, component of coal</td>
</tr>
</tbody>
</table>
**UCMR4 DBPs**

<table>
<thead>
<tr>
<th>HAA Groups (EPA Method 552.3 or 557)</th>
</tr>
</thead>
<tbody>
<tr>
<td>dichloroacetic acid (DCAA)</td>
</tr>
<tr>
<td>monochloroacetic acid (MCAA)</td>
</tr>
<tr>
<td>trichloroacetic acid (TCAA)</td>
</tr>
<tr>
<td>monobromoacetic acid (MBAA)</td>
</tr>
<tr>
<td>dibromoacetic acid (DBAA)</td>
</tr>
<tr>
<td>bromochloroacetic acid (BCAA)</td>
</tr>
<tr>
<td>bromodichloroacetic acid (BDCAA)</td>
</tr>
<tr>
<td>chlorodibromoacetic acid (CDBAA)</td>
</tr>
<tr>
<td>tribromoacetic acid (TBAA)</td>
</tr>
</tbody>
</table>

**HAA5**

**HAA9**

**HAA6Br**
## UCMR4 Algal Toxins

<table>
<thead>
<tr>
<th>Contaminant</th>
<th>MRL (µg/L)</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>“total microcystins”</td>
<td>0.3</td>
<td>EPA 546</td>
</tr>
<tr>
<td>microcystin-LA</td>
<td>0.008</td>
<td>EPA 544</td>
</tr>
<tr>
<td>microcystin-LF</td>
<td>0.006</td>
<td>EPA 544</td>
</tr>
<tr>
<td>microcystin-LR</td>
<td>0.02</td>
<td>EPA 544</td>
</tr>
<tr>
<td>microcystin-LY</td>
<td>0.009</td>
<td>EPA 544</td>
</tr>
<tr>
<td>microcystin-RR</td>
<td>0.006</td>
<td>EPA 544</td>
</tr>
<tr>
<td>microcystin-YR</td>
<td>0.02</td>
<td>EPA 544</td>
</tr>
<tr>
<td>nodularin</td>
<td>0.005</td>
<td>EPA 544</td>
</tr>
<tr>
<td>anatoxin-a</td>
<td>0.03</td>
<td>EPA 545</td>
</tr>
<tr>
<td>cylindrospermopsin</td>
<td>0.09</td>
<td>EPA 545</td>
</tr>
</tbody>
</table>
UCMR4 Algal Toxin “Trigger”

Collect EPTDS samples for 544, 545, 546

Analyze for Anatoxin-a and Cylindrospermopsin by 545 and report results

Analyze for total Microcystins by ELISA (546)

Analyse individual microcystins by 544 and report BOTH 544 and 546 results

Report ONLY total microcystins

>/>=0.3

ND (<0.3)
### UCMR4 Data Elements

<table>
<thead>
<tr>
<th>Utility Data Entry</th>
<th>Lab Data Entry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public Water System Identification (PWSID) Code</td>
<td>Sample Collection Date</td>
</tr>
<tr>
<td>Public Water System Name</td>
<td>Sampling Point Name</td>
</tr>
<tr>
<td>Public Water System Facility Identification Code</td>
<td>Sampling Point Type Code</td>
</tr>
<tr>
<td>Public Water System Facility Name</td>
<td>Disinfectant Type</td>
</tr>
<tr>
<td>Public Water System Facility Type</td>
<td>Treatment Information</td>
</tr>
<tr>
<td>Water Source Type</td>
<td>Disinfectant Residual Type</td>
</tr>
</tbody>
</table>

**Bloom Occurrence**

- Indicator of Possible Bloom – Treatment
- Cyanotoxin Occurrence
- Indicator of Possible Bloom – Source

**Water Quality Parameters**
UCMR4 CDX SET UP STEPS

1. CDX Account
2. SDWARS4
3. Profile Settings
4. Notification Letter
5. Add Contacts
6. Add Inventory
7. Confirm Schedule
8. Add Zip Codes
9. Notimate User
10. Confirm & Save
STEP 1 – CDX ACCOUNT

Log in to CDX
User ID

Password

Log In  Register with CDX

Forgot your Password?
Forgot your User ID?
Warning Notice and Privacy Policy

https://cdx.epa.gov/
STEP 2 – SDWARS4

[Image of the EPA Central Data Exchange website showing the SDWARS4 program service under Services.]
STEP 3 – PROFILE SETTINGS
STEP 4 – NOTIFICATION LETTER

Notification Letter

January 3, 2017

Dear Public Water System:

The purpose of this letter is to notify your public water system (PWS) of its monitoring requirements under the revision to the Unregulated Contaminant Monitoring Rule (UCMR4). The U.S. Environmental Protection Agency (EPA) published the final rule detailing the upcoming monitoring of unregulated contaminants at PWSs on December 20, 2016, establishing a new list of contaminants to be monitored and the conditions for that monitoring. This rule benefits public health by providing EPA and other interested parties with scientifically valid data on the national occurrence of selected contaminants in drinking water. This dataset is one of the primary sources of information on occurrence, levels of exposure and population exposure EPA uses to develop regulatory decisions for contaminants in the public drinking water supply.

Under the UCMR4, all community water systems and non-transient, non-community water systems serving more than 10,000 persons must participate in Assessment Monitoring (AM). Our records indicate that your surface water system must monitor for all List 1 contaminants: metals, pesticides, semi-volatile organic chemicals (SOCs), alcohols (AM 1), haloacetic acids (HAA5) (AM 2), and cyanotoxins (AM 3).

What must your PWS complete in SDWARS before December 31, 2017?

Similar to reporting under UCMR3, PWSs will use the Central Data Exchange (CDX) (https://cdx.epa.gov) to access the updated version of the Safe Drinking Water Accession and Review System (SDWARS). PWSs are required to:

- enter your official and technical contact information;
- review and, if necessary, update your sample location data by adding missing locations (e.g., Stage 1 and Stage 2 Disinfectants and Disinfection Byproduct Rules sampling locations for the HAA5), indicating ineligible locations or editing basic information about the locations; and
- review and, if you wish, revise your monitoring schedule assigned by the EPA.

What must your PWS do during UCMR4 monitoring?

Your PWS must ensure that samples are properly collected, packaged and shipped to a UCMR4 EPA approved laboratory. Your PWS is also responsible for providing the data elements required for each sampling location (e.g., disinfection type, treatment type etc.) in SDWARS. Once data are posted to SDWARS by your laboratory, your PWS will have 60 days to review and act upon these results. If you choose not to review these results in this time frame, they will be considered final. Additionally, community water systems are required to address their UCMR monitoring results in their annual Consumer Confidence Report (CCR) whenever unregulated contaminants are detected (https://www.epa.gov/ocr).

Where can I find more information about UCMR4?

EPA recommends that you review the complete rule and supporting reference materials addressing UCMR4 at https://www.epa.gov/dwumr/fourth-unregulated-contaminant-monitoring-rule-ucmr4:

- The “Revisions to the Unregulated Contaminant Monitoring Rule (UCMR4) for Public Water Systems and Announcement of Public Meeting” [EPA-HQ-OW-2015-0218; FRL-9556-71-OW];
- UCMR4 Implementation fact sheets: Metals, Pesticides, SOCs, and Alcohols (AM 1), Haloacetic Acids (HAA5) (AM 2), Cyanotoxins (AM 3) and General Information;
- EPA approved laboratories for UCMR4 (the list will be updated as additional laboratories are approved);
- Outreach materials and announcements for stakeholder meetings and trainings.

Analytical results from UCMR are publically available in the National Contaminant Occurrence Database (NCOD); for a summary of the NCOD results, tips for querying NCOD, and health effects information please refer to the UCMR Data Summary document.

This notification letter is being sent to you as the official representative of this PWS. If someone else at your PWS needs this information, such as the plant operator, please provide them with a copy of this letter. Your cooperation in meeting these requirements is appreciated.

For questions regarding SDWARS or CDX, please contact the CDX Help Desk at 1-888-890-1995. For implementation or general questions, please contact the UCMR Message Center at 1-800-945-1181 or ucmr4admin@epa.gov. Thank you for your cooperation.
STEP 5 – ADD CONTACTS
OFFICIAL & TECHNICAL CONTACTS
CONFIRM CONTACTS

All PWSs must have an "Official" contact defined as the administrative representative for the PWS and a "Technical" contact that may be contacted as an alternate representative. Specify additional contacts as "Other" contact types. Edit or delete these contacts using the appropriate links any time you experience changes in personnel. Click Add Contact to include a contact. Click the edit icon to revise the information for that contact. Click the delete icon to remove that contact.

You must assign a Technical and Official contact immediately. If you have just deleted either of these, you must add a new contact to comply with UCMR4. You cannot proceed in SDWARS until you assign a Technical and Official contact.

<table>
<thead>
<tr>
<th>Contact Name</th>
<th>Contact Email</th>
<th>Affiliation/Organization</th>
<th>Contact Type</th>
<th>Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Howard The Duck</td>
<td><a href="mailto:howard.duck@marvel.universe.org">howard.duck@marvel.universe.org</a></td>
<td>Marvel Universe</td>
<td>Official</td>
<td></td>
</tr>
</tbody>
</table>
STEP 6 – ADD INVENTORY
MANUAL OR IMPORT
IMPORT FROM SDWARS3

Select the sample locations from SDWARS3 which need to be loaded into SDWARS4. You must click Next > button to review your inventory before it is added to the database.

Select All

<table>
<thead>
<tr>
<th>Facility ID</th>
<th>Facility Name</th>
<th>Facility Type</th>
<th>Water Type</th>
<th>Sample Point ID</th>
<th>Sample Point Name</th>
<th>Sample Point Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>00001</td>
<td>Treatment Plant #1</td>
<td>TP</td>
<td>GW</td>
<td>EP001</td>
<td>EP from TP #1</td>
<td>EP</td>
</tr>
<tr>
<td>00002</td>
<td>Treatment Plant #2</td>
<td>TP</td>
<td>GW</td>
<td>EP002</td>
<td>EP from TP #2</td>
<td>EP</td>
</tr>
</tbody>
</table>

Next >  Cancel

Select the import button to add the inventory to the database.

<table>
<thead>
<tr>
<th>Facility ID</th>
<th>Facility Name</th>
<th>Facility Type</th>
<th>Water Type</th>
<th>Sample Point ID</th>
<th>Sample Point Name</th>
<th>Sample Point Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>00001</td>
<td>Treatment Plant #1</td>
<td>TP</td>
<td>GW</td>
<td>EP001</td>
<td>EP from TP #1</td>
<td>EP</td>
</tr>
<tr>
<td>00002</td>
<td>Treatment Plant #2</td>
<td>TP</td>
<td>GW</td>
<td>EP002</td>
<td>EP from TP #2</td>
<td>EP</td>
</tr>
</tbody>
</table>
MANUALLY ADD
STEP 7 – CONFIRM SCHEDULE
STEP 8 – ADD ZIP CODES

Zip codes can be copy/pasted or typed.
STEP 9 – NOMINATE USER
### STEP 10 – CONFIRM & SAVE

#### Facility ID: 91821  Facility Name: Oliver P. Roemer  Facility Type: IN  Water Type: SW

<table>
<thead>
<tr>
<th>Sample Point ID</th>
<th>Sample Point Name</th>
<th>Sample Point Type</th>
<th>SEH1</th>
<th>SEH2</th>
<th>SEH3</th>
<th>SEH4</th>
</tr>
</thead>
</table>

#### Facility ID: 91801  Facility Name: Well 54  Facility Type: TP  Water Type: GW

<table>
<thead>
<tr>
<th>Sample Point ID</th>
<th>Sample Point Name</th>
<th>Sample Point Type</th>
<th>SEA1</th>
<th>SEA2</th>
<th>SEA3</th>
<th>SEA4</th>
</tr>
</thead>
</table>

#### Facility ID: 91813  Facility Name: 213 E. Walnut  Facility Type: DS  Water Type: MX

<table>
<thead>
<tr>
<th>Sample Point ID</th>
<th>Sample Point Name</th>
<th>Sample Point Type</th>
<th>SEH1</th>
<th>SEH2</th>
<th>SEH3</th>
<th>SEH4</th>
</tr>
</thead>
</table>
UCMR4 Key Dates

### Key UCMR4 Dates

- **Jan. 19, 2017**: UCMR4 Effective Date
- **Jan. 23, 2017**: 1st Proficiency Test Sample issued
- **Feb. 21, 2017**: Laboratory Approval Registration Deadline
- **April 12, 2017**: EPA UCMR4 Webinar
- **April 19, 2017**: Laboratory Approval Application Packages Deadline
- **Aug.–Sept., 2017**: Last Proficiency Test Sample issued
- **Dec. 31, 2017**: Sample Inventory Location & Schedule Updates Deadline
- **Jan. 1, 2018**: Monitoring Commences
- **Dec. 31, 2020**: Monitoring Concludes

**Now 10-31-17**
UCMR4 Key Contacts

UCMR4_Sampling_Coordinator@epa.gov

Jake Jenzen
EPA Region 9
415-972-3570
Jenzen.Jacob@epa.gov

Rick Zimmer
SDWA Committee Chairperson
949-466-8266
RickZimmer@eurofinsus.com
Speaker #7

Principles of Efficient Water Well Design

Kevin McGillicuddy
Roscoe Moss Company
kmc@roscoemoss.com
Efficient Water Well Design and Construction

Designing for Optimum Strength and Efficiency

Water Replenishment District of Southern California

August 9, 2017

Kevin McGillicuddy, P.G.
Roscoe Moss Company
Key To Efficient Well Design

• Goal to construct well capable of producing the maximum rate with the least amount of drawdown and at the lowest energy cost
Well Efficiency

Aquifer Loss
Total drawdown

Drawdown in Well

Pumping Level

Static (non pumping) Level

Aquifer Loss

Well Loss
Cornerstones of Efficient Well Design

- Durable Casing and Screen
- Proper Gravel Pack Design
- Proper Screen Slot Size
- Thorough Well Development
Critical Components in Designing Efficient Gravel Envelope Wells - Steel Casing and Screen

• Select steel type for the casing and screen that maximizes the working life of the well

• Specify casing and screen wall thickness that:
  – meets physical requirements during construction
  – has capability of withstanding rigorous physical development and rehab methods as the well matures
Commonly Used Steels

Non - Corrosion Resistant

• Mild / Low-Carbon Steel

Corrosion Resistant Steels

• Copper-Bearing
• High-Strength Low-Alloy (ASTM A606 Type 4)
• Stainless – Types 304 and 316L
## Durability and Cost

<table>
<thead>
<tr>
<th>Steel Type</th>
<th>Metal Loss*</th>
<th>Corrosion Resistance*</th>
<th>Cost Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Carbon</td>
<td>2.8794 mills/yr</td>
<td>1X</td>
<td>1.0X</td>
</tr>
<tr>
<td>0.2% Copper</td>
<td>0.7438 mills/yr</td>
<td>4X</td>
<td>1.6X</td>
</tr>
<tr>
<td>HSLA</td>
<td>0.3131 mills/yr</td>
<td>9X</td>
<td>1.9X</td>
</tr>
<tr>
<td>SS Type 304</td>
<td>0.0118 mills/yr</td>
<td>244X</td>
<td>4X</td>
</tr>
</tbody>
</table>

* Source: GEOSCIENCE Support Services, 1999
Downhole video of El Paso well constructed in 1955
Gravel Pack Selection

• Begin with properly collected formation samples at the drilling site

• Conduct sieve analysis to determine Formation Gradation

• Select Gravel Pack gradation using a multiplier on the Formation Gradation
Determine Gradation of Aquifer Sediments
Gravel Pack Selection

6X larger than smallest 30% of Formation
Gravel/Filter Packs Comparison

- High Silica Content
- Well Rounded
- Uniform Grain Size

#4 (4.8mm)
#6 (3.4mm)
#8 (2.4mm)
#12 (1.7mm)
#16 (1.2mm)
#20 (0.8mm)
#30 (0.6mm)
Slot Size Selection

- Primary function of screen slot is to stabilize the gravel envelope, *not the formation*!

- Sized to pass 10 to 20% gravel pack (retain 90 to 80%)

- Slot size more critical than % open area
Slot Size Selection

- Use the largest, reasonable slot size

  - Provides best opportunity for distributing energy required for initial development and future redevelopment / rehabilitation procedures
Well Development

Any process used to improve permeability of an aquifer and repair drilling damage.

Accomplished by removing fines through the gravel pack and well screen.

Must be aggressive and directed.

Must be repeated at regular intervals throughout the life of the well
Phases of Well Development

Pre-development: Controlling drilling fluids during drilling and construction

Preliminary development: swabbing, jetting, flushing, airlifting, and bailing

Final development: pumping, surging, and backwashing
Repair Drilling Damage

Wall Cake

Filter Pack

Aquifer
Dual Swab Development

Figure 14.2. Double-flanged swab without bypass.
Dual Swab and Simultaneous Airlift

- The well is mechanically swabbed by raising and dropping the drill pipe equipped with a tight fitting dual swab on the bottom.
- During swabbing, water is airlifted from the well.
- Swabbing is started at the top of the screen to minimize the risk of sand locking the swabs.
Measuring Sand Content using Rossum Sand Tester
Properly Designed Gravel Envelope & Screen Slot Size
SUMMARY

• Corrosion resistant steels have proven effective in extending well life

• Steel and material selection must consider corrosion prevention, potential aggressive well development and rehabilitation procedures

• Life Cycle Cost Analysis demonstrates that payback period for stainless steel is relatively short, 7 – 8 yrs
SUMMARY

- Select appropriate gravel pack gradation to stabilize formation
- Select appropriate slot size to stabilize/retain gravel pack
- Employ rigorous and thorough well development methods
- Monitor the specific capacity and efficiency of the well to determine when rehab is needed and minimize operational costs
Questions?

Kevin McGillicuddy, P.G.
(323) 263-4111
Email:
kmc@roscoemoss.com
Website:
www.roscoemoss.com
Groundwater Basin Master Plan

Everett Ferguson
Water Replenishment District
eferguson@wrd.org
Groundwater Basins Master Plan
Central Basin and West Coast Basin

Everett Ferguson, Senior Hydrogeologist
Acknowledgements

- Central Basin Groundwater Pumpers
- West Coast Basin Groundwater Pumpers
- City of Los Angeles DWP and Sanitation
- County Sanitation Districts of LA County
- West Basin Municipal Water District
- Metropolitan Water District of Southern California
- CH2M and RMC
WRD Service Area: Central & West Coast Basins
420 square miles

43 cities

Population = 4 million
(over 10% of California’s population)

Groundwater provides up to 281,000 AFY of the total water supply
Over 400 Wells Provide Water Supply
Past History: 1900s-1950s
Pumping Double Natural Replenishment.

OVERDRAFT

- Plunging Water Levels
- Loss of Supply
- Wells going Dry
- Seawater Intrusion
1) WRD formed in 1959 to provide managed aquifer recharge to eliminate overdraft.

2) Pumping adjudicated at 281,835 acre feet/year. Higher than natural recharge, but WRD makes up the difference.

3) LA County installed 16 miles of wells along the coast to stop seawater intrusion. WRD buys the imported and recycled water used for injection.
RESULTS of Groundwater Management ...

... Rising Water Levels, Drought Protection, Seawater Intrusion Protection
No

- Continued challenges to balance pumping with groundwater replenishment programs in a cost-effective and reliable manner.

- 2016 WRD completed a Groundwater Basins Master Plan as a roadmap to maximize sustainable groundwater pumping and reduce reliance on imported water.
Why A Master Plan For Adjudicated Basins?

- Pumping in both basins currently below adjudicated limits. Unnecessary purchases of imported water when groundwater could be used.

- Recent Judgment amendments to adjudications allow for storage projects for the first time. Need to evaluate alternatives.

- Opportunities to replace nearly all imported water demands with groundwater if new recharge facilities and replenishment supplies can be found to offset the increase in pumping.
Adjudicated Limit

TODAY (through 2018)
- IMPORTED WATER (285,000 AFY)
- GROUNDWATER (240,000 AFY)

MAXIMIZE ADJUDICATED PUMPING (2018-2028)
- IMPORTED WATER (243,000 AFY)
- GROUNDWATER (282,000 AFY)

UTILIZE GROUNDWATER STORAGE (2028-2038)
- IMPORTED WATER (110,000 AFY)
- GROUNDWATER (415,000 AFY)
WRD’s Goals

• Maximize local water supplies.

• Reduce reliance on imported water.

• Increase water supply sustainability and reliability.

• Mitigate future cost increases of water.

• Partner with local water reclamation agencies to create new sources of water.
Phased approach

• Phase 1 – Interviews with basin stakeholders and identification of alternative management scenarios.

• Phase 2 – Detailed analysis of basin alternatives, including model runs and cost evaluations.

• Programmatic Environmental Impact Report.
The Groundwater Model Used for Analysis

- Built by USGS using Modflow Groundwater Code.
- Based on extensive hydrogeologic data collection.
- 4 model layers represent major aquifer systems.
- 1/2 mile grids, 67 rows, 70 columns (18,760 model cells).
- 30-Year Calibration Period.
- Well Documented USGS Report (03-4065).
Groundwater Basins Master Plan Concepts

Total Pumping in WCB:
64,468 AFY Base
30,000 AFY Additional
Total = 94,468 AFY

Total Pumping in CB:
217,367 AFY Base
57,770 AFY Additional - MFB
45,480 AFY Additional - LAFB
Total = 320,617 AFY

Notes:
CB = Central Basin
MFB = Montebello Forebay
LAFB = Los Angeles Forebay
WCB = West Coast Basin
West Coast Basin – Inland Injection
Central Basin – Concept B2
103,250 New Replenishment Supply
320,600 Pumping
West Coast Basin – Concept B
30,000 New Replenishment Supply
94,500 Pumping
Existing pumping patterns

WBMWD ECL
17,000 Existing
15,500 New (A)
7,500 New (B)
40,000 Total

LADWP TITP
5,000 Existing
2,500 New (A)
5,500 New (B)
13,000 Total
Figure ES-7. Annual Yield and Present Value Unit Cost for the West Coast Basin Alternatives
Figure ES-8. Annual Yield and Present Value Unit Cost for the Central Basin Alternatives
• Groundwater Basins Master Plan developed as a roadmap to identify ways to increase groundwater pumping that is balanced by increased groundwater recharge.

• Provides Central and West Coast Basin stakeholders with options and costs to replace imported supplies with sustainable groundwater pumping.

• Next phase is for WRD to work with groundwater producers to facilitate development of projects identified in the Plan.
Thank You
For more information visit www.wrd.org