TRACKING THE SOURCES OF GROUNDWATER THROUGH WELL PROFILING

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Well Profiling

- Introduction
- Potential Benefits
- How to
- Results
Borehole Profiling Using Geophysical Logs

Borehole logging

Geophysical logs (resistivity, gamma, neutron, spontaneous, magnetic)

Analysis (sands, clays, water quality)
Well Profiling Using Tracer Pulse and Microsampling Technology

Well logging

Cumulative Flow Rates and Composite Water Samples

Analysis
(Flow rates and water quality by zones)

Flow Rate (gpm)

Depth (ft)

Concentration (μg/L)
Reasons for Well Profiling

• Treatment Avoidance at Existing Wells
  • identify zones where “bad” water exists
  • modify well to block or reduce entry of “bad” water

• Optimal Design for Future Wells
  • well construction specifications to avoid pumping “bad” water
  • depth to base of fresh water

Approximately 800 Wells have been Profiled by BESST in California
Reasons for Well Profiling

- Determine Potential for Comingling of different water qualities
  - Vertical flows in unpumped wells between zones in long well screens
  - Range in TDS concentrations
  - Locations highs for rads, arsenic, iron

- Understand Aquifer Flow System
  - Groundwater availability
  - Well field design
Method & Equipment
Tracking Groundwater Flow Under Dynamic Steady State Pumping Conditions
• Tracer Pulse Flowmeter Test

• 1. Highly detailed, accurate flow and chemistry profile.

• 2. Very sensitive to detecting small zonal flow.

• 3. Low overall cost.

• 4. Groundwater supply well as a “monitoring well”.
Trinity Aquifer

Dynamic Flow Profile: Wagon Trail Well 1
192 GPM 2/20/12
Incremental Flow

Dynamic Chemical Mass Balance Profile Wagon Trail Well 1
192 GPM 2/21/12-2/22/12
Total Dissolved Solids by Depth
Gulf Coast Aquifer

Houston Well Morton Road MUD
Gross Alpha

MUD #81, Well #4
Arsenic

Gross Alpha
Well Head Average: 8.6 μCi/L
Total Flow: 1000 GPM

Total Arsenic
Well Head: 7.0 μg/L
Total Flow: 1500 GPM
Gulf Coast Aquifer

Houston Well MUD 9

Total Pumping = 1250 gpm

Alpha Concentration piC/L
(15 piC/L)

Radium Concentration piC/L
(5 piC/L)
ZONAL SOURCES OF GROUNDWATER
MEASURED UNDER PUMPING CONDITIONS
What is the difference between Cumulative and Incremental Flow?
HOW IT WORKS

Velocity Measurement
Cumulative Flow

\[ Q_1 = V_1 \times A_1 \]

\[ V_1 = \frac{(d_1 - d_2)}{(t_1 - t_2)} \]

\[ A_1 = \pi r^2 \]

Zonal Flow

\[ Q_1 - Q_2 \]

Zonal Flow Profiling

No Flow Contribution

Dye Injection Shot Points

GPM Distribution

Cumulative Flow

Ft. Below Ground Surface

4

6

8

100

120

140

160

180

200

220

240

260

280

300

320

340

360

380

400

Cumulative Flow

No Flow Contribution

HOW IT WORKS

Basic Idea

Flow From Well To Fluorometer

Fluorometer

Flow From Fluorometer To Waste
Zonal Water Chemistry Calculation

Zonal Mass Balance

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

Basic Idea
Tracking Groundwater Flow Under Ambient Steady State Pumping Conditions
Typical Profile Signatures for Iron and Uranium?

- Highly Localized / Stratified Assymetrically
- Iron Located at Permeability Barriers
- Uranium Associated With Clays
Gulf Coast Aquifer

IRON

HOUSTON TX
Gulf Coast Aquifer

RADIONUCLIDE EXAMPLES: HOUSTON TX

BESST Case Histories of Well Profiling for Radionuclides

Over the past 12 years, BESST has profiled approximately 750 municipal supply wells in California and at various locations in Texas. This experience includes a variety of wells tested for radionuclides. Our experience to date shows that radionuclide contaminants are typically very stratified, showing highly asymmetrical formation distribution. Since radionuclides are extremely mobile, it is worthwhile to consider well profiling to delineate formation stratification.

If concentrations are stratified, then this increases the probability that impacted wells can be hydraulically isolated to produce compliant groundwater without treatment, or by using a combination of hydraulic well modifications with reduced treatment. The examples that follow show zonal chemistry and flow distributions for various well profiling projects where wells have been impacted by radionuclides. The first two examples are for wells in Texas and the two examples thereafter are for wells in California.

Case History 1: Harris County MUD 22 Well 1

Located in the Houston TX coastal zone, Harris County MUD 22, Well 1 was analyzed for 3 constituents, including a) gross alpha, b) uranium 235, c) radium 226, and d) radium 228. The profiles for each constituent are presented below and all show a highly stratified distribution within the surrounding formation. Moreover, the highest concentrations of radionuclides are associated with minimal flow contribution.

ZONAL FLOW

Gross Alpha

Uranium

Radium

Gulf Coast Aquifer
RADIONUCLIDES

GROSS ALPHA: HOUSTON TX

URANIUM: MODESTO, CA

URANIUM; SANTA YNEZ, CA
ARSENIC, MANGANESE AND IRON
City of La Palma, CA: Arsenic, Manganese and Iron
Chemistry Profile
1860 gpm 11/20/13
Average Arsenic Well Head Concentration: **12.5 µg/L**

**ZONAL ARSENIC DATA**

![Diagram showing Zonal Arsenic Data](image)

**Figure 8:** Zonal arsenic concentration. Concentrations over the EPA MCL are highlighted in red.

Preliminary Flow and Chemistry Report City Yard Well
1,860 GPM
ZONAL MANGANESE DATA

Chemistry Profile
1860 gpm 11/20/13
Average Manganese Well Head Concentration: 64 µg/L
ZONAL IRON DATA
Well Modification Design

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), (620-720), (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 ft²
  - From 282'-786': 0.79 ft²
  - From 786'-1340': 0.55 ft²
- Reported new well bottom: 1190 ft. bgs
- Pump Intake Depth: 230 ft bgs
- Pumping water level: 143 ft bgs
- Flow rate: 1860 USG min⁻¹
NSF 61 Approved Rubber for Mechanical Packer