Hydraulic Fracturing and Groundwater: A Los Angeles Water District Perspective

By: Ted Johnson, Chief Hydrogeologist
Water Replenishment District of Southern California
January 24, 2013 – for LABGS
Focus on 2 LA Groundwater Basins: Central Basin and West Coast Basin (CBWCB)

Area = 420 mi², 43 Cities, 4 Million People

> 400 Water Wells
Pumping 240,000 acre feet/yr
(78 billion gallons/yr)
LA County Population Growth

5,700% increase in 110 years
1904 Groundwater Contour Map (Mendenhall, 1905). Gray shading indicates areas of flowing artesian wells.
1900s-1950s
Excessive Pumping caused
Groundwater OVERDRAFT

West Basin Key Well 3S/14W-22L01
- 50 Feet of Groundwater Level Drop (2.5 ft/yr)

Central Basin Key Well 2S/13W-10A01
- 160 Feet of Groundwater Level Drop (8 ft/yr)
Groundwater Management Solutions

- **SEAWATER BARRIER WELLS:** LA County installed injection wells along 16 miles of coastline to form a barrier to halt seawater intrusion into the coastal aquifers. Started in 1950s.

- **NEW REPLENISHMENT WATER:** WRD formed in 1959 by a local election to perform managed aquifer recharge to make up the annual overdraft.

- **CONTROL EXTRACtIONS:** Legal Action (adjudication) in 1960s reduced pumping to 281,835 acre feet per year (still greater than natural safe yield). Relied on WRD replenishment water to make up the difference and create an operational safe yield.
RESULTS of Groundwater Management ... 

... Rising Water Levels & Drought Protection
Where do CB and WCB get their Water?

- Imported River Water: 60%
- Groundwater: 40%
- Recycled Wastewater: Growing uses (irrigation, industrial applications, groundwater recharge)
Over 400 Groundwater Production Wells Operated by Various Cities and other Public/Private Entities
Quaternary & Late Pliocene Coastal Aquifers
Sand & Gravel. Folded & Faulted.

Groundwater Wells Tapping Coastal Aquifers

Mid Pliocene “Bedrock” Repetto & Lower Fernando Fms.

Modified from DWR (1962, Plate 4)
But There’s Oil & Gas in the Basins too
Over 30 Mapped Oil Fields and 9,700 Oil/Gas Wells in WRD Service Area
Cross-Section through LA showing Petroleum Target Zones

Recent, Pleistocene and late Pliocene. General area of Fresh Groundwater

Mid Pliocene to Mid Miocene. General Targets for Petroleum Recovery

Mesozoic Schist, Granite, Slate, Metasediments, Bedrock – No Petroleum

Modified from Davis – Namson, 1998
Southern California Cross Section Study
Oil Wells & Water Wells in LA
Over 100 Years of Co-Existing
So Why All The Concern Over Fracking?

Yoko Ono, Jimmy Fallon And Sean Lennon Sing 'Don't Frack My Mother'
National Issue

Investigation of Ground Water Contamination near Pavillion, Wyoming

Don’t Frack With Our Water

FRACKING = DEATH

Fracking = Death

The Tracking Truth

Marcellus

Fracking Drilling Spilling Killing

FRACK NATION

EPA

DRAFT
Are There Risks to Groundwater?

**INDUSTRY:**

“There have been over a million wells hydraulically fractured in the history of the industry, and there is not one, not one, reported case of a freshwater aquifer having ever been contaminated from hydraulic fracturing. Not one”

Rex W. Tillerson, the chief executive of ExxonMobil - Congressional hearing on drilling (NYTimes, 8/3/2011).

**ENVIRONMENTAL:**

*In Fracking’s Wake:* New Rules are Needed to Protect Our Health and Environment from Contaminated Wastewater

NRDC, May 2012, 12-05A

> 30 potential groundwater contamination cases from hydraulic fracturing

**SCIENCE:**

“The effects of unconventional oil and gas development...on regional water quality have not been previously described despite the fact that oil and gas development in the United States began nearly 150 years ago...”

USGS, April 2012, Fact Sheet 2012-3049
What is Hydraulic Fracturing (Fracking)?

- Method to enhance oil or natural gas production.

- Inject fluids (water, sand, chemicals) under high pressure to break open rock to enhance permeability and oil/gas flow.

- Improvements in horizontal drilling technologies have led to significant increase in fracking for gas, especially in the eastern and middle United States.
Conventional vs. Unconventional Fracking

Conventional: Fracking in permeable reservoirs like sandstone and limestone to improve oil/gas flows. Has been done by oil companies for > 50 years. Vertical or slant wells. Lower pressure and water. Common in CA and elsewhere.

Unconventional: Newer fracking in hard tight rock that is porous but not permeable (i.e. shale). Slant or horizontal wells used to expose more formation to mine. TX, PA, NY, WY, MO, CO, OH. CA next?

High-Rate Gravel Packing: Small scale fracking near the well bore to install gravel pack to improve flows at the oil/gas well and/or to prevent formation sand entry (like a gravel pack in a water well).
Why Frack?

- Creates a new energy resource. Unconventional drilling and fracking into now accounts for more than half the natural gas production in the U.S. Estimated 100 year supply.

- Allows extended production in older oil and gas fields.

- Allows recovery of petroleum from tight formations previously believed to be un-produceable.

- Reduced price of natural gas.

- Creates jobs in energy industry.

http://energytomorrow.org/blog/natural-gas-the-70-percent/#/type/all

Weekly Natural Gas Spot Prices
January 1998 to April 2012

Source: EIA
mjperry.blogspot.com
Injection Fluids

- Water is the main fluid. Average 5 million gallons per job for unconventional; < 400,000 for conventional; < 100,000 gravel pack.

- Sand/Silica (proppant) keeps fractures open; otherwise would close.

- Assorted chemical additives are site specific. Many purposes: inhibit corrosion, remove drilling mud, prevent scaling, reduce viscosity, etc.

http://fracfocus.org/water-protection/drilling-usage
Fracking Operations

1. Water Acquisition
2. Chemical Mixing
3. Well Injection
4. Flowback and Produced Water (Wastewaters)
5. Wastewater Treatment and Waste Disposal

Groundwater

Shale Oil/Gas Target Zone

http://www.epa.gov/hfstudy/hfwatercycle.html
Unconventional Fracking Operations

1. Water Acquisition
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Potential Threats to Groundwater

http://www.epa.gov/hfstudy/hfwatercycle.html
Potential Threats to Groundwater

Faults may act as a conduit

Threats: Chemicals, Saline Water, Natural Gas, Earthquakes

Old Gas/Oil Well – Not Abandoned Properly

Minor Earthquakes

Excessive Fracking

1. Water Acquisition
2. Chemical Mixing
3. Well Injection
4. Flowback and Produced Water (Wastewaters)
5. Wastewater Treatment and Waste Disposal

Groundwater

Casing Failure

Shale Oil/Gas

Natural gas flows from fissures into well
National Research on Fracking

EPA's Study of Hydraulic Fracturing and Its Potential Impact on Drinking Water Resources

At the request of Congress, EPA is conducting a study to better understand any potential impacts of hydraulic fracturing on drinking water and ground water. The scope of the research includes the full lifespan of hydraulic fracturing, from acquisition of the water, through the mixing of chemicals and actual fracturing, to the post-fracturing stage, including the management of flowback and produced water and its ultimate treatment and disposal.

A first report on the study will be released for peer review in late 2012. Certain portions of the research were released for peer review in 2014.

Hydraulic Fracturing Issues and Research Needs for the Water Community

Subject Area: Water Resources and Environmental Sustainability
Ways to Minimize Risk

- Baseline Monitoring.
- Proper well design to prevent leaks.
- Identify all artificial pathways and seal off.
- Proper waste collection and disposal.
- Monitor injection pressures, intervening “dead zone” aquifer, flowback ponds, deep and shallow groundwater monitoring, seismic monitoring.
- Vapor probes for soil gas monitoring at surface.
FracFocus.org – Tracks Fracking & Chemicals

http://www.hydrolicfracturingdisclosure.org/fracfocusfind/Map.aspx
Listed California Fracking Locations

646 listed in California, 11 in the WRD area (8 offshore).
http://www.hydraulicfracturingdisclosure.org/fracfocusfind/Map.aspx
## Hydraulic Fracturing Fluid Product Component Information Disclosure

### Last Fracture Date: 09/06/2012

<table>
<thead>
<tr>
<th>State</th>
<th>California</th>
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<tbody>
<tr>
<td>County</td>
<td>Los Angeles</td>
</tr>
<tr>
<td>API Number</td>
<td>4833741214</td>
</tr>
<tr>
<td>Operator Name</td>
<td>OXY USA Inc</td>
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<tr>
<td>Well Name and Number</td>
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<td>Longitude</td>
<td>-118.041667</td>
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<tr>
<td>Latitude</td>
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<td>Long/Lat Projection</td>
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<td>Production Type</td>
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<tr>
<td>True Vertical Depth (TVD)</td>
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<td>Total Water Volume (gal)</td>
<td>143,852</td>
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### FracFocus.org

**Chemical Listing**

<table>
<thead>
<tr>
<th>Trade Name</th>
<th>Supplier</th>
<th>Purpose</th>
<th>Ingredients</th>
<th>Chemical Abstract Service Number (CAS #)</th>
<th>Maximum Ingredient Concentration In Additive (%) by mass</th>
<th>Maximum Ingredient Concentration In HF Fluid (%) by mass</th>
<th>Comments</th>
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<tbody>
<tr>
<td>Water</td>
<td>Baker Hughes</td>
<td>Breaker</td>
<td>Water</td>
<td>7732-19-5</td>
<td>100.00%</td>
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<tr>
<td>X-Cide 207</td>
<td>Baker Hughes</td>
<td>EOR</td>
<td>2-Methyl-4-isothiazolin-3-one</td>
<td>2662-20-4</td>
<td>5.00%</td>
<td>0.0000%</td>
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<tr>
<td>High Perm ORB</td>
<td>Baker Hughes</td>
<td>Breaker</td>
<td>Sulfur Pentasulfide</td>
<td>7727-54-0</td>
<td>60.00%</td>
<td>0.0000%</td>
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<tr>
<td>Caustic Liquid, 25%</td>
<td>Baker Hughes</td>
<td>Buffer</td>
<td>Sodium Hydroxide</td>
<td>1310-73-2</td>
<td>28.00%</td>
<td>0.0033%</td>
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<tr>
<td>BF-5L, Tite</td>
<td>Baker Hughes</td>
<td>Buffer</td>
<td>Potassium Carbonate</td>
<td>584-38-7</td>
<td>66.00%</td>
<td>0.6530%</td>
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<tr>
<td>XLW-56, 200 gal</td>
<td>Baker Hughes</td>
<td>Crosslinker</td>
<td>D-Glucitol</td>
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<td>Tite</td>
<td>Hughes</td>
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<td>Crystal</td>
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<td>S5-1L</td>
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<td>Scale Inhibitor</td>
<td>Magnesium Iron Silicate</td>
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<td>Mg Light, 30/50</td>
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<td>Proppant</td>
<td>Magnesium Silicate</td>
<td>1303-28-0</td>
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<tr>
<td>Alfa/Bain Brookite, 40/100</td>
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<td>Proppant</td>
<td>Alfa Alumina</td>
<td>1344-28-1</td>
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<td>Stribe/Bain Brookite, 40/150</td>
<td>Baker Hughes</td>
<td>Proppant</td>
<td>Magnesium Silicate</td>
<td>1303-28-0</td>
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<td>0.0000%</td>
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<tr>
<td>InFly 75M, 300 gal</td>
<td>Baker Hughes</td>
<td>Surfactant</td>
<td>Cine Terpene</td>
<td>64-20-6</td>
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<td>0.0123%</td>
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<tr>
<td>ISF 6M, 300 gal</td>
<td>Baker Hughes</td>
<td>Surfactant</td>
<td>Cine Terpene</td>
<td>64-20-6</td>
<td>20.00%</td>
<td>0.0123%</td>
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<tr>
<td>ISF 6M, 300 gal</td>
<td>Baker Hughes</td>
<td>Surfactant</td>
<td>Cine Terpene</td>
<td>64-20-6</td>
<td>20.00%</td>
<td>0.0123%</td>
<td></td>
</tr>
</tbody>
</table>
DOGGR Regulates CA Oil, Gas, Geothermal

 Permitting agency for oil and gas wells in the State. Oversee well constructions and abandonments to protect CA groundwater.

 Class II Injection Well Program to regulate injecting fluids for oil or gas operations. Strict requirements for well completion.

 No specific regulations (yet) for hydraulic fracturing. In Progress.

[Image of website related to hydraulic fracturing]
Recent CA Action / Legislation

☑ Gov. Brown increasing DOGGR staff by 18 to step up regulation and permitting process.

☑ DOGGR released preliminary regulations (Discussion Draft) after holding State-wide workshops (www.conservation.ca.gov/dog/Pages/Index.aspx)

☑ 2012 SB 1054 (Pavley) – Failed. Would require notification of oil/gas drilling if the well will penetrate an underground water source.

☑ 2012 AB 591 (Wieckowski) – Failed. Would require disclosure of fracking chemicals and locations of fracking operations in the State.

☑ 2012 AB 972 (Butler) – Failed. CA moratorium on fracking .

☑ 2013 SB 4 (Pavley) and AB 7 (Wieckowski). Defines fracking, requires disclosure of nearby faults, requires State to develop fracking rules, requires notification of fracking jobs and chemicals.
Local Concern over Fracking

Protesters head to Culver City meeting to decry fracking

Oil drilling in Carson won't use 'fracking'

By Sandy Mazza, Staff Writer
Posted: 06/01/2012 07:23:59 PM PDT
Updated: 06/01/2012 09:04:56 PM PDT

A controversial hydraulic fracturing technique will not be used to extract oil and gas from deep beneath northern Carson as originally proposed, Occidental Petroleum Corp. officials announced this week.

The company would like to drill 200 wells on a 6.5-acre site in an industrial park near the Home Depot Center. The city is carefully reviewing plans for the project while Occidental is seeking
Inglewood Oil Field Fracking Controversy

Report on Baldwin Hills fracking raises community ire

Despite its findings, the environmental impact study has deepened tensions between an oil field owner and those opposed to the controversial hydraulic fracturing technique used to extract oil.
A coalition of environmental advocates has filed suit against California oil regulators over the controversial method of oil extraction called hydraulic fracturing, accusing state officials of illegally "rubber-stamping" drilling permits without performing key environmental reviews.
WRD Monitoring Wells & Oil Fields

300 Wells at 50 Locations
Minimum Depth 60 ft
Maximum Depth 1,990 ft
WRD Nested Monitoring Wells

- Injection Well
- Nested Monitoring Wells
- Water Supply Wells
- Fresh Groundwater
- Oil / Gas Fracking Target Zone
- Oil / Gas Reservoirs
- No Activity
- “Dead” Zone
Groundwater Level Hydrograph: Deeper Zones Anomalously Low

FLUCTUATIONS OF WATER LEVELS IN WRD NESTED MONITORING WELL WHITTIER NARROWS #2

Reference point elevation 209.08 feet above mean sea level

- Zone 1 (659.29' - 678.44', Pico Fm)
- Zone 2 (579.06' - 598.22', Pico Fm)
- Zone 3 (460.99' - 480.2', Pico Fm)
- Zone 4 (418.64' - 426.22', Pico Fm)
- Zone 5 (328.86' - 330.26', Pico Fm)
- Zone 6 (283.21' - 273.25', Not A Defined Aquifer)
- Zone 7 (213.71' - 223.39', Not A Defined Aquifer)
- Zone 8 (135.68' - 145.27', Not A Defined Aquifer)
- Zone 9 (90.8' - 100.3', Gardena)
## GROUNDWATER QUALITY TESTING

<table>
<thead>
<tr>
<th>Major Minerals</th>
<th>General Physical Properties</th>
<th>Volatile Organic Compounds</th>
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</thead>
<tbody>
<tr>
<td>Total Dissolved Solid (TDS)</td>
<td></td>
<td>Trichloroethylene (TCE)</td>
</tr>
<tr>
<td>Cation Sum</td>
<td>Lab pH</td>
<td>sec-Butylbenzene</td>
</tr>
<tr>
<td>Anion Sum</td>
<td>Odor</td>
<td>Bromomethane (Methyl Bromide)</td>
</tr>
<tr>
<td>Iron, Total, ICAP</td>
<td>pH of CaCO₃ saturation(25°C)</td>
<td>Tetrachloroethylene (PCE)</td>
</tr>
<tr>
<td>Manganese, Total, ICAP/MS</td>
<td>pH of CaCO₃ saturation(60°C)</td>
<td>1,1,1-Dichloroethane</td>
</tr>
<tr>
<td>Turbidity</td>
<td>Radium</td>
<td>1,1,2-Tetrachloroethene</td>
</tr>
<tr>
<td>Alkalinity</td>
<td>Specific Conductance</td>
<td>Dibromomethane</td>
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<tr>
<td>Boron</td>
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<td>Chlorobenzene</td>
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<tr>
<td>Bicarbonate as HCO₃, calculated</td>
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<td>Chlorodibromomethane</td>
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<td>Calcium, Total, ICAP</td>
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<td>Chloroethene</td>
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<td>Carbonate as CO₃, Calculated</td>
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<td>Chloroform (Trichloromethane)</td>
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<td>Hardness (Total, as CaCO₃)</td>
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<td>1,1-Dichloropropane</td>
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<td>Chloride</td>
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<td>1,2,3-Trichlorobenzene</td>
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<td>Fluorine</td>
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<td>Hexachlorobutadiene</td>
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<td>Hydroxide as OH, Calculated</td>
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<td>Carbon Tetrachloride</td>
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<td>1,2,3-Trichlorobenzene</td>
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<td>Magnesium, Total, ICAP</td>
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<td>Mercury</td>
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<td>1,3-Dichlorobenzene</td>
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<td>Nitrate-N by IC</td>
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<td>1,3,5-Trimethylbenzene</td>
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<td>Nitrite, Nitrogen by IC</td>
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<td>o-Dichlorobenzene</td>
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<td>Potassium, Total, ICAP</td>
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<td>p-Dimethylbenzene</td>
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<td>Sulfate</td>
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<td>o-Xylene</td>
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<td>Sulfate, Total, ICAP/MS</td>
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<td>p-Ethylbenzene</td>
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<td>Sulfate</td>
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<td>2,2-Dichloropropane</td>
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<tr>
<td>Surfactants</td>
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<td>2-Butanone (MEK)</td>
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<tr>
<td>Total Nitrate, Nitrite-N, CALC</td>
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<td>Dichlorodifluoromethane</td>
</tr>
<tr>
<td>Total Organic Carbon</td>
<td></td>
<td>4-Methyl-2-Pentanone (MDK)</td>
</tr>
</tbody>
</table>

Over 100 chemicals tested in each well twice per year, or over 50,000 results on water quality annually.

Have not yet sampled specifically for fracking chemicals.
Water Quality Results near Oil Fields

- Generally Good Water Quality or Typical of Greater Depths (color, odor, salinity).

- A few wells have elevated concentrations at depth:
  - Boron
  - Arsenic
  - TCE
  - TBA

- Sources have not yet been identified. Could be natural or may be associated with current or legacy oil field operations at surface or reservoirs. Difficult to determine.

- Additional testing for exotic compounds may help determine sources. Penn State Univ. recent study found radium and barium related to fracking flowback water in Marcellus Shale.
Fracking is used for Water Wells Too!

California Well Standards

Water wells • Monitoring wells • Cathodic protection wells

Bulletin 74-90
(Supplement to Bulletin 74-81)

Section 14. Well Development.

*Development, redevelopment, or reconditioning of a well shall be performed with care, by methods that will not damage the well structure or destroy natural barriers to the movement of poor quality water, pollutants, and contaminants.

Acceptable well development, redevelopment, or reconditioning methods include:

- Overpumping;
- Surging or swabbing by use of 'plungers';
- Surging with compressed air;
- Backwashing or surging by alternately starting and stopping a pump;
- Jetting with water;
- Introducing specifically-formulated chemicals into a well; and,
- Combinations of the above.

Hydraulic fracturing (hydrofracturing) is sometimes an acceptable well development and redevelopment method when properly performed. Good quality water shall be used in hydrofracturing. The water shall be disinfected prior to introduction into a well. Material used as 'propping' agents shall be free of pollutants and contaminants, shall be compatible with the use of a well, and shall be thoroughly washed and disinfected prior to placement in a well.

http://www.nhcontractors.net/2012/01/hydrofracking-nh/
Summary

Hydraulic Fracturing is a method used over 50 years to enhance oil and gas recovery. Newer methods are proving fruitful but controversial nationwide.

Fresh groundwater, oil and natural gas have been successfully produced in the CBWCB for over 100 years.

The two reservoirs are separated by thick layers of low permeability strata so that with appropriate precaution, construction, regulation and monitoring, the activities in one do not necessarily affect the other.

WRD continues monitoring and working with regulatory agencies for responsible fracking rules. We don’t want to unnecessarily hamper the energy industry, we just want to protect the groundwater quality in our service area.
THANK YOU!

Contact Ted Johnson - tjohnson@wrd.org