

Mandated Monitoring For Potential Hydraulic Fracturing Impacts Upon Groundwater In California: Update On SB-4 Expert Recommendations*

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Abstract

Hydraulic fracturing has unlocked previously untapped unconventional oil and gas resources in the U.S., leading to the U.S. surpassing Saudi Arabia and Russia in daily oil production in mid-2014. However, public concern of potential environmental impacts such as induced seismicity and reduced water quality has grown over time. In response, California passed State Bill 4 (SB4) in September, 2013 to develop and establish a regulatory structure for unconventional resource extraction (hydraulic fracturing, acidizing, and other stimulation techniques) for the state. SB4 requires the State Water Resources Control Board (SWRCB) to develop groundwater monitoring criteria to be implemented across a range of spatial scales (from well-by-well to regional) for water quality effects from oil and gas wells subjected to well stimulation treatment. The legislation also calls upon the state board to seek the advice of experts on the design of these criteria. The SWRCB has contracted Lawrence Livermore National Laboratory (LLNL) as an expert advisor. LLNL has utilized both internal and externally contracted expertise to engage with industry, academia, government agencies, and the general public in development of a scientifically based set of criteria for groundwater monitoring. In this presentation I will provide an overview of the process being followed and the latest developments from the team as we work toward our recommendations to the SWRCB. Disclaimer: This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

Mandated Monitoring for Potential Hydraulic Fracturing Impacts upon Groundwater in California: Update on SB4 Expert Recommendations

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Who am I and LLNL Computational Geosciences?

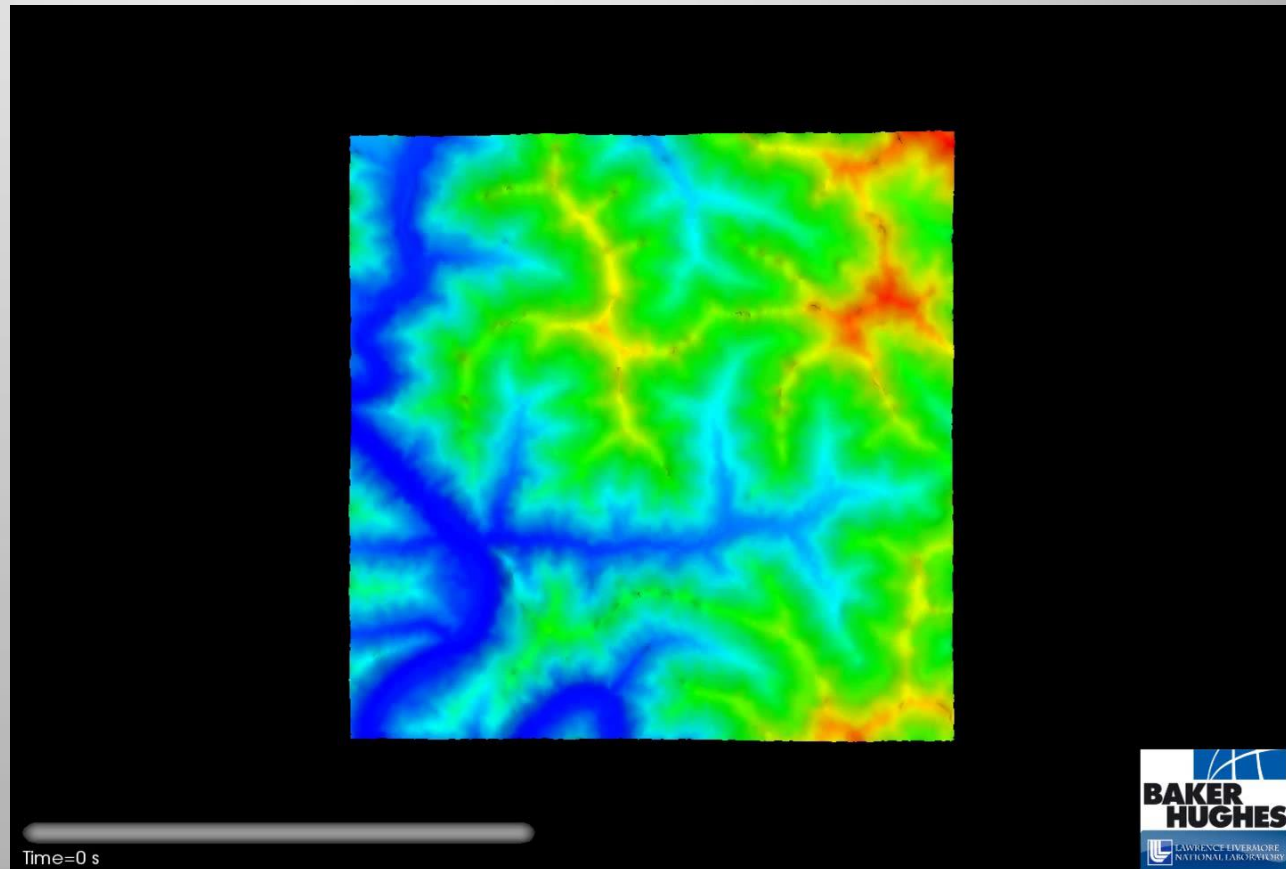
11 years - Lawrence Livermore National Laboratory

5 years – Schlumberger-Doll Research in Geomechanics Program

Currently: Computational Geosciences Group Leader (LLNL)

My group:

- Energy and National Security missions
- Developed open source 3D hydraulic fracturing simulator (GEOS)
- Waterless fracturing technologies
- Geothermal, CO₂ sequestration, ...



SB4 requires groundwater monitoring

Section 7. Groundwater Monitor Plan

- (c) Development of model groundwater monitoring criteria

*The State Board **shall develop model groundwater monitoring criteria***

- (d) Requirement for expert advice

— *The state board ... **shall seek the advice of experts** on the design of the model groundwater monitoring criteria..*



LLNL is responsible for providing expert advice on “model criteria” for groundwater quality monitoring

LLNL is using both internal and external expertise

Lawrence Livermore National Laboratory

Dr. Bradley K. Esser, Lead

Dr. Joseph Morris

Dr. Susan Carroll

Vic Madrid, PG, CHG

Lawrence Berkeley National Laboratory

Dr. William T. Stringfellow

Preston D. Jordan, PG, CHG, CEG

Dr. Harry Beller

Dr. Charu Varadharajan

CSU Bakersfield

Dr. Jan Gillespie

Stanford University

Dr. Rob Jackson

Duke University

Dr. Avner Vengosh

University of Guelph

Dr. Beth Parker

Dr. John Cherry

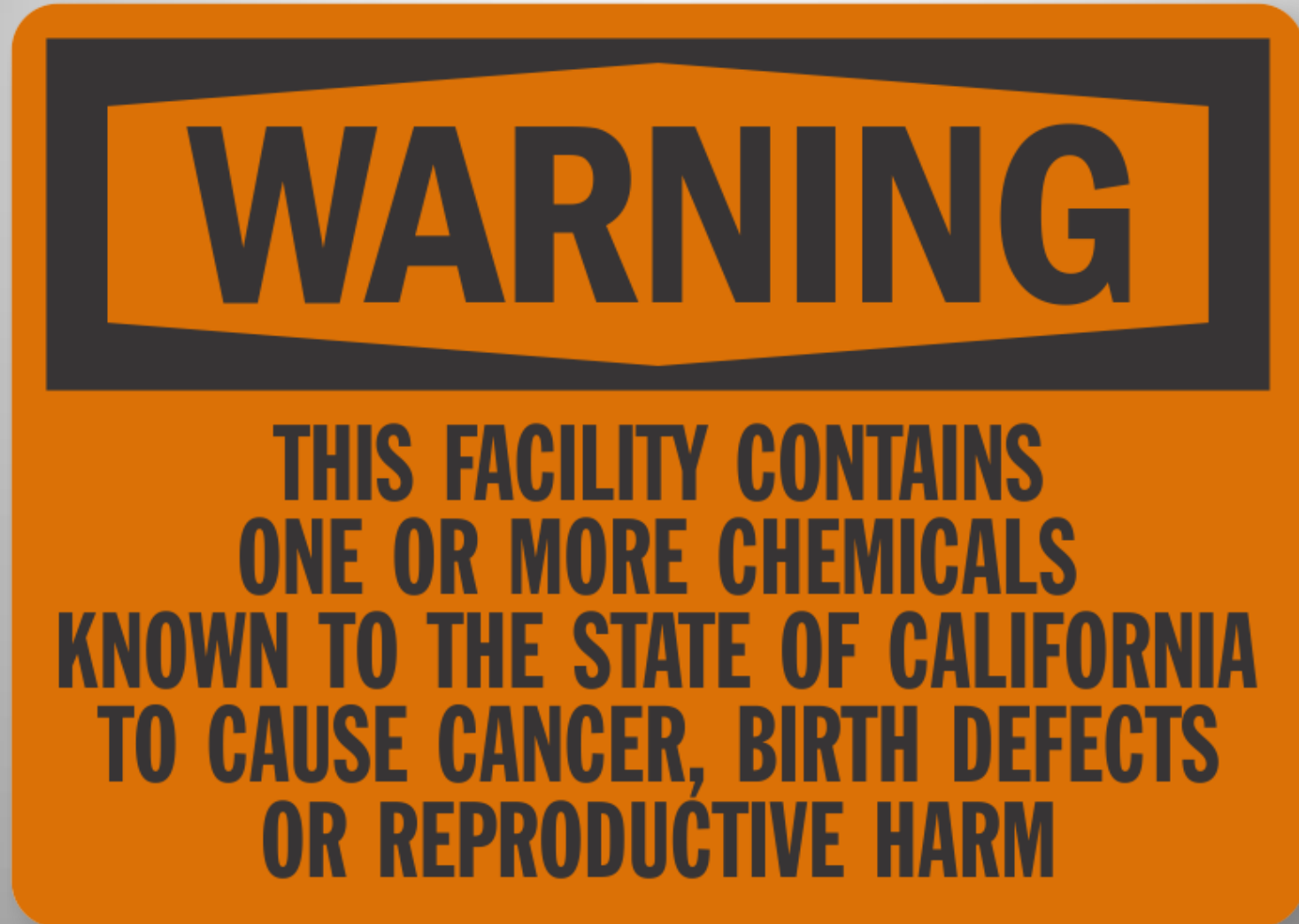
Short bios are on the SWRCB SB4 website

LLNL is the scientific expert chosen by the State

WARNING

**THIS FACILITY CONTAINS
ONE OR MORE CHEMICALS
KNOWN TO THE STATE OF CALIFORNIA
TO CAUSE CANCER, BIRTH DEFECTS
OR REPRODUCTIVE HARM**

We want a monitoring program to lead to meaningful, actionable information



More than one plan required

- **(7c) Development of model groundwater monitoring criteria**
 - *The model criteria shall address a **range of spatial sampling scales** from methods for conducting appropriate monitoring on individual oil and gas wells subject to a well stimulation treatment, to methods for conducting a regional groundwater monitoring program.*

Scale	Responsibility	What
Well by well, Neighbor “Early warning” → Area monitoring	Well Operator (Permit)	An individual or small set of oil & gas wells
		A nearby water well
Regional Large scale, long term O&G impact	Water Board	Groundwater basin
		Oil & gas field

For “well by well”, the DOGGR final rule requires approval of a groundwater monitoring plan by the Water Board

We have submitted draft recommendations for area-specific monitoring criteria to Water Board staff

Groundwater Sampling, Testing, and Monitoring for hydraulic fracture or acid well stimulations where protected groundwater is present.

- (a) The purpose of this section is to provide **groundwater monitoring model criteria** for groundwater sampling, testing, and monitoring related to well stimulation (WS) in areas where protected groundwater exists. Protected groundwater is defined as groundwater with Total Dissolved Solids (TDS) of less than 10,000 ppm in an aquifer of sufficient volume for beneficial use and for which the Water Board has not concurred on a request for exclusion from groundwater monitoring. These area-specific groundwater monitoring criteria do not apply to regional groundwater monitoring programs developed by the State Water Resources Control Board or the Regional Water Board.

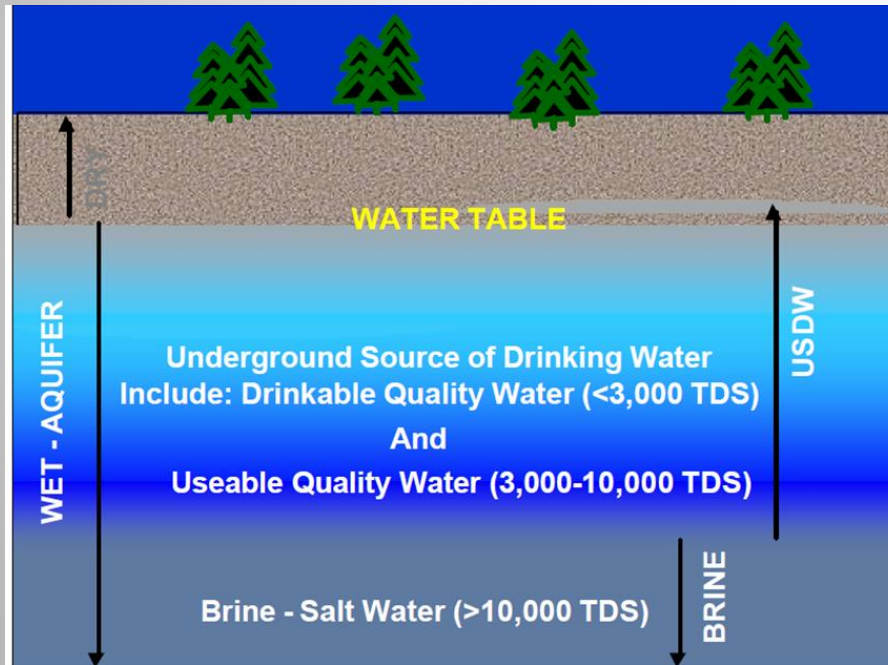
- **We use “area-specific” and not “well-by-well”**
 - In densely drilled oil fields, one monitor well may serve to monitor more than one stimulated well

What groundwater should be monitored?

- **We recommend monitoring groundwater up to 10,000 ppm (Total Dissolved Solids) TDS**
 - Contains fewer than 10,000 mg/l total dissolved solids
 - Sufficient quantity of ground water for beneficial use
 - Not excluded from a requirement to submit a groundwater monitoring plan
- **Rationale**
 - California is in the midst of an historic drought
 - *Any water with the potential for beneficial use should be protected*
 - Desalination of brackish groundwater is technically feasible
 - *More than a dozen plants desalinate brackish groundwater*

USDW groundwater should be monitored for impact

“Useable” groundwater needs to be mapped



The distribution of “useable” groundwater (TDS = 3,000 to 10,000 ppm) is poorly known

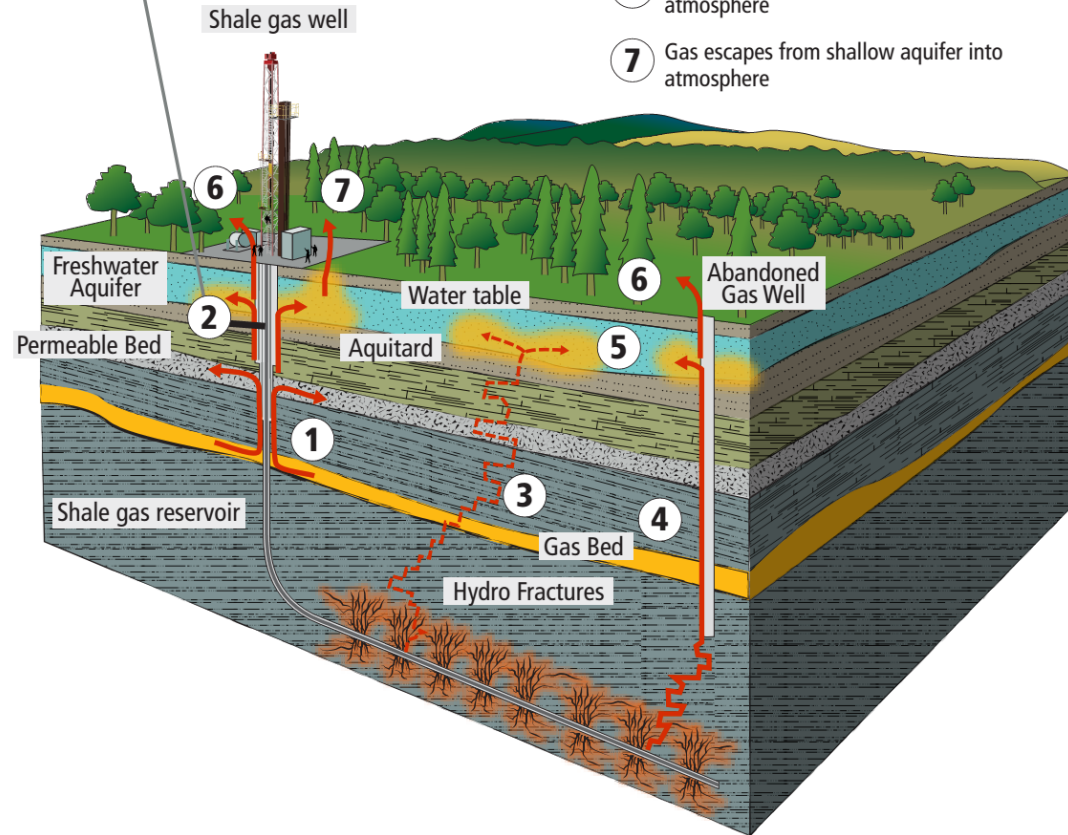
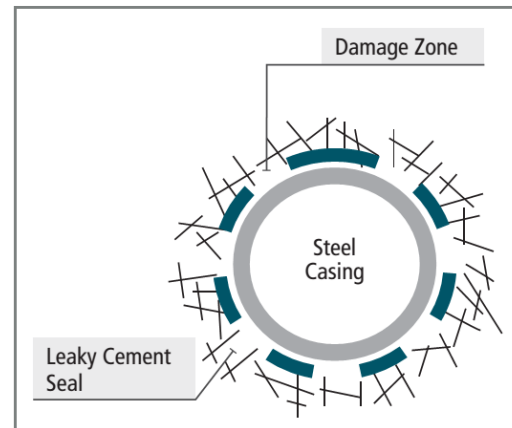
■ Recommendations

- Groundwater monitor plans should include data relevant to determining aquifer salinity
- The State should systematically determine the spatial and vertical distribution of useable (3,000 - 10,000 mg/L) groundwater in all basins containing oil & gas fields
- Currently, readily available data appears insufficient

Contaminant pathways

Contamination Source/Pathway	Shallow	Intermediate, Deep
Wastewater: sumps	X	
Wastewater: injection	X	X
Oil & gas wells	X	X
Inactive and abandoned wells	X	X
Natural fractures & faults	X	X
Hydrofracturing	X	X

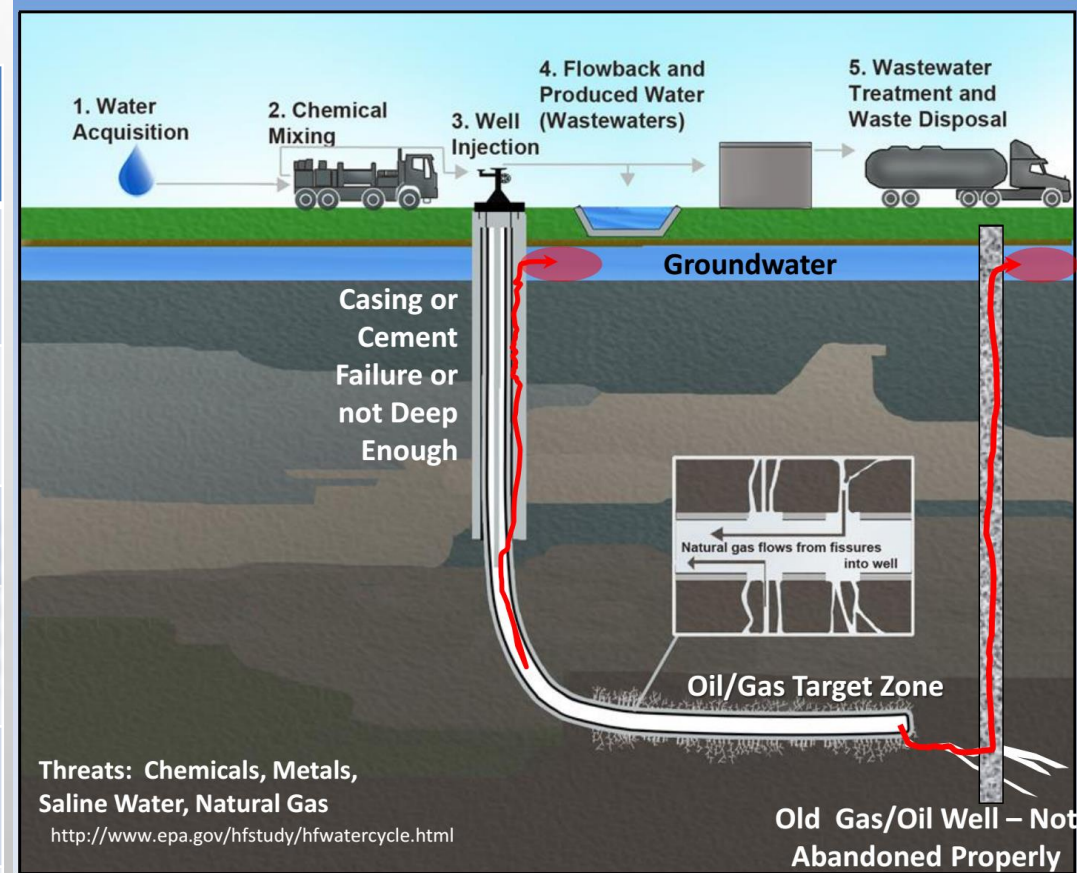
Contaminant sources & pathways were considered in developing monitoring plan criteria



- ① Gas leakage from gas bed up along casing pathway. A leaky seal could also occur within the well, in an improperly sealed abandoned well.
- ② Micro fissures along bore wall not sealed by cement
- ③ Hydro fractures connect to natural fractures and faults connecting to shallow aquifer
- ④ Hydro fractures connect to leaky seal along old well casing
- ⑤ Gas escapes into freshwater aquifer causing impact plumes
- ⑥ Gas escapes along leaky well seal into atmosphere
- ⑦ Gas escapes from shallow aquifer into atmosphere

Contaminant pathways

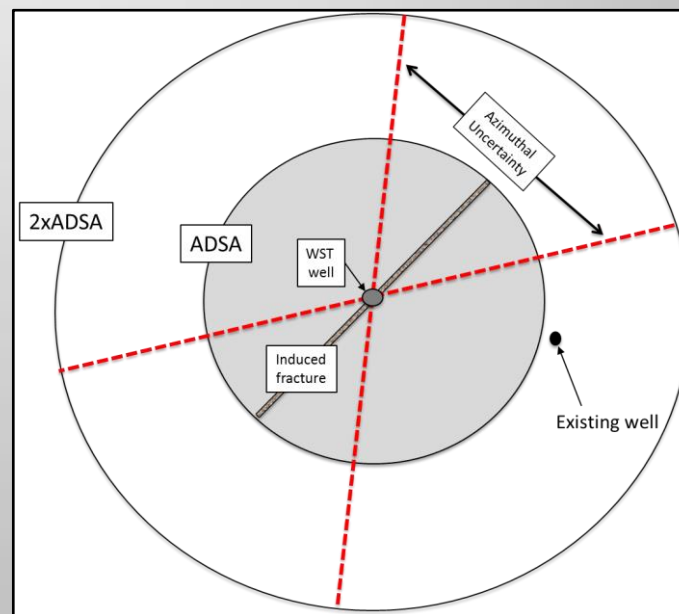
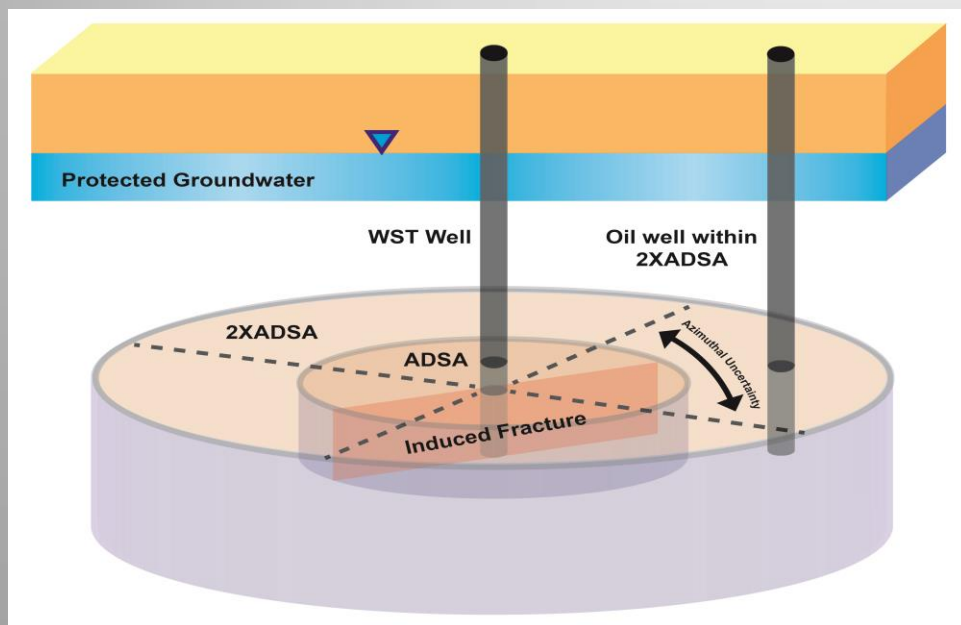
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Wells are a potential pathway of concern

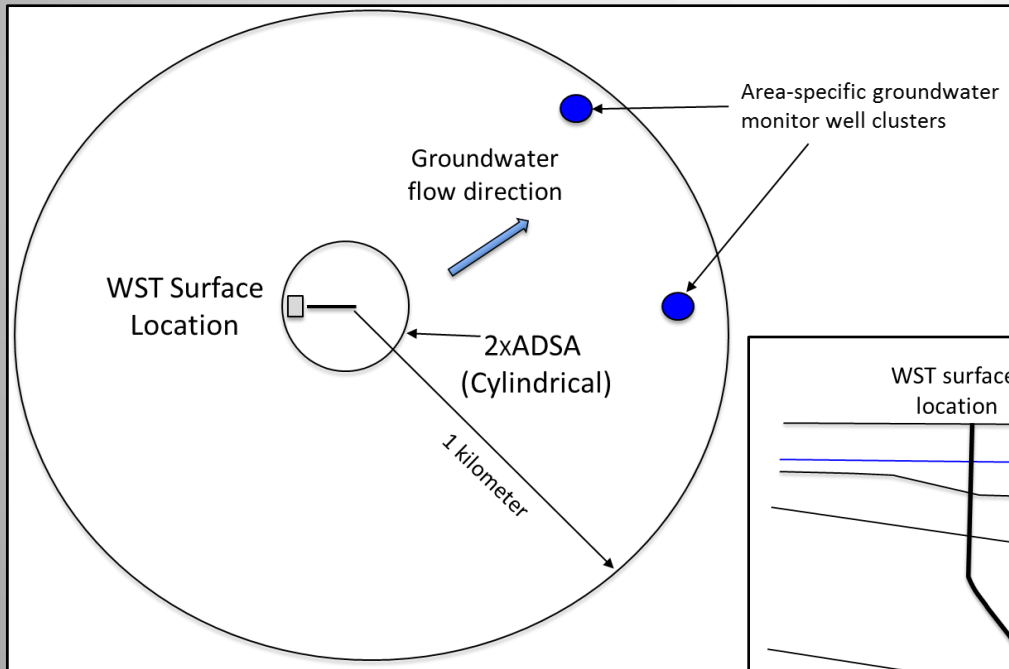
DOGGR regulation requires identification of wells and geologic features in close proximity to stimulated wells

- **DOGGR defined an “axial dimensional stimulation area” (ADSA)** as the projected volume of subsurface stimulated during WST.
- We recommend a conservative “groundwater-protective” cylindrical volume
 - Possibility in future for operator to provide data for a smaller azimuth angle



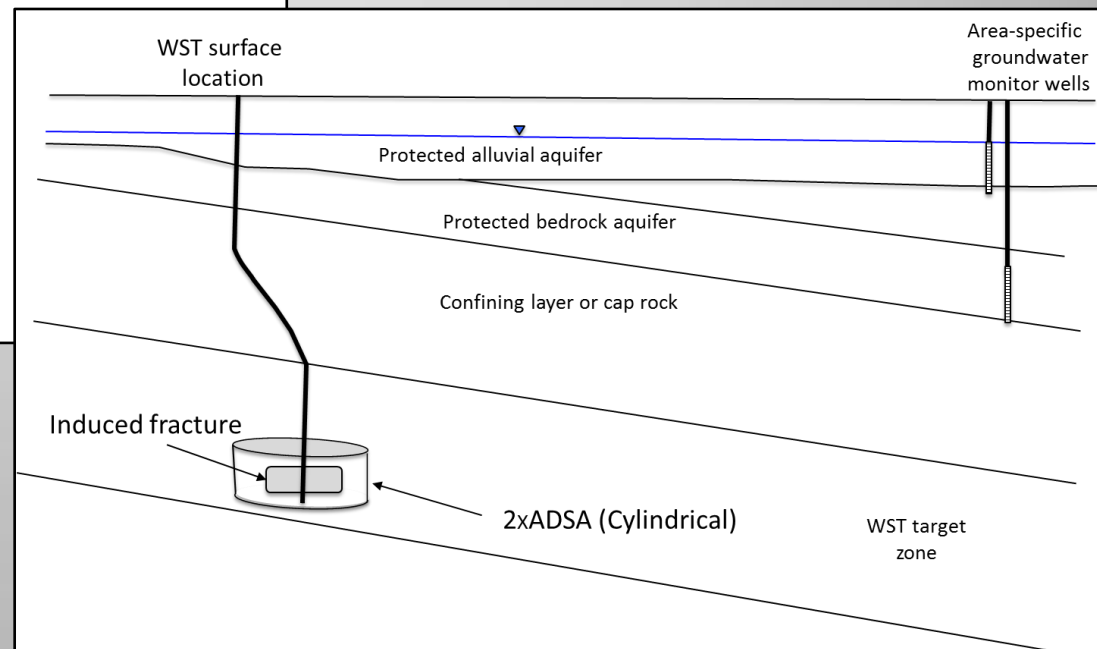
We recommend that groundwater monitoring always be required when wellbores are present within 2xADSA

We recommend monitoring of all protected groundwaters within one kilometer of the stimulated well

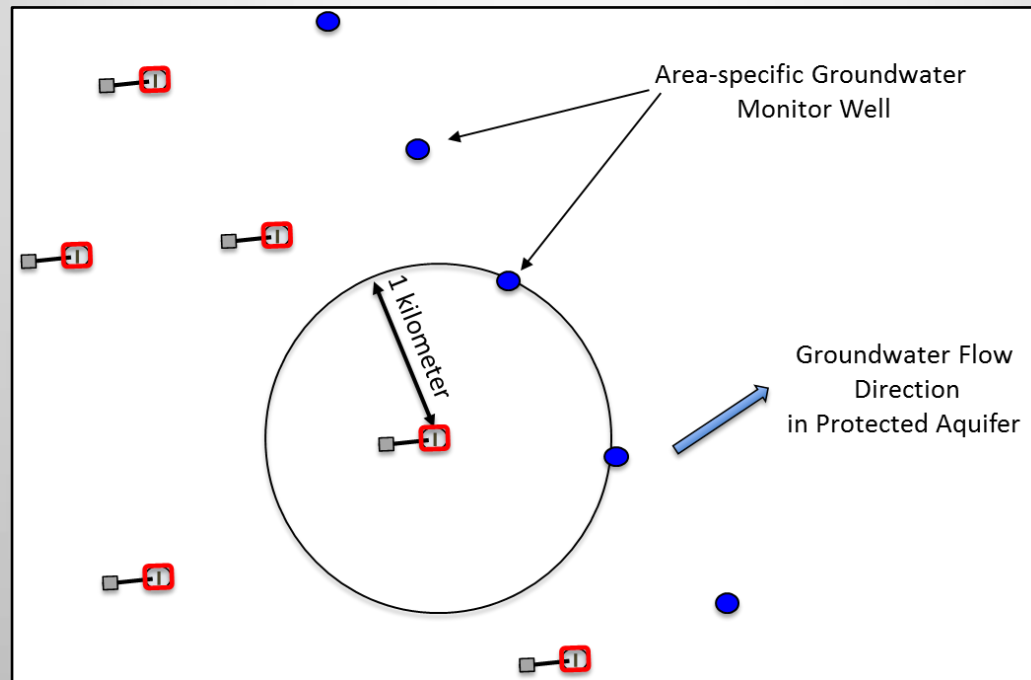


Multiple aquifers will require multiple monitor wells or a multi-level monitoring system.

We also recommend the use of “guard” wells between stimulated wells and water supply wells.



Projects of more than one stimulated well can share monitoring wells



- **We recommended to allow for scenarios where area monitoring may not be required**
 - No groundwater with TDS < **3,000 ppm** is present; AND
 - No vertical conduits within 2xADSA of the stimulated well are present; AND
 - A regional monitoring well is present within 1 mile of the stimulated well

We recommend semi-annual monitoring of a tiered list of water quality analytes

- **A core set of analytes analyzed for every sample**
 - Analytes in the interim regulation (e.g. Minerals, trace elements, radionuclides)
 - Methane and methane isotopic composition
 - Guar gum sugars
 - Two operator-chosen chemical additives based on mass used and persistence
- **A secondary set of analytes only if evidence for a change in water quality is observed**
 - Toxic well stimulation chemical additives (e.g. biocides, surfactants)
- **We recommend establishing a baseline and monitor for significant changes in water quality**

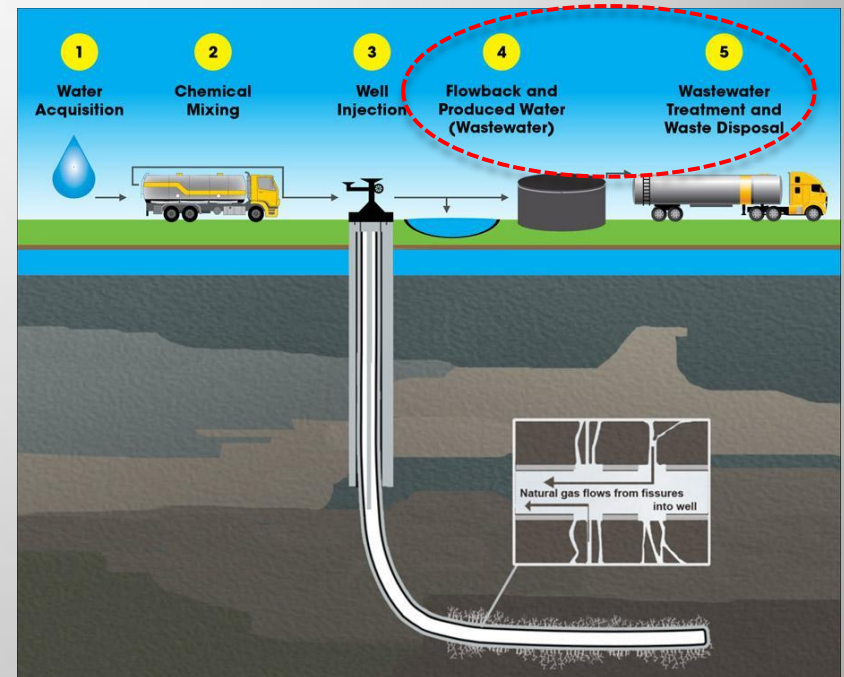
Regional monitoring goals

- **Detect migration of oil & gas fluids out of “isolated” zones into protected groundwater**
 - Does not distinguish between WST, EOR, and UIC (Underground Injection Control – placement of fluids for storage or disposal)
 - Requires mapping of protected groundwater resources
- **Investigate impact of wellbore integrity on water quality at a *regional scale***

We endorse these goals for the regional monitor plan

The regional program should monitor the impact of all oil & gas development on protected groundwater quality

- The contaminant pathways of most concern to regional groundwater quality are not unique to well stimulation
 - Wastewater disposal through discharge to unlined sumps
 - Wastewater disposal through underground injection into non-exempt aquifers
 - Well integrity failure
- A primary concern is *salinity and natural constituents* in formation fluids and produced fluids



- Many of the chemicals used in well stimulation are not unique to well stimulation
 - Biocides, surfactants

California is leading the nation in regulation of well stimulation

- Full disclosure of chemical additives
- Systematic groundwater monitoring of new well stimulation projects
- Regional groundwater monitoring of oil & gas fields
- **Moving forward**
 - The distribution of brackish groundwater will need to be better quantified,
 - Available data needs to be compiled and digitized;
 - Monitoring strategies need to be vetted
- The state acknowledges that these programs will require periodic review

Time will be required to implement a long-term regional groundwater monitoring plan



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