Appendix 5.A

Well Pattern Progression in the Cahn Pool of the Lost Hills Field

Most of the wells in the Cahn pool of the Lost Hills field are hydraulically fractured (Volume I, Appendix N). The animation of wells in operation in this pool each year that constitutes this appendix was developed from the California Division of Oil, Gas, and Geothermal Resources production database and AllWells Geographic Information System layer.

The time period covered by the production database commences in 1977. At this time, some wells are already in operation in the pool. The animation shows:

- The initial well pattern,
- The extension of this pattern,
- Initiation and operation of water flooding and infill wells in portions of the pool within areas whose shape is suggestive of survey or legal, rather than geologic, boundaries,
- Cyclic steam injection in three wells for two years each, and
- Cessation of production in an area whose shape is suggestive of survey or legal, rather than geologic, boundaries.

Viewing the animation can be assisted by using the player's controls to slow down playback.

Appendix 5.B

Potential Upper Limit Hydraulic Fracturing Constituent Concentrations in Produced Water from Select Oil Fields

The potential hydraulic-fracturing fluid upper-limit concentrations are available in spreadsheet and text format in association with this appendix, available online at http://ccst.us/projects/hydraulic_fracturing_public/SB4.php. This appendix lists the potential upper limit hydraulic-fracturing constituent concentrations in produced water from the fields in Table 5.4-4 (Volume III, Chapter 5). "Occurrences" lists the number of occurrences of each constituent in each field in the assembled constituent data set (discussed in Volume II, Chapter 2).

"Mean occurrences per operation" lists the average number of occurrences per operation, which is calculated by dividing the total number of occurrences by the estimated number of operations each year listed on Table 5.4-4 (Volume III, Chapter 5). A value less than one indicates a constituent that is not used in all operations. A value greater than one indicates a constituent that is used more than once in many operations, likely because it occurs as an additive in more than once constituent mixture.

"Mean mass per operation" is the mean mass per occurrence multiplied by the mean occurrences per operation. "2013 effluent concentration" is the potential upper limit concentration resulting from multiplying the mean mass per operation times the estimated annual number of operations per year (given in Table 5-4, Volume III, Chapter 5), divided by the water produced in 2013, also given in Table 5.4-4 (Volume III, Chapter 5).

Appendix 5.C

Comparison of Potential Hydraulic Fracturing Fluid Constituent Upper-Limit Concentrations in Produced Water to Available Maximum Contaminant Levels and Concentration Goals for Drinking Water

Figure 5.C-1 shows the distribution of potential hydraulic-fracturing-fluid constituent these concentrations in produced water, grouped by the lowest Globally Harmonized System (GHS) acute oral toxicity category from publicly available test results on mice, rabbits, and rats. Toxicity increases with decreasing category number. Only one of the hydraulic fracturing chemicals disclosed has a maximum allowable concentration in drinking water established by regulation (acrylamide), and a component of only one other has a concentration goal set by regulation (chloride). These goals and allowable concentrations are generally set with regard to preventing chronic effects, such as the development of cancer. Consequently, there is no regulatory guidance regarding whether the potential upper-limit concentrations are safe with respect to chronic effects.

In order to gain some perspective on the potential upper-limit concentrations relative to these effects, the distribution of potential upper-limit concentrations was compared to the distribution of concentration goals and maximum concentration limits (MCLs) established for constituents in the same GHS acute oral toxicity category. Hydraulic fracturing fluid constituents were assigned to GHS categories based on the acute oral toxicity data collated for analysis in Volume II. Constituents with concentration goals and MCLs were assigned to a GHS oral toxicity category based upon the lowest median acute toxic dose data for rats, mice, and rabbits available from the U.S. National Library of Medicine (undated). In this manner, hydraulic-fracturing-fluid constituents were compared to constituents with concentration goals and MCLs in the same acute oral toxicity category. Consequently, if the potential upper-limit concentrations are larger than the goals or MCLs for constituents in the same category, it is likely that some of the constituents occur at a concentration above the goal or MCL for that constituent if it were established.

The lower of the concentration goals established by the California State Water Resources Control Board (SWRCB) and the United States Environmental Protection Agency (U.S. EPA) for inorganic and organic chemicals and disinfection byproducts for which acute oral toxicity data for mice, rabbits, or rats were available from the U.S. National Library of (undated) were used for comparison (SWRCB, 2015; U.S. EPA, 2009). These included secondary standards from the U.S. EPA. The goals are the concentrations below which there is no known or expected risk to health.

The MCLs for inorganic and organic chemicals and disinfection byproducts established by the SWRCB, including the action level for copper and lead, along with MCLs set by the U.S. EPA for constituents not regulated by the SWRCB, for which acute oral toxicity data for mice, rabbits, or rats were available from the U.S. National Library of Medicine (undated) were available were used for comparison (SWRCB, 2015; U.S. EPA, 2009). These included the dose threshold established by the U.S. EPA for acrylamide and epichlorohydrin.

Figure 5.C-1 shows that some of the potential upper-limit concentrations are above the highest MCL for constituents in the same GHS acute oral toxicity category. This suggests that the potential concentrations of some constituents in produced water may be above safe drinking water concentrations, if such existed for those constituents. Figure 5.C-1 also shows that most of the potential upper-limit concentrations are greater by an order of magnitude or more than the drinking water goals for constituents in the same GHS acute oral toxicity category.

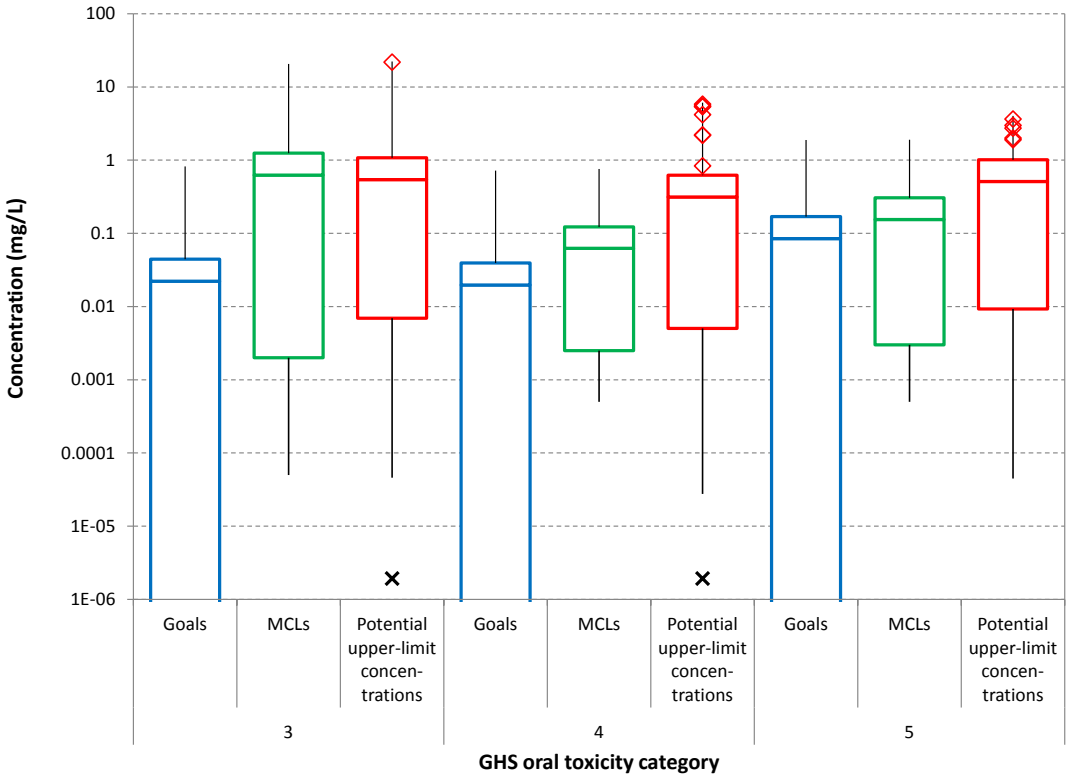

Figure 5.C-1. Distribution of drinking water concentration goals, maximum concentration limits for drinking water, and potential hydraulic fracturing fluid constituent upper-limit concentrations in produced water from the North and South Belridge, Lost Hills, and Elk Hills fields. Data are assigned by the minimum GHS acute oral toxicity category from testing on rats, mice, and rabbits for each constituent. Toxicity increases with decreasing category number. The lower and upper ends of the boxes indicate the first and third quartile concentrations respectively. The line within the box is the median concentration. Lines extend from the boxes vertically to the highest and lowest concentration that is within one and half times the concentration interval between the first and third quartile. Values shown by an "x" are beyond that range. The red diamonds indicate constituents at potential upper-limit concentrations above the highest MCL in the same GHS category. The first quartile concentration for the goals is less than the bottom of the range shown on the graph.

5.C.1. References

California State Water Resources Control Board (SWRCB), 2015. MCLs, DLRs, and PHGs for Regulated Drinking Water Contaminants. Dated February 27, 2015. Retrieved from http://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/Documents/MCLreview/MCLs-DLRs-PHGs.xls.

U.S. EPA, 2009. Nation Primary and Secondary Drinking Water Regulations. Dated May 2009. Available at http://water.epa.gov/drink/contaminants/upload/mcl-2.pdf.

United States National Library of Medicine, undated. ChemIDplus Advanced: A Toxnet Database. Available from http://chem.sis.nlm.nih.gov/chemidplus/.

Appendix 5.D

Additional Tables Regarding Population Demographics in Proximity to Hydraulically Fractured Wells And All Active Oil And Gas Production Wells In The San Joaquin Basin

Table 5.D-1. Number and percent of facilities with more sensitive population members in proximity to hydraulically fractured wells in the San Joaquin Valley Air Basin (SJVAB).

Proximity to a well (m; ft)	All active or HF wells?	Number of Daycare Facilities	Number of Schools	Number of Children Attending Schools	Number of Elderly Facilities
100 (330)	HF	0	0	0	0
		0.00%	0.00%	0.00%	0.00%
	All	1	0	0	0
		0.12%	0.00%	0.00%	0.00%
	HF/All	0.0%			
400 (1,300)	HF	0	3	1,223	1
		0.00%	0.34%	0.24%	0.17%
	All	8	11	6,572	14
		1.0%	1.2%	1.3%	2.3%
	HF/All	0.0%	27.3%	18.6%	7.1%
800 (2,600)	HF	4	9	2,626	5
		0.51%	1.01%	0.50%	0.86%
	All	25	36	23,343	33
		3.0%	4.0%	4.4%	5.3%
	HF/All	16%	25%	11%	15%
1,600 (5,300)	HF	29	15,963	26	13
		3.2%	3.1%	4.5%	1.6%
	All	109	72,646	95	84
		12.2%	13.8%	15.3%	10.2%
	HF/All	27%	22%	27%	16%

2,000 (6,600)	HF	16	36	21,283	37
		2.0%	4.0%	4.1%	6.4%
	All	112	129	91,733	110
		14%	14%	17%	18%
	HF/All	14%	28%	23%	34%
Any	All	772	846	495,223	538

Table 5.D-2. Population over 25 years of age with less than a high school education in proximity to hydraulically fractured and all active wells in the study area (based on the 2010 Census data at the block group level).

Proximity to a well (m; ft)	All active or HF wells?	Total Population	No High School Diploma
100 (330)	HF	355	94
		0.03%	0.02%
	All	6,016	1,303
		0.43%	0.32%
	HF/All	5.9%	7.3%
400 (1,300)	HF	2,652	583
		0.19%	0.14%
	All	28,059	6,731
		2.0%	1.6%
	HF/All	9.5%	8.7%
800 (2,600)	HF	8,422	1,810
		0.60%	0.44%
	All	67,144	16,611
		4.8%	4.0%
	HF/All	12.5%	10.9%
1,600 (5,300)	HF	31,920	7,322
		2.3%	1.8%
	All	175,167	44,051
		12%	11%
	HF/All	18%	17%
2,000 (6,600)	HF	47,467	10,898
		3.4%	2.7%
	All	230,604	58,482
		16%	14%
	HF/All	21%	19%
Any distance	All	1,360,784	399,988

Table 5.D-3. Employed and unemployed population in proximity to hydraulically fractured and all active wells in the study area (based on the 2013 Census data at the block group level).

Proximity to a well (m; ft)	All active or HF wells?	Total Population	Employed	Unemployed
100 (330)	HF	574	248	25
		0.02%	0.02%	0.02%
	All	9,910	4,562	490
		0.42%	0.43%	0.33%
	HF/All	5.8%	5.4%	5.1%
400 (1,300)	HF	4,315	1,870	190
		0.18%	0.18%	0.13%
	All	46,589	21,517	2,634
		2.0%	2.0%	1.8%
	HF/All	9.3%	8.7%	7.2%
800 (2,600)	HF	13,825	6,134	721
		0.59%	0.58%	0.48%
	All	111,475	51,555	6,551
		4.8%	4.8%	4.4%
	HF/All	12%	12%	11%
1,600 (5,300)	HF	52,530	24,378	2,895
		2.3%	2.3%	1.9%
	All	286,976	132,931	16,808
		12%	13%	11%
	HF/All	18%	18%	17%
2,000 (6,600)	HF	78,570	36,573	4,260
		3.4%	3.4%	2.9%
	All	378,819	174,958	22,422
		16%	16%	15%
	HF/All	21%	21%	19%
Any	All	2,258,319	1,026,844	144,881

Table 5.D-4. Total, limited English and impoverished households in proximity to hydraulically fractured and all active wells in the study area (households with limited English and below the food stamp income threshold based on the .2010 Census data at the block group scale, and households with income below the poverty line based on the 2013 Census data block group level).

Proximity to a well (m; ft)	All active or HF wells?	Total Households	Limited English Speaking Households	Households with Income Below Individual Food Stamp Threshold	Households with Income Below Poverty Line
100 (330)	HF	187	13	20	33
		0.03%	0.02%	0.02%	0.02%
	All	3,284	170	357	438
		0.46%	0.23%	0.35%	0.29%
	HF/All	5.7%	7.8%	5.5%	7.4%
400 (1,300)	HF	1,317	77	137	191
		0.18%	0.10%	0.13%	0.13%
	All	14,890	957	1,796	2,284
		2.1%	1.3%	1.8%	1.5%
	HF/All	8.8%	8.1%	7.6%	8.3%
800 (2,600)	HF	4,165	258	431	577
		0.58%	0.35%	0.42%	0.38%
	All	35,244	2,475	4,498	5,905
		4.9%	3.4%	4.4%	3.9%
	HF/All	11.8%	10.4%	9.6%	9.8%
2,000 (6,600)	HF	23,856	1,654	2,346	3,720
		3.3%	2.3%	2.3%	2.5%
	All	119,589	9,040	15,651	22,554
		17%	12%	15%	15%
	HF/All		18%	15%	16%
Any	All	690,476	71,805	99,523	147,340

Appendix 5.E

Calculation of Diversity Index

The Diversity Index is a metric that compares the perimeter of a given area to the perimeter of a circle of the same area (Patton, 1975). Circles have the lowest ratio of perimeter to area of any shape.

Analysis of the Elk Hills field provides an example. The vegetated areas in the Elk Hills field have an area of 160 km^2 (39,537 acres). A circle of that same area (160 km^2 or 39,537 acres) would have a perimeter (circumference) of 45 km (27.96 mi). The length of the boundary between vegetated and "barren" areas (such as well pads and roads), is 1,836 km (1,140.84 mi). Consequently, the DI for the Elk Hills Field is calculated as follows:

DI = 1,836 km (real perimeter) / 45 km (circle perimeter) = 40.8

5.E.1. References

Patton, D.R., 1975. A diversity index for quantifying habitat "edge." Wildlife Society Bulletin, pp.171–173.