Responses to CEC Data Requests Set Four: Nos. 219 through 244

DOCKET	
08-AFC-8	
DATE	FEB 08 2011
RECD.	FEB 08 2011

Revised Application for Certification (08-AFC-8)

for

HYDROGEN ENERGY CALIFORNIA Kern County, California

Prepared for:
Hydrogen Energy California LLC

Submitted to:
California Energy Commission

February 2011

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RESPONSES TO CEC DATA REQUESTS SET FOUR – NOS. 219 THROUGH 244

This material is based upon work supported by the Department of Energy National Energy Technology Laboratory under Award Number DE-FE0000663.

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LIST OF ACRONYMS AND ABBREVIATIONS USED IN RESPONSES

CEC	California Energy Commission
CO_2	carbon dioxide
EHOF	Elk Hills Oil Field
EOR	Enhanced Oil Recovery
GOR	gas/oil ratio
K	bulk modulus
M	magnitude
MBB	Main Body B
mm/yr	millimeters per year
Mpsi	million pounds per square inch
M_W	moment magnitude
OEHI	Occidental of Elk Hills, Inc.
psi	pounds per square inch
RFDG	Reef Ridge Shale
SPE	Society of Petroleum Engineers
UIC	Underground Injection Control
UMBB	Upper Main Body B

Technical Area: Carbon Dioxide Enhanced Oil Recovery
Author: Tadeusz W. Patzek and Abdel-Karim Abulaban

BACKGROUND

Carbon Capture and Sequestration

One very important premise of this project is the ability to store (carbon capture and sequestration – CCS) the excess amounts of carbon dioxide (CO_2) that would be produced by the Hydrogen Energy of California (HECA) project. The HECA project would produce approximately 2,300 lbs of CO_2 per gross megawatt-hour, which would be about 1,200 lbs more than permitted by the SB1368 Emission Performance Standard (EPS) for baseload power plants. Therefore, the applicant has to demonstrate that at least 1,200 lbs per megawatt-hour of CO_2 can be stored permanently. Additionally, the project's emissions of CO_2 must be analyzed in accordance with the California Environmental Quality Act (CEQA).

Occidental of Elk Hills, Incorporated (OEHI) proposes to inject the compressed CO_2 purchased from HECA into their Elk Hills reserve for enhanced oil recovery (EOR) and CCS. A storage rate or trapping ratio of 1:3 of CO_2 per pass was claimed by the applicant when injecting CO_2 for enhanced oil recovery (EOR) and for CCS. This trapping ratio seems unrealistic given that there is no basis from field data, especially when compared with many other documented injection projects that report an average recirculation rate of 100 percent of purchased CO_2 and thus a trapping ratio of zero. Staff is aware of the results of the study conducted at the University of Wyoming that indicates a trapping ratio on the order of 1:3 per pass, but cannot verify this ratio from pilot studies or reports. In 2005, OEHI conducted a 4-month, single pilot project EOR injection well in the Elk Hills Main Body of the B interval (MBB) sand with 3 producer wells, 345A-35S, 346-35S, and 356-35S, and one observation well 110 ft from the injector well. As OEHI stated in the CO_2 EOR project permit (sample permit) submitted to the Energy Commission in April 2010, critical information was gained during the pilot program, including confirmation of containment within the Stevens reservoir rock beneath the Reef Ridge (RR) Shale interval. This data may provide the basis for the trapping ratio and the ability of the project to comply with the EPS.

DATA REQUEST

219. Please provide the OEHI reports detailing the EOR/CCS injection pilot project performance at Elk Hills, especially CO_2 injectivity and estimates of volumetric sweep.

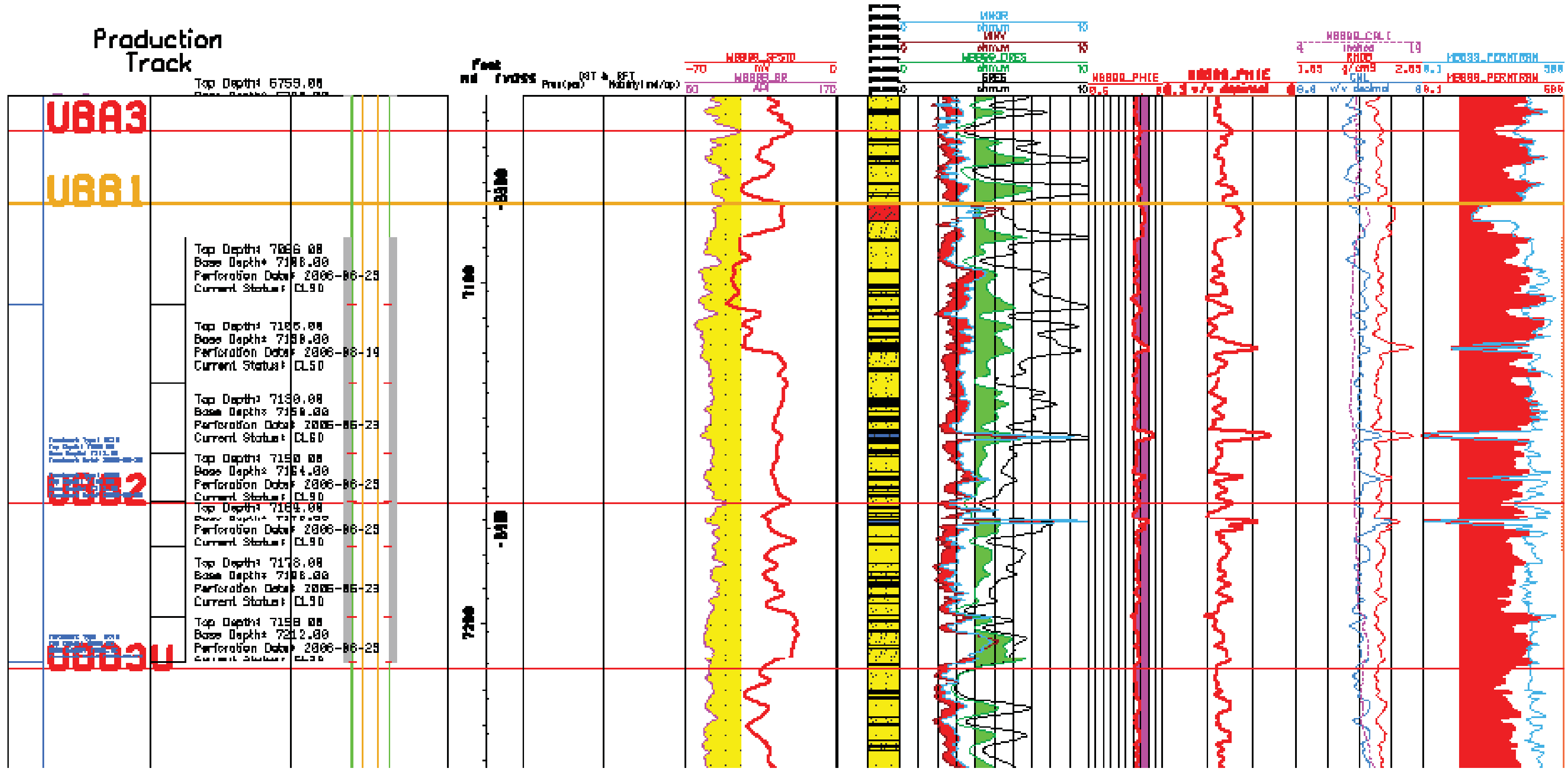
RESPONSE

A carbon dioxide (CO_2) Injection pilot was conducted in 2005 in the area of the Elk Hills Oil Field (EHOF) that is referred to as the 35S area. The project consisted of one injector (355A-35S), three observation wells (355-35S, 355B-35S and 355C-35S), and three producers (345A-35S, 346-35S and 356-35S). A purpose of the pilot was to prove that CO_2 injection into the Main Body B (MBB) sands would mobilize residual oil. The three observation wells were used to measure saturation changes and three offset producers measured production for a period of 6 months, after which the pilot's flaring permit expired and production had to be shut in. Water and CO_2 were injected into the UBB1 and UBB2 zones (illustrated on Figure 219-1) of the Stevens Reservoirs to contain the pilot to a manageable hydrocarbon pore volume for a pilot test, and to ensure that the target zone was at residual oil saturation to water flood. These intervals were considered to be at residual oil saturation to water flooding even before the brine pre-flush of the pilot.

Injection started on May 1, 2004 with 9 months of brine pre-flush to increase the salinity of the formation water in the pilot area. This pre-flush was necessary to ensure sufficient resistivity contrast between oil and formation water so that saturation changes could be measured. CO_2 injection commenced on January 18, 2005, with the injection rate and tubing head pressures shown on Figure 219-2.

Figure 219-3 shows a significant increase in injectivity index when the pilot injector was switched to CO_2 injection.

Volumetric sweep efficiency of the pilot has been estimated at between 50 and 70 percent. The short production time, necessitated by the duration of the flare permit, does not provide enough information to accurately estimate volumetric sweep efficiencies.



Note: Perforations in grey were those open for the CO_2 pilot

355A-35S CGM

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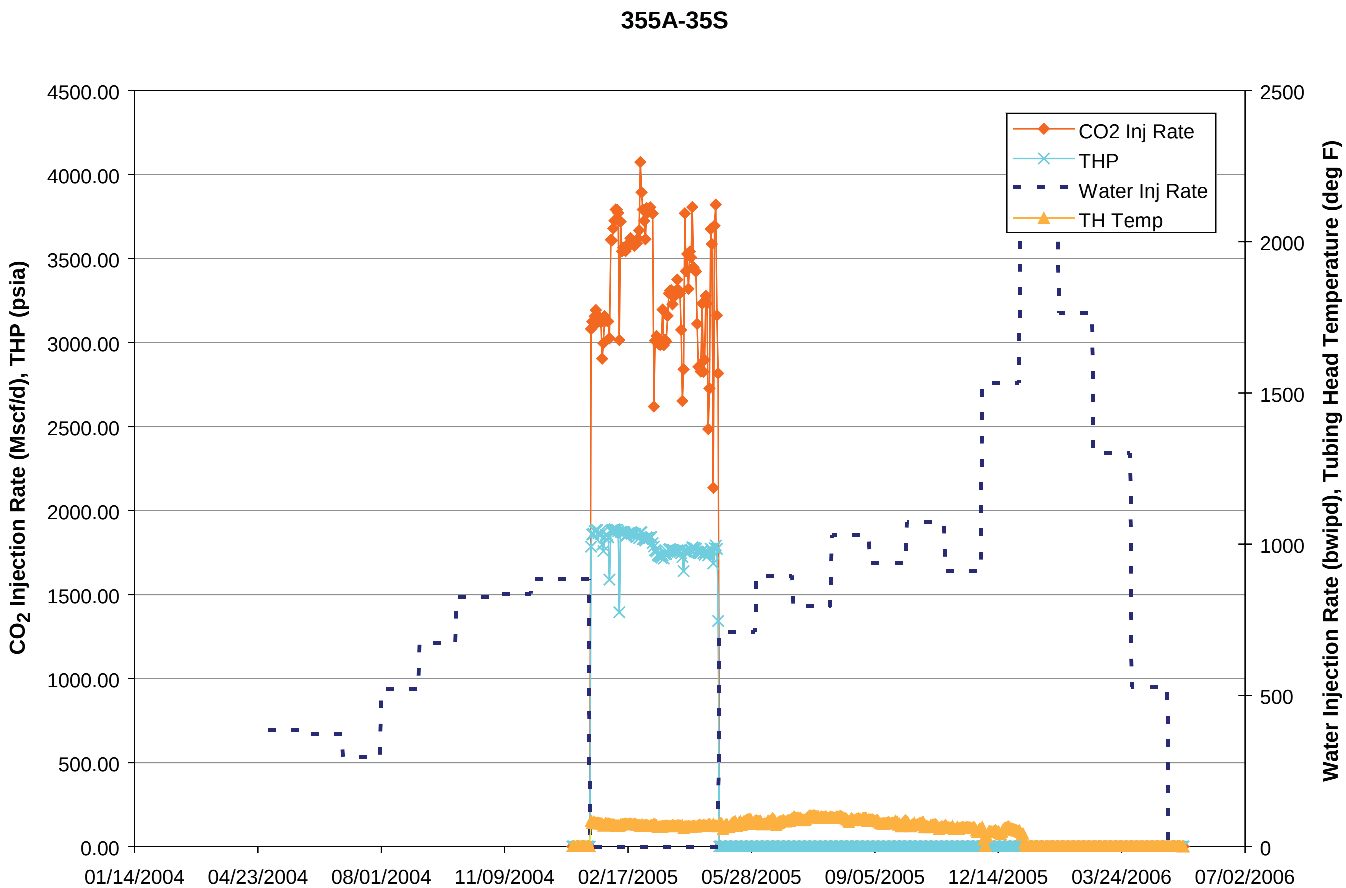
28067571 Kern County, California

Source:
OEHI, 2011

FIGURE 219-1

2/02/11 vsa..T:\HECA\GRAPHICS\Data Requests\DR Set 4 (219-244)\219-1_CGM.ai



Source:
OEHI, 2011

355A-35S INJECTION DATA

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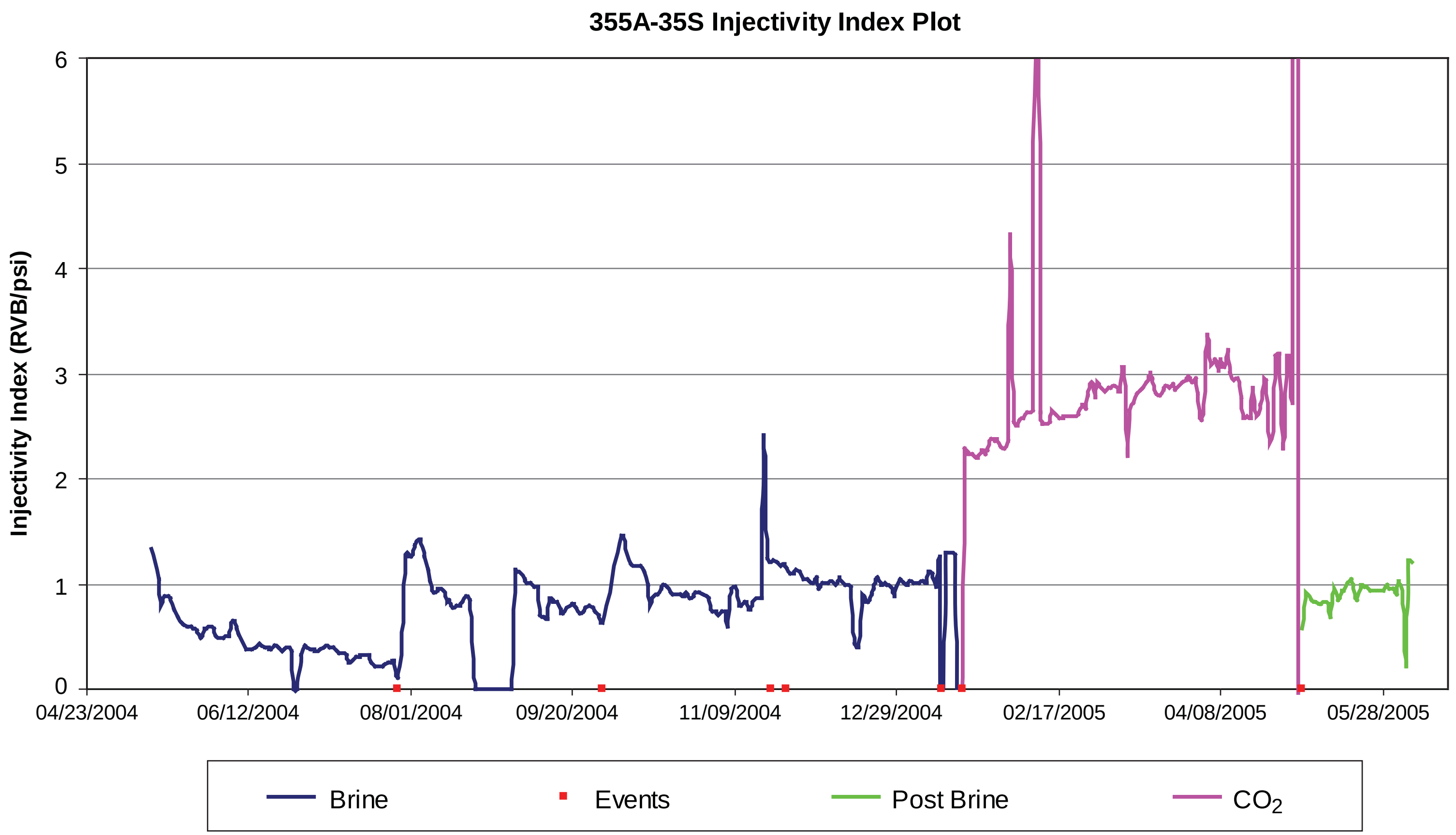
FIGURE 219-2

2/02/11 vsa..T:\HECA\GRAPHICS\Data Requests\DR Set 4 (219-244)\219-2_injection.ai



Source:
OEHI, 2011

355A-35S INJECTIVITY INDEX

February 2011 | Hydrogen Energy California (HECA)
28067571 | Kern County, California

FIGURE 219-3

DATA REQUEST

220. Please provide any evidence to show the basis for the assumed trapping ratio. It would be useful if the applicant specifically provides data and analysis obtained from the CO_2 injection pilot project that was conducted at the Elk Hills Oil Field (Stevens reservoirs).

RESPONSE

Occidental of Elk Hills, Inc.(OEHI) understands "trapping" to mean the physical, geophysical, or geochemical retention of CO_2 molecules in the subsurface in formations currently holding crude oil and hydrocarbon gas. "Trapping ratio" is more loosely defined as 1 minus the ratio of the volume of produced CO_2 over injected CO_2 for a given area of the reservoir, such as a pattern.

A trapping ratio of 30 to 50 percent is typical of OEHI's Enhanced Oil Recovery (EOR) experience (which is in line with the University of Wyoming study referenced in the background to the question) and is the basis of OEHI's base case expectations for this project. Ultimately, all of the CO_2 injected in the OEHI CO_2 EOR Project (net of fugitive CO_2 emissions and operational losses) will become trapped in the formation by structural, stratigraphic, solubility, and mineralization mechanisms, and will be sequestered. This is because CO_2 that is recycled through one of the early patterns will then be used to process other patterns in the EOR flood.

Any CO_2 produced from the MBB once those patterns go to chase water near the end of the project may be injected into the A1A2 Reservoir. This is a low-pressure, former gravity drainage reservoir from which OEHI expects to produce incremental oil. Due to the nature of production from a gravity drainage reservoir, OEHI expects very little of this CO_2 to be produced with the incremental oil.

OEHI was not able to run the Stevens CO_2 injection pilot long enough to determine a trapping ratio.

DATA REQUEST

221. Please identify how the EOR project design would be able to address the potential for a trapping ratio below that currently estimated. Specifically, please identify the minimum trapping ratio/maximum CO_2 recirculation rate that will be able to be accommodated by the EOR project design to assure economic oil recovery and CO_2 sequestration.

RESPONSE

OEHI understands "trapping" to mean the physical, geophysical, or geochemical retention of CO_2 molecules in the subsurface in formations currently holding crude oil and hydrocarbon gas. "Trapping ratio" is more loosely defined as 1 minus the ratio of the volume of produced CO_2 over injected CO_2 for a given area of the reservoir, such as a pattern. A trapping ratio of 30 to 50 percent is typical of OEHI's extensive CO_2 EOR experience and is the basis of OEHI's base case expectations for this project. A lower realized trapping ratio would allow OEHI to accelerate development of this EOR project while still ultimately trapping all the CO_2. A higher realized trapping ratio would lead OEHI to seek additional sources of CO_2.

BACKGROUND

Pore Space Characteristics

Many necessary pieces of technical data are missing from documentation submitted by the applicant in the revised application for certification and all subsequent submittals. The required data can be grouped in four categories: 1) Pore space characteristics and oil distribution, which are necessary to judge the availability and ease of pumping the carbon dioxide (CO_2); 2) Information needed to characterize the rock formations that will help determine the response of the rocks to available and additional stresses; 3) Pore pressure, which is needed to assess the pressure at which the CO_2 would have to be at so that it can be injected into the formation; and 4) Formation stresses, which are needed to assess the behavior of any faults that may be present.

DATA REQUEST

222. Please provide the cumulative oil produced from the EOR project area on primary in terms of percent original oil in place (%OOIP) and during the waterflood (%OOIP).

RESPONSE

A response to this data request has been prepared and submitted under confidential cover.

DATA REQUEST

223. Please provide information on current average oil and water saturations in the project area.

RESPONSE

A response to this data request has been prepared and submitted under confidential cover.

DATA REQUEST

224. Please provide information to support the estimate of 7.5 billion barrels as the pore space available for CO_2 injection.

RESPONSE

A response to this data request has been prepared and submitted under confidential cover.

DATA REQUEST

225. Please provide information about the average oil saturation, or the hydrocarbon pore volume (HCPV).

RESPONSE

OEHI refers to the published data in Society of Petroleum Engineers (SPE) 27877 "Phase Behavior of Reservoir Fluids in the Stevens Zone at Elk Hills Oil Field, California" by N. Ezekwe et al. This paper quotes a stock tank oil initially in place volume of 610 million barrels of oil for the MBB sands of the 31S structure.

Reference

Ezekwe, Nnaemeka, M.E. Querin,, U.S. Department of Energy; Michael Humphrey, Chevron USA, Inc., 1994. Phase Behavior of Reservoir Fluids in the Stevens Zone at Elk Hills Oil Field, California. SPE Western Regional Meeting, March 23 through 25, 1994, Long Beach, California.

DATA REQUEST

226. Please provide information about estimated current gas saturation in the CO_2 project area.

RESPONSE

The reservoir pressure in the initial phase (MBB Reservoir) of the CO_2 project area (except the A1A2 gravity drainage reservoir) is above bubble point pressure. The reservoir was allowed to drop below this pressure for a period of time by the previous operator, but OEHI has restored the reservoir pressure by injecting brine to replace the voided fluids using a pattern water flood development. The current producing gas/oil ratio (GOR) of the MBB Reservoir is near the initial GOR; thus, the current free gas saturation in the reservoir can be assumed to be negligible for the purposes of estimating the available pore space available for storage of CO_2.

DATA REQUEST

227. The applicant mentioned producing 3.4 billion bbl of fluid, but did not mention how much of that fluid was oil, and how much was water. Please provide this information.

RESPONSE

A response to this data request has been prepared and submitted under confidential cover.

DATA REQUEST

228. Please demonstrate how the measurements and calculations can be extrapolated to the reservoir for the life of the EOR and CCS project.

RESPONSE

Extrapolation of measurements and calculations is a challenge faced across all disciplines of science and engineering. Ultimately, when this is done, it is prudent to speak in terms of ranges of outcomes and degree of certainty. The measurements and calculations made by OEHI relating to EOR are no exception. Varying degrees of uncertainty relate to each measurement and calculation; however, each have been made and extrapolated in line with the latest science and industry best practice. OEHI has calibrated the compositional simulation modeling work to the results observed in the 2005 pilot and has confidence that the range of likely outcomes has been captured by this work. Experimental design procedures have been used to determine, at the detailed level, what ranges are appropriate; and these ranges are reflected in the model inputs.

DATA REQUEST

229. Please provide the following document referenced in the documents provided by the applicant: Merchant, D. (2006) Geologic Storage Options for CO_2 Sequestration, Elk Hills Oil Field, CO_2 Tertiary Evaluation. HEI (now HECA) Internal Report 56 pp.

RESPONSE

A response to this data request has been prepared and submitted under confidential cover.

DATA REQUEST

230. Please provide the American Petroleum Institute gravity, viscosity and composition of the targeted crude.

RESPONSE

The CO_2 EOR Project covers a large area within which a variation of oil properties is observed. The following data are considered representative of the target crude.

OEHI refers to Table 2 on page 6 of the Sample Class II Underground Injection Control (UIC) Permit Application that has been filed with the California Energy Commission (CEC) in regard to information on oil gravity and viscosity.

Oil Compositions for the 26R reservoir of the Stevens Reservoirs are quoted in Table 4 of SPE 24041, “An Application of Oil Vaporization Evaluation Methods” by W.W. Fleckenstein et al, 1992. This composition is assumed to be representative of the MBB oil composition as the two reservoirs are adjacent members of the Stevens zone and charged by the same source.

Reference

Fleckenstein, W.W., Bechtel Petroleum Operations Inc.; L.S. Bouck, P.D. Hudgens, Scientific Software-Intercomp; M.E. Querin, U.S. Department of Energy; L.L. Williams, Chevron USA Inc., 1992. An Application of Oil Vaporization Evaluation Methods. SPE Western Regional Meeting, March 30 through April 1, 1992, Bakersfield, California.

DATA REQUEST

231. Please provide experimental evidence of first contact or developed miscibility at reservoir conditions, as well as the measured maximum miscibility pressure (MMP) at Elk Hills.

RESPONSE

A response to this data request has been prepared and submitted under confidential cover.

DATA REQUEST

232. Please provide information on current reservoir pressure (if only one number of 2,499 pound per square inch as in the report, then how measured and wherein the structure was it measured. If multiple numbers then also provide locations (x,y) and depths of the measurements.

RESPONSE

OEHI is not aware of a reference to reservoir pressure being 2,499 pounds per square inch (psi) in its previously filed information.

OEHI monitors reservoir pressure using a combination of wire line formation tester data on new wells, shut-in fluid levels on producing wells, and static gradient surveys. These data show some variation in reservoir pressure over the CO_2 project area, as would be expected in a dynamic, heterogeneous system. However, CO_2 is not planned to be injected into any part of the field (except the A1A2 prior gravity drainage reservoir) until OEHI has restored the pressure above the minimum miscibility pressure (see the response to Data Request 231). OEHI refers to Table 1 on page 5 of the Sample Class II UIC permit that has been filed with the CEC for information regarding the pressures of the respective layers in the CO_2 project area. A gradient of 0.4 to 0.42 psi per foot can be used to extrapolate the aforementioned pressures to different depths within the reservoir.

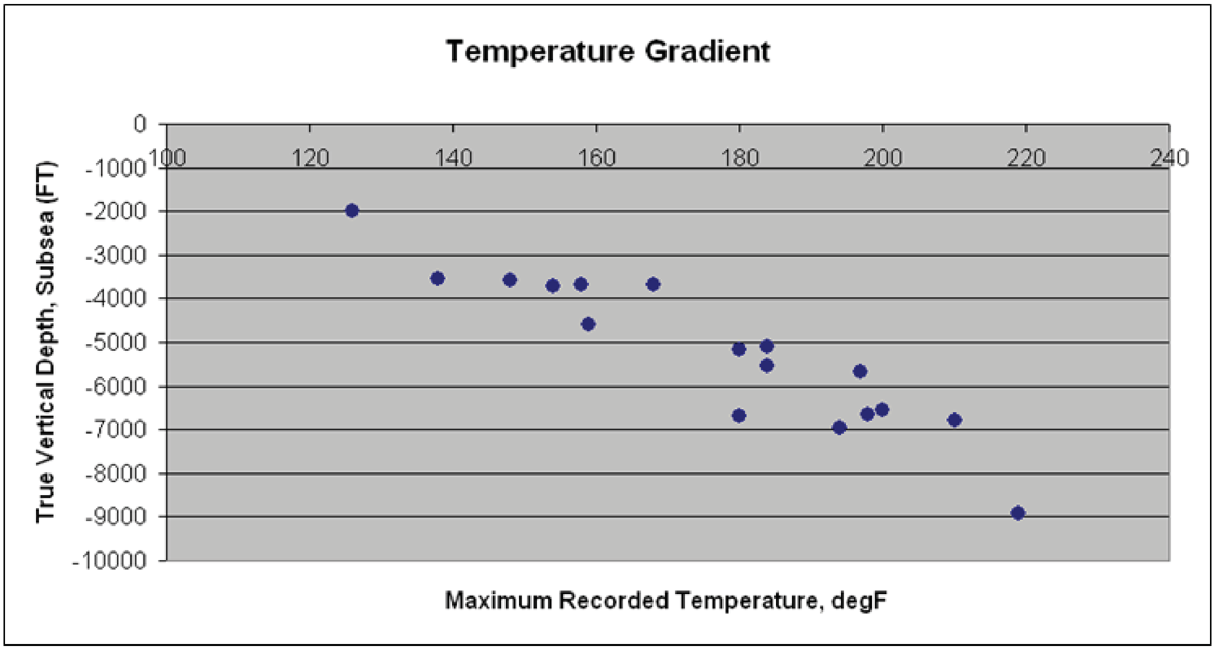
DATA REQUEST

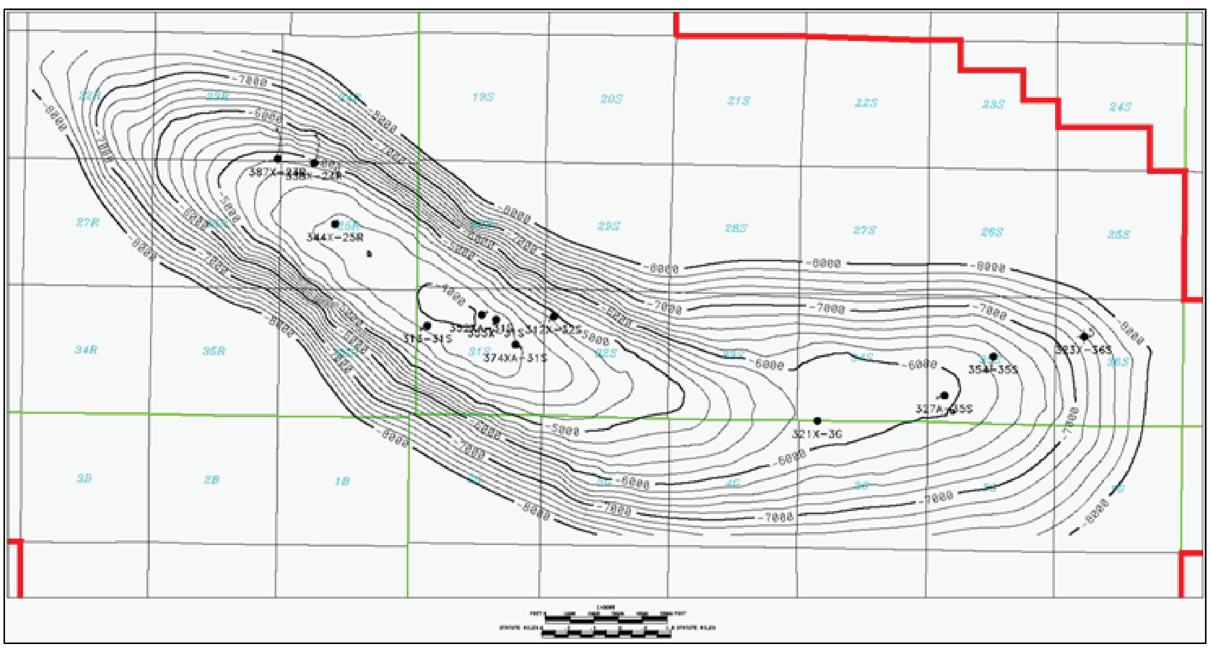
233. Please provide information on the current reservoir temperature profile, again where and how measured.

RESPONSE

The maximum temperature encountered on a logged well is recorded on the log's well header.

Figure 233-1 indicates the maximum recorded temperature for each corresponding well, along with the location of each well. The plot of those temperatures at different total depths shows the temperature profile.





MAXIMUM RECORDED TEMPERATURE

February 2011 — Hydrogen Energy California (HECA)
28067571 — Kern County, California

FIGURE 233-1

Source:
OEHI, 2011

BACKGROUND

Rock Mechanics

The applicant has not provided rock-mechanics data and Stevens reservoirs data that might justify the conclusions about the feasibility of the EOR and CCS project. Also, there are no *insitu* stress measurements at multiple locations. Furthermore, there are hundreds of wells that penetrate the Reef Ridge (RR) Shale, but no statements were given as to their integrity and keeping their casing cement/casing tubular from being corroded/eroded away by the combination of CO_2 and carbonic acid.

DATA REQUEST

234. Please provide the magnitude and orientation of the principal stress tensor(s) in the sand and shale, preferably at several locations, as well as a vertical profile of the measured/inferred reservoir pressure at several locations.

RESPONSE

A response to this data request has been prepared and submitted under confidential cover.

DATA REQUEST

235. Please provide the principal in-situ stress and the orientations of its three components as a function of depth and position in the anticline. These measurements would consist of density logs for minimum vertical stress, S_v, minifractures, and wellbore breakouts for minimum horizontal stress, S_h and the calculations for maximum horizontal stress, S_H. The S_H can be calculated if sufficient information is provided.

RESPONSE

A response to this data request has been prepared and submitted under confidential cover.

DATA REQUEST

236. Please provide the estimates of the bulk rock moduli, Poisson's ratios, and/or Young's moduli for the Stevens reservoir sandstone and the confining Reef Ridge Shale.

RESPONSE

From the Stevens MBB:

Table 236-1
Average from Core 358X-33S

	Average Bulk Modulus, K (Mpsi)	Average Compressibility, 1/K (1/Mpsi)	Poisson's Ratio	Young's Modulus, (Mpsi)
UMBB	0.44	2.6	0.24	2.8

Notes:

K bulk modulus
Mpsi million pounds per square inch
UMBB Upper Main Body B

From the Reef Ridge Shale:

Table 236-2
Post Fracture Stimulation Job Report (368-31S)

	Bulk Modulus, K (Mpsi)	Compressibility, 1/K (1/Mpsi)	Poisson's Ratio	Young's Modulus, (Mpsi)
RFDG	ND[1]	ND[1]	0.23	9.0

Notes:

1 No data.

K bulk modulus
Mpsi million pounds per square inch
ND not determined
RFDG Reef Ridge Shale

DATA REQUEST

237. Please provide information on the wells that penetrate the Reef Ridge Shale (well casing materials, well seals, annular space materials and method of construction). This information is necessary to assess the integrity of the wells and their annular spaces.

RESPONSE

Data requested will be included in the well data package being developed for the UIC Class II Permit Application. The Sample Class II UIC Permit Application for the Stevens CO_2 EOR Project that has been filed with the CEC shows an example of the analysis and detail that will be reported on each well.

DATA REQUEST

238. Please provide an analysis of the potential effects of corrosion due to CCS on well casings and annular seals for all wells in the project area.

RESPONSE

To mitigate corrosion of steel casing used in wells, a barrier needs to be established between the steel and the CO_2-enriched fluids. This can be achieved in various ways. EHOF is currently undergoing injection of produced water which, like CO_2, is corrosive. Methods currently employed or planned to mitigate both internal and external corrosion of casing in wells that will be part of the CO_2 Project at Elk Hills are discussed in the following paragraphs.

External Corrosion Mitigation

OEHI plans to place a column of cement between the formation and casing from total depth of the well bore to 500 feet above the shallowest open perforation in newly drilled wells. Cement is an effective and proven barrier to protect casing from external corrosion. For wells already in place at the start of the CO_2 injection project, an evaluation of the cement column will be done to ensure that Class II UIC permit conditions for injection are achieved. Any wells found to have an insufficient barrier will be remediated.

Internal Corrosion Mitigation

For injection wells, an inhibited fluid will be placed inside the casing above the packer, in the casing/tubing annulus, to protect the steel against corrosion. This annulus will be monitored for pressure fluctuations that may indicate contamination due to leaks in the tubing or packer. Periodic pressure tests will also be performed in accordance with UIC permit conditions. The tubing and packer will be internally coated with corrosion-resistant materials to prevent internal corrosion.

An internal barrier for production well casing will be established by exposing the steel to an inhibitor fluid, thereby placing a film of corrosion inhibitor directly on the steel surface. By design, this inhibitor film depletes over time and will be reestablished as needed according to a monitoring program. An accepted method to monitor the effectiveness of this film is to place a strip of steel similar in composition to the casing into the fluid stream and measure the steel strip for any weight loss through time, which is an indicator of the corrosion rate.

DATA REQUEST

239. Please demonstrate how the measurements and calculations can be extrapolated to the reservoir for the life of OEHI's CO_2 EOR project.

RESPONSE

Please see the response to Data Request 228. OEHI has the same view of extrapolation on rock mechanics measurements and calculations as for pore space characteristics.

BACKGROUND

Plunging Anticline

The Elk Hills Oil Field is characterized as a plunging anticline that forms a natural geologic trap for petroleum hydrocarbons. This anticline has formed as a result of faulting and folding of sedimentary rock in active tectonic region of California. Staff is concerned that the faulting and folding remain active and that there is potential for future rupture of existing or new faults in or along the plunging anticline which would allow for leakage and failure of the CCS component of the project.

DATA REQUEST

240. Please provide a map and figures showing the location of active and potentially active faults and time and magnitude of rupture along faults within 50 miles of the project site.

RESPONSE

The State of California Department of Conservation's 1972 Alquist-Priolo Geologic Hazard Zones Act (later renamed in 1996 to the Alquist-Priolo Earthquake Fault Zoning Act) "provides a mechanism for reducing losses from surface fault rupture on a statewide basis" by publishing fault zone maps for the purpose of "prohibiting the siting of most structures for human occupancy across traces of active faults that constitute a potential hazard to structures from surface faulting or fault creep" (http://www.consrv.ca.gov/cgs/rghm/ap/Pages/index.aspx).

The Act defines an active fault as one which has "had surface displacement within Holocene time (about the last 11,000 years)."

Potentially active faults were initially defined as those showing evidence of surface displacement during Quaternary time (the last 1.6 million years).

The California Geological Survey's Special Publication 42 (SP42) further explains that "a fault may be presumed to be inactive based on satisfactory geologic evidence; however, the evidence necessary to prove inactivity sometimes is difficult to obtain and locally may not exist" (pg. 5).

Table 240-1, taken from SP42, illustrates the time distinction characterizing an active and a potentially active fault.

Table 240-1
Time Distinction for an Active and a Potentially Active Fault

GEOLOGIC AGE			YEARS BEFORE PRESENT (estimated)
	Period	Epoch	
CENOZOIC	QUATERNARY	Historic	200
		Holocene	11,000
		Pleistocene	1,600,000
	TERTIARY	Pliocene	5,000,000
		pre-Pliocene	66,000,000
pre-CENOZOIC time Beginning of geologic time			4,600,000,000

Active: Faults along which movement has occurred during this interval and defined as *active* by Policies and Criteria of the State Mining and Geology Board.

Potential: Faults defined as *potentially active* for the purpose of evaluation for possible zonation.

Figure 240-1 highlights both active and potentially active faults within 50 miles of EHOF. Table 240-2 lists these faults along with an estimated range of maximum magnitude and the date and location of the last known event.

Table 240-2
Active and Potentially Active Faults and Estimated Maximum Magnitudes

Fault Name[1], Active[2] Potentially Active	Map Label	Closest Distance from EHOF (centered at 35R), miles	Estimated Maximum Magnitude	Slip Rate (mm/yr)	Date and Location of Last Known Earthquake Event (M_W)
Coast Ranges-Sierran Block Boundary Zone[3]	1	0	7.00	1.0 – 4.0	Possible association with 1985 Kettleman Hills (6.1)[4]
Buena Vista[5,6]	2	4	Unknown	~6.3[7]	Creep noted in 1933.
San Andreas	3	16	7.50 – 8.00	25	1857, Fort Tejon (7.9)
Big Pine	4	43	7.00	2.4	No Quaternary events cited
Breckenridege	5	52	6.25 – 6.50	0.1	No Quaternary events cited
Garlock (W)	6	45	7.50	10.5	1992, Mojave (5.7)[8]
Kern Gorge	7	36	6.50 – 7.00	0.1	No Quaternary events cited
Los Lobos Hills	8	23	6.50	3.6	No Quaternary events cited
Wheeler Ridge	9	25	7.00 – 7.25	1.3 – 4.5	1952, Kern County (7.3)
Pleito	10	26	7.00 – 7.25	1.4 – 20	Estimated 345-1465 years ago
Ozena	11	32	7.00	0.01	No Quaternary events cited
Pond-Poso Creek	12	26	6.00 – 6.75	0.01 – 0.05	No Quaternary events cited
Rinconada	13	59	6.75 – 7.50	2.5	No Quaternary events cited
San Juan	14	30	7.25	1.6	No Quaternary events cited
White Wolf	15	31	7.25	12.7	1952, Kern County (7.3)

Notes:

1 Unless otherwise cited, data in this table was taken from Woodward-Clyde (1991).
2 Active fault designations from California Department of Conservation SP42.
3 Unrecognized by Alquist-Priolo, but noted by Woodward-Clyde to be an extension of anticlinal folds associated with gently south-west dipping thrust faults (blind thrusts) beneath the folds.
4 Stein, 1992.
5 Southern California Earthquake Data Center: http://www.data.scec.org/fault_index/buena.html, accessed January 2011.
6 Coch, T., 1933
7 Hudson (1965) measured slip rate during the years 1933 – 1952 with the use of stakes set across the fault scarp.
8 Southern California Earthquake Data Center: http://www.data.scec.org/fault_index/garlock.html, accessed January 2011.

EHOF Elk Hills Oil Field
mm/yr millimeters per year
M_W moment magnitude

References

California Department of Conservation, Division of Mines and Geology, 2007. Fault-Rupture Hazard Zones in California: Special Publication 42, 46 p., accessed online at ftp://ftp.consrv.ca.gov/pub/dmg/pubs/sp/Sp42.pdf, January, 2011.

California Department of Conservation, California Geological Survey–Alquist-Priolo Earthquake Fault Maps. Accessed online at http://www.consrv.ca.gov/cgs/rghm/ap/Pages/index.aspx, January, 2011.

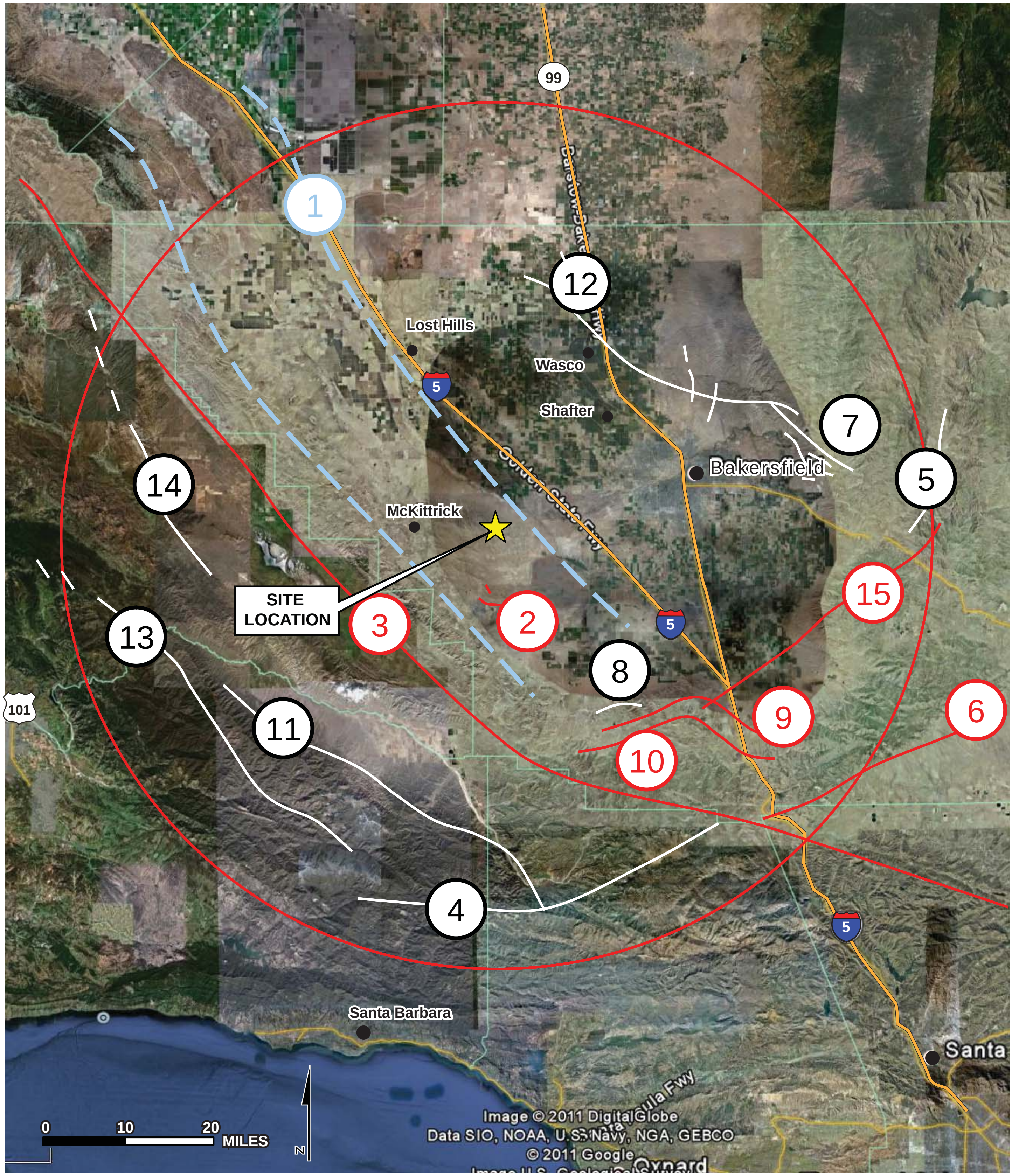
Coch, Thomas, 1933. Analysis and Effects of Current Movement on an Active Fault in Buena Vista Hills in Buena Vista Hills Oil Field, Kern County, California, Bulletin of the American Association of Petroleum Geologists, Vol. 17, No. 6. Accessed online at http://doi.aapg.org/data/bulletns/1931-37/images/pg/00170006/0650/06940.pdf, January, 2011.

Hudson, D.E. and Ronald F Scott, 1965. Fault Motions at the Baldwin Hills Reservoir Site, Bulletin of the Seismological Society of America Vol. 55, No. 1. Accessed online at http://mahabghodss.net/NewBooks/www/web/digital/nashrieh/bssa/1965/February%2055%20(1)/165.pdf, January, 2011.

Jennings, C.W., 1975. Fault map of California with locations of volcanoes, thermal springs, and thermal wells, California Division of Mines and Geology, Geologic Data Map No. 1, scale 1:750,000.

Stein, Ross and Goran Ekstrom, 1992. Seismicity and Geometry of a 110-km Long Blind Thrust Fault. Synthesis of the 1982 – 1985 California Earthquake Sequence, Journal of Geophysical Research, Vol. 97, No. B4. Accessed online at https://profile.usgs.gov/myscience/upload_folder/ci2010Jul021510494296647%20Stein_Ekstrom_JGR%201992.pdf, January, 2011.

Woodward-Clyde Consultants, 1991. Geotechnical and Earthquake Engineering Study.



Map Source: Google Earth Pro (2011); fault traces from Fault Map of California by C.W .Jennings, 1975 and California Geological Survey – Alquist-Priolo Maps (http://www.consrv.ca.gov/cgs/rghm/ap/Pages/index.aspx)

Source:
OEHI, 2011

ACTIVE AND POTENTIALLY ACTIVE FAULTS

February 2011 Hydrogen Energy California (HECA)
28067571 Kern County, California

FIGURE 240-1

2/07/11 vsa..T:\HECA\GRAPHICS\Data Requests\DR Set 4 (219-244)\240-1_active faults.ai

DATA REQUEST

241. Please provide an analysis of the tectonic framework of the anticline and how it fits within the regional tectonic framework proximal to the San Andreas Fault.

RESPONSE

The following excerpt from a recent technical publication by Fiore et al. (2007) presents a tectonic summary of the Elk Hills area. For a list of references cited in the excerpt, please see the article.

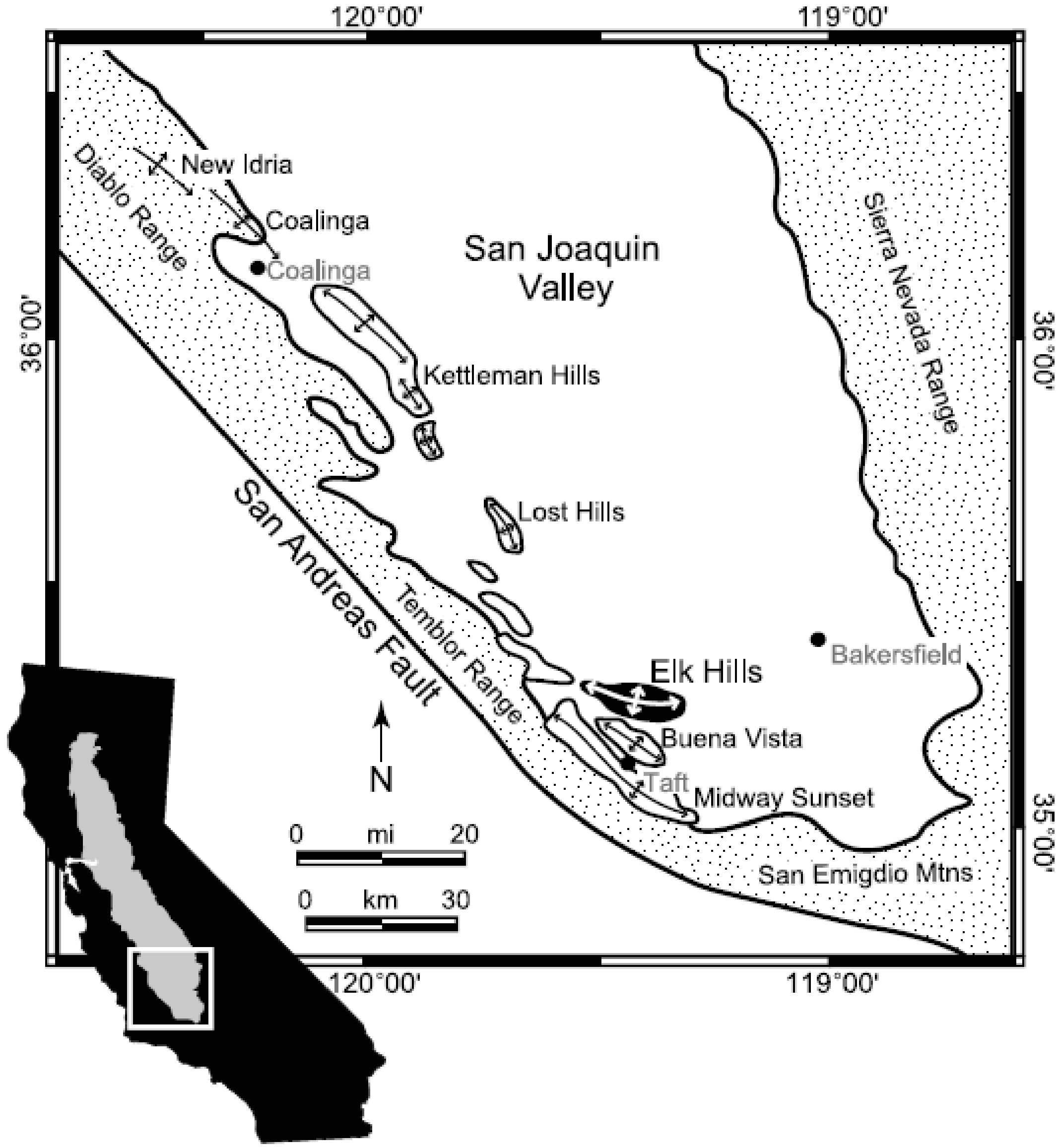
Elk Hills is located 25 kilometers (15.5 miles) north of the bend in the San Andreas fault (Figure 241-1) in the southern San Joaquin Valley within the fold and thrust belt that lines the west side of the valley (Nicholson, 1990). The deformation within this belt is linked to tectonism along the San Andreas fault, which lies just west of the Temblor Range that bounds the western limit of the valley. Coalinga, Kettleman Hills, and Lost Hills are similarly oriented antiforms proximal to Elk Hills.

Interpretation of the causal tectonic mechanism for these folds has varied. In the 1970s,Wilcox et al. (1973) and Harding (1974, 1976) suggested that these en echelon folds are the result of a wrenching mechanism related to slip along the San Andreas fault. In the following decade, interpretation of a seismic reflection profile across Kettleman Hills (Wentworth et al., 1984) led to the reclassification of these anticlines as thrust-related. This interpretation was later strengthened by the analysis of earthquakes near New Idria in 1982 (magnitude [M] = 5.5), Coalinga in 1983 (M = 6.5), and Kettleman Hills North Dome in 1985 (M = 6.1), which indicated the activity of thrust faults striking subparallel to the trend of these folds (e.g., Namson and Davis, 1988; Ekstrom et al., 1992; Stein and Ekstrom, 1992). In situ borehole studies that estimated the regional maximum horizontal compression direction as northeast-southwest (e.g., Mount and Suppe, 1987; Zoback et al., 1987; Castillo and Zoback, 1994), when combined with the northwest-southeast trend of the anticlinal hinges, are also consistent with the thrust-related hypothesis.

In light of these geological and geophysical data, all consistent with a thrust tectonic environment, the analysis of paleomagnetic data collected from Elk Hills and Kettleman Hills (White, 1987) is somewhat enigmatic. These data led to the proposition that the folds formed initially with trends oblique to the San Andreas fault, and were subsequently rotated to their subparallel orientations, with deformation style transitioning from wrench-related shearing to fault-perpendicular shortening (Miller, 1998).

Reference

Fiore, P.E., D.D. Pollard, W.R. Currin and D.M. Miner, 2007, Mechanical and stratigraphic constraints on the evolution of faulting at Elk Hills, California, AAPG Bulletin, v. 91, no. 3, p. 321-341.



Source:
OEHI, 2011

LOCATION OF THE ELK HILLS OIL FIELD IN THE SOUTHWESTERN SAN JOAQUIN VALLEY

February 2011
28067571

Hydrogen Energy California (HECA)
Kern County, California

FIGURE 241-1

DATA REQUEST

242. Please discuss whether other CCS sites that have been tested have been located in active tectonic environments similar to the proposed CO_2 EOR project site.

RESPONSE

OEHI does not have information about other CO_2 injection projects located in active tectonic environments similar to the proposed OEHI CO_2 EOR Project site. Please see the response to Data Request 243 for a discussion of the potential for CO_2 leakage from the OEHI CO_2 EOR Project due to tectonic activity.

DATA REQUEST

243. Please discuss the potential for fault rupture in or near the anticline and leakage of CO_2 from the storage area during the life of CCS from OEHI's CO_2 EOR project.

RESPONSE

A response to this data request has been prepared and submitted under confidential cover.

DATA REQUEST

244. Please discuss the pressures that would be necessary to cause seismic activity and/or fault rupture that could result in failure of the CCS. Please discuss how the project would be designed to stay below the pressures or mitigate conditions that could result in failure of the CCS due to faulting or other geologic fracturing.

RESPONSE

See the response to Data Request 243.

The risk of induced seismicity from CO_2 EOR is very low. A regional seismicity study was conducted in 2008 for the EHOF by Terralog Technologies. The study found: "Injection operations have in fact induced small scale seismicity at a limited number of oil and gas fields around the world, including some in California (most notably the Geysers geothermal operations). While there is no history of induced seismicity at Elk Hills during the many years of water flood and EOR operations, the possibility cannot be completely ruled out. Any such induced seismicity events would likely be less than magnitude 4, considering the geologic setting, areal extent and depth of proposed operations, and anticipated pressure and stress changes. Seismic events on the order of magnitude 3 to 4 would be felt in the local area but should not cause structural damage to facilities and buildings. Peak ground acceleration from such events should be on the order of 0.01g, well within seismic building code standards for the area. This is also at least an order of magnitude smaller than anticipated natural seismicity hazards for the area" (Terralog Technologies USA, Inc., 2008). Because induced seismic events should not cause structural damage, OEHI has reasonably concluded that a release of CO_2 from the subsurface due to induced seismicity is unlikely.

In addition, the Stevens reservoirs' trap integrity has withstood a wide range of seismic activity over a geologic time scale while preserving an oil and gas column of approximately 2,000 feet.

The anticipated reservoir pressures within the Stevens reservoirs post-CO_2 injection are similar to historic operating pressures (±500 psi) and will not be sufficient to activate faults more than 4 miles away from the project area (see the response to Data Request 240).

The lack of faults penetrating through the Reef Ridge shale further preclude any risk of leakage within the OEHI CO_2 project area.

Reference

Terralog Technologies USA, Inc., 2008. Potential for Induced Seismicity From CO_2 Injection Operations at Elk Hills.

BEFORE THE ENERGY RESOURCES CONSERVATION AND DEVELOPMENT COMMISSION OF THE STATE OF CALIFORNIA
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1-800-822-6228 – WWW.ENERGY.CA.GOV

APPLICATION FOR CERTIFICATION FOR THE *HYDROGEN ENERGY CALIFORNIA PROJECT*

Docket No. 08-AFC-8

PROOF OF SERVICE LIST
(Rev. 10/21/10)

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DECLARATION OF SERVICE

I, Dale Shileikis , declare that on February 8 , 2011, I served and filed copies of the attached Responses to CEC Data Requests Set Four: Nos. 291 through 244 , dated February, 2011. The original document, filed with the Docket Unit, is accompanied by a copy of the most recent Proof of Service list, located on the web page for this project at: **[www.energy.ca.gov/sitingcases/hydrogen_energy]**.

The documents have been sent to both the other parties in this proceeding (as shown on the Proof of Service list) and to the Commission's Docket Unit, in the following manner:

(*Check all that Apply*)

FOR SERVICE TO ALL OTHER PARTIES:

________ sent electronically to all email addresses on the Proof of Service list;

________ by personal delivery;

________ By delivering on this date, for mailing with the United States Postal Service with first-class postage thereon fully prepaid, to the name and address of the person served, for mailing that same day in the ordinary course of business; that the envelope was sealed and placed for collection and mailing on that date to those addresses **NOT** marked "email preferred."

AND

FOR FILING WITH THE ENERGY COMMISSION:

X sending an original paper copy and one electronic copy, mailed and emailed respectively, to the address below (***preferred method***);

OR

________ depositing in the mail an original and 12 paper copies, as follows:

CALIFORNIA ENERGY COMMISSION
Attn: Docket No. 08-AFC-8
1516 Ninth Street, MS-4
Sacramento, CA 95814-5512

docket@energy.state.ca.us

I declare under penalty of perjury that the foregoing is true and correct, that I am employed in the county where this mailing occurred, and that I am over the age of 18 years and not a party to the proceeding.

Dale Shileikis (signature)