



**2022 Annual Performance Report:
Model Criteria for Groundwater Monitoring in Areas of Oil
and Gas Well Stimulation**

Reporting Period: January 1, 2022 through December 31, 2022

STATE WATER RESOURCES CONTROL BOARD

March 16, 2023

Table of Contents

1.0	INTRODUCTION	7
1.1	BACKGROUND	7
2.0	AREA-SPECIFIC GROUNDWATER MONITORING	8
2.1	GROUNDWATER MONITORING PLANS	9
2.2	REQUESTS FOR EXCLUSION AND ADDED WELLS.....	10
3.0	PROPERTY-OWNER NOTIFICATIONS AND REQUESTED WATER SAMPLING	11
4.0	ASSESS IMPLEMENTATION COSTS	11
5.0	REGIONAL MONITORING PROGRAM	11
5.1	PUBLISHED REGIONAL MONITORING PROGRAM RESULTS AND FINDINGS- 2022.....	13
6.0	LESSONS LEARNED FROM IMPLEMENTATION OF THE MODEL CRITERIA.....	13
APPENDIX A - WEB LINK GLOSSARY		A-1
APPENDIX B - PERFORMANCE MEASURES		B-1
APPENDIX C - TABLES.....		C-1
APPENDIX D - REGIONAL MONITORING PROGRAM WORK CONDUCTED.....		D-1

GLOSSARY

Area-specific Groundwater Monitoring Plan (GMP) – A groundwater monitoring plan submitted by the oil and gas field operator to characterize baseline water quality conditions and detect potential impacts to protected water from well stimulation treatments. A GMP may be developed for a stimulated well or group of stimulated wells. The GMP should describe the groundwater monitoring design, as well as proposed groundwater sampling and analytical testing.

Addendum: An operator may propose an addendum to a GMP in which additional wells to stimulate in an area would be added to a GMP approved previously by State Water Resources Control Board (State Water Board) and Regional Water Quality Control Board staff (collectively, Water Boards).

Axial Dimensional Stimulation Area (ADSA) – The estimated maximum length, width, height, and azimuth of the area(s) stimulated by a well stimulation treatment (WST) (California Geologic Energy Management Division [CalGEM] Well Stimulation Treatment Regulations, July 1, 2015). CalGEM approves or denies the ADSA as part of the well stimulation permitting process. After approval of the ADSA, a well stimulation permit may be issued to an operator; however, stimulation cannot occur until State Water Board staff has approved either a groundwater monitoring plan or request for exclusion from groundwater monitoring associated with the permitted well(s).

Designated Contractors – State Water Board is required to designate one or more qualified independent third-party contractors to perform property owner requested water quality sampling and testing (Pub. Resources Code, §3160, subdivision (d)(7)(B)). The designated contractor must not work for or be affiliated with an oil and gas operator. A list of approved designated contractors is maintained by the State Water Board.

Exempted aquifer – As defined in 40 Code of Federal Regulations (CFR) part 146.4, an aquifer or a portion thereof which meets the criteria for an underground source of drinking water may be determined to be an “exempted aquifer” if:

- 1) It does not currently serve as a source of drinking water, and
- 2) it cannot now and will not in the future serve as a source of drinking water.

In addition, it must meet the requirements of California Public Resources Code (PRC) 3131(a):

- 1) Criteria set forth in Section 146.4 of Title 40 of the Code of Federal Regulations.
- 2) The injection of fluids will not affect the quality of water that is, or may reasonably be, used for any beneficial use.
- 3) The injected fluid will remain in the aquifer or portion of the aquifer that would be exempted.

Refer to 40 CFR part 146.4 and PRC 3131(a) for regulation specifics.

Groundwater Monitoring – Monitoring of protected water in a specific area to characterize baseline water quality conditions and to assess potential effects to beneficial use waters from well stimulation treatment activities (i.e., monitoring well sampling and gauging of water levels).

Interim Groundwater Monitoring Plan (interim GMP) – GMP approved during the interim period (January 1, 2014 – July 6, 2015) prior to the State Water Board adoption of the Model Criteria for Groundwater Monitoring in Areas of Oil and Gas Well Stimulation.

Model Criteria for Groundwater Monitoring in Areas of Oil and Gas Well Stimulation (Model Criteria) – Outlines the methods to be used for assessment, sampling, analytical testing, and reporting of water quality associated with oil and gas well stimulation treatments. Adopted by the State Water Board July 7, 2015.

Performance Measures – Performance measures are a means to evaluate the effectiveness and efficiency of the Model Criteria. Five (5) goals were developed through a process of meetings with stakeholder groups. Performance measures are included in the *Model Criteria for Groundwater Monitoring in Areas of Well Stimulation: Summary of Goals, Strategies, Proposed Performance Measures, and Plans for Implementation* (March 1, 2016).

Protected Water – Water with less than 10,000 milligrams per liter of total dissolved solids and located outside an exempt aquifer.

Regional Groundwater Monitoring Program (RMP) – As required by Senate Bill 4 (Pavley Statutes of 2013), and detailed in the Model Criteria, the State Water Board is to implement an oil and gas regional groundwater monitoring program in order to protect all waters designated for any beneficial use, while prioritizing the monitoring of groundwater that is or has the potential to be a source of drinking water. Factors considered for the RMP include well stimulation treatments, among other events or activities that have the potential to contaminate groundwater. The U.S. Geological Survey is the technical lead on the RMP.

Request for Exclusion from Area-Specific Groundwater Monitoring– A document submitted by the oil and gas field operator to request exclusion from groundwater monitoring before proceeding with well stimulation activities. State Water Board staff must provide a written concurrence to the operator for the exclusion from groundwater monitoring.

Request to Add Wells to an Existing Exclusion (Added Wells): An operator may submit requests to add wells to stimulate in an existing exclusion area approved previously by Water Boards staff.

Well stimulation treatment (WST) – A treatment procedure for a well to enhance production by increasing the permeability of the formation. WSTs include, but are not limited to, hydraulic fracturing treatments and acid well stimulation treatments.

Submittal Status:

Approved - Submittal was reviewed and has met the requirements of the Model Criteria.

Denied - Submittal did not meet the minimum requirements of the Model Criteria, or conditions of approved submittal have not been implemented and review discontinued by State Water Board.

Cancelled - Submittal was retracted by the operator.

Review in Progress - Submittal is being reviewed by Water Boards staff.

On Hold - Water Boards staff are not currently reviewing the submittal. Submittals may be put "On Hold" for the following reasons:

- Comments have been forwarded to the operator and the operator is working on a revised submittal.
- Water Boards staff are awaiting approval of the Axial Dimensional Stimulation Area (ADSA) from CalGEM.
- The submittal is on hold at the request of the operator.

ABBREVIATIONS AND ACRONYMS

ADSA	Axial Dimensional Stimulation Area
Annual Model Criteria Performance Report	Annual Performance Report: Model Criteria for Groundwater Monitoring in Areas of Oil and Gas Well Stimulation
bbbl	barrel(s) of oil
CalGEM	California Geologic Energy Management Division
CIPA	California Independent Petroleum Association
COGG	United States Geological Survey California Oil, Gas, and Groundwater Program (see RMP)
GeoTracker	GeoTracker Information System
GMP	Area-specific groundwater monitoring plan
GMR	Area-specific groundwater monitoring report associated with GMPs
Model Criteria	Model Criteria for Groundwater Monitoring in Areas of Oil and Gas Well Stimulation
neighbor notification	CalGEM Well Stimulation Treatment Neighbor Notification Form
operator	oil and gas field operator
RMP	Regional Monitoring Program (see COGG)
Regional Water Board	Regional Water Quality Control Board
reporting period	January 1, 2022 - December 31, 2022
State Water Board	State Water Resources Control Board
USGS	United States Geological Survey
Water Boards	State Water Resources Control Board and Regional Water Quality Control Boards
WellSTAR	Well Statewide Tracking and Reporting System
WSPA	Western States Petroleum Association
WST	Well Stimulation Treatment

1.0 INTRODUCTION

This Annual Performance Report summarizes work performed from January 1, 2022 through December 31, 2022 (reporting period) by staff from the State Water Resources Control Board (State Water Board) and associated agencies to implement the *Model Criteria for Groundwater Monitoring in Areas of Oil and Gas Well Stimulation* (Model Criteria).

State Water Board staff developed the Model Criteria to guide the process for assessing potential effects of well stimulation treatments (WSTs) on California's groundwater resources. It outlines groundwater monitoring requirements for area-specific groundwater monitoring conducted by oil and gas operators (operators), as well as the approach State Water Board staff will take to conduct a Regional Monitoring Program (RMP).

A WST cannot be performed until staff from the California Department of Conservation, California Geologic Energy Management Division (CalGEM) issues a WST permit and the State Water Board and the appropriate Regional Water Quality Control Board (collectively, Water Boards) staff have:

- approved an operator-submitted groundwater monitoring plan (GMP), or
- approved an operator-submitted request for exclusion from groundwater monitoring.

If the operator proposes WST for additional wells in an area where a GMP or exclusion was previously approved, an addendum to the GMP (addendum) or a request to add wells to an existing exclusion is required.

The requirement for a GMP is limited to areas where protected water is present. Protected water is defined as:

- Water with less than 10,000 milligrams per liter (mg/L) of total dissolved solids
- Located outside of an exempt aquifer

Efforts performed by State Water Board staff for implementation of the Model Criteria during the reporting period are presented in six sections of this report. Please note that URLs for hyperlinks can be found in the Web Link Glossary (Appendix A).

1.1 Background

Senate Bill 4 (Pavley, Statutes of 2013) required the State Water Board to establish and implement a comprehensive regulatory groundwater monitoring and oversight program for WSTs (including hydraulic fracturing) in areas of oil and gas operations (California Water Code section 10783). The State Water Board was also required to develop a "model criteria" for groundwater monitoring to assess potential effects of WSTs on California's groundwater resources. The Model Criteria was adopted by the State Water Board on July 7, 2015 (*Resolution No. 2015-0047*) and outlines requirements for groundwater monitoring conducted by operators, as well as the approach the State Water Board will take to conduct the RMP.

Prior to adoption of the Model Criteria, CalGEM developed *SB 4 Interim Well Stimulation Treatment Regulations* which included groundwater monitoring requirements. The interim regulations were effective from January 1, 2014 to June 30, 2015 and required operators to

submit either an approved groundwater monitoring plan (interim GMP) or a letter from State Water Board staff concurring that the well(s) planned for WST did not penetrate protected water. If no new WSTs were planned in an area with an approved interim GMP, the operator continued monitoring under the interim GMP. Several interim and Model Criteria GMPs were active during this reporting period. Data from both are uploaded to the State Water Board's GeoTracker information system (*GeoTracker*).

The State Water Board's *Model Criteria for Groundwater Monitoring in Areas of Well Stimulation: Summary of Goals, Strategies, Proposed Performance Measures, and Plans for Implementation* (Performance Measures) specifies that the State Water Board prepare and make publicly available an "Annual Model Criteria Performance Report" with the following five performance measures:

1. Provide transparent and availability of online information and documentation
2. Provide clear milestones and timely deliverables
3. Understand and mitigate impacts of well stimulation on water quality and public health
4. Provide region-specific or localized flexibility, where possible
5. Assess implementation costs

The original performance measures (Appendix B) were presented to the State Water Board on March 1, 2016 and included goals, strategies, and plans for implementing the Model Criteria.

2.0 AREA-SPECIFIC GROUNDWATER MONITORING

CalGEM issued permits are required prior to performing WSTs. The number and status of WST permits can be found on the CalGEM Well Statewide Tracking and Reporting System (*WellSTAR*). Effective December 17, 2019, the public can use WellSTAR to find information about WST permits and disclosures.

A GMP is required where protected water is present. If the operator proposes WST for additional wells in an area where a GMP is approved, then an addendum to the GMP is required. A GMP is not required where an operator can make a technical demonstration that the wells to be stimulated do not penetrate protected water. Process flowcharts for Water Boards staff review of operator submittals can be found on the *Additional Resources* webpage. A summary table of the 2022 submittals and review timelines is provided below.

Operators are required to submit data from groundwater monitoring wells sampled as part of GMPs to GeoTracker as Groundwater Monitoring Reports (GMRs). Water Boards staff review GMRs and provide comments to operators via comment letters that are also archived in GeoTracker.

2022 Summary Table: Submittals and Review Timeline Milestones

Type of Submittal	Approved	Denied	Review in Progress / On Hold	Cancelled	Total	Average Review Time (days)	Total No. of Approved WST Wells
GMPs	0	5	0	0	5	190	--
Addenda	0	3	0	0	3	141	--
Requests for Exclusions	0	1	1	0	2	51	--
Requests to Add Wells to an Existing Exclusion	0	1	0	0	1	9	--
<i>Note – Approved requests for exclusion do not include specific WST wells</i>							

2.1 Groundwater Monitoring Plans

Water Boards staff did not receive any new GMPs or addenda during the reporting period. Eight GMPs and addenda received in previous reporting periods were denied during this reporting period. The eight GMPs and addenda were denied for either: not fully implementing conditions of its previous Water Boards approval, the project status remained idle or on hold more than one year, or CalGEM denied the corresponding WST permit(s) that was affiliated with a previously approved submittal. Water Boards staff denied the submittals in GeoTracker and provided operators with a denial letter discussing project status and resubmittal requirements. The status and review timeline milestones for denied GMPs and addenda are summarized in Appendix C - Tables 1 and 2. The locations of approved and denied GMPs and addenda are shown in Figure 1. All GMPs and addenda reviewed were in the following counties and oil fields:

- Kern County – Lost Hills, South Belridge, Rhythm (Area), Terrebonne (Area), and Buena Vista (Nose Area).
- Kings County – Kettleman North Dome

Process and Timeline for Reviewing Groundwater Monitoring Plans

Water Boards staff standard review process when reviewing new submittals is to conduct a completeness check to verify all required information is included when a GMP or addendum has been uploaded to GeoTracker. Water Boards staff develop comments to obtain additional information from the operator. If Water Boards staff provide comments or deny a GMP and the operator chooses to pursue WST, the operator is required to submit a revised GMP or addendum. The Axial Dimensional Stimulation Area (ADSA) must be approved by CalGEM before a GMP or addendum can be approved. When submittals are placed “On Hold”, that time is not included in the calculation of total review time. State Water Board staff did not receive any new GMPs or addenda during the reporting period.

Groundwater Monitoring Plans Submitted that Propose Alternative Methods

The Model Criteria allows Water Boards staff to consider proposed alternatives and modifications to the methods for GMPs based on factors such as site-specific conditions (e.g., terrain, geology, access), number and depth of aquifers containing protected water, potential pathways, and risk to receptors (e.g., groundwater resources). Water Boards staff shall provide at least 15 days' notice and an opportunity for public comment on the proposal prior to approving a proposed alternative or modification. State Water Board staff did not receive an alternative proposal for groundwater monitoring during the reporting period.

2.2 Requests for Exclusion and Added Wells

Water Boards staff may grant an exclusion from groundwater monitoring requirements if staff concur with the absence of protected water. Operators must obtain approval for additional WST wells to be stimulated in an existing exclusion from groundwater monitoring. During this reporting period, Water Boards staff are currently reviewing one request for exclusion. No requests to add wells to an existing exclusion (added wells) were submitted.

Review of one request for exclusion and one added wells, received in previous reporting periods, were discontinued and the submittals were denied during this reporting period. Water Boards staff discontinued review of the request for exclusion because CalGEM denied the corresponding WST permit. The added wells submittal was denied due to the project's idle status for more than one year. Water Boards staff denied the submittals in GeoTracker and provided operators with a denial letter discussing project status and resubmittal requirements. The status and review timeline milestones for exclusions and added wells submittals denied or under review are summarized in Appendix C - Tables 3 and 4. The locations of approved, under review, and denied requests for exclusions are shown in Figure 2. All requests for exclusion and added wells reviewed were in the following county and oil fields:

- Kern County – North Belridge, South Belridge, and McKittrick

Process and Timeline for Reviewing Requests for Exclusion

Water Boards staff standard review process when reviewing new submittals is to conduct a completeness check to verify all required information is included when a request for exclusion or added wells has been uploaded to GeoTracker. If necessary, comments are developed to obtain additional information from the operator. After staff have completed their review, the request for exclusion is either approved or denied. When submittals are placed "On Hold", that time is not included in the calculation of total review time. Request for exclusion approval does not depend on CalGEM approving an ADSA but is based solely on whether sufficient technical information was submitted to clearly demonstrate the absence of protected water. The time for Water Boards staff to review requests for exclusion and added wells submittals during the reporting period is summarized in Appendix C - Tables 3 and 4.

3.0 PROPERTY-OWNER NOTIFICATIONS AND REQUESTED WATER SAMPLING

Operators are required to use an independent third-party to notify property owners, or tenants of a property, located within 1,500 feet of the well to be stimulated or within 500 feet of the surface representation of the horizontal path of the area of stimulation. CalGEM is responsible for maintaining records regarding the third-party notification process. The third-party sends the property owners or tenants a Well Stimulation Treatment Neighbor Notification Form (neighbor notification), which includes information such as the earliest date the well may be stimulated and how the property owner may request water quality testing on an existing water well or surface water suitable for drinking. Additional information regarding this process can be found on the [CalGEM Well Stimulation Treatment Neighbor Notification and Water Sampling](#) webpage. As of October 29, 2019, neighbor notification forms must be submitted through the WellSTAR electronic database. CalGEM staff provided to Water Boards staff the count of neighbor notifications sent to property owners. Historical notification counts are found in Appendix C - Table 5. No neighbor notifications were sent during this reporting period.

State Water Board staff maintain a [List of Designated Contractors for Water Sampling](#) (designated contractor) to perform property owner requested water quality sampling. Once a property owner receives a notification regarding WST from an operator, the property owner may choose a designated contractor to perform water quality sampling. Designated contractors are required to notify State Water Board staff prior to sampling and upload the results to GeoTracker after analysis. State Water Board staff did not receive any notifications of water sampling requests during this reporting period.

4.0 ASSESS IMPLEMENTATION COSTS

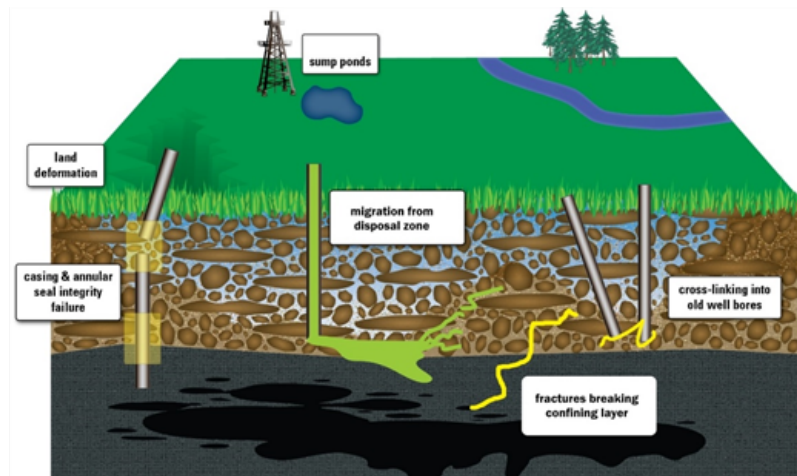
State Water Board staff, in cooperation with operators and representatives from California Independent Petroleum Association (CIPA) and Western States Petroleum Association (WSPA), developed a list of information needed to assess operator costs. CIPA, in collaboration with WSPA, used a third-party aggregator to collect and report estimated operator costs associated with the implementation of the Model Criteria. During the reporting period, estimated cost for operators to perform tasks associated with area-specific monitoring was \$420,238. These costs are described in detail in Appendix C - Table 6.

Water Boards have a total of 14 staff positions dedicated to WST activities budgeted at \$2.45 million per year and the RMP has a budget of \$7.4 million per year. Both are funded through the Oil, Gas, and Geothermal Administrative Fund.

5.0 REGIONAL MONITORING PROGRAM

The goal of the RMP is to evaluate potential impacts from WST and oil field operations, and to characterize the risk to water designated for any beneficial use (e.g., drinking water). The RMP evaluates pathways (see illustration below) by determining which WSTs and other oil and gas operations have the potential to contaminate groundwater. Potential pathways include the injection of water and/or steam during enhanced oil recovery practices, oilfield water disposal

via injection, leakage along improperly constructed and/or compromised wells, surface disposal ponds, or natural geologic sources.



Potential Pathways between Oil & Gas Activities and Protected Groundwater
 (Source: USGS, <https://ca.water.usgs.gov/projects/oil-gas-groundwater/science/pathways/>)

The United States Geological Survey (USGS) is the technical lead of the RMP, which the USGS refers to as the California Oil, Gas, and Groundwater (COGG) Program. The approach used by the USGS includes mapping groundwater salinity, characterizing and monitoring groundwater near oil fields, and characterizing oilfield fluids. Together, with site-specific information about the local geology, hydrology, and historic disposal areas, this approach helps to systematically and comprehensively collect and interpret information that will help support the protection of beneficial use water in California.

USGS and Water Boards staff select study areas using results from the prioritization analysis (*Davis and others, 2018*). Well depth, water chemistry, geophysical, geologic, and oilfield operational data were compiled by USGS into numerical databases for use in the regional analyses. Appendix D presents a summary of work conducted for each of these major tasks:

1. Salinity mapping
2. Groundwater sampling
3. Oilfield fluid sampling
4. Interpretative analysis of the collected data from tasks 1 through 3 in selected fields.

During the reporting period, the USGS identified suitable locations of groundwater wells, oil production wells, and injectate sites that met water and fluid sample criteria for the RMP. Once the well locations were determined, the USGS worked with operators to obtain access to collect samples. Samples collected include 81 water supply and monitoring wells in six study areas and 18 oilfield fluid sample sites in one study area (Appendix D). State Water Board staff hosted an Oil and Gas Groundwater Monitoring Update on December 15, 2022, where USGS presented a summary of activities and findings. This program update was available to the public and provided an opportunity to submit questions regarding newly published work from the reporting period.

5.1 Published Regional Monitoring Program Results and Findings-2022

In 2022, the RMP completed groundwater salinity mapping studies and a groundwater quality assessment near areas of oil and gas operations. Complete references to USGS publications are available on the [State Water Board RMP webpage](#). The observations below summarize results from publications in 2022.

- Flowers et al., 2022 “*Geologic controls on groundwater salinity reversal in North Coles Levee Oil Field, southern San Joaquin Valley, California, USA*”
 - Salinity was mapped using groundwater quality data and borehole geophysical logs. Results show a salinity inversion is present, where higher salinity overlies lower salinity, and is likely due to the original depositional environment.
- Anders et al., 2022 “*Occurrence of water and thermogenic gas from oil-bearing formations in groundwater near the Orcutt Oil Field, California, USA*”
 - Please see the [Anders et al. article summary](#) for key findings from the study.
- Gillespie et al., 2022 “*Mapping aquifer salinity gradients and effects of oil field produced water disposal using geophysical logs: Elk Hills, Buena Vista, and Coles Levee Oil Fields, San Joaquin Valley, California*”
 - Please see the [Gillespie et al. article summary](#) for key findings from the study.
- Zamudio et al., 2022. “*Airborne electromagnetic survey results near the Poso Creek oil field, San Joaquin Valley, California, fall 2016: U.S. Geological Survey Data Report 1155*”
 - Airborne electromagnetic surveys near the Poso Creek Oil Field show resistivity models largely represent changes in lithology in this area with small variations due to changes in salinity.

6.0 LESSONS LEARNED FROM IMPLEMENTATION OF THE MODEL CRITERIA

A summary of opportunities identified by ongoing program evaluation based on performance measures is provided below with highlights of actions completed in 2022 and actions planned for 2023:

- Provide transparent and available information online:
 - New groundwater monitoring data was uploaded to GeoTracker and updates were made to the State Water Board Oil and Gas program webpage to include recent USGS publications. A new symbol was added to the GeoTracker Map to visually display operator submittals that were denied by Water Board staff.
 - In 2023, State Water Board staff will continue to evaluate opportunities to improve data visualizations and data sharing strategies within GeoTracker and on the State Water Board Oil and Gas program webpage.
- Provide clear milestones and timely deliverables:
 - Water Boards staff met with operators to discuss new operator submittals and provide feedback on submittal criteria and processes to expedite review. State

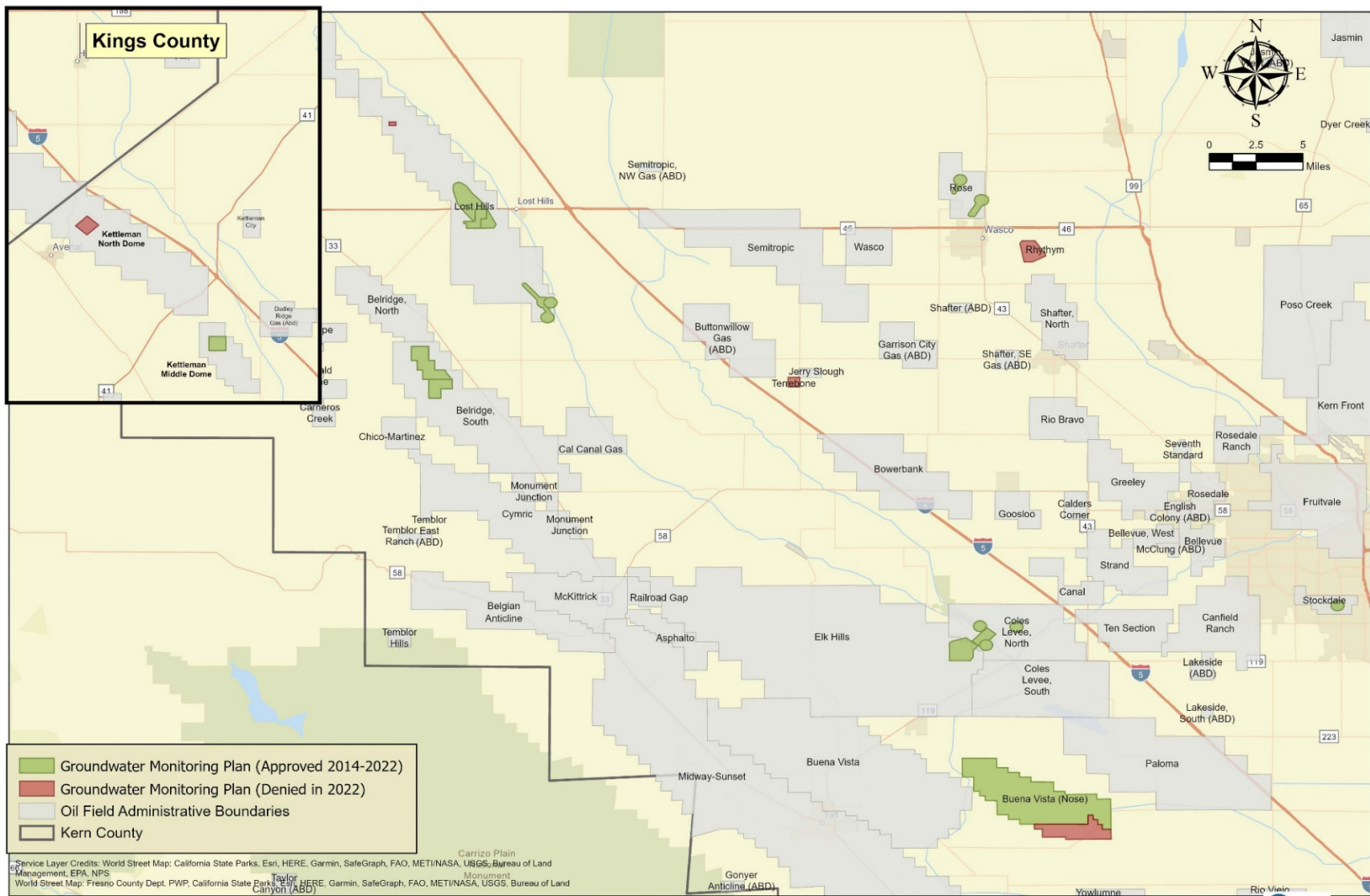
Water Board staff coordinated with Regional Board staff monthly to streamline and prioritize operator submittals. Additionally, State Water Board staff denied operator submittals that remained inactive for extended periods of time, as explained in Section 2.1 and 2.2.

- In 2023, State Water Board staff will continue evaluating opportunities to increase review efficiency.
- Understand and mitigate impacts of well stimulation on water quality and public health:
 - State Water Board staff hosted an Oil and Gas Groundwater Monitoring Update on RMP activities and facilitated kick off meetings with the USGS and operators prior to RMP sampling. Additionally, State Water Board staff sent GMR review comments to operators to ensure Model Criteria compliance.
 - In 2023, an Oil and Gas Groundwater Monitoring Update will be held and made available to the public to present technical findings following RMP publications.
- Provide region-specific or localized flexibility:
 - State Water Board staff received no alternative proposals for groundwater monitoring during the reporting period.
- Assess implementation costs:
 - State Water Board staff will continue to identify and assess implementation costs.

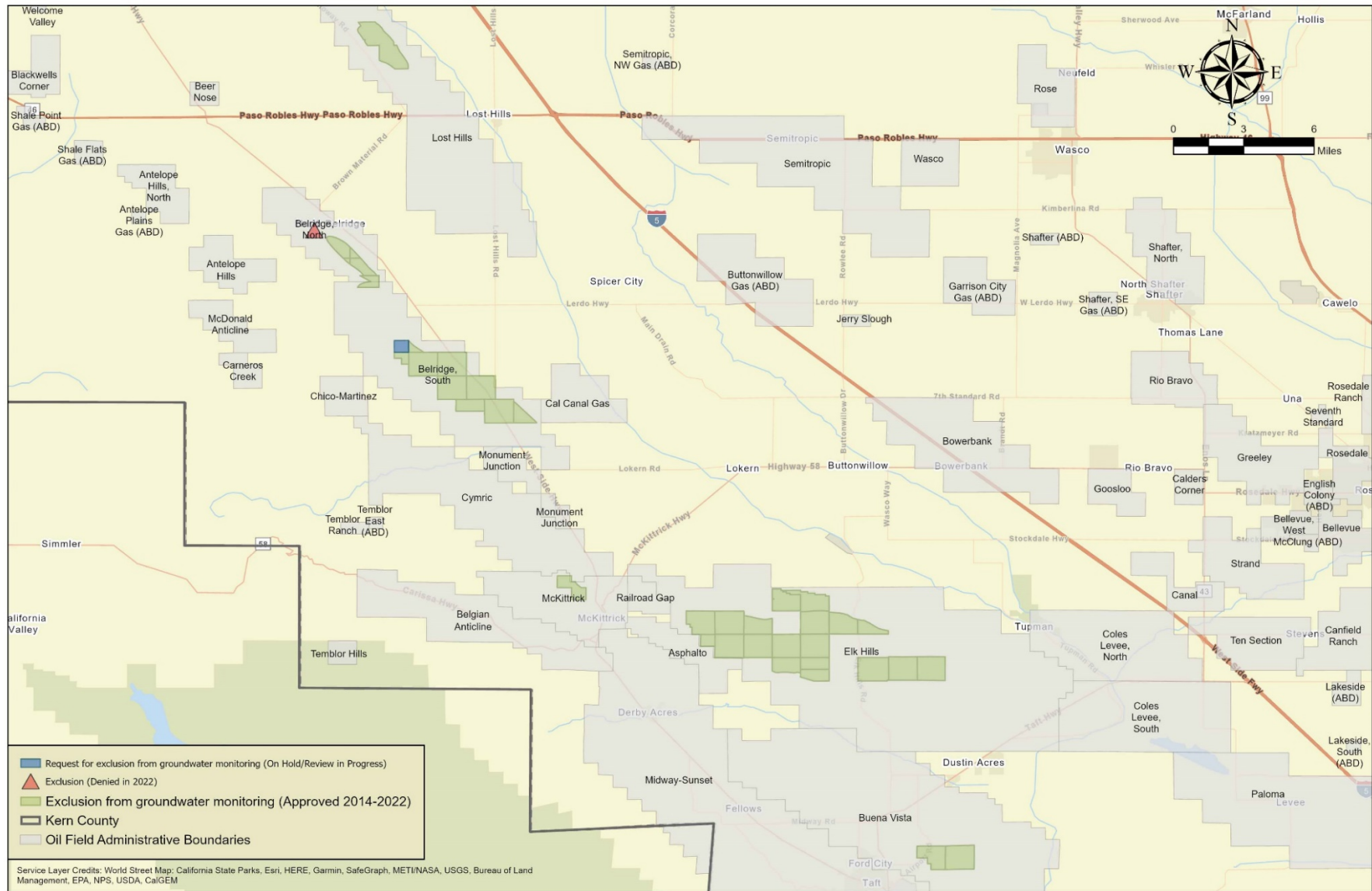
FIGURES

FIGURE 1 GROUNDWATER MONITORING PLANS (JANUARY 1, 2022 - DECEMBER 31, 2022)

FIGURE 2 REQUESTS FOR EXCLUSION FROM GROUNDWATER MONITORING (JANUARY 1, 2022 - DECEMBER 31, 2022)



**Figure 1. Groundwater Monitoring Plans
(January 1, 2022- December 31, 2022)**



**Figure 2. Requests for Exclusion from Groundwater Monitoring
(January 1, 2022- December 31, 2022)**

Appendix A - WEB LINK GLOSSARY

Link Text	URL Address	Section
Model Criteria for Groundwater Monitoring in Areas of Oil and Gas Well Stimulation	https://www.waterboards.ca.gov/water_issues/programs/groundwater/sb4/well_stimulation/index.shtml	1
40 Code of Federal Regulations (CFR) part 146.4	https://www.waterboards.ca.gov/rwqcb3/board_info/agendas/2017/january/item9/item9_att1.pdf	1
Resolution No. 2015-0047	https://www.waterboards.ca.gov/board_decisions/adopted_orders/resolutions/2015/rs2015_0047.pdf	1
SB4 Interim Well Stimulation Treatment Regulations	https://www.conservation.ca.gov/index/Pages/prpsregs.aspx	1
GeoTracker	https://geotracker.waterboards.ca.gov/	1
Model Criteria for Groundwater Monitoring in Areas of Well Stimulation: Summary of Goals, Strategies, Proposed Performance Measures, and Plans for Implementation	https://www.waterboards.ca.gov/water_issues/programs/groundwater/sb4/performance_measures/index.shtml	1
WellStar	https://wellstar-public.conservation.ca.gov/	2
Additional Resources	https://www.waterboards.ca.gov/water_issues/programs/groundwater/sb4/additional_resources/	2
CalGEM Well Stimulation Treatment Neighbor Notification and Water Sampling	https://www.conservation.ca.gov/calgem/Pages/WSTNeighborNotificationAndWaterSampling.aspx	3
List of Designated Contractors for Water Sampling	https://www.waterboards.ca.gov/water_issues/programs/groundwater/sb4/docs/list_of_designated_contractors_sept_2019.pdf	3
Davis and others, 2018	https://pubs.er.usgs.gov/publication/sir20185065	5
State Water Board RMP webpage	https://www.waterboards.ca.gov/water_issues/programs/groundwater/sb4/regional_monitoring/	5
Geologic controls on groundwater salinity reversal in North Coles Levee Oil Field, southern San Joaquin Valley, California, USA”	https://doi.org/10.1007/s12665-022-10362-4	5
Occurrence of water and thermogenic gas from oil-bearing formations in groundwater near the Orcutt Oil Field, California, USA	https://doi.org/10.1016/j.ejrh.2022.101065	5
5Anders et al. article summary	https://www.waterboards.ca.gov/water_issues/programs/groundwater/sb4/regional_monitoring/docs/2022/orcutt-gw-quality-article-summary.pdf	5

2022 Annual Model Criteria Performance Report

Mapping aquifer salinity gradients and effects of oil field produced water disposal using geophysical logs: Elk Hills, Buena Vista, and Coles Levee Oil Fields, San Joaquin Valley, California	https://doi.org/10.1371/journal.pone.0263477	5
Gillespie et al. article summary	https://www.waterboards.ca.gov/water_issues/programs/groundwater/sb4/regional_monitoring/docs/elk-hills-salinity-article-summary.pdf	5
Airborne electromagnetic survey results near the Poso Creek oil field, San Joaquin Valley, California, fall 2016: U.S. Geological Survey Data Report 1155	https://pubs.er.usgs.gov/publication/dr1155	5

Appendix B - PERFORMANCE MEASURES

Goals	Strategy
<p>Goal #1: Transparency and availability of online information and documentation.</p>	<p>1.1 Improve and expand upon available datasets and the ability to analyze and manipulate that data.</p>
	<p>1.2 Improve online user experience with simplified and clear messaging to make data easier to access.</p>
	<p>1.3 Create data communication/sharing strategy to optimize data and information sharing between the State Water Board, Regional Water Boards, CalGEM, and other agencies, as appropriate.</p>
<p>Goal #2: Provide clear milestones and timely deliverables.</p>	<p>2.1 Make milestones and deliverables outlined in the Model Criteria and Senate Bill 4 (Chapter 313, Statutes of 2013, including Water Code section 10783), publicly available.</p>
	<p>2.2 Prepare review processes, flowcharts, and timelines for reviewing GMPs and requests for exclusion from groundwater monitoring, including interagency collaboration and program efficiencies.</p>
<p>Goal #3: Understand and mitigate impacts of well stimulation on water quality and public health.</p>	<p>3.1 Provide regular assessments of monitoring data, including pilot study results and identification of any chemicals of concern.</p>
	<p>3.2 Mitigate problems as they occur and share mitigation efforts with stakeholders.</p>
	<p>3.3 Develop a plan to re-evaluate the effectiveness of monitoring. Modify the scope of work and approach based on evaluation of the data collected and evaluated.</p>
	<p>3.4 Coordinate with other agencies to identify risk.</p>
<p>Goal #4: Provide region-specific or localized flexibility where possible.</p>	<p>4.1 Consider local conditions when reviewing groundwater plans.</p>
	<p>4.2 Clearly communicate why region-specific activities are occurring.</p>
	<p>4.3 Use consistent flexibility criteria for monitoring.</p>
<p>Goal #5: Assess implementation costs.</p>	<p>5.1 Assess implementation cost for the State Water Board and stakeholders.</p>

Appendix C - TABLES

LIST OF TABLES

Table 1	Groundwater Monitoring Plans Reviewed (January 1, 2022 – December 31, 2022)
Table 2	Groundwater Monitoring Plans (addenda) Reviewed (January 1, 2022 - December 31, 2022)
Table 3	Requests for Exclusion Reviewed (January 1, 2022 - December 31, 2022)
Table 4	Requests for Exclusion (added wells) Reviewed (January 1, 2022 - December 31, 2022)
Table 5	Number of Neighbor Notifications sent by Operators
Table 6	Estimated Operator Costs Provided by CIPA and WSPA

Notes and Acronyms for all tables:

-- = not applicable

ADSA = Axial Dimension Stimulation Area

CalGEM = California Geologic Energy Management Division – Department of Conservation

GMP = Groundwater Monitoring Plan

WST = Well Stimulation Treatment

Bbl = Barrel(s) of oil

1. Located in Kern County, unless otherwise noted.
2. Date of Revised Plan submission to GeoTracker or other action by Operator.
3. On Hold indicates that Water Boards staff are waiting on additional information from the operator, waiting for the approved ADSA from CalGEM, or the submittal has been placed On Hold at the request of the operator.
4. Days to complete the process equates to the elapsed time between the "GMP Date Accepted" to "Status/Determination Date". For GMPs (new and addenda) with multiple revisions, days to complete the process equates to the sum of days to review the original submittal and the days to review each of the revisions. This time includes communications with the operator, Regional Water Board staff, and CalGEM, review of data and the submittal, and preparation and review of agency correspondence. Refer to the Process Flowchart for Uploading and Reviewing GMPs (new or addenda) on the Additional Resources webpage for the detailed flowchart of the GMP review process.
5. Days to complete the process equates to the elapsed time between the "Request for Exclusion Accepted Date" to "Status/Determination Date". For Requests for Exclusions with multiple revisions, days to complete the process equates to the sum of days to review the original submittal and the days to review each of the revisions. This time includes communications with the operator, Regional Water Board staff, and CalGEM, review of data and the submittal, and preparation and review of agency correspondence. Refer to the Process Flowchart for Reviewing Requests for Exclusion from Groundwater Monitoring on the Additional Resources webpage for the detailed flowchart of the Exclusions from Groundwater Monitoring review process.
6. Days to complete the process equates to the elapsed time between the "Date Accepted Request for Exclusion (added wells)" to "Status/Determination Date". For Request for Exclusion (added wells) with multiple revisions, days to complete the process equates to the sum of days to review the original submittal and the days to review each of the revisions. This time includes communications with the operator, Regional Water Board staff, and CalGEM, review of data and the submittal, and preparation and review of agency correspondence. Refer to the Process Flowchart for Reviewing Well Stimulation Permit Applications on the Additional Resources webpage for the detailed flowchart of the Exclusions from Groundwater Monitoring review process.
7. Reporting period equal to 2.5 years
8. "Production from wells with GW Monitoring (bbl)" = Operators provided 2022 production data for wells stimulated between 2016 and 2021 that required groundwater monitoring. Previous years data only aggregated production for wells stimulated that year.

Table 1: Groundwater Monitoring Plans Reviewed (January 1, 2022 – December 31, 2022)

GeoTracker Global Identification	Oil Field or (Area)	Township (T), Range (R), Section (S) ¹	Operator	GMP Date Accepted	New or Addendum GMP	Days for Initial Response	Interim Review Actions (GeoTracker Submittal Date(s)) ²	Status/ Determination ³	Number of WST Wells Approved	Status/ Determination Date	Days to Complete Process ⁴	Comments
GAOG10011823	Kettleman North Dome	T22S, R17E, S11 (Kings County)	California Resources Corporation	7/23/2018	New	85	Operator submitted a revised GMP (2/11/2019) Operator placed the project on hold (4/9/2019)	Denied	--	4/15/2022	85	Water Boards staff sent comment letter on 10/16/2018. Water Board staff accepted revised GMP on 2/11/2019. Water Boards review complete on 2/22/2019, but issuance of approval on hold without receipt of ADSA narrative. Operator placed the project on hold on 4/9/2019. CalGEM denied the associated WST well permits on 8/3/2021. Water Boards staff denied the GMP on 4/15/2022.
GAOG10011238	(Terrebonne)	T28S, R23E, S 22	California Resources Corporation	10/20/2016	New	140	Operator submitted a revised GMP (8/7/2017) Operator submitted a sentry well installation work plan (3/6/2020) Operator submitted a revised sentry well installation work plan (7/8/2020)	Denied	--	4/15/2022	355	Water Board staff sent comment letter on 3/9/2017. Water Board staff conditionally approved of GMP on 11/24/2017. Sentry well installation work plan on 3/6/2020. Water Boards staff sent comments via email on 5/20/2020. Operator submitted a revised sentry well installation work plan on 7/8/2020. CalGEM denied the associated WST well permit on 8/3/2021. Water Board staff denied the GMP on 4/15/2022.

GeoTracker Global Identification	Oil Field or (Area)	Township (T), Range (R), Section (S) ¹	Operator	GMP Date Accepted	New or Addendum GMP	Days for Initial Response	Interim Review Actions (GeoTracker Submittal Date(s)) ²	Status/ Determination ³	Number of WST Wells Approved	Status/ Determination Date	Days to Complete Process ⁴	Comments
GAOG10011556	Lost Hills	T26S, R20E, S11	California Resources Corporation	4/19/2018	New	92	Operator submitted a revised GMP (9/12/2018) Operator submitted a revised GMP (1/31/2019)	Denied	--	4/15/2022	252	Water Board staff sent comment letter on 7/20/2018. Water Board staff accepted revised GMP on 9/12/2018. Water Board staff sent comment letter on 12/3/2018. Water Board staff accepted revised GMP on 1/31/2019. Water Boards staff review complete on 3/14/2019, but issuance of approval on hold without receipt of ADSA narrative. Water Boards staff conditionally approved (9/25/2019) CalGEM denied the associated WST well permits on 8/3/2021. Water Boards staff denied submittal on 4/15/2022.
GAOG10011753	(Rhythm)	T27S, R25E, S8, S9, S16, S17	California Resources Corporation	4/18/2019	New	47	Operator submitted a revised GMP (8/20/2018) Operator submitted a revised GMP (4/18/2019)	Denied	--	4/15/2022	203	Water Board staff sent comments via email on 8/7/2018. Operator submitted a revised GMP on 8/20/2018. Water Board staff sent comments via email on 10/8/2018. Operator submitted a revised GMP on 4/18/2019. Water Boards staff conditionally approved GMP on 7/30/2019. CalGEM denied the associated WST well permits on 8/3/2021. Water Boards staff denied submittal on 4/15/2022.
GAOG10009209	Buena Vista (Nose)	T32S, R25E, S13-16 T31S, R25E, S22-24	California Resources Corporation	9/13/2018	New	56	--	Denied	--	4/15/2022	56	Water Board staff sent comments requesting additional information on 11/8/2018. Water Boards staff denied submittal on 4/15/2022.

Table 2: Groundwater Monitoring Plans (addenda) Reviewed (January 1, 2022 - December 31, 2022)

GeoTracker Global Identification	Oil Field or (Area)	Township (T), Range (R), Section (S) ¹	Operator	GMP Date Accepted	New or Addendum GMP	Days for Initial Response	Interim Review Actions (GeoTracker Submittal Date(s)) ²	Status/ Determination ³	Number of WST Wells Approved	Status/ Determination Date	Days to Complete Process ⁴	Comments
GAOG10010391	Lost Hills	T26S, R21E, S29, S32, S33, T27S, R21E, S4, S5	Chevron USA, Inc	6/18/2019	Addendum	74	--	Denied	--	6/7/2022	74	Water Boards staff informed the operator of the completion of addendum review but could not issue approval without receipt of the CalGEM ADSA on 8/20/2019. CalGEM denied the associated WST well permits on 10/27/2020. Water Boards staff denied the addendum on 6/7/2022.
GAOG10010391	Lost Hills	T26S, R21E, S29, S32, S33, and T27S, R21E, S4, S5	Chevron USA, Inc	6/8/2020	Addendum	67	Operator submitted a revised Addendum (2/26/2021)	Denied	--	6/7/2022	116	Water Board staff provided comments to operator by email on 8/14/2020. Revised addendum uploaded to GeoTracker on 2/26/2021. Water Board staff contacted CalGEM regarding the status of the associated WST package on 4/16/2021, and CalGEM response indicated the WST Package requires operator to submit CEQA documentation. Water Board staff denied addendum on 6/7/2022.
GAOG10009277	Belridge, South	T28S, R20E, S12, S13, T28S, R21E, S18	Aera Energy LLC	7/8/2019	Addendum	--	--	Denied	--	4/15/2022	232	Addendum was under Water Board staff review but could not be completed without receipt of ADSA narrative. CalGEM denied the associated WST well permits on 6/11/2021. Water Board staff denied the GMP on 4/15/2022.

Table 3: Requests for Exclusion Reviewed (January 1, 2022 - December 31, 2022)

GeoTracker Global Identification	Oil Field or (Area)	Township (T), Range (R), Section (S) ¹	Operator	Request for Exclusion Accepted Date	Days for Initial Response	Interim Review Actions (GeoTracker Submittal Date(s)) ²	Status/ Determination ³	Number of WST Wells Approved	Status/ Determination Date	Days to Complete Process ⁵	Comments
GAOG10012394	Belridge, North	T27S, R20E, SE 1/4 of S27	Aera Energy LLC	12/12/2018	51	-	Denied	--	5/19/2022	51	Water Boards staff and CalGEM reviewed the exempt status of the Mclure Shale unit and sent comment letter on 2/1/2019. Water Boards staff review is on hold due to information deficiencies in operator provided documentation. Water Boards staff denied the request for exclusion on 5/19/2022 due to submittals prolonged idle status.
GAOG10018584	Belridge, South	T28S, R21E, S19	Aera Energy LLC	2/17/2022	62	Operator submitted a revised Exclusion (7/26/2022)	Review in Progress	--	--	--	Water Boards staff provided comments to Operator on Exclusion (4/20/2022). Revised Exclusion submitted on 7/26/2022.

Table 4: Requests for Exclusion (added wells) Reviewed (January 1, 2022 - December 31, 2022)

GeoTracker Global Identification	Oil Field or (Area)	Township (T), Range (R), Section (S) ¹	Operator	Date Accepted Request of Additional WST Wells	Days for Initial Response	Status/ Determination ³	Number of WST Wells added to Approved Exclusion	Status/ Determination Date	Days to Complete Process ⁶
GAOG10011060	McKittrick	T30S, R22E, S7,8,9,16,17,18	Chevron USA, Inc	10/31/2017	9	Denied	--	4/15/2022	9

Table 5: Number of Neighbor Notifications sent by Operators

Operator	2014	2015	2016	2017	2018	2019	2020	2021	2022
Aera Energy, LLC	818	960	29	138	250	233	73	5	-
Berry Petroleum Company, LLC	-	-	-	-	160	219	-	-	-
Breitburn Energy Co., LLC	18	-	-	-	1	-	-	-	-
Central Resources, Inc	19	-	-	-	-	-	-	-	-
Chevron USA, Inc	35	6	-	-	42	-	27	17	-
Crimson Resource Management	194	-	-	-	-	-	-	-	-
DCOR, LLC	11	-	-	-	-	-	-	-	-
Occidental of Elk Hills, Inc	57	36	-	-	-	-	-	-	-
Seneca Resources Corporation	19	4	-	-	-	-	-	-	-
Vintage Production California, LLC	108	-	-	-	-	-	-	-	-
California Resources Elk Hills, LLC	-	5	42	2	93	57	-	-	-
Linn Operating, Inc	-	273	-	-	-	-	-	-	-
Salt Creek Oil, LLC	-	-	2	-	-	-	-	-	-
Total	1,279	1,284	73	140	546	509	100	22	-

Table 6: Estimated Operator Costs Provided by CIPA and WSPA

Operator Cost Category	2014 – 2016 ⁷	2017	2018	2019	2020	2021	2022
Number of GMPs Developed	19	7	16	20	1	0	0
GMP Cost	\$517,250	\$207,843	\$131,719	\$864,872	\$17,645	\$0	\$0
Wells Installed	19	12	8	5	2	1	0
Well Installation Cost	\$5,806,232	\$2,000,673	\$351,744	\$1,450,014	\$514,860	\$117,000	\$0
Samples Collected	105	85	106	95	103	79	89
Reports Submitted	28	12	12	20	24	15	12
Sampling and Reporting Cost	\$990,000	\$418,702	\$273,423	\$293,253	\$310,615	\$267,126	\$281,687
Samples Analyzed	86	80	106	95	101	77	56
Sample Analysis Cost	\$172,500	\$188,490	\$288,345	\$243,469	\$226,620	\$249,183	\$138,551
Other Subcontractor and Consultant Fees	\$111,969	\$150,000	\$98,601	\$20,000	\$17,000	\$2,371	\$0
Total Cost (Capital + Operating Expenses)	\$7,597,951	\$2,965,708	\$1,143,831	\$2,871,608	\$1,086,740	\$635,680	\$420,238

Requests for Exclusion	2014 – 2016 ⁷	2017	2018	2019	2020	2021	2022
Requests for Exclusion	11	7	29	32	10	5	0
Requests for Exclusion Cost	\$73,710	\$76,075	\$46,400	\$525,600	\$5,400	\$3,000	\$0

Total Area-Specific Costs	2014 – 2016 ⁷	2017	2018	2019	2020	2021	2022
GMP + Exclusion Costs	\$7,671,661	\$3,041,783	\$1,190,231	\$3,397,208	\$1,092,140	\$638,680	\$420,238

Regional Monitoring Program	2014 – 2016 ⁷	2017	2018	2019	2020	2021	2022
RMP Estimated Total Operators Cost	\$15,000	\$18,000	\$265,525	\$0	\$135,700	\$95,296	\$0

Well Stimulation Treatments and Production	2014 – 2016 ⁷	2017	2018	2019	2020	2021	2022 ⁸
WSTs Performed - GMP	176	34	129	96	26	12	0
Oil Production from WSTs - GMP (bbl)	1,362,969	451,478	312,501	362,810	18,728	68,774	637,871
WSTs Performed - Exclusions	1,089	122	115	70	34	6	0
Oil Production from WSTs - Exclusions (bbl)	9,438,976	296,336	523,299	166,875	25,903	28,140	--

Summary	2014 – 2016 ⁷	2017	2018	2019	2020	2021	2022
Oil Produced subject to Model Criteria Requirements (bbl)	10,801,945	747,814	835,800	529,685	44,631	96,914	--
Estimated Groundwater Monitoring Cost per Sample	\$72,361	\$34,891	\$10,791	\$30,227	\$5,381	\$6,566	\$4,722
Groundwater Monitoring Cost per bbl of oil	\$5.57	\$6.57	\$3.66	\$7.91	\$58.03	\$9.24	\$0.66
Average Cost of Compliance per Well Stimulated	\$43,170	\$87,227	\$8,867	\$29,913	\$41,798	\$52,973	--

Appendix D - REGIONAL MONITORING PROGRAM
WORK CONDUCTED

Appendix D Summary of USGS Work Conducted to date through December 31, 2022

Oil Field	County	Salinity Mapping	Groundwater Sampling	Oilfield Fluid Sampling	Interpretive Analysis Published
Various	Kern, Los Angeles	X	X	X	X
Ant Hill	Kern		X		
Buena Vista	Kern	X	X	X	X
Bellevue	Kern	X	X		
Bellevue West	Kern	X	X		
Cal Canal Gas	Kern	X			X
Canfield Ranch	Kern	X	X	X	
Cat Canyon	Santa Barbara	X	X	X	
Edison	Kern	X	X	X	
Elk Hills	Kern	X	X		X
Fruitvale	Kern	X	X	X	X
Greeley	Kern	X	X	X	
Kern River	Kern		X	X	
Lost Hills	Kern	X	X	X	X
Midway-Sunset	Kern	X	X	X	X
Montebello	Los Angeles	X	X		X
Mountain View	Kern	X	X	X	
North Belridge	Kern	X	X	X	X
North Coles Levee	Kern	X	X		X
Orcutt	Santa Barbara		X	X	X
Oxnard	Ventura		X	X	X
Placerita	Los Angeles		X	X	
Poso Creek	Kern	X	X	X	X
Rio Bravo	Kern	X	X	X	
Rosedale	Kern	X	X		
Rosedale Ranch	Kern	X	X	X	X

2022 Annual Model Criteria Performance Report

Oil Field	County	Salinity Mapping	Groundwater Sampling	Oilfield Fluid Sampling	Interpretive Analysis Published
San Ardo	Monterey	X	X	X	
Santa Fe Springs	Los Angeles		X	X	
Santa Maria Valley	Santa Barbara		X		
South Belridge	Kern	X	X	X	X
South Coles Levee	Kern	X			X
South Cuyama	Santa Barbara	X			X
Strand	Kern	X	X		
Ten Section	Kern	X	X	X	
Wilmington-Torrance	Los Angeles		X	X	X
Yowlumne	Kern	X			