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Re: Panoche Energy Center, LLC follow up December 18, 2020 meeting with EPA on UIC Permit No. R9UIC-CA1-FY17-2R

Dear Michele:

Through this letter, Panoche Energy Center, LLC (PEC) provides its comments on the draft Underground Injection Control permit R9UIC-CA1-FY17-2R (Draft Permit) under docket number **EPA-R09-OW-2021-0147** to the U.S. Environmental Protection Agency (EPA), Region 9. The Draft Permit would authorize PEC to continue operating four (4) Existing Wells, known as IW1, IW2, IW3 and IW4, and construct and operate two Potential Wells, IW5 and IW6 once all permit conditions pertaining to the wells have been met for PEC's power generation facility (the "Facility"). In addition, the Draft Permit would require PEC to install a monitoring well to assess subsurface conditions associated with identified underground sources of drinking water (USDW).

Functioning as a simple-cycle peaking power generation plant, the Facility is a critical part of California's energy infrastructure and supports California's goal of continued integration of renewable energy. Specifically, the Facility provides in excess of 400 megawatts of electricity during peak demand when other power sources are unavailable or have already been dispatched to meet current load demands.

Fluids disposed by injection at the facility consist of cooling tower blowdown water, reverse osmosis system reject water, evaporative cooler blowdown water, combustion turbine intercooler condensate, enhanced wastewater water, and oil/water separator discharge water associated with operations of a simple cycle power generation plant that consists of four natural gas-fired combustion turbine generators. If issued, this Permit would authorize injection by Existing Wells IW1, IW2, IW3, IW4 and Potential Wells IW5 and IW6 to dispose of these wastewaters into the Panoche Formation at depths ranging between approximately 7,199 to 8,897 feet below ground surface. The Panoche Formation at the location of the wells has greater than 10,000 mg/L total

dissolved solids and is confined above by the approximately 1,148-foot-thick Tierra Loma Member of the Moreno Formation and the 308 foot-thick Marca Member of the Moreno Formation.

This letter provides PEC's comments on the technical terms and conditions in the Draft Permit, and in particular, on the proposed monitoring condition associated with Silver Creek #18 well.

As EPA is aware, for the past two years PEC has developed information and analysis to support EPA's issuance of a renewed UIC permit for the Facility. Over that time, PEC has demonstrated that there is no empirical basis to conclude that ongoing injection activities present a potential endangerment to USDW. Likewise, PEC has demonstrated through an extensive evaluation of California Geologic Energy Management Division (CalGEM) records that none of the wells within the Area of Review (AoR) were improperly plugged and abandoned. EPA accepted that analysis in reaching the conclusion in the Draft Permit that no "corrective action" is required because PEC has demonstrated, consistent with 40 CFR §§ 144.55 and 146.7, that there is no potential for endangerment to the USDW.

Despite reaching this conclusion, EPA has taken an element of "corrective action" from a prior draft of the permit—a draft shared with PEC on July 27, 2020—and relabeled it a "monitoring condition" in the Draft Permit.

The proposed "monitoring condition" in the Draft Permit is the same "corrective action" condition that EPA had proposed in its July 2020 draft.[1] Because EPA no longer believes it has the authority to include that provision as "corrective action", it is now proposing the exact same provision in the Draft Permit as a "monitoring condition."

Yet, relabeling the provision does not make the proposed monitoring condition justifiable under EPA's UIC authority for the following simple reason: EPA has provided no site-specific facts, empirical evidence, or supporting analysis to conclude that the hydrogeologic setting and the characteristics of the PEC operation require the company to install and operate a multi-million dollar monitoring well. Rather, EPA's sole basis for imposing this condition is the Region's belief that there is a "possibility" the Silver Creek #18 well, which was abandoned using mud-based and cement-based systems, may not prevent the movement of fluid from the injection zone into the USDW. PEC disagrees with this conclusion.

To date, EPA has not provided any information anywhere in the record to support its position that Silver Creek #18 was improperly plugged or abandoned, or to demonstrate why the Silver Creek #18 well may be a conduit for the movement of fluid into the USDW. In fact, EPA has provided no site-specific facts or analysis to explain why a monitoring well is needed next to Silver Creek #18, how PEC's injection activity could constitute an endangerment to the USDW located near Silver Creek #18, or how the agency would determine that any constituents that may be found in the

[1] Draft Underground Injection Control permit R9UIC-CA1-FY17-2R, Section II.C.1.b (dated July 27, 2020).

USDW could be the result of PEC injection activities. In short, the agency has not demonstrated that its proposed monitoring condition is an appropriate exercise of EPA's authority under the UIC program. Rather, including the monitoring condition renders EPA action arbitrary and capricious, and EPA's inconsistent with law. EPA's single reference to 40 CFR §§ 146.13 (b) and (d) as the basis to recast a "corrective action" as "monitoring condition" because there is a "possibility" of endangerment to a USDW does nothing to cure this critical defect in the Draft Permit.

Indeed, the regulations set forth at 40 CFR §§ 146.13 (b) and (d) do not authorize the agency to impose a monitoring condition on a permittee without demonstrating that such monitoring is needed to ensure compliance with the UIC program and protect a USDW. Moreover, neither 40 CFR § 146.13 nor any other provision under the UIC regulations allow EPA the authority to demand access to private land, to drill a 4,000 foot well, and to operate that well for the life of a UIC Class I permit. Yet, that is exactly what EPA is proposing here. PEC does not own the land within 100 feet of the Silver Creek #18 well, and PEC has no right to demand access to that land simply because EPA has imposed a monitoring condition in PEC's UIC Class I permit.[2]

By comparison, the Draft Permit includes several monitoring conditions, which are empirically and rationally linked to PEC's activities, are within PEC's control to implement on its property, and are appropriate to assess how PEC's injection activity may be affecting (if at all)the injection zone, the USDW, and endangering the same.

The monitoring conditions outlined in Part II.E include continuous monitoring of injection conditions and volumes, continuous monitoring of well integrity, and an annual demonstration of internal and external mechanical integrity for IW1, IW2, IW3, and IW4.

The monitoring conditions, coupled with performance of an annual Fall off Test (FOT) consistent with 40 CFR § 146.13, are used to provide an assessment of pressures within the Panoche Injection Interval and provide a mechanism to increase the AoR, if necessary. Likewise, the annual Zone of Endangering Influence (ZEI) reassessment allows for a specific check and verification of the pressure buildup at the Silver Creek #18 well—and all of the other wells within the AoR—versus the allowable pressure buildup, which are rational triggers for enhanced monitoring or corrective action. Each of these monitoring conditions is an appropriate exercise of EPA's UIC authorities; and each ensures compliance with the UIC program and confirmation of continued safe operations. Furthermore, Part II.C provides a clear mechanism to require corrective action if monitoring under Part II.E warrants such action.

PEC has evaluated every UIC Class I permit that EPA Region 9 has issued since 2008. Not a single permit includes a USDW monitoring condition like the one proposed in the Draft Permit.

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[2] *See e.g.*, Draft Permit, Section III.A: "Issuance of this Permit does not convey property rights of any sort or any exclusive privilege, ***nor does it authorize any injury to persons or property, any invasion of other private rights, or any infringement of State or local law or regulations***." (emphasis added); *see also*, 40 CFR § 144.35(b) and (c).

Without a site-specific and empirical basis to show why monitoring the condition of the USDW next to Silver Creek #18 is an appropriate application of 40 CFR §§ 146.13 (b) and (d), the condition should be removed from the Draft Permit.

Permit History and Background

PEC submitted the Renewal Application to Region 9 on October 20, 2017. Thereafter, a series of communications and submittals began. *See* Attachment 1.

On December 20, 2018, PEC had a conference call with Mr. George Robin from EPA who noted that the ½ mile fixed radius for AoR, as defined in the Original Permit application for the PEC wells, would not be applicable for the permit renewal application. Mr. Robin also directed PEC to propose an alternative basis for defining the AoR (*i.e*., a different methodology to the then approved 25 psi pressure-differential to define the AoR).

On December 21, 2018, PEC had a follow-up call with Mr. Robin to discuss alternative methodologies for defining the AoR. During that meeting, Mr. Robin indicated that a reservoir pressure increase of approximately 40 psi had been used previously for another Class I UIC project within Region 9. PEC and Region 9 agreed to a reasonable and conservative approach for determining the Facility's AoR: *i.e*., assuming that drilling mud weights (for wells not plugged with cement between the top of the injection zone and base of the USDW) and pre-injection reservoir pressures were in balance, then drilling mud gel strength would be the remaining factor providing resistance to entry pressure from injection and the potential upward displacement of fluids into the USDW.

The parties agreed that this calculation would likely result in an AoR contour somewhere between 25 and 40 psi of pressure differential. PEC and EPA also agreed that an assumed mud gel strength in the range of 20 to 25 pounds/100 square feet (lbs./100 ft^2) of borehole face surface area would be reasonable and conservative based on the available literature and standard practice in other EPA regions. Mr. Robin expressed his opinion that if any well(s) within the AoR based on mud weight and minimum gel strength resistance were found to be improperly plugged and abandoned, then that that might be an issue for CalGEM to address.

Based on input from Region 9, PEC developed a "Gel Strength Entry Pressure" methodology to provide a more quantitative basis for defining the AoR. This method is described in a detailed step by step process below. In summary, it quantified the minimum pressure differential in the injection zone required to overcome a gel strength of 25 lbs./100 ft^2. This resulted in a displacement pressure of 41.96 psi, which was presented as part of a revised permit renewal application submitted on March 1, 2019.

On June 22, 2019, PEC revised the AoR analysis—based on the above dialogue with and comments from Region 9 staff—to a more conservative approach that utilized a gel strength of only 20 lbs./100 ft^2 instead of 25 lbs./ 100 ft^2. This resulted in a minimum displacement pressure

of 34.8 psi for the subset of mud-plugged wells within the 3-mile preliminary search radius used for the Facility. The AoR was then recalculated based on this new displacement pressure.

On January 17, 2020, PEC submitted a comment letter (Attachment 2) to Region 9 that included a comprehensive review of: (1) the Gel Strength Entry Pressure" methodology, which was based on the overall AoR and corrective action analysis protocol approved by EPA Region 6, which regulates through primacy or direct implementation more Class I industrial wells than any other EPA region; (2) the plugging and monitoring field plan recommended by EPA Region 9 (including costs and potential risks); and (3) a field plan for implementing corrective action if needed.[3]

On July 27, 2020, EPA shared a draft of the UIC permit with PEC (Attachment 1 - 7/27/20 Draft Permit). That draft included the following "corrective action":

> a. Within sixty (60) days of the effective date of this Permit, the Permittee shall submit a plan for approval by EPA to re-enter, plug, and abandon the Souza #2 well in a way that prevents the migration of fluids into an USDW.
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> The Souza #2 well shall be re-entered and cement plugs placed to isolate USDWs from potential fluid entry. Formation pressures shall be measured. Geophysical logs shall be run and formation fluid samples obtained from selected intervals for analysis of specific conductance and determination of the USDW base in the Souza #2 well. The Permittee shall also collect data on the mud level and its density with depth. If log analyses are inconclusive with respect to the depth of the USDW base and formation pressure determinations, the Permittee shall run a wireline tool for fluid sampling and pressure testing zones of interest. The Plugging Program shall be reviewed and modified, if necessary, based on the log evaluations, fluid sample analyses, and pressure measurements.
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> b. The Permittee shall install two (2) monitoring wells to perform chemical analysis and measure specific conductance and formation pressure in order to evaluate injection zone conditions in the vicinity of two nearby abandoned wells and identify potential changes in the USDW as described in Section E of this Permit. The wells shall be located as follows:

[3] Panoche Energy Center, January 17, 2020. Attachment A, Response to USEPA Comment No. 1d from Letter Dated December 3, 2019.

i. One (1) monitoring well shall be located within 100 feet to the south-southwest of the Silver Creek 18 Well; and

ii. One (1) monitoring well shall be located within 100 feet south of the England 1-31 Well.

c. Prior to drilling the monitoring wells the Permittee shall submit to EPA, for review and approval, detailed construction plans and procedures, including proposed field coordinates (Section, Township, Range, with latitude/longitude) for the surface locations of the proposed monitoring wells. The plans and procedures must describe how the Permittee will:

i. Drill the wellbore to the Panoche Formation injection zone;

ii. Record a static pressure measurement in the Panoche Formation, obtain a fluid sample from the injection zone, and perform a chemical analysis of the injection zone fluid for the following parameters using the Analytical Methods in Section E.1.a: TDS, alkalinity, anions and cations, hardness, pH, specific conductance, specific gravity, total sulfide, oil and grease, and total metals;

iii. Plug the wellbore to the base of the USDW, located at the stratigraphic contact between the Kreyenhagen Shale and the sandy interval in the overlying Tumey Formation;

iv. Equip the well with transducers to monitor pressure and specific conductance within the USDW, and with water quality monitoring equipment to allow sampling of the USDW; and

v. Perform a baseline chemical analysis of the USDW for the following parameters using the Analytical Methods in Section E.1.a: TDS, alkalinity, anions and cations, hardness, pH, specific gravity, total sulfide, oil and grease, and total metals.

On September 25, 2020, PEC submitted a detailed letter (Attachment 3) to Region 9 explaining why PEC disagrees with Region 9's conclusions and proposed actions for the Souza #2, and the

monitoring wells associated with the Silver Creek #18 and England #1-31 wells (collectively, the "Corrective Action Wells"). Absent a regulatory requirement and/or an empirical basis showing that the Facility's operation endangers the USDW, PEC respectfully submitted there was no adequate technical or legal basis for EPA's proposed corrective actions.

After reviewing the September 25, 2020 letter, EPA revised its position on the Corrective Action Wells and proposed a single corrective action that would require PEC to monitor the Silver Creek #18 well and USDW.

On December 16, 2020, PEC submitted a white paper to EPA providing additional empirical analysis evaluating site-specific mud column characteristics and conditions in all 23 wells within AoR and the Cheney Ranch Field (Attachment 6).

On December 18, 2020, the parties met to discuss the revised corrective action condition. At that meeting, Region 9 noted that the corrective action was required for two reasons: (a) because PEC has not provided any "empirical evidence" to conclude that there is no endangerment to USDW within the AoR; and (b) wells that lack cement plugs across the base of the USDW must be deemed "improperly plugged and abandoned." PEC responded with several questions and concerns related to a corrective action condition imposing monitoring at Silver Creek #18. EPA, unable to provide responses to PEC's questions, asked that PEC submit additional information related to its corrective action analysis, its evaluation of plugged and abandoned wells, and its questions related to monitoring Silver Creek #18 in writing. The parties agreed to confer after EPA received and reviewed PEC's submissions.

On January 25, 2021, PEC provided a follow up letter (Attachment 4) to Region 9 explaining its continuing objection to the proposed monitoring well because empirical evidence demonstrates that wells within the AoR were properly plugged and abandoned, and that empirical evidence demonstrates there is no endangerment to the USDW. In addition, PEC submitted several questions related to the monitoring requirement for Silver Creek #18.

Region 9 declined to respond to PEC's letter or address any questions it raised about Silver Creek #18, and on April 12, 2021, EPA published the Draft Permit for public comment. The Draft Permit recasts the corrective action as a "monitoring condition:"

> The Permittee shall install one (1) monitoring well to perform chemical analysis and measure specific conductance and formation pressure in order to identify potential changes in the USDW in the vicinity of one (1) nearby abandoned well, as described below in Monitoring Requirements. The one (1) monitoring well shall be located within 100 feet to the south-southwest of the Silver Creek 18 Well.
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> Within 60 days of the effective date of this Permit, and prior to drilling the monitoring well, the Permittee shall submit to EPA, for

> review and approval, a detailed construction plan and procedures, including the proposed field coordinates (Section, Township, Range, with latitude/longitude) for the surface location of the proposed monitoring well. The plans and procedures must describe how the Permittee will:
>
> > i. Drill the wellbore to the base of the USDW, located at the stratigraphic contact between the Kreyenhagen Shale and the sandy interval in the overlying Tumey Formation;
> >
> > ii. Equip the well with a transducer to monitor pressure and specific conductance within the USDW, and with water quality monitoring equipment to allow sampling of the USDW; and
> >
> > iii. Perform baseline characterization of ground water chemistry, to meet the analytical requirements [i.e.] . . . Sample and perform chemical analysis for the following parameters using the Analytical Methods in Section E.1.a: TDS, alkalinity, anions and cations, trace metals, hardness, pH, specific gravity, total sulfide, oil and grease, and total metals. This analysis shall be performed monthly for the first year of monitoring, and quarterly thereafter.

PEC General Comments on Draft Permit Technical Terms and Conditions

PEC has reviewed the Draft Permit and as identified several comments in Attachment 5.

PEC Comments on the Monitoring Condition

Region 9 states in its Fact Sheet for R9UIC-CA1-FY17-2R (Fact Sheet), that the "Permittee is not required to conduct any corrective action, in accordance with 40 CFR §§ 144.55 and 146.7."[4] Region 9 goes on to say that "Corrective action may be required after permit issuance to address any wells within the area of review that may allow migration of fluids into USDWs. EPA will use the annual FOT results and re-calculation of the ZEI, along with USDW monitoring results from the monitoring well."[5]

[4] Fact Sheet at 4.

[5] *Id*.

PEC agrees that no corrective action is required because it has demonstrated, consistent with 40 CFR §§ 144.55 and 146.7, that there is no potential for endangerment to the USDW. However, as described below, PEC disagrees with the EPA's proposed monitoring condition for Silver Creek #18.

1. No Empirical Basis for an Endangerment Finding

On January 17 and September 25, 2020,[6] PEC submitted to Region 9 a comprehensive review of its methodology and analysis to complete a corrective action evaluation. While PEC reviewed every artificial penetration within the AoR, per EPA direction, PEC focused its analysis on those specific wells within the AoR that do not have a cement plug at the base of the lowermost USDW.

To determine remaining wellbore conditions at the time of well plugging, the corrective action evaluation conservatively assumed a maximum initial reservoir fluid pressure gradient, a maximum modeled pressure buildup in the reservoir due to injection, and only relied on official well records and logs filed with and certified by CalGEM. Because of the availability of certified well records for all of the wells, no assumptions had to be made to address inadequate well records or orphan wells.

Applying this methodology and relying on empirical evidence available through CalGEM, PEC's analysis shows that ***all wells*** within the AoR have sufficient mud column weight to resist fluid entry without relying on mud gel strength. In fact, PEC's analysis shows that reservoir pressures would have to increase by 35% over their 2017 value to overcome the mud weight alone and by 125% to overcome the combination of gel strength and mud weight based on the 2017 reservoir buildup value.[7] Therefore, no corrective action is required for any of the plugged and abandoned wells within the AoR because there is no likelihood for the movement of fluids from the injection zone into the USDW.

Furthermore, in its September 25, 2020 letter, PEC demonstrated through an empirical analysis that operation of its Enhanced Wastewater System ("EWS") reduced injection rates by up to 80 percent. As a result, Facility operations will not increase pressures within the injection zone as much as indicated in PEC's January 17, 2020, analysis. The September 25, 2020 analysis shows that the minimum pressure level needed to potentially cause the movement of fluids from the injection zone into the USDW will not be reached at any of the wells located within the AoR, including those wells with no cement plug across the base of the USDW.

To the contrary, the analysis shows that injection zone pressures will be significantly less than previously predicted because the EWS, both as currently configured and with respect to likely

[6] Panoche Energy Center, January 17, 2020 (Attachment A, Response to USEPA Comment No. 1d from Letter Dated December 3, 2019); Panoche Energy Center, September 25, 2020.

[7] Panoche Energy Center, September 25, 2020, Panoche Energy Center, LLC comments on UIC Permit No. R9UIC-CA1-FY17-2R (Figure 3).

future optimization, will continue to reduce injection volumes and associated rates of reservoir pressure increase within the injection zone over time. Based on this new information, PEC re-evaluated each well within the AoR, including the Souza #2, Silver Creek #18, and England #1-31 wells, and determined that reduced injection volumes will add an even greater safety factor because mud weight alone will resist the upward movement of formation fluids in each well (i.e., mud gel strength resistance is not needed at any well, including Souza #2).

On December 16, 2020, PEC submitted additional empirical analysis evaluating site specific mud column characteristics and conditions in the Cheney Ranch Field, which encompasses the AoR (Attachment 6). This analysis, which is based on 80 years of empirical analysis,[8] shows that the Cheney Ranch wells do not constitute a possible conduit for movement of fluids into the USDW. Furthermore, the muds evaluated in the December 16, 2020 report are the same types of muds used in the plugged and abandoned wells within the AoR. The Cheney Field records confirm that all of the wells within the field (i.e., within the AoR and in the larger field area) were drilled and plugged using clay-based muds and rotary-drilling methods.

Therefore, these clay-based mud systems will act in a similar manner. In Section 1.3.1 of Attachment 4 PEC provides additional analysis derived from empirical data for three wells (Lockhart England #1-31, American Hunter Souza #1, and Bender Silver Creek #57X-18) document and detail that thick, heavy static mud conditions were encountered during well activities (drilling and/or plugging). These thick, heavy muds provide significant displacement resistance to inflow of formation fluids into the wellbores.

<u>Question 1:</u> If there is no evidence to suggest potential for endangerment, what is EPA's technical basis for monitoring the Silver Creek #18 well and USDW?

2. <u>No Improperly Plugged and Abandoned Wells or Orphan Wells</u>[9]

EPA regulations state that for any wells within the AoR that are "improperly sealed, completed, or abandoned, the applicant shall also submit a plan consisting of such steps or modifications as are necessary to prevent movement of fluid into underground sources of drinking water ("corrective action")."[10] The regulations also state that identifying such "improperly sealed, completed or abandoned" wells is a ***<u>condition precedent</u>*** to any required corrective action.[11] As part of its

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[8] Panoche Energy Center, September 25, 2020, Panoche Energy Center, LLC comments on UIC Permit No. R9UIC-CA1-FY17-2R (Appendix 4).

[9] PEC's corrective action evaluation and AoR did not identify any orphan wells - *i.e.*, any wells that were abandoned and not plugged consistent with CalGEM regulations.

[10] 40 C.F.R. § 144.55(a).

[11] Environmental Appeals Board ("Board") decisions affirm this approach to evaluating wells within an AoR. For example, in the matter *In Re: Jordan Development Co., L.L.C.*, 2019 WL 3816212, at *25, the Board

current permit requirements, PEC is, in fact, monitoring pressures in the Injection Interval on an annual basis and these pressures are considered in its analysis of whether any wells in the AoR are "improperly sealed, completed, or abandoned."

By contrast, no EPA regulations require a cement plug to be present at the base of the USDW in every historic artificial penetration within an AoR; nor do EPA regulations require corrective action for every historic artificial penetration within an AoR that was not plugged with cement at the base of the USDW.

Rather, 40 C.F.R § 146.7 states that when "determining the adequacy of corrective action proposed by the applicant under 40 CFR 144.55 and in determining the additional steps needed to prevent fluid movement into underground sources of drinking water", EPA shall evaluate a range of the factors to determine if a well within the AoR may become a conduit for the movement of fluids from the injection zone and into the USDW. In particular, 40 C.F.R § 146.7 identifies the following relevant factors: the history of the injection well operations, completion and plugging records for artificial penetrations, and artificial penetration plugging and abandonment procedures in effect at the time the well was plugged and abandoned.

Here, PEC relied on existing well records, logs and schematics, which provide reported weight(s) of the drilling fluid left in the artificial penetrations and reported height(s) of the drilling fluid column remaining in each artificial penetration. PEC confirmed that all wells within the AoR filed plugging and abandonment records with CalGEM. These records show that each well within the AoR was plugged and abandoned as required by CalGEM, and concurrence letters were issued by CalGEM. Moreover, each of these wells currently meet plugging and abandonment requirements as specified in CalGEM 2020 regulations. Barring evidence that these CalGEM records are untrue, inaccurate or do not contain complete information, there is no basis to conclude that the wells evaluated in the AoR were improperly plugged and abandoned. On December 16, 2020, PEC sent EPA a white paper reviewing CalGEM records for the 23 wells within the AoR (Attachment 6).[12] The report showed that these Cheney Ranch wells do not constitute a possible threat under the non-endangerment standard to human health or the environment as currently abandoned.

EPA has not provided PEC any data or records to demonstrate that any of the wells within the AoR were improperly plugged and abandoned, and EPA's statements during the parties'

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restated the regulation and clarified the condition precedent: "If any such existing well (whether producing, injecting, temporarily abandoned, or plugged and abandoned) could provide a conduit for fluid migration into USDWs because it is improperly constructed, sealed, or plugged, the applicant must develop a corrective action plan to address the deficiency. 40 C.F.R. §§ 144.55, 146.7."

[12] *See,* Mud Column Characteristics and Conditions in the Cheney Ranch Field, December 16, 2020. PEC expanded this analysis in its January 25, 2020, letter to EPA (see Attachment B).

December 18th meeting of the "need for empirical data" does not justify including the monitoring well requirement in the Draft Permit.

Based on the discussions on December 18th, Region 9 appears to be defining any well that does not have a cement plug across the base of the USDW to be an "improperly sealed, completed or abandoned well". Region 9's approach means that any well without a cement plug across the base of the USDW, regardless of other factors, requires corrective action. This approach is not in accordance with 40 C.F.R §§ 146.7 or 144.55 and renders all of the other factors listed to be evaluated superfluous.

PEC's September 25, 2020, and January 25, 2021, letters provide Region 9 an empirical and evidentiary basis—relying on state certified records—that each well within the AoR was plugged consistent with procedures in effect at the time the well was abandoned; and that all wells within the AoR are protective of the USDW.

Question 2: ***If there is no empirical basis to conclude that any wells within the AoR were improperly plugged or abandoned wells, what is EPA's technical basis to impose a monitoring condition at the Silver Creek #18 well and USDW?***

3. Implementation of the EWS Demonstrates that Formation Pressures are Decreasing

PEC invested $10.8 million (CapEx) and additional $1.7 million, for a total of $12.5 million, in the EWS. Since the EWS was installed at the Facility in 2016, injection rates and annually injected volumes have dropped by up to 80%. The distribution in reservoir pressure within the injection interval is directly related to the rate and volume of wastewater injected. As such, injection of a smaller volume results in a decrease in formation pressure.

As a result, Facility operations will not increase pressures within the injection zone as much as indicated in the January 2020 Analysis that was based on higher injection rates that were modeled through the end of 2018. The September 2020 Analysis shows that the minimum pressure level needed to potentially cause the movement of fluids from the injection zone into the USDW will not be reached at any of the wells located within the AoR, including the mud-plugged wells.

To the contrary, the analysis shows that injection zone pressures will be significantly less than previously predicted because the EWS, both as currently configured and with respect to likely future expansion, will continue to reduce injection volumes and associated rates of reservoir pressure increase within the injection zone over time. Based on this new information, PEC re-evaluated each well within the AoR, including the Souza #2, Silver Creek #18, and England #1-31 wells, and determined that reduced injection volumes will add an even greater safety factor showing that mud weight alone will resist the upward movement of formation fluids in each well (i.e., mud gel strength resistance is not needed at any well, including Souza #2).

The methodology for the September 2020 Analysis differs from the January 2020 Analysis as follows:

- Because the EWS has reduced injection volumes, the maximum reservoir pressure has peaked and is now declining throughout the reservoir; as a result, the maximum increase in reservoir pressure has been updated through August 2020 to reflect current benefits of the EWS.

- In the original analysis a reservoir fluid pressure gradient of 0.47 psi/ft, which was rounded up from 0.4665 psi/foot, was used to calculate the reservoir pressure. Prior to the step-rate injection test, an initial formation pressure of 3,510 psi was measured in IW2 at a depth of 7,604 ft KB.[13] The true formation pressure gradient is actually 0.462 psi/ft. Therefore, basing the well screening analysis on a pressure gradient of 0.4665 psi/ft is conservative as it reduces the resulting allowable pressure.

The methodology remains conservative for the following reasons:

- Only the weight of the mud was utilized in calculating the hydrostatic pressure of the mud column in the evaluation of mud-plugged wells. Under this representative-case evaluation approach, the resistive forces that would result from mud gel strength were not used or needed to demonstrate that maximum reservoir pressure in the injection interval will not exceed the mud column hydrostatic pressure and displace the mud column upward.

- In order to add a margin of safety in calculating the static mud column pressure, a fallback of 50 feet in the mud column height was assumed in the calculations. This is conservative because, as plugging regulations require, all un-cemented intervals in a well be filled with mud.

- Undulations in the borehole wall, which are known to increase mud gel strength, are discounted in the analysis. Under this evaluation approach, the additive resistive forces that would result from increased mud gel strength due to borehole rugosity were not used or needed to demonstrate that maximum reservoir pressure will not exceed the mud column hydrostatic pressure and displace the mud column upward. Collins and Kortum (1989)[14] found that non-uniformities in hole diameter may increase the pressure necessary to break the strength of the gel in a borehole by a factor of three to five over gel strength alone. This would add a significant margin of safety to abandoned well modeling calculations. In in many cases the gel strength might contribute more to sealing pressure than hydrostatic head of the static mud column.

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[13] Panoche Energy Center, LLC, UIC Well IW2 Well Completion Report (March 30, 2009).

[14] *See* Attachment 7 - Supporting Technical Literature.

- The additional protection afforded from cement plugs was not quantitatively added as a mechanism for preventing flow into or up the well. All wells have multiple cement plugs per CalGEM standards, but the flow resistance provided by cement plugs in the wellbore and/or well casing was not included in the hydrostatic pressure analysis.

- Lastly, closure/collapse of the borehole over the long term was not considered in the evaluations. shales are known to exhibit viscoelastic deformational behavior that causes natural fractures to close rapidly under the action of in situ compressive stresses (Aumman, 1966; (pers. comm. to R. E. Collins) Neuzil, 1986;; Collins, 1986).[15] Evidence of rapid borehole closure is often encountered while drilling and running casing in oil and gas wells (Johnston and Knape, 1986; Clark et al., 1987).[16] Furthermore, old abandoned boreholes have been observed to heal across shale sections to the extent that reentering them requires drilling a new hole (Clark et al., 1987).[17] Borehole closure by caving sands and swelling shales common in areas with relatively young sediments because of the unconsolidated nature of the shallow sedimentary section (Johnston and Greene, 1979; Davis, 1986; Johnston and Knape, 1986; Warner, 1988; Agency Information Consultants, 19878).[18] Therefore, discounting borehole closure results in a very conservative approach and adds a significant degree of safety in the criteria used to evaluate artificial penetrations.

  Davis (1986)[19] summarized the ability of shales to absorb water, a process that commonly results in desiccation and ultimate borehole blockage. Water wetting of shales causes instability, resulting primarily from overburden pressure, pore pressure, or tectonic stress. The hydration of the shales causes the platy nature of shale to become unstable and tend to flow in a plastic manner. Natural borehole closure mechanisms and shale “sloughing” can be directly attributable to adsorption of water by shale formations. As shales are buried with depth, more water is squeezed out of the platy sheets by overburden pressures, and the force present is equal to the matrix stress. As the formation is drilled, compacting force is relieved on the borehole face by the drill bit. Consequently, hydration force equal to the degree of relief develops. For example, in a normally pressured (assume 9.0 lb./gal mud weight equivalent) shale at 10,000 ft deep, the shale hydration force in normal pore pressure is expected to be

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[15] *See* Attachment 7 - Supporting Technical Literature.

[16] *Id*.

[17] *Id*.

[18] *Id*.

[19] *Id*.

5,320 psi, which is much greater than the 250 psi pressure differential as exerted on the face of the borehole wall (based on 9.5 lb./gal mud at 10,000 ft).

In addition, the wells within the AoR were drilled through young shales. In geologic formations such as these, studies demonstrate that boreholes through young shales will naturally seal and close off as a function of the plastic properties of the sediments any potential conduits for flow.[20]

A summary of the September 2020 Analysis is presented below in Table 1. A further analysis of the three Corrective Action wells in the July 27, 2020 permit, shows that the hydrostatic pressure of the mud column in the wells has always been in excess of the maximum reservoir pressure required for entry, and that the magnitude of this differential will continue to improve throughout the life of the permit given the EWS's current and future benefits to reducing reservoir pressure.

[20] For example, in 1991, the DuPont Borehole Closure Test Well was conducted as an integral part of an EPA No-Migration Petition demonstration for DuPont Sabine River Works to document and quantify natural borehole closure in abandoned wells (Clark et al., 1991). A test well was drilled to provide additional information on the sealing effectiveness of young formations, especially "shales", in a simulated abandoned borehole located on the flanks of a salt dome, Orange Dome. The borehole was flushed with brine and the 100-foot shale test section was straddled with pressure transducers. The well was allowed to remain in a static state for a week. Injection was initiated into the underlying sand and pressure was increased to 90 psi, 110 psi, and 140 psi above static conditions, with no response being recorded in the gauge above the test shale interval. Additionally, during injection the Schlumberger Water Flow Log (oxygen activation tool) was run at several stations within the test shale interval without showing any indication of upward flow through the shale test interval. The closure test offered an additional margin of safety, in that it quantified and demonstrated that shales can act as an effective seal to fluid migration both in the short and the long terms. Therefore, discounting borehole closure results in a very conservative approach and adds a significant degree of safety in the criteria used to evaluate artificial penetrations.

Table 1

Operator Well ID	Properly Plugged and Abandoned per DOGGR [1]	Total Confining Layer Thickness Above Injection Zone (ft)	Total Thickness Cement Plugs (ft)	Total Number of Plugs (cement and mechanical)	Cement Plug at Base USDW	Hydrostatic Pressure from mud weight in excess of maximum reservoir pressure [2][3]	Does the hydrostatic pressure always exceed reservoir pressure [4]	Corrective Acrion Needed
Russell Giffen 1 ***	YES	2,355	344	3	YES	NA	YES	**NO**
Silver Creek 77X ***	YES	2,475	507	3	YES	NA	YES	**NO**
Cheney Ranch 1	YES	2,431	536	11	YES	NA	YES	**NO**
Cheney Ranch 2	YES	2,478	577	6	YES	NA	YES	**NO**
Silver Creek 14X	YES	2,269	600	3	YES	NA	YES	**NO**
Silver Creek 27X	YES	2,433	714	4	YES	NA	YES	**NO**
Silver Creek 54X	YES	2,229	380	2	YES	NA	YES	**NO**
Silver Creek 32X	YES	2,350	631	3	YES	NA	YES	**NO**
Cheney Ranch 15X	YES	2,342	605	3	YES	NA	YES	**NO**
Souza 1	YES	2,030	460	14	YES	NA	YES	**NO**
Cheney Ranch 3 ***	YES	2,760	117	2	NO	NA	YES	**NO**
Cheney Ranch 81X-30***	YES	2,640	424	3	NO	NA	YES	**NO**
Silver Creek 72X ***	YES	2,879	611	2	NO	336	YES	**NO**
Silver Creek 22X ***	YES	2,368	256	3	NO	341	YES	**NO**
England 1-31	YES	2,452	487	5	NO	725	YES	**NO**
Souza 1-36	YES	2,158	110	3	NO	862	YES	**NO**
Roberts 1	YES	2,016	228	3	NO	642	YES	**NO**
Silver Creek 18	YES	2,558	429	3	NO	327	YES	**NO**
Souza 2	YES	1,933	360	4	NO	12	YES	**NO**
Blue Agave 1	YES	2,308	842	3	NO	636	YES	**NO**

NOTES:

[1] All wells have a concurrence letter documenting that they were Properly Pugged and Abandoned per CalGEM requirements

[2] See Table 3 for calculation details

[3] Where wells have a cement plug between the injection zone and the base of the USDW, or were outside the 2018 AoR entry pressure analysis was not calculated

[4] See Table 3 for calculation details

*** Wells outside the 2020 AoR "September 2020 Analysis"

a. Evaluation of Specific Wells within the AoR

PEC's September 2020 Analysis for the EWS and reduced injection volumes (Figure 2) shows that the mud column hydrostatic pressures in Souza #2, Silver Creek #18 and England #1-31 (Figures 3, 4, and 5, respectively) have always been in excess of the maximum reservoir entry pressures. In addition, the EWS evaluation also shows that each well experienced its highest increase in reservoir pressure in 2017; and since then, induced pressure within the reservoir has and will continue to decrease, due to lower injection volumes, throughout the life of the permit. These improvements are a direct result of the EWS commissioning in 2016.

The hydrostatic pressures shown in Figures 1, 2, and 3 below represent the forces exerted on the injection reservoir from the mud weight in Souza #2, Silver Creek #18 and England #1-31 for the September 2020 Analysis compared to the modeled injection zone reservoir pressures.

The minimum pressure increase required in the injection zone reservoir to overcome the off-setting mud column hydrostatic pressure in any of the plugged and abandoned well was calculated to be in the Souza #2 well. Because this well had the lightest drilling mud weight, and therefore, the lowest hydrostatic differential value, it was used as an example to demonstrate that in no instance during the injection history evaluated in the September 2020 Analysis did the reservoir pressure exceed the mud column hydrostatic pressure of the well, and thus, mud gel strength was not needed but would provide an additional safety factor.

When injection into the Panoche Formation began in mid-2009, pressures began to increase within the formation. The highest injection rates for the Facility occurred in 2015 and because of a delay due to the large distance from the injection operations in the pressure front reaching Souza #2, the highest modeled reservoir pressures at Souza #2 did not occur until June of 2017. In parallel, in mid-2016 the Facility completed construction of the EWS.

Prior to the EWS being commissioned, injection rates on a gallon per megawatt hour ("gal/MWhr") were as high as 112 gal/MWhr. Since the EWS was commissioned, injection rates have decreased significantly. Year-to-date in 2020, injection rates have reduced by approximately 70% to 34 gal/MWhr. Through continued optimization the Facility has been able to achieve injection rates as low as 22 gal/MWhr. *See* Figure 1 below.

Based on the September 2020 Analysis, the current reservoir pressure differential (above initial pressure) at Souza #2 is 38.3 psi (see Figure 2 below). This pressure differential will continue to decrease through the permit term. Figure 2 shows the effect of the EWS on the differential hydrostatic pressures exerted at Souza # 2; Figure 3 shows the effect of the EWS on the differential hydrostatic pressures exerted on at the England # 1-31 well; and Figure 4 shows the effect of the EWS on the differential hydrostatic pressures exerted at Silver Creek #18.

Figure 1

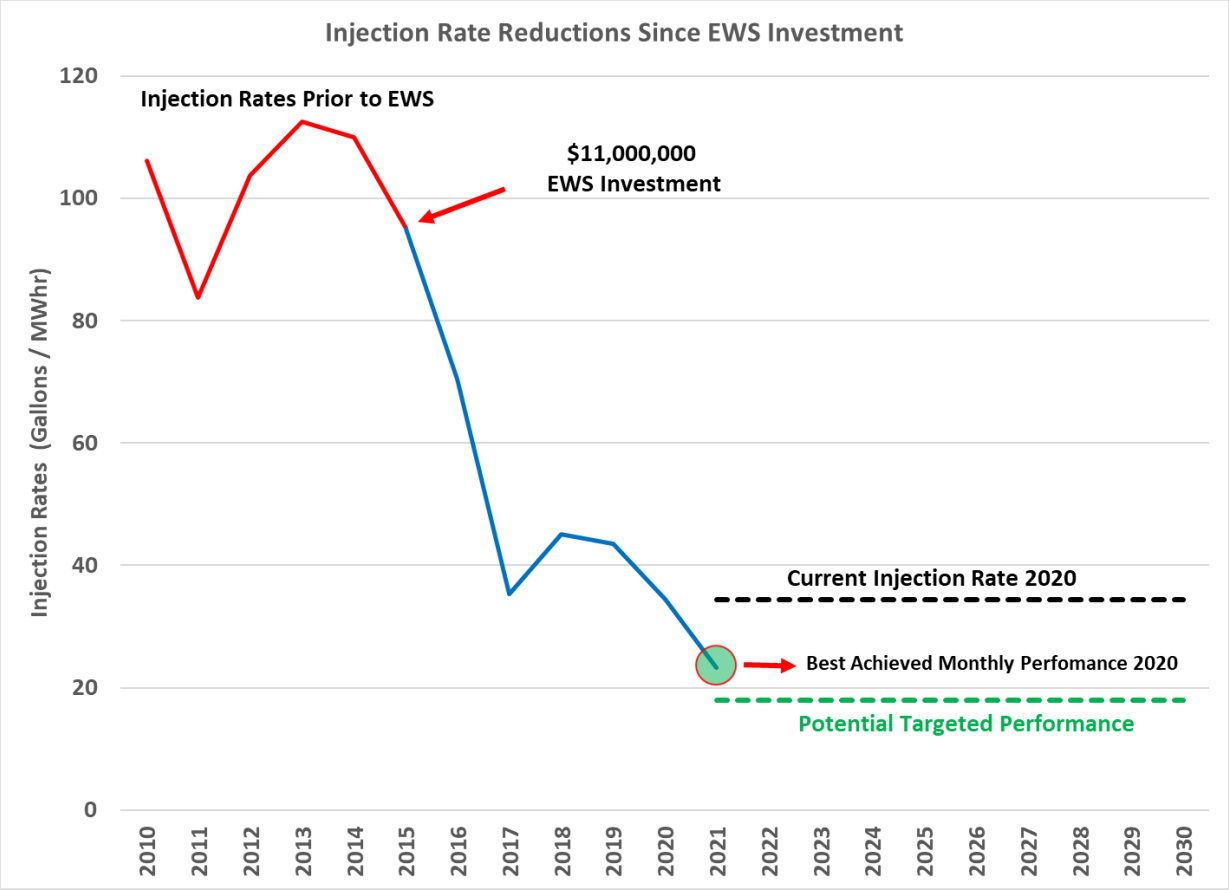


Figure 2

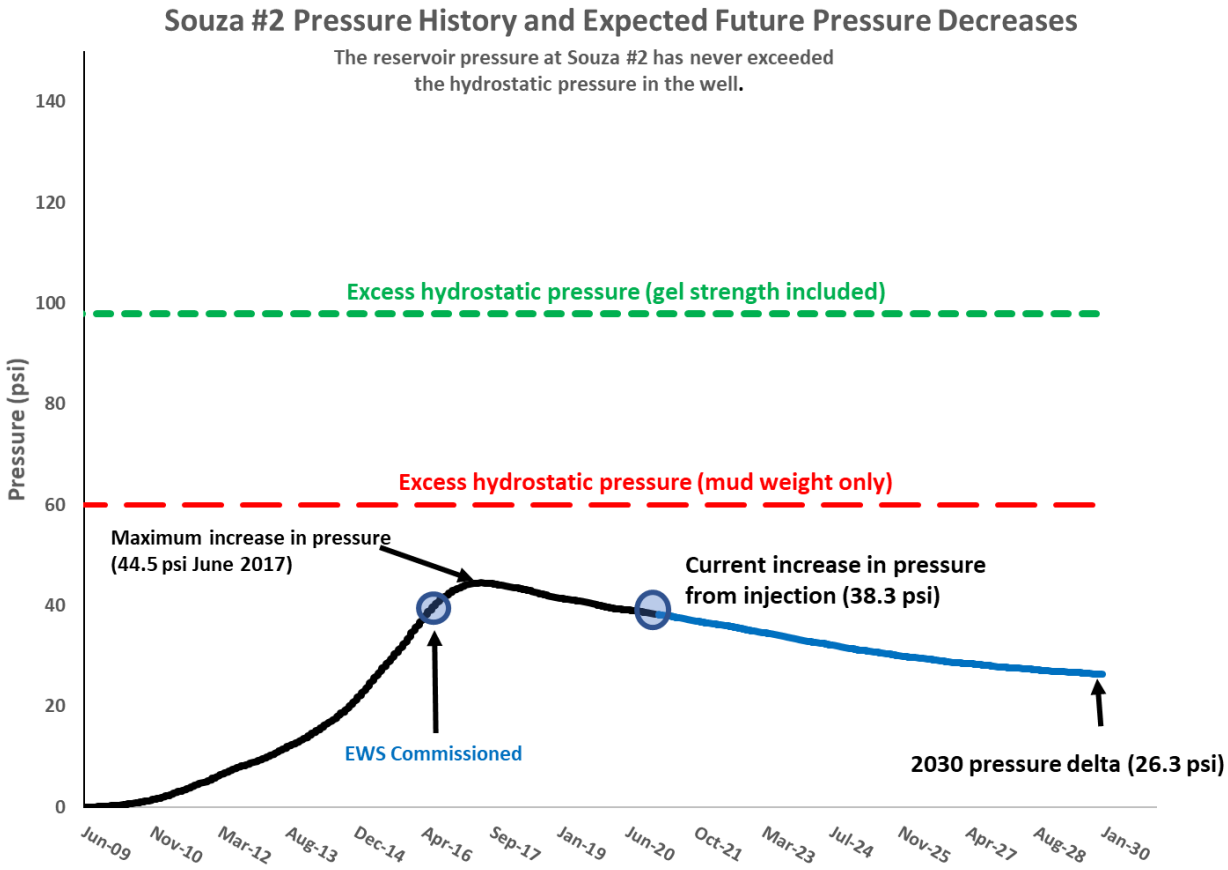

Souza #2 Pressure History and Expected Future Pressure Decreases
The reservoir pressure at Souza #2 has never exceeded the hydrostatic pressure in the well.
Pressure (psi)
140
120
100
80
60
40
20
0
Excess hydrostatic pressure (gel strength included)
Excess hydrostatic pressure (mud weight only)
Maximum increase in pressure (44.5 psi June 2017)
Current increase in pressure from injection (38.3 psi)
EWS Commissioned
2030 pressure delta (26.3 psi)
Jun-09
Nov-10
Mar-12
Aug-13
Dec-14
Apr-16
Sep-17
Jan-19
Jun-20
Oct-21
Mar-23
Jul-24
Nov-25
Apr-27
Aug-28
Jan-30

Figure 3

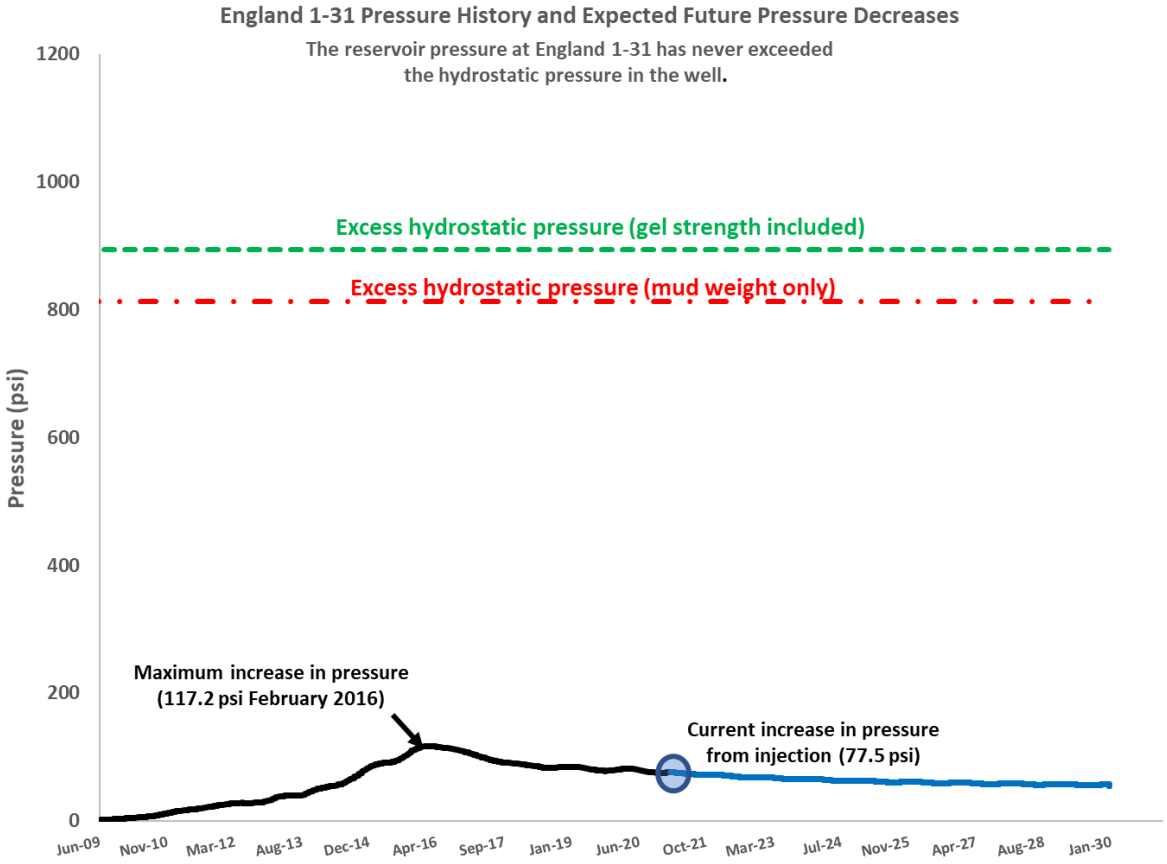
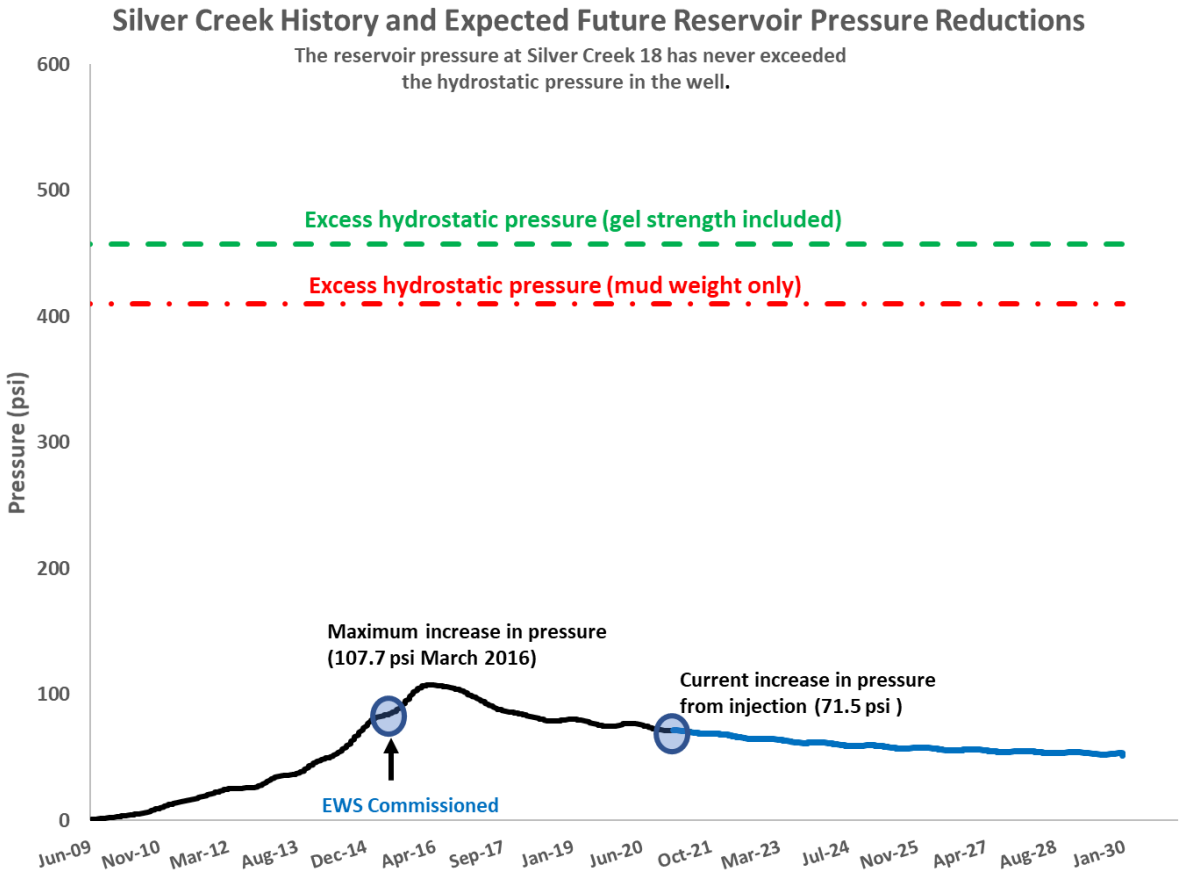
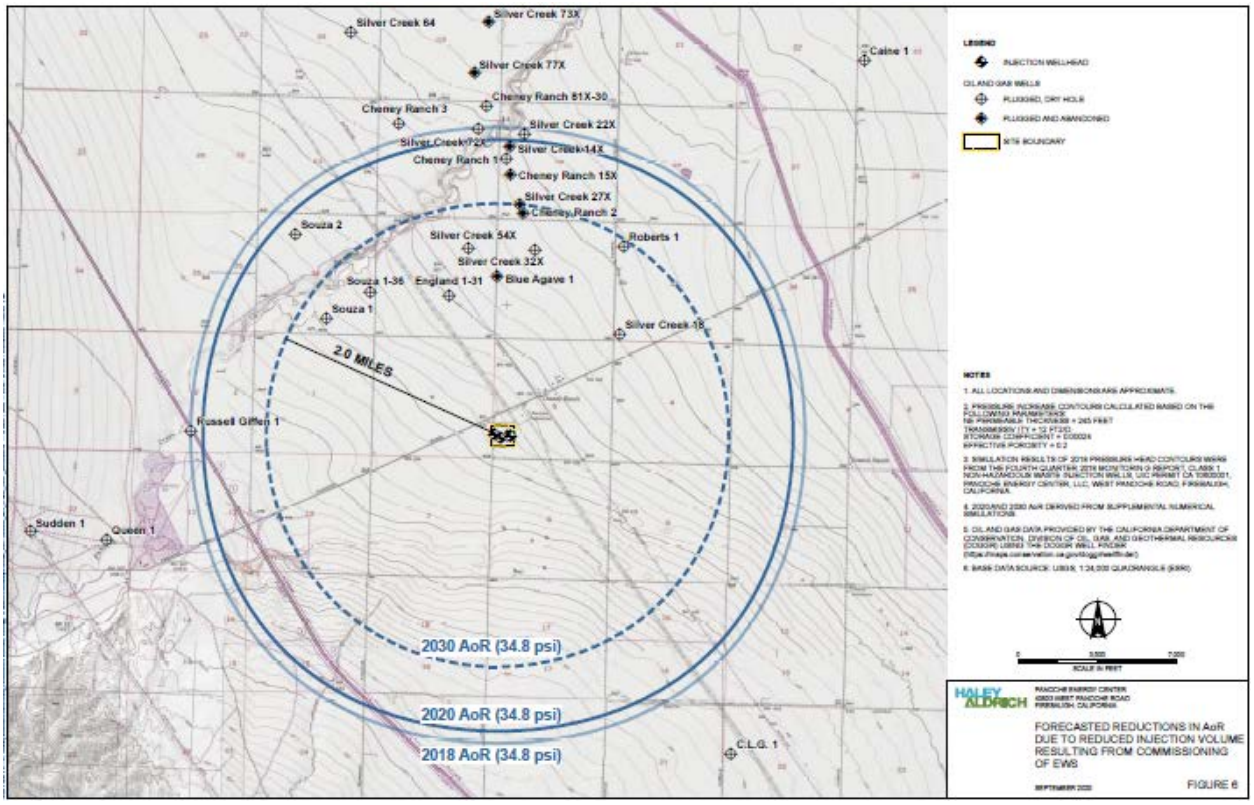

England 1-31 Pressure History and Expected Future Pressure Decreases
The reservoir pressure at England 1-31 has never exceeded the hydrostatic pressure in the well.
Excess hydrostatic pressure (gel strength included)
Excess hydrostatic pressure (mud weight only)
Pressure (psi)
1200
1000
800
600
400
200
0
Maximum increase in pressure (117.2 psi February 2016)
Current increase in pressure from injection (77.5 psi)
Jun-09
Nov-10
Mar-12
Aug-13
Dec-14
Apr-16
Sep-17
Jan-19
Jun-20
Oct-21
Mar-23
Jul-24
Nov-25
Apr-27
Aug-28
Jan-30

Figure 4



In addition, PEC has modeled how the EWS will reduce the AoR as a function of reduced injection volume over the life of the permit. As shown Figure 5 below, the AoR has contracted from 2018 to August 2020, and will continue to contract inward significantly by 2030.

Figure 5



<u>Question 3:</u> If there is declining influence of pressure in the injection zone, and no evidence to conclude a potential for endangerment, and no improperly plugged or abandoned wells in the AoR, what site-specific information is EPA relying on to impose a monitoring condition at the Silver Creek #18 well and USDW?

4. <u>Monitoring Silver Creek #18 is Not Supported by Empirical Evidence</u>

The Silver Creek #18 well was initially drilled to a total depth of 8,696 feet in April 5, 1974. Form 111 issued by the Division of Oil and Gas (dated February 21, 1974) specifies that the base of usable fresh water should be encountered at a depth of approximately 1,650 feet. Drilling of the well was started on March 23, 1974, with surface casing set to a depth of 768 feet and cemented with 600 sacks of cement (450 sacks of Class G cement with 8% gel and 150 sacks of Class G cement with 3% calcium chloride. Approximately 100 cubic-feet of cement returns were noted at surface. The well was logged at 7,908 feet and the well was drilled to total depth at 8,696 feet using 10.03 lb./gal Cypan mud (Cypan is a fluid loss control additive) with a funnel viscosity 40 to 43 seconds, demonstrating that the mud had gel. The 8-1/2-inch open hole was plugged with Class G cement with 4% gel and 3% calcium chloride with the drill pipe at 1,700 feet. The top of the plug was tagged at 1,437 feet, which was witnessed by Mr. E.V. Kaarlela of the Division of Oil and Gas. This plug straddles the base of usable fresh water. A second plug, consisting of 50 sacks of Class G cement with 4% gel and 3% calcium chloride was set from 678 feet to 817 feet.

This plug straddles above and below the surface casing at 768 feet. A final plug was set from 8 feet to 35 feet and a steel plate welded to the top of casing. The Division of Oil and Gas issued a Report of Well abandonment (Form 159) approving the well plugging (June 19, 1974), which states that the "requirements of this Division, which are based on all information files with it, have been fulfilled". State records for this well are included in Attachment 6.

In order to pose a potential threat to a USDW, the pressure buildup from injection must be sufficient to drive fluids into a USDW. Therefore, the pressure increase in the injection interval would have to be greater than the pressure necessary to displace the material residing within the borehole. This pressure necessary to displace the material residing within the borehole is defined as the allowable buildup pressure. In the evaluation for the E. A. Bender, Silver Creek 18-33 well under the non-endangerment standard, a calculation of the potential displacement pressure (allowable buildup pressure) versus the modeled pressure increase in the Panoche Injection Interval is made. It is only at a point where the modeled pressure at the well is greater than the calculated allowable buildup pressure that monitoring or some other action is warranted.

The methodology used in the PEC permit renewal for calculating the allowable buildup pressure at the Silver Creek #18 well is generally consistent with previous methods (Barker, 1981; Clark et al., 1987; Collins, 1986; Davis, 1986; Johnson and Greene, 1979; Johnson and Knape, 1986; Warner, 1988; Warner and Syed, 1986).[21] The methodology has also been approved by EPA (see for example Chemours Delisle Plant, 2017 HWDIR Exemption Petition Reissuance Application – Section 4.0 Area of Review[22] and California Specialty Cheese San Joaquin County, California, Permit Application for Injection Well[23]).

In the case of Silver Creek #18, the following facts apply:

- cement plugs were set at the surface, at the casing shoe, and in the open borehole across the base of usable quality water; and
- the remaining portions of the borehole are filled with heavy drilling mud.

Common drilling mud is largely composed of clays and water, forming a colloidal base. Typically, bentonite (sodium montmorillonite) is added to the drilling mud as the clay and is used to obtain viscosity in the slurry and promoting the formation of wall cake (the low-permeability layer of clay

[21] *See* Attachment 7 - Supporting Technical Literature.

[22] Underground Injection Control Program; Hazardous Waste Injection Restrictions; Petition for Exemption Reissuance-Class I Hazardous Waste Injection; The Chemours Company, FC, LLC, Chemours Titanium Technologies DeLisle Plant, Pass Christian, Mississippi (https://www.epa.gov/sites/production/files/2019-11/documents/section_4_area_of_review.pdf)

[23] *See* Attachment 7 - Supporting Technical Literature.

lining the borehole). Oil and gas wells are commonly drilled at a mud weight that provides 200 psi or more overbalance to the formations encountered during the drilling activity (Pearce, 1989).[24] Bentonite is hydrophilic (it readily absorbs water), and its flat platy shape is the primary reason it is desired for use in common drilling fluids. The Cypan mud used in the Silver Creek #18 well is exactly this type of colloidal base mud. The development of gel strength in a drilling mud is due to the tendency of the clay platelets to align in a configuration where positively charged edges are adjacent to negatively charged surfaces, resulting in a medium with thixotropic properties (Baker Hughes, 2006).[25] Thixotropy is the characteristic whereby certain gels evolve to a semi-solid state when allowed to stand undisturbed but liquefy upon shock disturbance. The gel phase is desirable because it assists in suspending cuttings released by the drilling procedure, producing the required viscosity and mud cake properties in the circulating mud system. These mud properties also allow for stability of the borehole and keep formation fluids from entering the borehole when circulation of the drilling mud system is stopped.

These physical characteristics that make clay-based drilling mud useful during active drilling operations also make it an effective barrier to vertical fluid movement within abandoned boreholes. In thixotropic behavior, under static conditions the clay platelets aggregate (flocculate) in three ways: 1) face-to-face, 2) edge-to-edge, or 3) edge-to-face, because the platelets are electrically charged. This thixotropic or gelling property of a clay-based bentonite slurry is what gives drilling mud its gel strength. In clay-based mud systems, gel structures build with time (progressive gel) as the positive edge of one particle or plate moves toward the negative surface of another; that is, when the platelets are layered (Gray et al., 1980).[26] Laboratory studies have shown that although the exact relationship between gel strength and time varies, depending on specific mud composition and additives, the gel strength always increases with time. Additionally, this orientation of the clay plates reduces the vertical permeability of the mud column significantly because tortuosity through the mud is increased.

The permeability of drilling mud in abandoned wells depends on the amount and size of the clay particles and other colloidals available in the slurry, as well as the time the mud has been left in the hole. The permeability of other similar bentonite clay mixtures, such as those used in slurry wall construction and bentonite grout slurry mixtures used to plug shallow borings, has been measured and quantified; and Daerman and Ren (1968)[27] show that compacted bentonite has a

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[24] *See* Attachment 7 - Supporting Technical Literature.

[25] *Id.*

[26] *Id*.

[27] *Id.*

permeability ranging from 10^{-15} to 10^{-21} meters^2 depending on its compacted density, where more compacted bentonite has less void space for fluid flow..

Kelessidis et al. (2007)[28] investigated the characteristics of filter cakes produced from water-bentonite solutions, including their permeability and porosity. Kelessidis et al. focused on the ability of a bentonite mud to form a filter cake with a low enough permeability to ensure that there would not be fluid flow through the filter cake. Measured filter cake permeabilities were determined from the filter cake formed in a standard filter press filtration test run for 30 minutes. The cake that formed on the filter paper was then placed between sandstone plugs and tested with water to determine the cake's permeability. The cake using Wyoming bentonite had measured permeabilities ranging from 4×10^{-3} millidarcies, which is regarded as a low enough permeability to prevent fluid flow into or out of the borehole.

A static mud column exerts both pressure and thixotropic behavior. Both of these properties need to be assessed and for a well to provide a pathway for fluid movement, the pressures acting on the mud column (pressure due to the injection activity plus original formation pressure) must be greater than the mud column pressure and the gel strength of the mud. In this case, for upward fluid movement to begin, original formation pressure (Pf) plus the pressure due to injection (Pi) must be greater than the static fluid column pressure plus the gel strength of the mud. This relationship is based on a simple balance of forces (Davis, 1986):[29]

$$P_f + P_i > P_s + P_g$$

Where:

P_f = original formation pressure (psig)

P_i = formation pressure increase due to injection (psi)

P_s = static fluid column pressure (psig)

P_g = gel strength pressure (psi)

Therefore, pressure increase due to injection must be greater than mud column pressure and gel minus original formation pressure:

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[28] Attachment 7 - Supporting Technical Literature.

[29] *Id*.

$$P_i > P_S + P_g - P_f$$

The pressure exerted by the mud column is calculated using the following equation:

$$P_S = 0.052 \times h \times M$$

Where:

P_S = pressure of static mud column (psi)

h = depth to the injection reservoir from the 50-foot fallback (feet)

M = fluid weight (lb./gal)

and 0.052 is the conversion factor so that Ps is in psi. For the Silver Creek #18 well, with a mud weight of 10.03 lbs./gal. the mud column pressure is equal to the depth (h) times 0.5216 psi/ft (10.03 lb./gal. x 0.052 conversion factor), or 521.6 psi per 1,000 feet of depth.

The additional pressure due to gel strength (G) in an open borehole can be calculated from the following equation:

$$P_g = \frac{0.00333 \times G \times h}{d}$$

Where:

P_g = pressure due to gel strength (psi)

G = gel strength (lb./100 ft^2)

d = borehole diameter (inches)

Where: 0.00333 is the conversion factor, such that P_g is in psi.

Using a very conservative value of 20 lb./100 sq. ft. for the gel strength and a borehole radius of 8.5-inches, the additive pressure due to gel strength in the mud is 0.0078 psi, or 7.8 psi per 1,000 feet of depth.

The specific comparison between the modeled formation plus the pressure buildup due to injection at the Silver Creek #18 well and the calculated allowable pressure based on the above formula were included in the September 2020 correspondence with EPA. This calculation is presented as follows:

The pressure exerted by the mud column in the Silver Creek #18 well is calculated using the following equation:

$$P_S = 0.052 \text{ x h x M} = 0.052 \text{ x (7,735 feet -50 feet fallback) x 10.03 lb./gal.= 4,007 psi.}$$

The additional pressure due to gel strength (G) in an open borehole can be calculated from the following equation:

$$P_g = \frac{0.00333 \text{ x G x h}}{d}$$

$$P_g = \frac{0.00333 \; x \; 20\frac{lb}{100}-sq-ft \; x \; (7{,}735 \; feet - 1{,}700 \; feet)}{8\frac{1}{2}}$$

Pg. = 47.3 psi (*note that only that portion of the mud column below the deepest cement plug and the top of the injection interval is considered)

Therefore, the allowable buildup at Silver Creek #18 is 4,054 psi.

The original formation pressure at Silver Creek #18 can be calculated from the original formation pressure gradient multiplied by the depth of 7,735 feet. Using a formation pressure gradient of 0.4665 psi/ft results in a formation pressure of 3,608 psi at the Silver Creek #18 well. The difference between the original formation pressure and the pressure exerted by the mud column is 457 psi. This allowable pressure of 457 psi is well above the maximum modeled pressure increase at the well of 78 psi in 2017 and the current modeled pressure of 38.3 psi (see Figure 5, above). With startup of the EWS, formation pressure is expected to decline through the end of 2030 to a value of 26.3 psi. As the conservatively calculated allowable buildup pressure exceeds the maximum modeled value by almost a factor of 6, PEC contends that this well is safe as abandoned and that monitoring is not warranted.

Several margins of additional safety are present in the above calculations. These are:

a. <u>Gel Strength Likely Exceeds 20 lb./100 ft2</u>

The relationship between gel strength and time varies with the mud type, depending on such variables as composition, pH, temperature, pressure, solids, and degree of flocculation. Srini-Vasan (1957) investigated the effect of temperature (up to 220 °F) on water-based muds with drilling weights like the wells in the Cheney Ranch Field. Annis (1967)[30] showed that the gelling

[30] *See* Attachment 7 - Supporting Technical Literature.

process is depends on both time and temperature, with 18 parts per billion (ppb) bentonite solution at any temperature having a gel strength six times that of the initial gel strength of the mud. Vryzas et al. (2016)[31] found that the gel-like structure of water/bentonite suspensions proved to be rheologically stable after an aging period of 30 and 60 days.

As shown in Davis and Pearce (1989),[32] Chevron conducted laboratory experiments to determine the expected condition of mud left in wellbores. Chevron formulated muds like those used in Mississippi and "aged" the mud samples at temperature and pressure for a two-week period. The testing showed that the muds developed significant compressive strength and was described as a "plug", with a gel strength too high to measure with standard equipment (Davis and Pearce, 1989).[33]

Field evidence of the longevity of mud as a plugging material has been demonstrated during well reentries. The Nora Schulze No. 2, located in Nueces County, Texas, was reentered by Envirocorp in the late 1980's. The well was plugged with 10.6 to 11.0 lb./gal mud when abandoned in 1959 (Pearce, 1989).[34] Mud samples were taken upon reentry to a depth of approximately 754 feet using tubing pushed into the mud column from a depth of 120 feet. Below a depth of 754 feet, the mud could only be displaced from the well by breaking circulation (Pearce, 1989). Results of measured mud characteristics are presented in Figure 2. The average mud weight of the recovered samples was 11.1 lb./gal, showing that the mud did not appreciably change over the intervening 29 years following abandonment. The gel strengths of the samples ranged between 217 lb./100 ft2 to greater than 320 lb./100 ft2. These values are over an order of magnitude greater than the 20 lb./100 ft2 value required in California plugging rules and commonly used for modeling purposes (Pearce, 1989). In addition, shear strengths of the mud samples ranged from 170 lb./100 ft2 to 7,000 lb./100 ft2, increasing with depth (Pearce, 1989).

Calculating the gel strength using a value 100 lb./100 ft2 would increase that component of the calculation by a factor of 5.

b. Full Length of Mud Column in Calculating Gel Strength

The calculation of gel strength only considers that portion of the mud column below the base of the deepest cement plug in the well, located at a depth of 1,700 feet. Recalculating the gel strength using the full mud column, as was performed for the static column pressure would result in an increased value of 60 psi versus the 47 psi value used in the screening calculation.

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[31] *See* Attachment 7 - Supporting Technical Literature.

[32] *Id*.

[33] *Id*.

[34] *Id*.

c. The Original Formation Pressure Gradient is Overestimated

The original formation pressure was measured in IW2 at a value of 3,510 psi at 7,604 ft KB during the February 10, 2009 Step Rate Test (SRT) (*see* Panoche Energy Center, LLC, UIC Well IW2 Well Completion Report (March 30, 2009)). The true formation pressure gradient is actually 0.462 psi/ft. Recalculating the allowable buildup using the actual formation pressure gradient would result in a value of 481 psi versus the 457 psi value used in the screening calculation (presuming no change to the gel strength).

These calculations clearly show that the Silver Creek #18 well is safe as abandoned and that monitoring is not warranted.

***Question 4:* Based on the foregoing discussion of the conservative analysis of wells in the AoR, why did EPA select Silver Creek #18 for monitoring and what is EPA's site-specific and empirical basis to conclude that the well may be a conduit for the movement of fluids from the injection zone into the USDW?**

5. Proposed Injection and Facility Monitoring is Adequate

The Draft Permit, Part II.C.1-Annual Zone of Endangering Influence Review, states that PEC "shall review the ZEI calculation based on any new data obtained from the FOT and static reservoir pressure observations…" The Draft Permit requires that PEC "shall provide to EPA a copy of the modified ZEI calculations, along with all associated assumptions and justifications, with the next Quarterly Report." The Draft Permit also adds in Part II C.2.a that PEC must provide a list of any additional wells found within the modified ZEI, along with their location and construction data. In addition, under Draft Permit, Part II.E.1, PEC performs annual temperature surveys in each well. Under existing rules, the operator must check for fluid movement behind the casing and for leaks in the tubing, casing, or packer at least once every five years. PEC is performing this required testing every year, without indication any movement of fluid.

Based on these provisions, the Draft Permit requires monitoring and a detailed assessment of pressure buildup in the Panoche Injection Interval. As such, the proposed annual assessment of pressures throughout the Panoche Injection Interval provides a mechanism to increase the AoR, if necessary. In addition, the proposed monitoring and annual ZEI reassessment allows for a specific check of the pressure buildup at the Silver Creek #18 well versus the allowable pressure buildup (and all of the other wells in the AoR as presented in Table 1, above), which is a trigger for enhanced monitoring or corrective action.

The use of fluid flow modeling, such as those used by PEC to perform the annual ZEI reassessment, is a well-developed and mature science and has been used for many years in the hydrology and petroleum industry. These models provide the capability to analyze pressure build up and lateral plume geometry and can be used with confidence to assess the potential for leakage through artificial penetrations and endangerment to USDW.

<u>Question 5:</u> Given that the Draft Permit includes robust monitoring and assessment provisions in Parts II.C and II.E, as discussed above, what information does EPA expect to gain through monitoring Silver Creek #18, and what is the technical basis for requiring that information?

6. <u>Monitoring Silver Creek #18 is Not Supported under EPA Regulations</u>

EPA states in the Draft Permit, Part II, Section C, that "Prior to EPA granting authorization to inject under this Permit, the Permittee is not required to conduct any corrective action, in accordance with 40 CFR §§ 144.55 and 146.7."[35] EPA then goes on to state:

> Corrective action may be required after permit issuance to address any wells within the area of review that may allow migration of fluids into USDWs. EPA will use the annual FOT results and re-calculation of the ZEI, along with USDW monitoring results from the monitoring well, as described in Section V. Monitoring, Recordkeeping, and Reporting of Results below, to determine the potential need for any future corrective action.[36]

EPA's approach to the Draft Permit is flawed. The Well Operation aspects of the Draft Permit set forth in Part II, Section D, already require a host of measures to ensure there is no movement of fluid containing contaminants into the USDW, including mechanical integrity tests (MITs) of the injection wells (demonstrating no significant leaks), pressure fall-off tests (FOTs) to monitor formation characteristics, and operation of the existing injection wells in a manner that will not initiate or propagate fractures in the injection or confining zones.

In addition, in Section II, Part E, PEC is required to engage in continuous monitoring of injection fluid temperature, injection rate, daily injection volume, total cumulative volume, well head injection pressure, and annular pressure in each injection well (among other things). Against this backdrop, the requirement that PEC install a new USDW monitoring well near the Silver Creek 18 well, has no place in the Draft Permit.

EPA sole basis requiring monitoring at Silver Creek #18 is "to perform chemical analysis" "pursuant to 40 CFR §§ 146.13 (b) and (d)." However, as set forth above, there is no technical or empirical basis to include the Silver Creek #18 condition in the Draft Permit. Moreover, as a legal matter, EPA's reliance on 40 CFR § 146.13 (b) is misplaced and not in accordance with law.

EPA regulation 40 CFR § 146.13 (b) states:

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[35] Fact Sheet, p. 4.

[36] *Id*.

> (b) Monitoring requirements. Monitoring requirements shall, at a minimum, include:
>
> > (1) The analysis of the injected fluids with sufficient frequency to yield representative data of their characteristics;
> >
> > (2) Installation and use of continuous recording devices to monitor injection pressure, flow rate and volume, and the pressure on the annulus between the tubing and the long string of casing;
> >
> > (3) A demonstration of mechanical integrity pursuant to § 146.8 at least once every five years during the life of the well; and
> >
> > (4) The type, number and location of wells within the area of review to be used to monitor any migration of fluids into and pressure in the underground sources of drinking water, the parameters to be measured and the frequency of monitoring.

A review of those requirements demonstrates that PEC is already performing such monitoring, and will continue to do so under provisions of the Draft Permit, without having to install a multi-million dollar monitoring well[37] on property it does not own or control and may not get access to.[38]

EPA regulation 40 CFR § 146.13 (d) states:

> (d) Ambient monitoring.
>
> > (1) Based on a site-specific assessment of the potential for fluid movement from the well or injection zone and on the potential value of monitoring wells to detect such movement, the Director shall require the owner or operator to develop a monitoring program. At a minimum, the Director shall require

[37]PEC's "AFE" cost for a 4,000 foot monitor well with 5-1/2-inch casing to allow for sufficient access for sampling and pressure/conductance monitoring is $1,633,350 CAPEX. This does not include acquisition/access (if even possible) costs for the location, permitting costs, or costs to provide power to the monitoring well location.

[38] The Silver Creek #18 well is located on land not owned by PEC; and PEC has no right to enter or use that property.

> monitoring of the pressure buildup in the injection zone annually, including at a minimum, a shut down of the well for a time sufficient to conduct a valid observation of the pressure fall-off curve.
>
> (2) When prescribing a monitoring system the Director may also require:
>
> > (i) Continuous monitoring for pressure changes in the first aquifer overlying the confining zone. When such a well is installed, the owner or operator shall, on a quarterly basis, sample the aquifer and analyze for constituents specified by the Director;
> >
> > (ii) The use of indirect, geophysical techniques to determine the position of the waste front, the water quality in a formation designated by the Director, or to provide other site specific data;
> >
> > (iii) Periodic monitoring of the ground water quality in the first aquifer overlying the injection zone;
> >
> > (iv) Periodic monitoring of the ground water quality in the lowermost USDW; and
> >
> > (v) Any additional monitoring necessary to determine whether fluids are moving into or between USDWs.

Similar to the above and as described in this letter, a review of these requirements reveals that PEC is already undertaking such activities, and will continue to do so under the provisions of the Draft Permit that have been in place, and that PEC has no objection with keeping as part of its requirements as the permittee.

While PEC is unsure of the true basis for Region 9 requiring the installation of a monitoring well to perform chemical analysis, the Fact Sheet states that “EPA is requiring USDW monitoring near the Silver Creek 18 *well to help determine whether there is any impact on the lowermost USDW,*

including potential fluid migration from the injection zone as part of PEC's injection activities."[39] EPA goes on to say: "The abandoned Silver Creek 18 well does not have a cement plug between the injection zone and the lowermost USDW so *there is a possibility that this well could be a conduit for fluids to migrate from the over-pressurized injection zone to the shallower USDW*."[40]

As described above, PEC has produced significant information to demonstrate that there is no endangerment and that all wells in the AoR were properly plugged and abandoned; and therefore, no USDW monitoring is justified under 40 CFR § 146.13.

In Re Windfall Oil & Gas, Inc. is instructive in this regard. In that EAB decision, Region III had determined that no corrective action plan was needed because there were no wells within the AOR; and, therefore, there were no wells that could serve as conduits for injection fluid.[41] The EAB went on to conclude that a corrective action plan is not required for properly sealed, completed, or abandoned wells.[42] There, the EAB confirmed that three operating wells that were outside the area of review would not require corrective action even if they were located within the AoR because they were not potential conduits for fluid migration into USDW.[43] Specifically, "the plugging certificates served as confirmation that each of the three identified wells . . . was plugged properly and in accordance with Pennsylvania state requirements in effect at the time."[44] Likewise here, PEC has provided Region 9 with detailed, technically based evidence that the Silver Creek 18 well was in fact properly plugged, in accordance with California state requirements.

And while EPA in the Draft Permit is not requiring PEC to now plug Silver Creek 18, EPA is recasting the exact same "corrective action" requirement from its proposed in July 27, 2020, permit as a "monitoring condition" in the Draft Permit, and the agency is doing so on purely speculative grounds—*i.e.*, that there is "a possibility" that the well could be a conduit. In this regard, the EAB in *In Re Windfall Oil & Gas, Inc.* cited with support the fact that "monitoring wells do not monitor groundwater quality."[45] The EAB went on to state: "A monitoring well only can measure an increase in reservoir pressure once the pressure has extended radially far enough from the wellbore to reach the monitoring well. In contrast, the Windfall Permit's required pressure

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[39] Fact Sheet, p. 6 (*emphasis added*).

[40] *Id*. (*emphasis added*).

[41] 2015 WL 3782844, at *28.

[42] *Id*. at *9.

[43] *Id*.

[44] *See also id*. at *19 ("[W]here appropriate, [applicant must] submit a corrective action plan to address any improperly sealed, completed, or abandoned wells . . ." [emphasis added]).

[45] *Id*., at *23.

fall-off test will detect changes in reservoir pressure at the wellbore, ostensibly providing more protection against reservoir pressure increases than a monitoring well can."[46]

In addition, the preamble to the rule promulgating 40 CFR § 146.13 offers further insight into EPA's authority to impose monitoring. The preamble states:

> The Agency has been investigating methods of ambient monitoring which might be useful and will continue to do so. With one exception, there appears to be no single technique which could provide meaningful data at all sites. *The question of what might prove effective at a given site depends on the hydrogeologic setting and the characteristics of the operation* . . . There were several commenters who requested a language change in this section that would allow the Director more discretion to conduct ambient monitoring. Other commenters sought to require monitoring in the injection zone, the first aquifer above the injection zone, and the lowermost USDW. Still other commenters indicated that ambient monitoring should be strictly a site-specific requirement. *The Agency agrees that ambient monitoring requirements should be site-specific* and has indicated this in the proposed rule (see 52 FR 32463 and 32464) and today's final rule, and gives the Director discretion in determining an acceptable program.[47]

Here, EPA has offered no facts, evidence, or analysis to justify why site-specific circumstances justify imposing a monitoring condition associated with the Silver Creek #18 well. Rather, the sum total of EPA's rationale is a generalized statement that "*there is a possibility* that [Silver Creek 18] could be a conduit for fluids to migrate." In reviewing all available, online, UIC Class I permits issued by Region 9 since 2008, no facility has been subject to a similar monitoring condition as proposed in the Draft Permit.

Question 6: What is EPA Region 9's site-specific basis to exercise its discretion under 40 CFR § 146.13 for the first time to evaluate the condition of the USDW near the Silver Creek #18 well?

Furthermore, the monitoring condition EPA proposes here includes equipping the well with transducers to monitor pressure and specific conductance within the USDW on a minimum daily basis; and water quality monitoring equipment to allow sampling of the USDW. The baseline

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[46] *In Re Windfall Oil & Gas, Inc.,* 2015 WL 3782844, at *23.

[47] Underground Injection Control Program: Hazardous Waste Disposal Injection Restrictions; Amendments to Technical Requirements for Class I Hazardous Waste Injection Wells; and Additional Monitoring Requirements Applicable to all Class I Wells, 53 Fed. Reg. 28118 (July 26, 1988) (emphasis added).

chemical analysis of the USDW fluids consists of TDS, alkalinity, anions and cations, hardness, pH, specific gravity, total sulfide, oil and grease, and total metals using the analytical methods outlined in Section E.1. of the Draft Permit. These chemical analyses must be performed monthly for the first year of monitoring, and quarterly thereafter.

PEC's wastewater does not contain unique indicator parameters. Modeling included in the renewal application shows that the injected plumes will be contained within close proximity to the PEC injection wells and will be no closer to the monitoring location than a mile or more. Additionally, there are other changes that are currently occurring, such as the withdrawal of groundwater that will be perturbing the aquifer system.

Equally problematic is the provision to locate the proposed monitoring well within 100 feet of Silver Creek #18. As stated earlier, PEC does not own the land within 100 feet of the Silver Creek #18 well, and PEC has no right to demand access to that land.[48] Moreover, the "Deviation Record" for the Silver Creek #18 well (CalGEM Form 103) indicates inclination deviations from vertical of up to 3 degrees from vertical above a depth of 4,500 feet. These recorded levels of deviations, without knowing the exact path of the Silver Creek #18, increase the chance of intersection of the monitoring well with the Silver Creek #18 borehole. Prudent well planning would provide for a better justification of safe well-to-well proximity that exceeds 100 feet separation.

In addition to having a site-specific and rationale basis to impose a monitoring condition under 40 CFR § 146.13, EPA must also explain why the monitoring program it proposes is effective at the Silver Creek #18 site based on the hydrogeologic setting and the characteristics of the PEC operation.

a. Questions related to proposed monitoring condition

For the reasons described above, PEC has several questions concerning the proposed Silver Creek #18 monitoring:

- ***Question 7:*** ***Given that the Draft Permit includes monitoring and assessment provisions that evaluate changes in formation pressure, what is specific basis and rationale for the Silver Creek #18 monitoring condition?***

- ***Question 8:*** ***How will the pressure monitoring and the constituent monitoring data from the monitoring well be used to identify potential issue(s) resulting directly from PEC's injection; and how will the Region then identify and propose potential corrective action(s) for those issues?***

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[48] *See e.g.*, Draft Permit, Section III.A: "Issuance of this Permit does not convey property rights of any sort or any exclusive privilege, ***nor does it authorize any injury to persons or property, any invasion of other private rights, or any infringement of State or local law or regulations***." (emphasis added); *see also*, 40 CFR § 144.35(b) and (c).

- ***<u>Question 9:</u> How will EPA identify and account for possible contamination in the USDW from other potential sources not associated with PEC's injection activity?***

- ***<u>Question 10:</u> How will the pressure dissipation due to reduced injection volumes from the PEC Injection Zone affect pressure monitoring and constituent monitoring results from the monitor well?***

- ***<u>Question 11:</u> How will EPA account for impacts of area water wells/irrigation wells on monitoring well results? For example, what is the effect of State Well Number 15S13E06J001M, which is an irrigation well located within 0.25 mile of the PEC facility wells?***

- ***<u>Question 12:</u> How will large-volume withdrawals of groundwater in the Fresno Irrigation District affect pressure monitoring and constituent monitoring; and how will EPA Region 9 discern the difference in causation from the irrigation district versus the Facility?***

- ***<u>Question 13:</u> Under what authority does EPA propose PEC to invoke to demand access to private land, to drill a 4,000 foot well, and to operate that well for the life of the UIC permit?***

- ***<u>Question 14:</u> Given that there are 1,000s of feet of confining layers between the USDW and the injection zone, with intervening pressure bleed-off zones, how will EPA account for that decrease in pressure with the proposed monitoring condition for the Silver Creek #18 well?***

Without resolving the questions presented above, there is simply no technical, regulatory, or legal basis for EPA to require the installation of the Silver Creek #18 monitoring well in this matter, and the requirement should therefore be removed from the Draft Permit.

* * *

Thank you for the opportunity to comment on the Draft Permit. PEC remains open to discussing an alternative monitoring condition with EPA Region 9 that is consistent with the technical analysis and UIC regulations.

Please let me know if you have any questions or require additional information.

Included at the end of this document is a list of Attachments to this letter.

Sincerely,

Ankur K. Tohan

CC:

Desean Garnett (EPA Region 9)
Robin Shropshire (Panoche Energy Center)
Daniel Collins (Geostock Sandia, LLC)
Steve Morton (K&L Gates)
Robert Hines (Farella Braun + Martel)

List of Attachments - Panoche UIC Class I Well Draft Permit Comments

Attachment	Description
1	Chronology of PEC / EPA Region 9 Correspondence.
	7.27.20 Draft Permit
2	Panoche Energy Center, January 17, 2020. Attachment A, Response to USEPA Comment No. 1d from Letter Dated December 3, 2019.
3	Panoche Energy Center Comments on draft UIC Permit No. R9UIC-CA1-FY17-2R, dated September 25, 2020.
4	Panoche Energy Center letter regarding follow up from December 18, 2020 meeting with EPA, dated January 25, 2021.
5	Panoche Energy Center: Comments on Draft Permit.
	Panoche Wastewater Injection Schematic
	PEC IW1 Schematic
	PEC IW2 Schematic
6	Report titled “Mud Column Characteristics and Conditions in the Cheney Ranch Field, dated December 16, 2020.
7	Appendix 4-3g “Report of Examination of Mud Conditions,’ dated 1988.
	“High-Temperature Flow Properties of Water-Base Drilling Fields,” *Journal of Petroleum Technology*, 1980.
	“Drilling Fluids Reference Manual,” Baker Hughes, revised 2006.
	“Determining the Area of Review for Industrial Effluent Disposal Wells,” University of Texas at Austin Graduate Program, S.E. Barker, 1981.

Attachment	Description
	"Permit Application for Class I Non-Hazardous Injection Well, California Specialty Cheese," dated October 2005.
	"Chemours Delisle Plant 2017 HWDIR Exemption Petition Reissuance Application, Section 4.0 Area of Review," September 2018.
	"Factors that Can Cause Abandoned Wells to Leak as Verified by Case Histories from Class II Injection, Texas Railroad Commission Files," by Clark, J.E., Howard, M.R., and Sparks, D.K., 1987, International Symposium on Subsurface Injection of Oilfield Brines.
	"Gulf Coast Borehole Closure Text Well Orangefield, Texas," by Clark, J.E., Papadeaus, P.W., Sparks, D.K. and McGowen, R.R., presented at Texas Water Commission Annual Meeting in October 1991 by E.I. du Pont de Nemours & Co., Inc.
	"Technical Basis for Area of Review, An Engineering Study Prepared for the Chemical Manufacturers Association," by Collins, R.E., 1986.
	"Drilling Mud as a Hydraulic Seal in Abandoned Wellbores," by Collins, R.E. and Kortum, D., Research & Engineering Consultants, Inc., Englewood, Colorado, 1989.
	"Draft Report: A Review of Literature and Laboratory Data Concerning Mud Filled Holes," by Chemical Manufacturing Association, Washington, D.C., October 1989.
	"Bentonite as a Waste Isolation Pilot Plant Shaft Sealing Material," by Jaak Daeman, J. and Ran, C., Prepared by Sandia National Laboratories Albuquerque, New Mexico and Livermore, California, for the United States Department of Energy under Contract DE-AC04-94AL85000, 1996.
	"Factors Affecting the Area of Review for Hazardous Effluent Disposal Wells," by Davis, K.E., Proceedings of the International Symposium on Subsurface Injection Liquid Wastes, 1986.
	"Composition and Properties of Oil Well Drilling Fluids," by Gray, George R., Darley, E.C.H, and Rogers, Walter, Fourth Edition, Gulf Publishing Co., 1980, Excerpt.

Attachment	Description
	"Investigation of Artificial Penetrations in the Vicinity of Subsurface Disposal Wells," by Johnson, O.C. and Green, C.J., Texas Department of Water Resources, 1979.
	"Pressure Effects of the Static Mud Column in Abandoned Wells," by Johnson, O.C. and Knape, B.K., Texas Water Commission, 1986.
	"Permeability, porosity and surface characteristics of filter cakes from water-bentonite suspensions," by Kelessidis, V.C., Tsamantaki, C., Pasadakis, N., E. Repouskou, E., and Hamilaki, E., WIT Transactions on Engineering Sciences, Vol 56, 2007.
	"Groundwater Flow in Low-Permeability Environments," by Neuzil, C.E., Water Resources Research, Vol. 22, No. 8, pages 1163-1195, August 1986, Water Resources Division, U.S. Geological Survey, Reston, VA.
	"Long-Term Properties of Clay, Water-Based Drilling Fluids," by Pearce, Mark S., PhD., Envirocorp Services & Technology, Inc., 1989.
	"The Effect of Temperature on the Flow Properties of Clay-Water Drilling Methods," by Srini-Vasan, A. and Gatlin, C., University of Tulsa, Tulsa, OK, Technical Note 2025, 1958.
	"Understanding the Temperature Effect on Rheology of Water-Bentonite Suspensions," by Vryzas, Z., Wubulikasimu, et al., Annual Transactions of the Nordic Rheology Society, Vol. 24, 2016.
	"Abandoned Oil and Gas Industry Wells and Their Environmental Implications," by Warner, D.L., UIPC Summer Meeting Proceedings, 1988.
	"Confining Layer Study: Supplemental Report," by Warner, D.L. and Syed, T., Engineering Enterprises, Inc., prepared for EPA Region V under contract No. 68-01-7011,1986.