Puna Geothermal Venture (PGV)
Class V Geothermal Injection Well Permit No. R9-UIC-HI5-FY16-1R

Description of Changes to the Draft Permit

Pursuant to Title 40 Code of Federal Regulations (C.F.R.), 40 C.F.R. § 124.17(a)(1), the United States Environmental Protection Agency, Region IX (EPA), hereby specifies which provisions of the draft Permit have been changed in the final Permit decision, and the reasons for those changes. The changes are specified below in Items 1 through 39.

In response to commenters' questions about groundwater monitoring and concerns about whether PGV's operations impact the groundwater aquifer, EPA updated the Permit, including Appendix G, the Hydrologic Monitoring Program, to require additional monitoring. In particular, the Permit reflects the recommendations of the USGS Scientific Investigations Report 2015–5139 to monitor groundwater for isopropanol, because this constituent is a potential indicator of contamination from geothermal operations. *See* EPA Response to Comment No. 2a. EPA made the following changes to the Permit:

1. Revised Part II.E.1 of the Permit to reflect the date of the updated Hydrologic Monitoring Program.
2. Updated the analytical parameters in Appendix G (Hydrologic Monitoring Program) to include additional inorganic parameters, temperature, salinity, bicarbonate, and additional organic compounds (including isopropanol).

Because groundwater monitoring wells MW-1, MW-2, and MW-3 were inundated by lava during a June 2018 eruption of the Kilauea volcano, new groundwater monitoring wells were needed to maintain the number of monitoring wells at the site. Therefore, PGV replaced the inundated wells with two onsite monitoring wells, MW-4 and MW-5, and one offsite and downgradient monitoring well (Lippe Well at Pohoiki or MW-6). *See* EPA Response to Comment Nos. 2a and 5. EPA made the following changes to the Permit and its appendices to reflect the new groundwater monitoring wells:

3. Updated the map in Appendix A to show the two onsite groundwater monitoring wells (MW-4 and MW-5).
4. Updated Appendix G (Hydrologic Monitoring Program) to include a map that identifies the three replacement groundwater monitoring wells (MW-4, MW-5, and MW-6).
5. Updated the financial assurance provisions in Part II.G.1(a) to cover the cost of plugging the PGV-owned groundwater monitoring wells.
6. Updated Appendix I to include EPA Forms 7520-19 for the onsite monitoring wells.

In May 2021, EPA approved the conversion of KS-20 to an injection well under Section II.D.2.a. of the existing, administratively extended Permit. As a result, the final Permit consists of six (6) existing wells and up to ten (10) converted wells, instead of the five (5) existing wells and up to eleven (11) converted wells described in the draft Permit. EPA made several minor changes to the Permit and its appendices to reflect the updated status of KS-20 including:

7. Revised the description of the wells authorized under the Permit in Part I of the Permit to describe six (6) existing wells instead of five (5), as well as adding "Kapoho State 20 (KS-20)" to the list of existing wells.
8. Revised the description of the wells the Permittee may be authorized to construct and operate in Part I of the Permit to describe up to ten (10) converted wells, instead of eleven (11).
9. Updated the "existing well locations" in Part II.A.1. of the Permit to describe six (6) existing wells and added "Kapoho State 20 (KS-20)" to the list of existing wells.
10. Updated Table 1 in Part II.A.1. of the Permit to include the well location and wellhead elevation of KS-20.
11. Updated the address of the wells under "existing well locations" in Part II.A.1. to describe six (6) existing wells.
12. Updated the "proposed well locations" in Part II.A.2. of the Permit to describe up to ten (10) proposed geothermal injection wells and removed KS-20 from the list of proposed wells.
13. Updated the number of proposed wells to ten (10) in the second paragraph of Part II.B.1(a).
14. Added KS-20 to the list of wells to which the specifications in Appendix B (Injection Well Schematics) apply, in Part II.B.3.
15. Updated Part II.D.2. of the Permit to include the approved Maximum Injection Wellhead Pressure of 520 pounds per square inch for KS-20.
16. Updated the financial assurance provisions in Part II.G.1(a) to reflect the updated cost to potentially plug and abandon the wells, and the new dates of the financial instrument that covers the cost of plugging the six (6) existing injection wells and the two (2) onsite monitoring wells.
17. Updated the number of wells on the first page of Appendix A to reflect the operational status of KS-20.
18. Revised the map in Appendix A to show the status of well KS-20 as operational.
19. Added a revised plugging and abandonment form (7520-19) for KS-to 20 Appendix I (Plugging and Abandonment Plans).

EPA made minor changes to the Permit and its appendices to clarify the mechanical integrity testing (MIT) requirements and resolve inconsistencies or duplicative text. These changes include:

20. Revised Part II.D.1(a) of the Permit to: (1) fix an incorrect Permit reference (which should be to Part II.E.2(a), not Part II.D.1.) and (2) to delete duplicative text regarding the requirement to demonstrate that there are not significant leaks in the casing and hangdown liner, and that there is not significant fluid movement into or between underground sources of drinking water through the casing wellbore annulus or vertical channels adjacent to the injection wellbore.
21. Revised the text in Part II.E.2(b) to reflect the correct name of the "Program for Mechanical Integrity Testing," in Appendix F.

22. Deleted the second part of Appendix E (injectate testing), which contained an outdated "Program for MIT of the Injection Wells."
23. Revised Appendix F (Well Testing and Logging) to include updated standard operational procedures for MITs that clarify the reporting requirements for MIT results.

EPA made additional minor changes to the reporting requirements in the Permit and its appendices to include the relevant Hawaiian state agencies, including:

24. Added a reporting requirement in Part II.E.9(g) of the Permit to require that digital copies of all quarterly reports be sent to the Hawaii Department of Health (DOH) and Hawaii Department of Land and Natural Resources (DLNR).
25. Added a reporting requirement in Part III.E.9(c) of the Permit to require that digital copies of all quarterly reports be sent to DOH and DLNR.

EPA made several minor changes to the Permit and its appendices to fix typographical errors, address incorrect references, include referenced documents, or delete duplicative text in the draft Permit, including:

26. Added EPA Form 7520-18 to the reporting forms in Appendix J to reflect the reference to this form in Part II.B.2(b) of the Permit.
27. Updated Part II.E.3. of the Permit to clarify that quarterly injectate sampling is required.
28. Updated the cover page of the Permit to reflect that it is "final" rather than "draft."
29. Updated the footers in the Permit to reflect that it is "final" rather than "draft."
30. Updated the total number of pages in Part I of the Permit and the footers to 34 pages.
31. Updated Table 1 in Part II.A.1 of the Permit to reflect updated information from the Permittee about the wellhead elevations of KS-1A, KS-3, KS-11, and KS-13.
32. Edited Part II.B.1.a of the Permit to refer to a "well conversion plan," rather than a "well construction plan" to more closely reflect conversion of the proposed wells.
33. Revised Part II.B.2(b) to correct the reference to the location of Form 7520-18, which is in Appendix J, not Appendix C.
34. Edited Part II.B.6.d of the Permit to more accurately describe the flow metering transmitter equipment in place at the Permittee's facility.
35. Revised Part II.B.7(c) to correct the reference to the location of the reporting forms, which are in Appendix J, not Appendix C.
36. Revised the reference to "paragraphs (a)-(d) above" in Part II.D.4 to fix a typographical error.
37. Deleted an extraneous period between Parts III.E.10(e)(i)(b) and (c).
38. Deleted the notes on the cover page of Appendix C because they were duplicative of Permit text.
39. Deleted the notes on the cover page of Appendix G because they were duplicative of Permit text.

Summary of Significant Public Comments and EPA Response to Comments

Pursuant to 40 C.F.R. § 124.17(a)(2), the EPA hereby describes and responds to all significant comments received during the public comment period for the above-referenced draft Permit, which was open from June 22, 2020 to October 9, 2020, including all significant comments raised during the public hearing on October 7, 2020.

In total, EPA received one-hundred-twenty-one (121) timely public comments on the draft Permit, including one-hundred-six (106) written comments and fifteen (15) oral comments presented at the public hearing. Several comments were also accompanied by attachments. The complete index of comments, which also identifies the attachments submitted to EPA by each comment, is listed at the end of this document in the Appendix.[1] Some of the Attachments are also discussed in this document, where necessary. EPA organized the significant comments and EPA's responses under topical headings below.

EPA wishes to thank the public for their participation in this indispensable part of the permit process. EPA greatly values public input and appreciates the time all commenters took to express their informative and thoughtful comments related to the proposed Class V permit for the PGV injection wells.

General and Out of Scope Comments

Several commenters raised concerns about matters that the EPA Underground Injection Control (UIC) program does not have jurisdictional or regulatory authority to address in the UIC permitting process. When making a decision on whether to issue a UIC permit, EPA's UIC jurisdiction is limited to determining whether the proposed injection operation will safely protect underground sources of drinking water (USDWs) from the subsurface emplacement of fluids and a determination that the injection operation as proposed will be in compliance with all federal UIC regulations. *See e.g.*, *In re Puna Geothermal Venture*, 9 E.A.D. 243 (EAB 2000). EPA acknowledges the submittal of these comments and clarifies that, because they raise matters that are not addressed by the UIC regulations and are therefore outside the scope of the UIC permit process, EPA will not respond to them in this document. However, in a few limited cases, EPA responded to comments that fell outside of the scope of the permitting decision where it was believed that clarification would be helpful to the commenters, such as comments pertaining to induced seismicity, hydraulic fracturing, or the Supreme Court's recent *County of Maui v. Hawaii Wildlife Fund* ruling.

Comments falling out of the scope of the UIC regulations (from 44 commenters), including Attachments 18, 19, 22, 23, 24, and 36 as identified in the Appendix, focus on topics, including:

- General statements of opposition without a specific comment or assertion regarding the draft Permit

[1] Hereafter, "Attachment" as used in this document will refer to the comment-letter attachments submitted to EPA during the public comment period, as identified in the Appendix. For example, Attachment 01, refers to "*Ariel View, New Volcanic Vents, PGV Boundary*," which was submitted to the EPA by Robert Petricci by electronic mail on July 22, 2020, as identified in the Appendix.

- Excerpts from or references to Attachments that are out of the scope of the draft Permit or the UIC regulations
- Allegations of impropriety or incompetence by Ormat Technologies Inc.
- Allegations of impropriety or incompetence by the state of Hawai'i or local agencies
- Issues regarding other, non-UIC, PGV permits
- Real property values
- Economic or employment considerations
- Background information on the commenters
- Other, non-UIC federal, state, and local laws and requirements
- Requests to change laws
- Air pollution
- Storage of hazardous chemicals
- Climate change and energy policy
- Noise, odors, and similar health and wellness issues[2]

In addition to these out-of-scope comments, EPA received several comments submitted after the public comment period closed. EPA's regulations for UIC permits require a public comment period of at least thirty (30) days. Here, EPA held the comment period open for roughly three-and-one-half (3½) months. EPA is not responding to comments submitted outside of the public comment period.[3]

Finally, EPA also received thirty-one (31) comments in support of the issuance of the Permit, which were supported by Attachments 32, 33, 34, and 35 as identified in the Appendix. EPA acknowledges and appreciates these comments and notes that no response is necessary.

Comments that address topics that are within the scope of this permitting decision, along with EPA's responses, are included in the sections below.

1. **Requests for a Public Hearing** (36 commenters)

Comment No. 1:
Many commenters requested a public hearing to receive more information and to hear the concerns and opinions of the community. Commenters requested that the hearing be held in Pahoa. Alternately, to protect public health during the COVID-19 pandemic, commenters suggested that EPA conduct a virtual hearing either online, or for people who do not have reliable internet access, via telephone.

[2] Although these comments raise issues beyond the scope of the UIC regulatory requirements pertaining to USDW protection, EPA will also address them in EPA Response to Comment No. 4 regarding environmental impact statements.
[3] EPA notes that one commenter who submitted several comments outside of the public comment period also submitted several comments within the public comment period.

EPA Response to Comment No. 1:
EPA conducted a virtual public hearing via a phone-based operating service on October 7, 2020 from 5:00 – 8:00 p.m. local time. Thirty-nine (39) people attended the public hearing and fifteen (15) comments were received during the hearing. A transcript of the hearing has been uploaded on regulations.gov under docket number EPA-R09-OW-2020-0405.

2. **Groundwater Contamination Concerns** (25 commenters; Attachments 11, 12, 14, 20, and 21)

Comment No. 2a:
EPA received numerous comments regarding the potential impact of PGV's injection operations on groundwater quality, including: whether PGV's operations have ever impacted a source of drinking water; how EPA can protect drinking water sources, including those outside of the area of review or downgradient from the facility; how EPA can ensure the injectate does not migrate to contaminate groundwater through existing fractures or through fractures that commenters assert are created by PGV's drilling or injection; whether groundwater sources are known and monitored; and whether the increased stream pressure from the 2018 eruption may have impacted the underground dike complex and created new passages for injectate to spread to drinking water sources.

EPA Response to Comment No. 2a:
EPA must first take the opportunity to clarify the difference between the "geothermal reservoir," into which PGV draws and injects geothermal brine/fluids, and the "groundwater aquifer," which is a potential underground source of drinking water (USDW).[4] Many commenters refer to these two formations interchangeably, as if they are the same, which is not correct. The term "geothermal reservoir," as used by EPA in this document, refers to the deep volcanic rock formation into which PGV draws and injects geothermal fluids, at a depth of approximately 4,000 to 8,000 feet below the ground surface. The geothermal reservoir is not a potential drinking water supply due to its composition, depth, and temperature. The geothermal reservoir is separated from the groundwater aquifer in the Lower East Rift Zone (LERZ) by a semi-impermeable confining layer, or "cap rock," that is located at a depth of approximately 2,750 to 4,000 feet below the ground surface. The "groundwater aquifer," as used by EPA in this document, which can be used interchangeably with the term potential USDW, refers to the shallow basal groundwater body in the LERZ. The portion of the groundwater aquifer that serves as water supply in the area is at least 2,000 feet above the cap rock. As described below, the fluids injected into the geothermal reservoir do not migrate to the basal groundwater layer because injection pressures are too low to allow upward migration; rather, injected fluids flow towards the production wells used to produce the geothermal fluids and generate electricity.

[4] EPA notes that the terms "aquifer" and "reservoir" may definitionally overlap. However, to avoid conflating the two distinct water-bearing formations, EPA will use "reservoir" when referring to the deeper body (unsuitable for drinking) into which geothermal fluids are drawn for production and reinjection, and will use "aquifer" when referring to the shallower groundwater that could be a potential USDW.

In response to specific concerns about drinking water sources located downgradient of the facility, EPA notes that the applicant's study of the area of review of the injection project, which is attached to the permit application as "Attachment B," verified the absence of drinking water wells downgradient of the facility. Comments stating that drinking water wells are located downgradient of the PGV site did not provide or identify evidence to support this assertion, and EPA is not aware of any such evidence either.

In response to questions about whether groundwater sources are known and monitored, PGV is required to monitor the quality of shallow groundwater twice each year under Part II.E. of the Permit. The hydrologic monitoring program (in Appendix G to the Permit) includes sampling at two shallow onsite groundwater monitoring wells (MW-4 and MW-5) and one offsite groundwater monitoring well ("Lippe Well at Pohoiki" or MW-6). The Permittee is required to analyze the groundwater samples for a suite of parameters, including pH, temperature, conductivity, salinity, total dissolved solids, silica, bicarbonate, sulfate, isopropanol, pentane, chloride concentration, volatile organics and semi-volatile organics. In addition, the Permit's groundwater monitoring program requires monitoring of dissolved inorganic constituents that can be present in geothermal fluids, such as trace metals and dissolved solids.

In response to whether PGV operations have ever contaminated the groundwater aquifer, EPA notes that the groundwater aquifer, at its closest, is thousands of vertical feet above the upper-most portion of the geothermal reservoir. All available evidence shows that there is no migration of fluids from the geothermal reservoir, and EPA is not aware of any evidence that PGV's injectate has ever escaped the geothermal reservoir or breached the groundwater aquifer. EPA refers commenters to a 2015 joint report by the United States Geological Survey (USGS) and the University of Hawai'i (Scientific Investigations Report 2015–5139), which sought to determine whether geothermal power production in the Puna area had affected the characteristics of regional groundwater. This report is found in Attachment D of the Permit application. For the study, the USGS analyzed groundwater samples from shallow wells and coastal springs near the PGV site for a variety of chemical species that have been injected into the wells over time, including trace elements, stable isotopes of water, and two organic compounds (isopropanol and pentane). Isopropanol was not detected in any of the groundwater samples; pentane was detected in one monitoring well near the power plant at a concentration that was too low to determine its source (i.e., it may be naturally present). No other indicators of potential geothermal contamination were noted in the findings of the report; specifically, lower pH or increased temperature, electrical conductivity, or salinity. The study concluded that the comparison between the USGS' sampling results, the results of PGV's required monitoring over the previous twenty (20) years, and the results from groundwater samples taken in the 1970s–1990s (which pre-date PGV's operations), indicate that geothermal production at the PGV site has not had a significant impact on groundwater chemistry. The USGS study also recommended some changes to PGV's monitoring program, including analyzing for isopropanol at least annually, and more frequently, if casing pressures indicated leakage. As suggested by this study, EPA modified Part II.E.3. of the Permit to require the Permittee to monitor groundwater for isopropanol (the Permittee was already monitoring for pentane). A subsequent 2020 USGS report (Open-File

Report 2020–1017) confirmed the conclusions of the 2015 report and affirmed that no geothermal constituents in the shallow groundwater came from the geothermal reservoir (see Response No. 6 for additional information about this report). These reports are in the administrative record for the final Permit.

EPA reviewed all attachments to the comments on this topic (i.e., Attachments 14 and 20) and, where applicable, incorporated recommendations that were relevant to assessing potential geothermal contamination. For example, the Geothermal Public Health Assessment Study Group (Attachment 14) advised that the USGS should perform baseline groundwater geochemical studies, which USGS has performed, as described in Scientific Investigations Report 2015–5139. The Study Group also recommended additional monitoring (including for isopropanol and pentane), which is required in Part II E.1. of the Permit.

Notwithstanding any past limitations or practices in regard to the injection activities covered by the Class V Permit, EPA notes that the UIC Program requirements and the terms and conditions in the Permit are specifically designed to ensure that injected fluids do not endanger USDWs. The applicable Permit conditions to ensure this protection include:

- Part II.B. of the Permit defines well construction requirements that are designed to prevent the movement of injected fluids into any USDW. For example, the injection wells are designed with three redundant cemented casing strings that extend through the groundwater aquifer and are cemented to the surface. A 20-inch string is completed to approximately 1,000 feet, which spans the upper portion of the groundwater aquifer. The second string is cemented to approximately 2,000 feet, essentially to the bottom of the groundwater aquifer. In addition to these cemented casing strings, the wells are equipped with hangdown liners that extend below the confining zone to isolate the injectate from the cemented casing.
- Part II.D. of the Permit identifies injection pressure limitations that are based on the fracture pressure of the injection zone to ensure that injection does not create fractures through which injected or other fluids could potentially move to USDWs.
- Part II.D. of the Permit requires PGV to demonstrate and maintain mechanical integrity as a condition for operation. This includes continuously monitoring the tubing/casing annulus pressure of each permitted injection well to verify that internal mechanical integrity is maintained during operations, along with annual external mechanical integrity testing. If any well loses mechanical integrity, PGV must cease injection into the well, notify EPA, and take action to repair the well and demonstrate to the satisfaction of EPA that the well has achieved mechanical integrity prior to recommencing injection.
- Part II.E. of the Permit requires continuous monitoring of the injection wells to verify that the project is operating as designed. This part of the Permit also requires hydrologic monitoring for any potential effects on groundwater quality from the injection activity and analyzing the composition of the fluids being injected.

Regarding concerns that injection is creating fractures, EPA's Response to Comment Nos. 5 and 6 below contain a more in-depth discussion. Briefly, the Permit includes several conditions designed to ensure that fractures will not be created as a result of injection activities. Pursuant to Part II.D. of the Permit, the injection and pressure rates for each well are limited such that the pressure at the bottom of the injection well is below the fracture pressure of the injection formation. This pressure limit is based on the results of formation pressure tests of the injection zone. To ensure that the injection pressure limit is not exceeded, Part II.E.2. of the Permit requires PGV to continuously monitor the wellhead pressure for each injection well. Additionally, each injection well is equipped with a relief valve to reduce the injection pressure, should the pressure ever approach the injection pressure limit. EPA acknowledges Attachments 11 and 12 regarding groundwater contamination associated with hydraulic fracturing operations, however, as described more in EPA's Response to Comment No. 7, PGV's operation does not involve hydraulic fracturing.

Comments stating that the 2018 eruption has increased underground steam pressure and may have created new passages in the underground dike complex identified no evidence to support this assertion. EPA is not aware of any evidence to support this assertion either (see, e.g., EPA's evaluation of studies attached to comments about volcanic impacts in EPA's Response to Comment No. 6). As noted above, injection pressures are limited by the Permit to prevent the creation of fractures as a result of injection activities. In addition, and as further discussed in EPA's Response to Comments No. 3 and 6 below, the PGV Class V wells inject geothermal fluids into the same geothermal reservoir from which they were produced, and the production flow rate and injection flow rate are equivalent. This type of flow rate equivalency, by design, results in a very limited pressure increase within the injection zone—just enough for the injected fluid to flow from the injection wells to the production wells. These pressure changes are insufficient to push fluids through any existing dikes, much less to fracture the formation.

Comment No. 2b: 4 comments
EPA received a number of comments regarding the fluid PGV injects, including: the composition of the injectate; how EPA determines that the fluids are not harmful; where the contaminants go after injection; and concerns regarding the additives PGV injects to improve well performance.

EPA Response to Comment No. 2b:
The Permittee may only inject the fluids listed in Part II.D.4. of the Permit, which include: geothermal fluids (geothermal brine, steam condensate, and non-condensable gases that are produced during operations); chemical additives for process system and well casing biofouling, corrosion, and scale control (which are listed in Appendix H to the Permit); and supplemental water. The injectate does not contain any substances at concentrations which would make them hazardous; this is based on an injectate analysis that was performed as part of the Permit application process (with the results provided to and reviewed by EPA and made public by their inclusion in the Permit application). Further, as required in Part II.E. of the Permit, the injectate must be sampled quarterly throughout the duration of the Permit term to ensure the

quantities/values of all constituents are in compliance with this Permit. Any proposed changes to the additives must be submitted for review and approved by EPA before their injection.

Responding to the comment asking where the constituents of the injected fluids go, as mentioned above, the geothermal reservoir is both the source of geothermal fluid for PGV's operation and the receiving zone into which the same geothermal fluid (and added constituents) is injected. The referenced constituents are a very small component by volume of the injected fluids. Geothermal fluid (i.e., fluids produced from the geothermal reservoir itself) averages approximately 99% of the total injectate volume. The chemical additives, which comprise roughly 1% of total injectate volume, are listed in Appendix H to the Permit. Additives are used for biofouling, corrosion, and scale control, and are injected along with the geothermal fluid into the geothermal reservoir. As noted in EPA's Response to Comment No. 2a above, the flow rate equivalency (of production to injection) allows the injectate to remain in the geothermal reservoir, which is thousands of feet below the groundwater aquifer.

Comment No. 2c: 2 comments
EPA received a number of comments regarding protocols in the event of an upset, including: where injectate goes if a well is blocked; whether PGV has an Emergency Response Plan (ERP) to address breaches of the aquifer; and what are the potential impacts of contamination of the groundwater, drinking water wells, or near shore waters such as at Pohoiki.

EPA Response to Comment No. 2c:
Based upon past experiences and analysis of the hazards posed to PGV, lava inundation or a similar event is the likeliest cause of a blocked injection well at PGV. In the event of a volcanic hazard with the potential to threaten the facility or block a well, all production and injection wells would be shut-in (i.e., pumps stopped and injection ceased) and PGV would follow its Emergency Response Plan (ERP).[5] The injection wells are also equipped with systems for timely responses to adverse events, including automatic shut-off valves that immediately stop the flow of fluids into the well (and divert the flow of fluids to other injection wells) or shut-in the well if all other wells are at risk. If a well were to lose mechanical integrity, per Part III.E.11. of the Permit, 40 C.F.R. § 144.51(q), and in accordance with its own standard operating procedures for MITs, the Permittee must cease injection into that well until it has demonstrated to the satisfaction of EPA that the well has mechanical integrity. For example, following the 2018 eruption, injection well KS-11 was shut-in and then inundated by lava. The Permittee subsequently performed testing of KS-11 and determined that the damage was limited to the wellhead equipment and that the wellbore itself was in good condition. The Permittee repaired the wellhead and performed a casing caliper survey, MIT, and a pressure test of all casing strings and submitted the test results to EPA. Only after demonstrating that the well complied with all applicable provisions in the Permit, including that it had mechanical integrity, did EPA allow PGV to resume injection into KS-11.

[5] PGV's Emergency Response Plan is available at: https://punageothermalproject.com/wp-content/uploads/2021/05/PGV-Combined-ERP-2021-210524.pdf.

Regarding potential impacts of and responses to breaches of the aquifer, the Permittee must monitor the status of the wells and perform groundwater monitoring to provide early indication of any potential fluid movement that could endanger USDWs. Under Part II.E. of the Permit, the Permittee must report to EPA within twenty-four (24) hours of any evidence of endangerment of a USDW. In addition, the presence of the confining zone (which separates the geothermal reservoir from the groundwater aquifer by over one-thousand feet of rock), the design of the injection wells (i.e., with redundant cemented casing strings), and the flow rate equivalency between production and injection prevents injected fluids from moving into the shallow groundwater aquifer. Should any of the monitoring indicators demonstrate potential fluid movement that could endanger USDWs, under Part II.D.1. of the Permit, PGV must cease injection into the well until it demonstrates to EPA that injection will not endanger any USDW. EPA notes that based upon past sampling of groundwater, PGV's operations have never caused a breach of the aquifer, including after the 2018 eruption.

Regarding comments about impacts to nearby or downgradient drinking water wells, as noted in EPA Response to Comment No. 2a above, there are no drinking water supply wells within the vicinity or downgradient of the site. Nevertheless, in the unlikely event of injection fluids commingling with groundwater, the Permittee would implement their ERP, which includes steps to notify emergency response organizations (including the Hawai'i County Civil Defense Agency and Department of Health, local fire and police departments, the Hawai'i Department of Land and Natural Resources, and the public), and evaluate any potentially hazardous situations. Under Part III.D.1. and 2. of the Permit, EPA may also require an assessment of any endangerment, and if necessary, a remedial response.

Regarding impacts to near shore waters, such as Pohoiki, EPA first notes that impacts to surface waters are outside the scope of the UIC Permit, which is limited to protection of USDWs. Further, no evidence of impacts to near shore waters from PGV's geothermal operations was provided by commenters, and EPA is not aware of any such evidence. EPA refers the reader to its Response to Comment No. 3 for further discussion about this topic. Notwithstanding, the intent of the Permit provisions (i.e., well construction and confinement of injection fluids) is to ensure that injected fluids remain in the designated injection formation, which would have the ancillary benefit of protecting surface waters. In the unlikely event that the injected fluids were to impact near shore waters at Pohoiki, which would likely indicate that Permit conditions were not being met due to migration, existing monitoring wells can be used to evaluate the conditions and enable appropriate response actions to be taken, if necessary.

Comment No. 2d: 2 comments; see Attachment 21
EPA received a number of comments regarding the properties of the injection fluid, including: what is meant by "supplemental water" in the Permit; whether PGV may extract water from the groundwater aquifer for injection; and whether PGV may experiment with new equipment and processes.

EPA Response to Comment No. 2d:
Regarding concerns that PGV may experiment with new equipment and processes, the Permit only authorizes PGV to operate the injection wells as Class V geothermal injection wells. The Permit limits operation to the injectate described (i.e., geothermal fluids; chemical additives for biofouling, corrosion, and scale control; and supplemental water). The construction of the existing wells is described in the Permit, and the construction of any proposed wells (e.g., as mentioned in Attachment 21) are subject to the construction requirements in Part II.B. of the Permit and EPA approval. Any changes to the construction or use of the permitted wells requires written approval and authorization by EPA. PGV is not experimenting with new equipment or processes.

Regarding concerns about the Permittee's use of "supplemental water" and the source of such water, Part II.D.4. of the Permit only authorizes the injection of fluid produced from the geothermal reservoir. PGV is not currently authorized by the Hawai'i Department of Land and Natural Resources to produce fluids from the shallower groundwater aquifer for injection. The "supplemental water," as outlined in Part II.D.4.b., may consist of: steam turbine seal water, rinsate from the water softener system, sulfatreat heat exchanger cooling water, raw/quench water, production well bleed system, abatement fluids, sulfatreat system vacuum pump seal water, condensate from the sulfatreat system, periodic produced drilling fluids, and fluids from the plant water storage tank and the emergency steam release facility. Any change in the source of the injected fluids, including the use of groundwater from sources other than the geothermal reservoir, requires notification to and approval by EPA. If PGV requested to change the source of the injected fluids, the Permit would need to be modified; this would require public notification and an opportunity for public comment. Any new production well permit would be issued by the Hawai'i Department of Land and Natural Resources, which is outside the Federal UIC Program's authority.

Comment No. 2e: 2 comments
EPA received comments asking whether there is any new or updated information regarding the current magma and groundwater table movement below the facility to ensure EPA is relying upon the most recent data.

EPA Response No. 2e:
EPA is not aware of additional studies of groundwater movement in the area of the injection wells other than those that have been identified, and none were provided in public comments. As described in Responses to Comment No. 5 and 6 below, USGS Open-File Report 2020–1017 examined eruptive and seismic events in the LERZ and found that there have been no significant changes in patterns or trends of seismicity, volcanism, or groundwater quality due to human activity. EPA reviewed other studies and information about groundwater movement and hydrology, which are documented in Attachment D to the Permit application. EPA notes that studies of magma movement are out of the Federal UIC Program scope because the magma chamber is not hydrologically connected to the injection zone or any USDWs.

3. Supreme Court ruling in *County of Maui v. Hawaii Wildlife Fund* (19 commenters)

Comment No. 3:
EPA received a number of comments asserting the applicability of the recent Supreme Court case *County of Maui v. Hawaii Wildlife Fund*, 140 S. Ct. 1462 (2020), and also asserting that PGV's impact on nearby ocean waters is tantamount to a direct discharge to the Pacific Ocean. Commenters also asked about potential impacts to the ocean and coastal ecosystems from PGV's operation and the degree to which PGV's injectate is filtered by the time it reaches the ocean.

EPA Response to Comment No. 3:
While EPA acknowledges and is bound by the *Maui* decision, PGV's operations are not the "functional equivalent of a direct discharge… into navigable waters" as articulated by the Supreme Court in *Maui*. 140 S. Ct. at 1477. First, unlike most facilities with injection operations, including the injection wells at issue in *Maui*, the injection wells at the PGV facility are part of a "closed loop" or pressure-balanced system, in which fluids are injected into the same formation from which they were produced with minimal changes in pressure. PGV has two types of wells operating at the facility: production wells and injection wells. The production wells have been drilled to about 4,000 to 7,000 feet deep into the geothermal reservoir. After the power plant extracts energy from the geothermal fluids brought up from the production wells, the fluids are returned to the geothermal reservoir by means of the injection wells, which are about 6,000 to 8,000 feet deep. The rate of production and reinjection of geothermal fluids are equivalent, which by design limits pressure buildup and allows the injected fluid to flow only from the injection wells to the production wells. The injection wells are structurally the same as the production wells, with the difference being that the injection wells encounter the geothermal reservoir at a greater depth. This greater depth makes the reservoir more conducive to accepting the fluids from the injection well, which closes the loop and renews the geothermal reservoir.

Second, all available evidence shows that there is no migration of fluids from the geothermal reservoir, much less migration to the ocean or other surface waters. The commenters claiming PGV's injection is tantamount to ocean dumping, or that the injection has an adverse impact on ocean waters, have not provided or identified evidence to indicate this is accurate. Indeed, as mentioned above, the 2015 USGS study, which sought to determine whether PGV's operations have affected the characteristics of regional groundwater (including coastal springs), concluded that the similarity between USGS's sampling results, the results from mandated monitoring over the previous 20 years, and results from samples from the 1970s–1990s indicate that PGV's operations have not had a significant impact on groundwater chemistry. In addition, the PGV facility is not in close proximity to the ocean, being more than 3.5 miles from the nearest point.

4. **Environmental Impact Statement** (15 commenters; Attachment 15)

Comment No. 4:
EPA received a number of comments asserting the need for a new Environmental Impact Statement (EIS) for the PGV facility, citing the following: the length of time since the last EIS; alleged geologic or hydraulic changes caused by the 2018 eruption; and alleged geologic or hydraulic changes caused by PGV's injection operations over the past thirty years.

EPA Response to Comment No. 4:
The National Environmental Policy Act (NEPA) is the federal law that compels all federal agencies to consider environmental impacts in their decision-making process when there is federal funding involved in the project. That consideration may take the form of an Environmental Impact Statement. However, UIC permits are "not subject to the environmental impact statement provisions… of the [NEPA]." 40 C.F.R. § 124.9(b)(6). Courts have consistently recognized that EPA's procedures and environmental reviews under enabling legislation (such as the Safe Drinking Water Act) are functionally equivalent to the NEPA's EIS process. This means that EPA is not required to prepare a separate EIS for this Class V UIC permit. *See also In Re American Soda, LLP*, UIC Appeal Nos. 00-1 & 00-2, Order Denying Review, decided June 30, 2000 at 291-292. EPA also reviewed Hawai'i's Environmental Impact Statement Rules submitted by one commenter (Attachment 15), but again notes that an EIS is not required for this federal EPA UIC permitting action.[6]

EPA also received comments regarding PGV's alleged noise and odor. To the extent these comments can be interpreted as seeking a cumulative EIS, EPA notes that such cumulative analysis is not relevant in this UIC action, where the analysis is limited to the UIC regulations and the impacts of specific wells on USDWs. Cumulative impacts may be relevant in the context of Area Permits. *See* 40 C.F.R. § 144.33. PGV is not operating under an Area Permit.

Notwithstanding, EPA will respond to some of the concerns raised by commenters regarding the need for an EIS. PGV's EIS, which was finalized in 1987, evaluated the environmental impacts of the entire facility, including its wells. In response to concerns that PGV's existing EIS is outdated, EPA notes that the information provided by PGV that was collected during the installation of production wells and during the conversion of production wells to injection wells is still relevant because it includes subsurface information that is still accurate. For example, the description of the subsurface environment (i.e., the depths and lithologic characteristics of the injection and confining formations) has not changed since the EIS was prepared. Second, despite the concerns of some commenters, no injection well wellbores were damaged during the 2018

[6] Despite NEPA not applying to this federal permit action, EPA notes that the Hawai'i Department of Health decided in September 2020 that no new or supplemental environmental review was required for the renewal of PGV's Noncovered Source Permit (a state air pollution control permit) to continue operation. The Department's decision was appealed by three parties, including one commenter who submitted comments during the public comment period for this UIC permit. Judge Nakamoto of the Circuit Court of the Third Circuit for the State of Hawai'i dismissed all appeals, holding the Court lacked appellate jurisdiction. *See Steiner v. Soh, Dept. of Health et al.,* 3CCV-20-0000398; *Kon v. Doh,* 3CCV-20-0000394; *In re: Doh et al.,* 3CC-20-0000390.

eruption. The wellhead of KS-11, KS-13, and KS-15 were damaged by lava, but damage to a wellhead would not negate the relevance of the information collected from when the well was drilled. The integrity of the wellbores for each of these three injection wells were tested and verified before EPA authorized any reinjection to commence. EPA also refers the reader to EPA Response No. 5, below, for additional information regarding how the Permittee has responded to volcanic events at the site to demonstrate that the wells associated with the injection activities are not losing integrity and not impacting USDWs.

5. **Volcanic Impacts** (37 commenters total; see Attachments 01, 27, 29, and 30)

Comment No. 5: 35 comments
EPA received numerous comments expressing concerns about ongoing and potential volcanic activity and asserting that PGV's injection operations have led to volcanic instability, including that: PGV's injection operations cause geological instability and disrupt natural volcanic activity; PGV's injection cause unknown subsurface changes and unintended damage; PGV caused the 2018 eruption and may cause future eruptions; PGV's injection wells exploit a "hidden" 8,000 foot fault; PGV's injection correlates to the intensity of the 2018 eruption; PGV's injection is intentionally weakening the LERZ and/or is fracturing the area under Leilani Estates; and that PGV's injection has created most of the local fissures, expressing particular concern about Fissures 8 and 17. Commenters also assert that: the Puna area is being used as a geologic experiment; operation of injection wells on Hawai'i is more hazardous than on the continental United States; the PGV site is subsiding; and PGV is injecting volatiles into what is described as "porous and unstable strata" of the LERZ.

EPA Response to Comment No. 5:
EPA acknowledges that the 2018 lower Puna eruption was a tragic event that uprooted many people. EPA takes these allegations of causality seriously, even though the SDWA regulations for Class V wells do not require consideration of volcanic activity (e.g., tracking magma movement). EPA carefully reviewed each comment and acknowledges that the project area is a volcanically active zone, and that changes have occurred at the site (e.g., resulting in the presence of new lava flows that formed during the 2018 eruption, as described in Attachments 01 and 27). However, PGV's operation is not a geologic experiment. The Permit is for the operation of Class V geothermal wells, using injection well design, processes, and fluids that are not experimental technologies. Commenters have not provided or identified any credible evidence to support their claims that PGV's geothermal injection operations or well-drilling has resulted in increased risks for geological instability, including changes within the magma chamber or increases in the frequency or intensity of volcanic eruptions. EPA refers the readers to its Response to Comment No. 6 for a more in-depth discussion of Attachment 10, which is a self-published, non-peer reviewed report that attempts to link PGV's operations to increased geologic and volcanic instability. EPA is not aware of any other evidence to support these assertions and has reviewed all studies submitted by commenters.

At the time of the 2018 lower Puna eruption, PGV was not drilling any wells. The volcanic activity that makes the site a suitable location for Class V geothermal injection wells has

occurred in the area for hundreds of thousands of years, including recent eruptive events during the project's life. As mentioned above, the PGV site is a natural geothermal reservoir in which geothermal brine is brought to the surface by production wells, heat is extracted, and then cooled water is reinjected through the injection wells back into the same geothermal reservoir.

Regarding comments attributing the 2018 lower Puna eruption to PGV, the Hawaiian Volcano Observatory (HVO) evaluated the possibility of human influence on the volcanic activity of Kilauea and published their results in a 2020 USGS Open-File Report: 2020–1017. The report examined eruptive events since 1790 and found that there have been no significant changes due to human activity in patterns or trends of deformation or seismicity in the LERZ in the last 35–50 years (i.e., before and during PGV's geothermal operations). The USGS report concludes that there is no evidence to support claims that human activity triggered or influenced the 2018 eruption. It states that the 2018 eruption was caused by an intrusion of magma downrift from Puʻu ʻŌʻō and the summit of Kilauea and is similar to many previous eruptions along the East Rift Zone. The report adds that the intensity of the eruption (both volume and eruption rate) was probably not out of the range estimated for previous LERZ eruptions and that the 2018 fissures were located in the same area that has experienced many past eruptions.

Regarding concerns about the presence of subsurface fractures, the semi-impermeable caprock naturally fractures and then reseals itself in an ongoing cycle. Fractures that form naturally are sealed by rapid mineral deposition and clay formation caused by the high-temperature geothermal fluid. The ability of these clays to self-seal is documented in the scientific literature (*see e.g.,* Cumming, 2016, which is included in the administrative record for the Permit). No evidence has been provided nor is EPA aware of any evidence to suggest that PGV's injection has impacted the natural formation of fractures or their ability to self-seal.

Regarding comments that injection is causing the development of volcanic fissures, as mentioned previously in this document, the Permit's operating limits are designed to prevent the formation of fractures in the injection zone. The maximum injection pressure limits in Part II.D. of the Permit are set such that the pressure at the bottom of each injection well is below the fracture pressure of the injection formation. To ensure that the injection pressure limit is not exceeded, PGV must continuously monitor the wellhead pressure in each injection well; additionally, each injection well is equipped with a relief valve to reduce the injection pressure, should the pressure ever approach the limit in the Permit. PGV must also continuously monitor the internal mechanical integrity of the wells, per Part II.D. of the Permit; this would provide early warning of any damage to the wells that might occur as a result of operational or geologic conditions. EPA also refers the reader to its Response to Comment No. 3 for further discussion of the limits of any potential pressure increase in the injection zone.

EPA is not aware of any evidence of an 8,000-foot "hidden" fault, as some commenters suggest, and none was provided or identified. The location of fissures and associated structures has been well documented by the USGS/HVO and mapped in detail (see, e.g., USGS Open-File Report 2020–1017). Moreover, even if there were an 8,000-foot fault in the area where injection occurs, USDWs would not be endangered, given the presence of thousands of vertical feet of rock that

separate the injection zone and the groundwater aquifer. A rift zone is a natural geologic formation that hosts many permeable faults and fractures, and there are many faults and fractures at that depth associated with the formation of the LERZ over tens of thousands of years. The Permittee's wells target several fractures at various depths, with no record of contamination to a USDW associated with any of its wells. And, as described in EPA Response to Comment No. 2a, the design of the injection wells and the presence of a confining zone prevent fluid movement that could contaminate a USDW.

EPA also reviewed Attachments 29 and 30 which were offered to support the assertion that the PGV site is subsiding. However, no evidence is identified or offered in the Attachments to support the conclusion that this minimal subsidence is affecting the integrity of any wells or any other aspects of the injection operation. For example, Attachment 29 states: "the natural subsidence rate within the PGV property has remained relatively constant at approximately 1 cm/yr since the beginning of measurements by the USGS in 1958." Further, neither study claims this natural, minimal subsidence is problematic or impacts well integrity and neither study directly attributes subsidence to PGV's operations. As noted above, the Permittee is subject to the UIC construction requirements, including demonstrating mechanical integrity prior to commencing injection in any well (and periodically over the life of the well).

Comments characterizing injection in Hawai'i as more hazardous than on the continental United States did not offer or identify evidence to support this assertion. Each UIC permit application is evaluated based on site-specific conditions to identify whether any aspects of the project or the site have a potential to endanger USDWs. Based on this evaluation, each UIC permit contains unique conditions that are designed to mitigate the risk of adverse events and USDW endangerment associated with the specific geologic and operating conditions. In the case of the PGV Permit, these conditions include, but are not limited to: injection pressure limits (Part II.D.) that are based on formation testing to reduce the potential for the creation of fractures, and well construction requirements (Part II.B.) to ensure that injected fluids do not migrate to and endanger USDWs. During injection operations, a required project-specific monitoring and testing program (Part II., Sections D. and E.) is designed to ensure that (1) each injection well has mechanical integrity and (2) groundwater is monitored for any potential indicators that may suggest water quality impacts from the injection activity.

In the permit application, PGV described the status of the injection and monitoring wells at the site following the 2018 eruption. For each injection well that was impacted by the eruption, which includes KS-11, KS-13, and KS-15, the Permittee has performed well maintenance and cleaning and conducted mechanical integrity tests. PGV has demonstrated mechanical integrity for each of these wells and shown that they can safely resume operation. The Permittee has also replaced monitoring wells MW-1, MW-2, and MW-3, which were inundated by lava, with new monitoring wells identified as MW-4, MW-5, and MW-6.

Regarding comments that the injection formation is unstable, volcanic rift zones like the LERZ of Kilauea are regions of the crust along the flank of an active volcano that are in a continual

state of extension, which results in an array of high-angle permeable faults and fractures within the rift. Rift zone formation is a natural geologic process associated with the formation of a volcano, and many rift zones around the world are sites for hydrothermal systems because of their natural permeability. But the fact that rift zones are permeable does not mean they are unstable. To the contrary, the strata or formations at depth in the injection zones must be stable to maintain open permeable fractures. EPA was unable to locate any USGS recommendation against injection into the LERZ, and the comments identified no specific documentation or evidence to support any such recommendation.

6. **Induced Seismicity** (14 commenters; see Attachments 03, 04, 05, 07, 08, 09, 10, 17, 25, 26, 28, and 31)

Comment No. 6:
EPA received a number of comments pertaining to induced seismicity, including the assertion that increased seismic activity is a known and expected risk associated with geothermal technology; PGV's operation is exacerbating seismic activity at the site and causing earthquake swarms; injected fluids lubricate faults or fractures, causing an increased risk that they slip and allow the aquifer to be contaminated; and that PGV is not following U.S. government protocols related to placement of geothermal operations in areas of high seismicity.

EPA Response to Comment No. 6:
First and foremost, the SDWA regulations for Class V wells do not require consideration of seismicity, unlike the UIC regulations for Class I wells for the injection of hazardous waste or Class VI wells for geologic sequestration of carbon dioxide. Nevertheless, given the number of comments on the issue, EPA has decided to use its discretion to respond to these comments. EPA must first distinguish PGV's geothermal injection operations from two inherently different operations called "enhanced geothermal systems" (EGS) and "hydraulic fracturing." EPA believes several comments mistakenly confused these different types of operations, with entirely different designs, processes, and geological impacts (e.g., Attachments 08, 09, 25, and 26). EGS are defined as activities that are undertaken to increase the permeability in a targeted subsurface volume via injecting and withdrawing fluids into and from the rock formations that are intended to result in an increased ability to extract energy from a subsurface heat source. This can be done through such approaches as fluid pressurization, hydrofracture, and chemical stimulation. In other words, an EGS is a man-made reservoir created where there is hot rock but insufficient natural permeability or fluid saturation in order to create permeability and saturation for geothermal energy production. In an EGS, fluid is injected into the subsurface under controlled conditions, which cause pre-existing fractures to re-open, creating permeability. The U.S. Department of Energy has issued a protocol for addressing induced seismicity in the EGS context.[7] Hydraulic fracturing, commonly referred to as "fracking," is a short-term operation designed to create cracks or permeable avenues, primarily in lower permeability hydrocarbon-bearing formations. EPA discusses hydraulic fracturing in more depth in Response to Comment

[7] *Protocol for Addressing Induced Seismicity Associated with Enhanced Geothermal Systems*, 2012, available at: https://www.energy.gov/sites/default/files/2014/02/f7/geothermal_seismicity_protocol_012012.pdf

No. 7, below. EPA has issued a guidance on managing induced seismicity in the context of hydraulic fracturing for hydrocarbon production.[8]

Conversely, PGV is a geothermal energy conversion plant located above a natural geothermal reservoir in which geothermal fluids are brought to the surface by production wells, heat is extracted, and then cooled water is reinjected through the injection wells. As mentioned in EPA Response to Comment No. 2a, the production flow rate and injection flow rate are equivalent. PGV's system is not designed to significantly increase subsurface pressure—the injection pressure is just enough for the injected fluid to flow from the injection wells to the production wells. Unlike hydraulic fracturing or EGS, PGV's injections do not seek to increase the permeability of or fracture the injection formation.

Indeed, PGV's Permit has several provisions to ensure that there is no sustained build-up of pressure. Part II.D.2. of the Permit limits the injection pressure to a level below the fracture pressure of the injection formation, which is based on formation testing, to reduce the potential for the creation of new fractures. Part II.E.2. of the Permit requires continuous monitoring of the injection pressure and notification to EPA if the Permit limit is exceeded. Part II.E.6.b. of the Permit requires that each injection well be equipped with a relief valve to reduce the injection pressure, should the actual pressure ever approach the injection pressure limit. Part II.D.1.b. of the Permit requires PGV to shut in any well causing a pressure build-up and seek EPA approval before injection may resume. Commenters have not provided any credible evidence to show that PGV's injection operations create sustained pressure build-up, as alleged. In fact, the Permittee follows several key recommendations in the 2015 EPA report, *Minimizing and Managing Potential Impacts of Injection-induced Seismicity from Class II Disposal Wells: Practical Approaches*, including pressure control and monitoring and deployment of an extensive seismic monitoring network, despite not operating a Class II disposal well.

EPA acknowledges that a linkage has been shown between injection activity in certain contexts and seismic events, for example in Oklahoma and Ohio, and we will discuss the geological and operational precursors in more detail here. Injection-related seismic activity is typically associated with an increase in subsurface pressure that activates stressed faults, rather than "lubrication" of faults, as a commenter suggests. As identified in EPA's 2015 report *Minimizing and Managing Potential Impacts of Injection-induced Seismicity from Class II Disposal Wells: Practical Approaches*, seismicity caused by injection wells is likely to occur only when all the following conditions are present: (1) there is a fault in a near-failure state of stress; (2) the fluid injected has a path of communication to the fault; and (3) the pressure exerted by the fluid is high enough and lasts long enough to allow movement along the fault line. The risk of pressure build-up is related to the volume of injected fluids and the rate of injection; the likelihood of triggering a significant seismic event due to injection increases with the volume and rate of fluid injected. Most examples of injection-induced seismicity occur in geological formations with low

[8] *Minimizing and Managing Potential Impacts of Injection-induced Seismicity from Class II Disposal Wells: Practical Approaches*, 2015, available at: https://www.epa.gov/sites/production/files/2015-08/documents/induced-seismicity-201502.pdf

permeability and/or where the pressure or volume of fluid injected over time is quite large. Specifically, formations such as crystalline basement rock (deeper geological formations of igneous or metamorphic rock that underlie layers of sedimentary rock) have very low permeability. Where permeability is low, injected fluid cannot flow easily through the pores and therefore flow is oriented mainly through existing fractures or faults.

The relevant factual precursors of induced seismicity are not present at PGV. First, PGV injects geothermal fluids into a volcanic rock formation which has high permeability; it does not inject into a sedimentary formation with low permeability. Second, PGV's injections do not create a sustained increase of pressure. PGV Class V wells inject geothermal fluid into the same reservoir from which it is produced, and the production flow rate and injection flow rate are equivalent. As a result, pressure increase in the injection zone is very limited. The Permittee provided static downhole pressure measurements in five wells demonstrating that there has been no significant buildup of pressure in the injection zone since injection began in April 1993. The minimal pressure changes are insufficient to induce significant seismic events, as the comments assert.

EPA is aware that seismic activity preceded the last volcanic eruption. USGS studies have shown that the area where the facility is located is subject to thousands of small earthquakes (less than 0.5 magnitude) every year, or 8 earthquakes per day on average, noting that this is not a constant average (USGS Open-File Report 2020–1017). However, the commenters have provided no credible evidence or studies demonstrating a linkage between PGV's geothermal injection wells and seismicity at Kilauea. The 2020 USGS Open-File Report 2020–1017 evaluating possible human influence on volcanic activity at Kilauea (see EPA Response to Comment No. 6) also addressed seismic activity at the site. The report notes that earthquakes have been recorded frequently in the LERZ for as long as seismic networks have operated in the Puna area, and for many years before any geothermal production or reinjection wells were operational. A seismic array, installed in 1993 and operated for three months before PGV's operations began, recorded frequent earthquakes in the area. The USGS report concludes that the only significant seismicity observed in the area is consistent with natural sources—the subsurface hydrothermal system and the rift zone fault to the south.

EPA also takes note of two location-specific studies that considered the possibility of induced seismicity as a result of PGV operations. The first study (Cooper and Dustman, 1995) found that "no significant change in the background seismicity rate was observed during the 5 days after Well KS-9/10 was brought to full production levels. (A single seismometer left running at the Puna Research Center from August 1994 to June 1995 also measured no significant change in background seismicity)." The second study (Kenedi and others, 2010) found that between 2006 and 2009 "there was a few percent increase over background in the number of earthquakes weaker than magnitude 0.5 over a linear trend," and then speculatively concludes that this "may be attributed to reinjection of geothermal fluid." The study is not dispositive on causation and does not support its conclusion beyond merely stating that certain earthquakes are "possibly associated" with PGV. Even if there was non-speculative evidence demonstrating causation, which there is not, EPA notes that such small magnitude earthquakes (weaker than 0.5

magnitude) are not felt at the surface and are extremely unlikely to cause major fault movement or endanger a USDW.

The comments also provide no evidence that seismic activity has damaged any of PGV's injection wells or endangered a USDW. Moreover, of the hundreds of thousands of injection wells operating in the United States, EPA is not aware of any case where a seismic event caused an injection well to contaminate a USDW. The Permit includes conditions designed to provide early warning if any event, including a seismic event, were to potentially damage the mechanical integrity of any injection well so that the Permittee can take timely and necessary steps to prevent USDW endangerment. Specifically, Part II.D.1. of the Permit requires PGV to continuously monitor the tubing/casing annulus pressure of each injection well to verify that the internal mechanical integrity of the wellbore is being maintained during operations. In case of a well failure associated with a seismic or other adverse event, the injection wells are equipped with shut off valves that immediately stop the flow of fluids into the well. Furthermore, the Permittee's injection wells are designed to withstand stresses from pressure, temperature, and geomechanical stress, with a margin of safety to compensate for shear and pressure waves emanating from small or distant earthquakes.

EPA reviewed the papers that commenters attached to comments examining possible links between geothermal exploration and seismic activity in Iceland and Tuscany (Attachments 03, 04, and 31). These papers do not conclude that large magnitude events are associated with injection activities but assert that geothermal exploration may be associated with low-magnitude seismic events. As noted above, small seismic events are not felt by humans and do not damage local structures or compromise well integrity. Also, some of these papers conclude that seismic monitoring is recommended, which the Permittee's Geothermal Resource Permit requires (see below). Some papers (e.g., Attachments 17 and 28) describe potential linkages of injection into sedimentary formations and seismic activities. EPA clarifies that PGV's permitted activity involves injection into a porous volcanic rock formation and the injection results in only a very slight pressure increase within the injection zone. EPA also reviewed information provided about the M7.7 Kalapana Earthquake (Attachment 05), and notes that this event occurred before construction of the PGV facility.

EPA is aware that the U.S. Department of Energy (DOE) and the U.S. Bureau of Land Management (BLM) have protocols for responding to seismic events (as described in Attachments 07, 08, and 09), but notes that these protocols are not required for EPA UIC-permitted facilities. Notwithstanding, EPA clarifies that PGV operates under many of the recommended DOE and BLM guidelines related to seismic monitoring and response. For example, the USGS and HVO closely monitor seismic and volcanic hazards related to the Kilauea volcano and associated rift zones using a network of monitoring stations along the LERZ. These stations include seismometers to measure seismic activity, tilt-meters to measure vertical ground movement, and GPS stations to measure horizontal ground movement. In addition, the Permittee's Geothermal Resource Permit issued by the Planning Commission for the County of Hawai'i requires PGV to respond within forty-eight (48) hours of any earthquake

registering M6 or above or an eruption by examining all wells within ten (10) kilometers of the epicenter or eruptive center for any physical changes that could alter its downhole integrity.

Finally, EPA reviewed Attachment 10, "*A geophysical and geochemical review of Puna Geothermal* Venture *and the 2018 Kilauea*,"[9] which attempts to connect injection operations at PGV to the seismic events around the 2018 Kilauea eruption. EPA notes that the author of the paper stated during the public hearing that he is "not a professional geologist or geophys[icist]." EPA also notes that the paper appears to be self-published and has not been subject to peer review.

While the paper describes about 300 earthquakes during a 9-day "quenching" period and 168 earthquakes during the 25-day interval between May 10 and June 4, these align with the established historic baseline seismicity for the area. For example, a 2020 USGS study, based on surface seismometer data between 1993 and 2018, found that earthquakes typically occur in this locality "as multiplets, i.e. 2-10 small-magnitude earthquakes with similar wave forms within a period of 2-20 minutes, and as swarms lasting for several hours." This establishes a seismic baseline or natural behavior that explains the assertion relating to seismic frequency that the paper attributes to PGV operations. The seismic events that occurred in the PGV area during and after injection activities were not an anomaly, as the paper suggests.

Additionally, the paper attributes the swarm of earthquakes beginning on May 10, 2018 in the Leilani area to simultaneous "cooling" operations of PGV wells. However, the paper provides no explanation for why this area, along with Halemau'ma'u, demonstrated the greatest amount of seismicity amongst all areas just six (6) days prior. This suggests that both areas were the most prone to seismicity during this time. Increased seismicity occurs after the magnitude 6.9 earthquake on May 4, 2018, then dissipates by May 10; then, from May 10 to 20, earthquake swarms occur in both areas, most likely related to a regional rather than local occurrence, as the paper suggests. The paper also does not present applicable data about the "lineaments of significance" shown in Figure 6. These lineaments and seismic events appear to be random, and no evidence is provided that they follow any geological lineament (i.e., a fault). The seismic event cluster is not well-defined, and the geometric subdivisions presented are unsupported by any geologic evidence. Finally, the assertion that injection in PGV's wells blew dacite "directly down-rift and out Fissure 17 as a result of explosions induced by pumping water into their wells during the eruption," is geologically not possible. The amount of pressure needed to physically inject, fracture, and transport solid rock in the subsurface (especially within the short time period between injection on May 9 and the opening of Fissure 17 on May 12), is extremely unlikely to be achieved given the permitted injection pressures at PGV's wells. The more geologically sound

[9] One commenter submitted multiple versions of Attachment 10, including the draft version during the public comment period and the final version on May 26, 2021. Although the final version of the paper contained in Attachment 10 was submitted more than six (6) months after the public comment period closed, and therefore EPA does not need to consider it, EPA exercised its discretion and reviewed its contents to ensure that no new facts or information were included that may have altered EPA's analysis of the timely submitted paper—and there were none. In this document, EPA references the draft version that was timely submitted.

conclusion is that a dacite source exists beneath both the PGV well field and Fissure 17 to the east.

7. **Hydraulic Fracturing** (17 commenters; see Attachments 06, 13, 16, 37, and 38)

Comment No. 7:
EPA received a number of comments regarding hydraulic fracturing, asserting that: PGV is performing hydraulic fracturing, which they assert causes earthquakes, weakens the rock, or creates lava fissures and is illegal in Hawai'i. Commenters also assert that PGV's Permit should be for Class II wells instead of Class V.

EPA Response to Comment No. 7:
EPA respectfully refers the readers to EPA Response Nos. 5 and 6 for a discussion on induced seismicity and impacts to the volcanic formation. Hydraulic fracturing is generally exempt from federal regulation under the Safe Drinking Water Act Section 1421(d)(1)(B)(ii), though states or municipalities may regulate hydraulic fracturing if they choose to do so (e.g., Attachments 16 and 37 as identified in the Appendix). Accordingly, even if the permitted activity did constitute hydraulic fracturing, it would not be subject to federal UIC requirements. Nevertheless, as stated in Response No. 6, PGV is not performing hydraulic fracturing. Commenters claiming PGV is conducting hydraulic fracturing have not provided or identified evidence to support these assertions. Hydraulic fracturing is a drilling method used primarily to extract petroleum hydrocarbons from rock formations (typically in low permeability sedimentary formations) using a process that stimulates the flow of natural gas and/or oil, thereby increasing the volumes that may be recovered. This process is not similar to activities at the PGV facility, which produces geothermal brine, converts the heat from the brine and then reinjects the cooled fluid via injection wells back into the same geothermal reservoir, thereby replenishing the resource. Further, the injection pressure at PGV's facility is limited at all times to a pressure that is below the fracture pressure of the injection formation, based on the results of formation pressure tests of the injection zone.

EPA acknowledges the Attachments provided with these comments. However, these materials raise no issues specific to PGV's permitted injection activity. Instead, they provide general questions and answers about geothermal energy (Attachment 13), results of Internet searches on hydraulic fracturing (Attachment 16), and a study of the institutional and socioeconomic effects of hydraulic fracturing (Attachment 38). However, as noted above, hydraulic fracturing is not regulated by EPA, is not addressed by the UIC regulations, is not occurring or authorized at the PGV facility, and is therefore not applicable to PGV's UIC permit.

In response to comments asserting that PGV's operations are Class II wells, EPA notes that Class II injection wells are permitted only to inject fluids associated with the production of oil and natural gas. The PGV facility produces geothermal energy, via geothermal fluids/brine, which the UIC regulations classify as a Class V injection activity. The fluid that is injected does not meet the definition of a Class II injectate pursuant to the regulations at 40 C.F.R. Part 144.6, and therefore, the Class II requirements and the Class II checklist items (in Attachment 06) do not apply.

8. **Concerns about PGV's Operational Expansion** (9 commenters; see Attachment 02)

Comment No. 8:
EPA received a number of comments regarding the rationale behind PGV's application to increase the number of injection wells and/or increase their generating capacity, including: questioning why new wells are needed when there is allegedly more steam and less brine since the 2018 eruption, and asserting that PGV is requesting new wells because they improperly maintained the existing wells.

EPA Response No. 8:
The expansion of PGV's generating capacity is outside the scope of the UIC Program, as it is under the jurisdiction of the Hawaii Public Utilities Commission (PUC). EPA's evaluation of the Permit application is limited to ensuring that the existing injection wells, and any added injection wells, do not endanger USDWs pursuant to UIC Program requirements. To ensure this, the proposed wells identified in the Permit are subject to conditions for construction, testing, operation, maintenance, and financial assurance to ensure that they operate in accordance with all UIC program requirements, including maintenance of mechanical integrity throughout the life of the well and proper closure. Before any new well may be put into service, the Permittee must, per Part II.B. of the Permit, submit plans for converting the well that describe how the well was drilled and constructed to meet the UIC construction requirements for EPA's approval. Following conversion of the well, the Permittee may not commence injection until it performs a mechanical integrity test, demonstrates that the well was converted as described, and receives authorization from EPA to do so.

In response to comments asserting that new wells are required because prior wells have not been properly maintained, EPA notes that PGV has complied with all permit requirements under their existing and previous UIC permits for every applicable well. Each injection well at PGV is subject to the mechanical integrity requirements in Part II.D. of the Permit. Specifically, the Permittee must demonstrate the mechanical integrity of each injection well via continuous monitoring of the tubing/casing annulus pressure in the well and perform annual external mechanical integrity tests. If this testing were to provide any indication that a well has lost mechanical integrity or could otherwise endanger USDWs, the Permittee must notify EPA and, if necessary, shut down the well, make repairs, and demonstrate to the satisfaction of EPA that the well has achieved mechanical integrity prior to recommencing injection.

In response to concerns that the production wells that are being converted to injection wells are inadequately constructed, EPA reviewed the newspaper article describing a blowout at a PGV well in 1991 (Attachment 02). However, the article does not describe whether the well was an injection well or a production well and makes no assertions about mechanical integrity or drilling issues. As EPA notes above, each well used for injection must meet UIC Program requirements (including a demonstration of mechanical integrity) before injection may be authorized. The

Permit application includes schematics of the production wells which, EPA has determined, were constructed to meet the UIC Program's requirements for injection wells.

Appendix: List of Comments and Attachments

Name	Date of Comment	Format of Submission	Attachments to Comment
Dona Mueller	7/6/2020	Email, phone	
Nicki Conti	7/7/2020	Email	
Dominique Pajot	7/17/2020	Email	
Jared Goldsmith	7/18/2020	Email	
Catherine Ridder	7/18/2020	Email	
Bonnie McCarroll	7/18/2020	Email	
Jimmy Leritz	7/19/2020	Email	
Spiro Theofilatos	7/19/2020	Email	
Sherri Carden	7/19/2020	Email	
George Douvris	7/19/2020	Email	
Stephanie Douvris	7/19/2020	Email	
Hannique Ruder	7/19/2020	Email	
John Douvris	7/20/2020	Email	
Ariel Douvris	7/20/2020	Email	
Julie Stitz	7/20/2020	Email	
Jim Albertini	7/20/2020	Email	
Janice Palma-Glennie	7/21/2020	Email	
Steve Holmes	7/21/2020	Email	
Steve Holmes	7/21/2020	Email	
William Smith	7/21/2020	Email	
Hank Hawaiian	7/21/2020	Email	
Dea Rackley	7/21/2020	Email	
Sharon Willeford	7/21/2020	Email	
Heather Culp	7/21/2020	Email	
Deborah Davis	7/21/2020	Email	

Name	Date of Comment	Format of Submission	Attachments to Comment
Koohan Paik-Mander	7/21/2020	Email	
Cory Harden	7/21/2020	Email	
Martha Bouchard	7/22/2020	Email	
Dr. Georgina Fong	7/22/2020	Email	
Robert Petricci	7/22/2020	Email	Attachment 01: Ariel View, New Volcanic Vents, PGV Boundary Attachment 15: Hawaii Administrative Rules: Title 11, Environmental Impact Statement Rules Attachment 19: More intervenors in PGV docket Attachment 21: PGV eyes new wells Attachment 23: PGV parent company settles stimulus fraud lawsuit Attachment 27: Volcanic lava flows affect geothermal power generation on Big Island
Mary Whispering Wind	7/22/2020	Email	
Kieba Blacklidge	7/22/2020	Email	
Dave Kisor	7/22/2020	Email	
Cynthia Massa	7/22/2020	Email	
Sara Steiner	7/22/2020	Email	
Blair Matthews	7/22/2020	Email	
Cheryl Carocci	7/22/2020	Email	
Norris Thomlinson	7/22/2020	Email	
Dr. Georgina Fong	7/22/2020	Email	
Janelle Williams	7/22/2020	Email	Attachment 03: Detecting Induced Seismicity Resulting from Geothermal Exploitation in Iceland Attachment 04: Does Geothermal Exploitation Trigger Earthquakes in Tuscany? Attachment 25: Lessons from Pohang: Solving geothermal energy's earthquake problem Attachment 31: Geological Risk Associated with Drilling into Magma at Krafla Caldera, Iceland: Preliminary Evaluation
Richard Ha	7/22/2020	Email	
Leslie Iijima	7/22/2020	Email	
Fred Hofer	7/22/2020	Email	
Stephen Yundt	7/22/2020	Email	
Suzanne Wakelin	7/22/2020	Email	

Name	Date of Comment	Format of Submission	Attachments to Comment
Cory Harden	7/23/2020	Email	Attachment 36: Docket No. 2019-0333 - HELCO-PGV Amended and Restated Power Purchase Agreement - PGV Responses to CA/PGV-IR-1 to 13 - Tranche 1
Debbie Ward	7/23/2020	Email	
Phaethon Keeney	7/23/2020	Email	
Lynn Cox	7/23/2020	Email	
Janelle Williams	7/23/2020	Email	
Jerry Greer	7/23/2020	Email	Attachment 11: Far away from any witnesses, my small town poisoned by fracking waste Attachment 12: fracking contamination groundwater - Google Search Attachment 14: Geothermal Public Health Assessment Attachment 16: fracking poisons humans - Google Search Attachment 17: Injection wells can induce earthquakes miles away from the well Attachment 20: pentane hawaii eruption 2018 - Google Search Attachment 26: UCSC study: Energy production causing quakes Attachment 38: Hydraulic fracturing and water resources in California: Evaluating the emerging regulatory framework
Senator Russell Ruderman	7/23/2020	Email	
Kai Sorte	7/23/2020	Email	
Alexey Katko	7/23/2020	Email	
Lesha Mathes	7/23/2020	Email	
Wesley Sayers	7/23/2020	Email	
Naomi & Yoav Melamed	7/23/2020	Email	
Steven Jacquier	7/24/2020	Email	Attachment 02: Blowout Shuts Geothermal Unit in Hawaii Attachment 18: Israeli-owned geothermal plant girds for possible lava from Hawaii volcano Attachment 22: PGV fined for operational, emission and notification violations Attachment 23: PGV parent company settles stimulus fraud lawsuit Attachment 24: PGV Settles with EPA for 2013 Violations
Vashti Campbell	7/24/2020	Email	
Chad Baybayan	7/24/2020	Email	
Nana-Honua Manuel	7/24/2020	Email	
Terry Ford	7/24/2020	Email	
Xavier Stewart	7/24/2020	Email	

Name	Date of Comment	Format of Submission	Attachments to Comment
Diana Miller	7/24/2020	Email	
Lizo	7/24/2020	Email	
Shanti Devi	7/24/2020	Email	
Wallace, Jr Ishibashi	7/24/2020	Email	
Delia Montgomery	7/24/2020	Email	
Frederick Kennedy	7/24/2020	Email	
Sara Steiner	7/24/2020	Email	Attachment 05: M7.7 - Kalapana Earthquake Attachment 06: United States Environmental Protection Agency Underground Injection Control (UIC) Program Class II Permit Application Completeness Review Checklist Attachment 07: Induced Seismicity Screening Worksheet Attachment 08: Protocol for Addressing Induced Seismicity Associated with Enhanced Geothermal Systems Attachment 09: Establishment of the Frontier Observatory for Research in Geothermal Energy (FORGE) at Newberry Volcano, Oregon Attachment 10: A preliminary review of Puna Geothermal Venture and the 2018 Kilauea Eruption Attachment 13: Geothermal FAQs Attachment 36: Docket No. 2019-0333 - HELCO-PGV Amended and Restated Power Purchase Agreement - PGV Responses to CA/PGV-IR-1 to 13 - Tranche 1 Attachment 37: Hawaii County Code: Chapter 14, General Welfare
Joy Yoshina	7/25/2020	Email	
Zachary Adachi	7/30/2020	Email	
Kaitlyn Ashida	7/30/2020	Email	
Leialii Dias	7/31/2020	Email	
Laurisa Nishimoto	7/31/2020	Email	
Jordan Hara	7/31/2020	Email	
Redentor Moreno	8/3/2020	Email	
David Meeker	8/3/2020	Email	
Cindy Conda	8/18/2020	Email	
Steve Holmes	8/24/2020	Email	
Ron Quesada	9/8/2020	Submitted to regulations.gov	
Stanley Magnuson	9/9/2020	Submitted to regulations.gov	
Anonymous	9/9/2020	Submitted to regulations.gov	
Jason Simonson	9/9/2020	Submitted to regulations.gov	

Name	Date of Comment	Format of Submission	Attachments to Comment
Jeff Sayles	9/9/2020	Submitted to regulations.gov	
Shannon Costa	9/9/2020	Submitted to regulations.gov	
Todd Gaskin	9/9/2020	Submitted to regulations.gov	
Gary Dahl	9/9/2020	Submitted to regulations.gov	
Cesar Ramirez	9/10/2020	Submitted to regulations.gov	
Ralph LeVitt	9/11/2020	Submitted to regulations.gov	
Allan Onishi	9/17/2020	Submitted to regulations.gov	
Mike Miyahira	9/17/2020	Submitted to regulations.gov	
Rachel Solemsaas	9/18/2020	Submitted to regulations.gov	
Vern Yamanaka	9/30/2020	Submitted to regulations.gov	
Joseph Skruch	10/1/2020	Submitted to regulations.gov	
Paul Kuykendall	10/2/2020	Email	
Don Thomas	10/6/2020	Email	Attachment 32: A Geochemical Model of the Kilauea East Rift Zone Attachment 33: Seismic Studies On Kilauea Volcano, Hawaii Island Attachment 34: Groundwater Chemistry in the Vicinity of the Puna Geothermal Venture Power Plant, Hawai‘i, After Two Decades of Production Attachment 35: Hydrology and Geochemistry of a Hawaiian Geothermal System: HGP-A
Larry Wood	10/7/2020	Submitted to regulations.gov	Attachment 10: A preliminary geophysical and geochemical review of Puna Geothermal Venture and the 2018 Kilauea Eruption
Tim Richards	10/7/2020	Email	
Andrew Rosenhof	10/7/2020	Oral comment at hearing	
Chevy Cardin	10/7/2020	Oral comment at hearing	
Cory Harden	10/7/2020	Oral comment at hearing	
Dave Kisor	10/7/2020	Oral comment at hearing	
Donald Thomas	10/7/2020	Oral comment at hearing	
Larry Wood	10/7/2020	Oral comment at hearing	
Mike Kaleikini	10/7/2020	Oral comment at hearing	

Name	Date of Comment	Format of Submission	Attachments to Comment
Paul Kuykendall	10/7/2020	Oral comment at hearing	
Robert Petricci	10/7/2020	Oral comment at hearing	
Ron Quesada	10/7/2020	Oral comment at hearing	
Sara Steiner	10/7/2020	Oral comment at hearing	
Sherri Carden	10/7/2020	Oral comment at hearing	
Steve Sparks	10/7/2020	Oral comment at hearing	
Suzanne Wakelin	10/7/2020	Oral comment at hearing	
Valvrette Natrishi	10/7/2020	Oral comment at hearing	
Tim Richards	10/7/2020	Email	
Anonymous	10/8/2020	Submitted to regulations.gov	
Anonymous	10/8/2020	Submitted to regulations.gov	
Richard Ha	10/8/2020	Email	
Sondra Olson	10/9/2020	Submitted to regulations.gov	Attachment 28: Oklahoma's earthquakes strongly linked to wastewater injection depth
Anonymous	10/9/2020	Submitted to regulations.gov	
Amanda Putman	10/9/2020	Submitted to regulations.gov	
Toby Taniguchi	10/9/2020	Email	
Ryan Garcia	10/9/2020	Submitted to regulations.gov	
Anonymous	10/9/2020	Submitted to regulations.gov	
Sara Steiner	10/9/2020	Submitted to regulations.gov	Attachment 05: M7.7 - Kalapana Earthquake Attachment 10: A preliminary geophysical and geochemical review of Puna Geothermal Venture and the 2018 Kilauea Eruption Attachment 29: Dacite Melt at the Puna Geothermal Venture Wellfield, Big Island of Hawaii Attachment 30: Geodetic Studies of the Puna Geothermal Ventures Site and Vicinity Attachment 37: Hawaii County Code: Chapter 14, General Welfare
Anonymous	10/9/2020	Submitted to regulations.gov	