Appendix A

Existing and Proposed Wells and Well Pad Locations

UIC Permit R9UIC-HI5-FY16-1R

Footnotes (*) for the UIC Permit Application Form

*1 Puna Geothermal Venture (PGV) also conducts drilling activities, which are included under SIC Code 1781.

*2 PGV is currently operating five (5) Class V geothermal injection wells pursuant to:

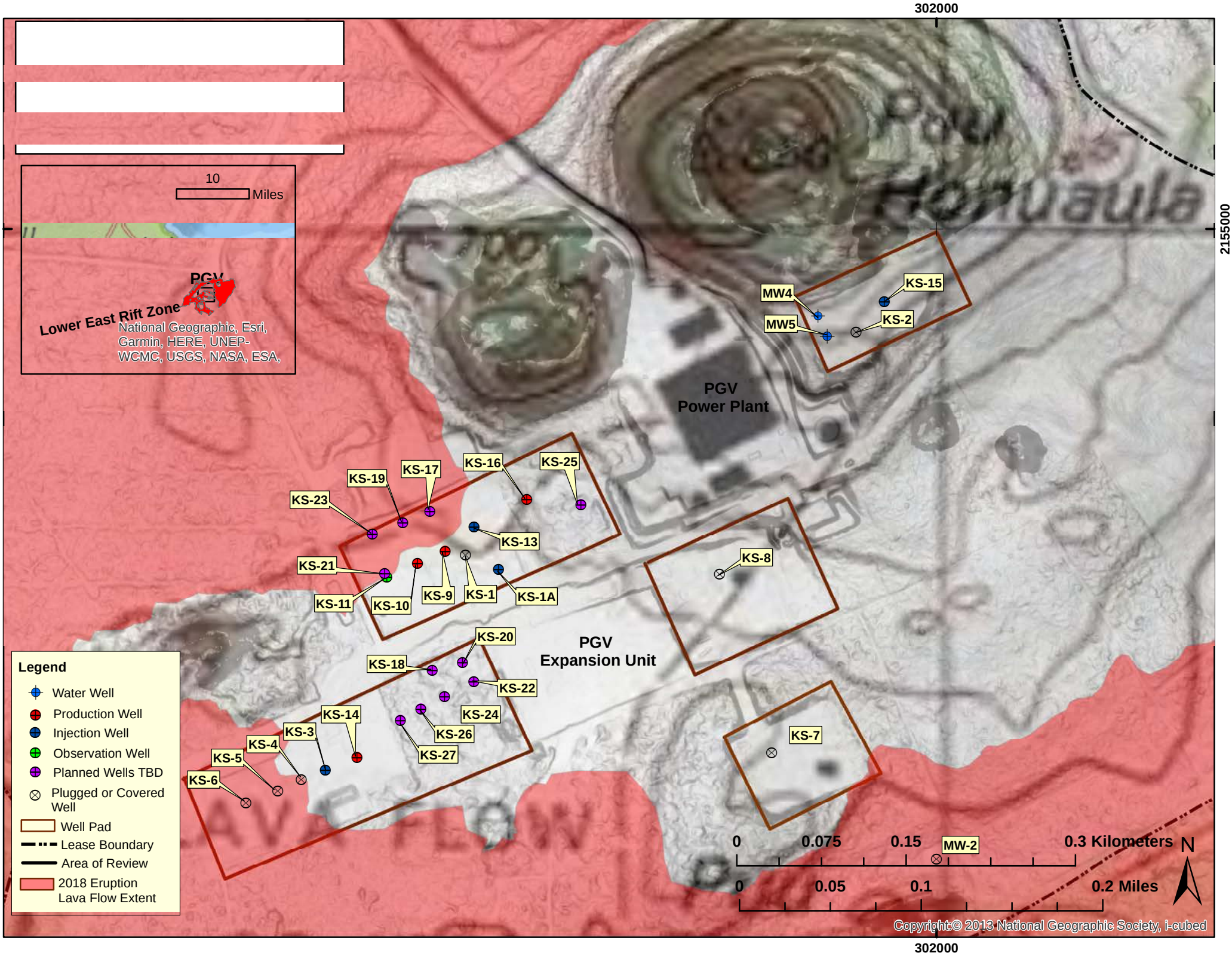
a. U.S. EPA Region 9 UIC Permit #HI596002.

b. A valid State of Hawaii UIC Permit #UH-1529 issued by the Hawaii Department of Health (HDOH).

EXISTING INJECTION WELL NO.	LOCATE ON WELL PAD	APPROXIMATE WELL HEAD ELEVATION ABOVE MEAN SEA LEVEL
KS-1A	A	617
KS-3	E	618
KS-11	A	617
KS-13	A	618
KS-15	B	743

PROPOSED INJECTION WELL NO.	LOCATE ON WELL PAD	APPROXIMATE WELL HEAD ELEVATION ABOVE MEAN SEA LEVEL
KS-17	A	610
KS-18	E	620
KS-19	TBD	TBD
KS-20	TBD	TBD
KS-21	TBD	TBD
KS-22	TBD	TBD
KS-23	TBD	TBD
KS-24	TBD	TBD
KS-25	TBD	TBD
KS-26	TBD	TBD
KS-27	TBD	TBD

*3 The latitude and the longitude provided identifies the approximate center of the Area of Review and existing well locations as described in Attachment A.


302000
2155000
10
Miles
PGV
Lower East Rift Zone
National Geographic, Esri, Garmin, HERE, UNEP-WCMC, USGS, NASA, ESA,
PGV
Power Plant
PGV
Expansion Unit
MW4
MW5
KS-15
KS-2
KS-8
KS-7
KS-16
KS-25
KS-19
KS-17
KS-23
KS-13
KS-21
KS-11
KS-10
KS-9
KS-1
KS-1A
KS-20
KS-18
KS-22
KS-24
KS-26
KS-27
KS-14
KS-3
KS-4
KS-5
KS-6
MW-2
Legend
Water Well
Production Well
Injection Well
Observation Well
Planned Wells TBD
Plugged or Covered Well
Well Pad
Lease Boundary
Area of Review
2018 Eruption Lava Flow Extent
0
0.075
0.15
0.3 Kilometers
0
0.05
0.1
0.2 Miles
N
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Appendix B

Injection Well Schematics

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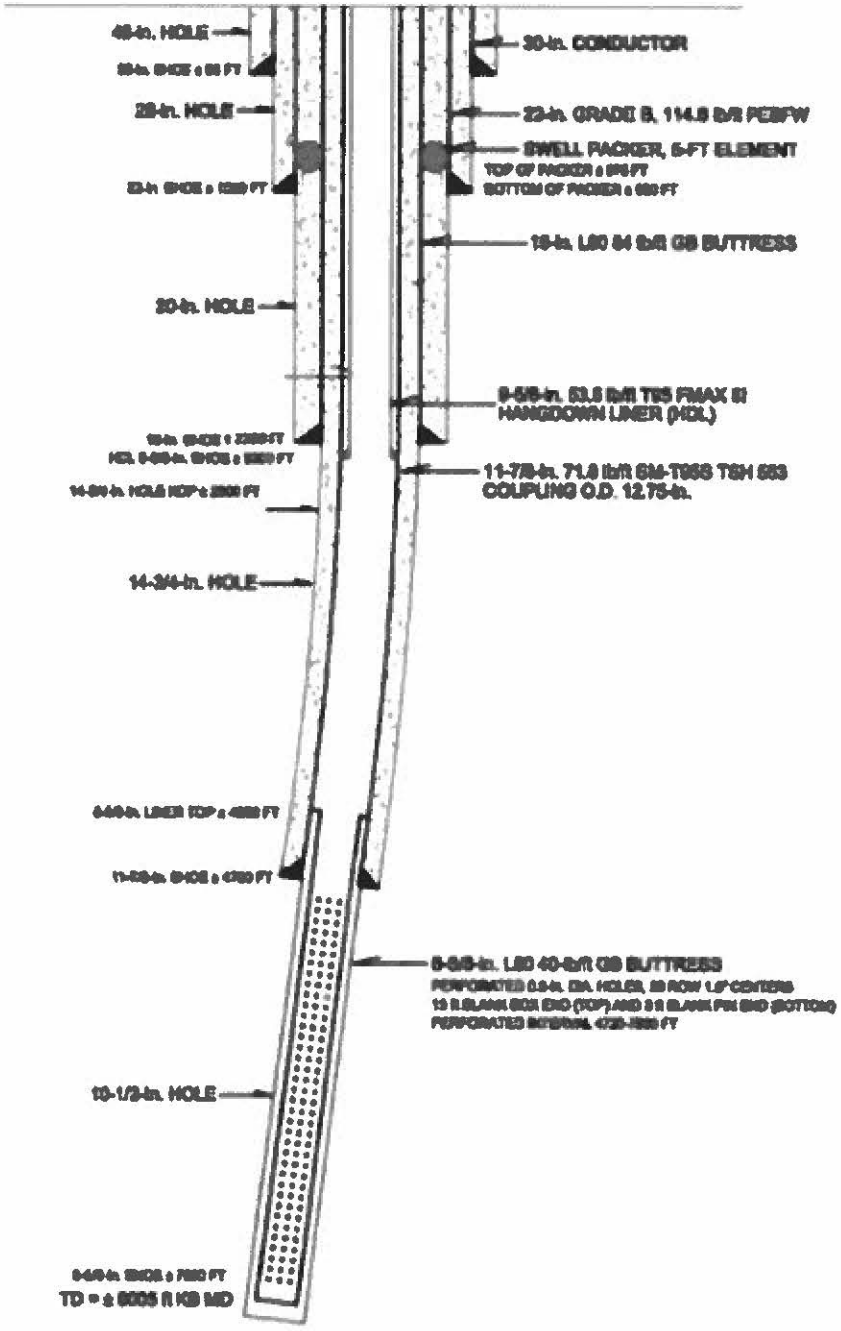
PUNA GEOTHERMAL VENTURE
STANDARD WELL DIAGRAM-INJECTION WELL



NOT TO SCALE

December 19, 2019

Appendix C

Approved Changes and Workover Program

UIC Permit R9UIC-HI5-FY16-1R

Attached is a list of generic procedures, actual procedures performed when required will use these as a guideline and incorporate the best available current technology. A job specific version shall be submitted to all agencies for review and approval prior to commencing operations.

PUNA GEOTHERMAL VENTURE GENERIC CHEMICAL TREATMENT TO REMOVE WELLBORE SCALE

JANUARY 2, 2017

Objective

Dissolve wellbore scale formation with approved chemical: hydrochloric (HCl) acid for calcite; hydrofluoric (HF) acid or chealate (example: Nitrilotriacetate, C6H9NO6) for silica; or a blend of nitric (N), phosphoric (H3PO4) and hydrofluoric (HF) acids for sulfate scale.

Safety

Before job commences, hold a safety meeting for all personnel who will be on location. Meeting will be conducted jointly by Operator (PGV) and Service Company supervisors. As a minimum, the following points will be covered in Pre-Job Safety Meeting (PJSM);

Procedure

- Review of applicable safety rules from common geothermal industry practice and site specific rules Puna Geothermal Venture
- Review evacuation plan
- Rules regarding mandatory use of face shields, gloves, hard hats and other personal protective equipment
- Rules regarding safe areas for non-essential personnel during pumping and displacement of acid (as a minimum, areas around high-pressure lines will be marked off with a tape barrier)
- Identify location(s) of eye wash station(s) per Pre-Job Safety Meeting (PJSM)
- Notify Central Station Control (CSC) for all emergency notifications
- Identify location all plant SDS's per PJSM
- Identify all procedures for neutralizing drips or minor spills on the ground
- Identify all procedures for containment and neutralizing of acid spill

Service Company will have to supply sodium carbonate (Na2CO3) or suitable substitute on location to neutralize minor acid spills.

Procedure

1. Shut in well by closing block valve on flow line. Shut master valve.

2. Rig up steel lines from pump truck to 3 inch casing head valve. Pressure test lines.

3. Pump at least one wellbore volume of fresh water ahead at approximately 5 BPM. Do not exceed 400 psi injection pressure without authorization of Operator representative. Well is expected to take water and chemical on a vacuum.

4. Pump chemical treatment with corrosion inhibitor, surfactant, and chelating agent as necessary to protect casing and prevent precipitation.

5. Wait for treatment to dissolve scale.

6. Displace acid with at least one wellbore volume of water.

7. Rig down pumping unit.

8. Return will to injection.

PUNA GEOTHERMAL VENTURE - GENERIC PROGRAM COILED TUBING CLEANOUT OF WELLBORE SCALE

JANUARY 2, 2017

Objective

Remove wellbore scale with coiled tubing wash tools or hydroblast to improve injection capacity.

Safety

Before job commences, hold a safety meeting for all personnel who will be on location. Meeting will be conducted jointly by Operator (PGV) and Service Company supervisors.

Procedure

1. Mobilize coiled tubing rig and associated equipment.
   1.1. Notify all applicable Local, State & Federal agencies prior to rig up.
   1.2. Comply with all GRP, NSP, DLNR & UIC permits that pertain to well work.
   1.3. Ensure that contractors and drilling related personnel have been provided with the required safety training including H2S training and operation of H2S abatement system.

2. Nipple up to well and function test BOPE.

3. Make up wash tool or hydroblast nozzle

4. Run in hole with tubing, pumping water through wash tool or hydroblast nozzle, to bottom of well or as deep as tubing will go.

5. Set up for flow if necessary to cleanout well
   5.1. Rig up flow line and muffler with H2S abatement system according to PGV H2S abatement procedures
   5.2. Pump nitrogen and run tubing and attempt to unload and flow well while pumping caustic according to PGV H2S abatement procedures. Throttle well to keep flow below 100 kph of steam and zero carry over from muffler.
   5.3. Once well is flowing switch back to fluid to wash casing
   5.4. Continue to flow well until returns are clean and free of solids.

6. Shut in well and rig down tubing unit.

7. Comply with all applicable local, state and federal permits prior to placing the well back in service.

PUNA GEOTHERMAL VENTURE
GENERIC PROGRAM TO DRILL OUT WELLBORE SCALE WITH RIG

JANUARY 2, 2017

Objective

Clean scale out of wellbore to improve injection capacity.

Procedure

1. Mobilize suitable rig and associated equipment.
   1.1. Notify all applicable Local, State & Federal agencies prior to rig up.
   1.2. Install direct communications between rig floor, tool pusher and company man.
   1.3. Comply with all GRP, NSP, DLNR & UIC permits that pertain to drilling.
   1.4. Ensure that the applicable drilling contractors have current well control training.
   1.5. Ensure that additional drilling related personnel have been provided with the required safety training.
2. Nipple up BOPE.
3. Kill well and keep water going into hole during cleanout.
4. Pull hang down liner if there is one.
5. Clean out scale.
   5.1. Run in hole with bit and stabilizer to fit I.D. of casing. Rotate and circulate as necessary to drill out scale.
   5.2. Run in hole with bit and stabilizer to fit I.D. of liner and/or open hole. Rotate and circulate as necessary to drill out scale
6. Rerun hang down liner, if applicable.
7. Secure well and rig down.
8. Comply with all applicable local, state and federal permits prior to placing the well back in service.

PUNA GEOTHERMAL VENTURE - GENERIC PROGRAM TO REMOVE AND/OR INSTALL PERFORATED LINER

JANUARY 2, 2017

Objective

Remove damaged liner and/or install new liner to improve injection capacity and wellbore stability.

Procedure

1. Mobilize suitable rig and associated equipment.
   1.1. Notify all applicable Local, State & Federal agencies prior to rig up.
   1.2. Install direct communications between rig floor, tool pusher and company man.
   1.3. Comply with all GRP, NSP, DLNR & UIC permits that pertain to drilling.
   1.4. Ensure that the applicable drilling contractors have current well control training.
   1.5. Ensure that additional drilling related personnel have been provided with the required safety training.

2. Nipple up BOPE.

3. Kill well and keep water going into hole while working in hole.

4. Pull hang down liner if there is one.

5. Clean out scale.
   5.1. Run in hole with bit and stabilizer to fit I.D. of casing. Rotate and circulate as necessary to drill out scale.
   5.2. Run in hole with bit and stabilizer to fit I.D. of liner and/or open hole. Rotate and circulate as necessary to drill out scale as deep as necessary.

6. Pull liner, if necessary.
   6.1. If only part of liner is to be pulled, RIH with casing cutter and cut off liner at appropriate depth.
   6.2. RIH with casing spear, spear and pull liner.

7. Install liner, if necessary.
   7.1. Make up liner and run to TD.

8. Rerun hang down liner, if applicable.

9. Secure well and rig down.

10. Comply with all applicable local, state and federal permits prior to placing the well back in service.

PUNA GEOTHERMAL VENTURE - GENERIC PROGRAM TO SQUEEZE CEMENT

JANUARY 2, 2017

Objective

Squeeze cement into formation to seal off undesired injection zone.

Procedure

1. Mobilize suitable rig and associated equipment.
   1.1. Notify all applicable Local, State & Federal agencies prior to rig up.
   1.2. Install direct communications between rig floor, tool pusher and company man.
   1.3. Comply with all GRP, NSP, DLNR & UIC permits that pertain to drilling.
   1.4. Ensure that the applicable drilling contractors have current well control training.
   1.5. Ensure that additional drilling related personnel have been provided with the required safety training.

2. Nipple up BOPE.

3. Kill well and keep water going into hole while working in hole.

4. Pull hang down liner if there is one.

5. Clean out scale.
   5.1. Run in hole with bit and stabilizer to fit I.D. of casing. Rotate and circulate as necessary to drill out scale to below area to be cemented.
   5.2. If necessary, run in hole with bit and stabilizer to fit I.D. of liner and/or open hole. Rotate and circulate as necessary to drill out scale below area to be cemented.

6. Establish plug below area to be cemented.
   6.1a Run bridge plug and set below area to be cemented,
   6.1b or pump cement plug below area to be cemented
   6.1c or fill hole with sand and cinders to below area to be cemented.
   6.2 Check plug back depth and pump cement plug

7. Squeeze cement.
   7.1. Pump squeeze cement across area to be cemented.
   7.2. Pressure up as necessary to squeeze cement.
   7.3. Wait for cement to set and then run in with bit and clean out cement and plug.

9. Rerun hang down liner, if applicable.

10. Secure well and rig down.

11. Comply with all applicable local, state and federal permits prior to placing the well back in service.

PUNA GEOTHERMAL VENTURE - GENERIC PROGRAM TO SQUEEZE CEMENT AND INSTALL CASING PATCH OR CEMENTED LINER

JANUARY 2, 2017

Objective

Squeeze cement into undesirable injection zone and cover with casing patch or cemented liner.

Procedure

1. Mobilize suitable rig and associated equipment.
   1.1. Notify all applicable Local, State & Federal agencies prior to rig up.
   1.2. Install direct communications between rig floor, tool pusher and company man.
   1.3. Comply with all GRP, NSP, DLNR & UIC permits that pertain to drilling.
   1.4. Ensure that the applicable drilling contractors have current well control training.
   1.5. Ensure that additional drilling related personnel have been provided with the required safety training.

2. Nipple up BOPE.

3. Kill well and keep water going into hole while working in hole.

4. Pull hang down liner if there is one.

5. Clean out scale.
   5.1. Run in hole with bit and stabilizer to fit I.D. of casing. Rotate and circulate as necessary to drill out scale to below area to be cemented.
   5.2. If necessary, run in hole with bit and stabilizer to fit I.D. of liner and/or open hole. Rotate and circulate as necessary to drill out scale below area to be cemented.

6. Establish plug below area to be cemented.
   6.1a. Run bridge plug and set below area to be cemented,
   6.1b. or pump cement plug below area to be cemented
   6.1c. or fill hole with sand and cinders to below area to be cemented.
   6.2. Check plugback depth and pump cement plug.

7. Squeeze cement.
   7.2. Pump squeeze cement across area to be cemented.
   7.3. Pressure up as necessary to squeeze cement.
   7.4. Wait for cement to set and then run in with bit and clean out cement.

8a. Install casing patch, if necessary
    8a.1 Clean out cement and fill to TD
    8a.2 Make up casing patch and set across cemented area

8b. or Install liner, if necessary
    8b.1 Clean out cement and fill to bottom of liner installation
    8b.2 Make up and run liner
    8b.3 Cement liner in place, wait for cement to set
    8b.4 Clean out cement and fill to TD

9. Rerun hang down liner, if applicable.

10. Secure well and rig down.

11. Comply with all applicable local, state and federal permits prior to placing the well back in service.

PUNA GEOTHERMAL VENTURE - GENERIC PROGRAM TO PLUG BACK WELLBORE

JANUARY 2, 2017

Objective

Plug back well to seal off undesirable injection zone at bottom of well.

Procedure

1. Mobilize suitable rig and associated equipment.
   1.1. Notify all applicable Local, State & Federal agencies prior to rig up.
   1.2. Install direct communications between rig floor, tool pusher and company man.
   1.3. Comply with all GRP, NSP, DLNR & UIC permits that pertain to drilling.
   1.4. Ensure that the applicable drilling contractors have current well control training.
   1.5. Ensure that additional drilling related personnel have been provided with the required safety training.

2. Nipple up BOPE.

3. Kill well and keep water going into hole while working in hole.

4. Pull hang down liner if there is one.

5. Clean out scale.
   5.1. Run in hole with bit and stabilizer to fit I.D. of casing. Rotate and circulate as necessary to drill out scale as deep as necessary for plug back.
   5.2. If necessary, run in hole with bit and stabilizer to fit I.D. of liner and/or open hole. Rotate and circulate as necessary to drill out scale as deep as necessary for plug back.

6. Plugback.
   6.1a. Run bridge plug and set below new TD
   6.1b. or pump cement plug below new TD
   6.1c. or fill hole with sand and cinders to below new TD
   6.2. Check plugback depth and pump cement plug above.

9. Rerun hang down liner, if applicable.

10. Secure well and rig down.

11. Comply with all applicable local, state and federal permits prior to placing the well back in service.

Appendix D

Casing Monitoring Program

UIC Permit R9UIC-HI5-FY16-1R

Puna Geothermal Venture

Production and Injection Well Casing Monitoring Program

1. Introduction

1.2 Purpose

The purpose of this CMP is to specify the observations, tests, and drilling operations required to insure that the integrity of production and injection casing remains intact throughout the drilling, testing, and operations of PGV wells. The cemented and hung casing strings that are used in the PGV wells are designed to prevent contamination of shallow aquifers by either reservoir fluid in production wells or power plant effluent in injection wells. Contamination of the shallow aquifers might occur if the casing strings are breached due to corrosion or mechanical failure thus allowing the escape of geothermal brine or injectate to the formation. The casing monitoring program described below is designed to indicate the presence of casing leaks and accurately define their location.

1.3 Scope

This CMP covers all production and injection wells drilled by PGV and all existing wells that were drilled by previous operators on the PGV site which to date have not been plugged and abandoned.

1.4 Hydro geologic Basis for the Casing Monitoring Program

The hydro geologic basis for the CMP is derived from data available from the drilling of wells to depths ranging to 8300' and by three shallow monitoring wells drilled to depths of 640' and 720'. Based on the static temperature profiles, well testing, and behavior of drilling fluid during drilling, it is possible to divide the hydrologic regime it the project area into five major horizontally extensive zones. These zones are reflected in the typical temperature-depth profiles measured in the deep production wells.

1.4.1 The shallowest zone extending from surface to about 6' above sea level is unsaturated and consists of a highly permeable sequence of subareal basalt flows and interflow breccias. Within the project area this zone varies in thickness from 600' to 720' depending on the surface elevation. Numerous cracks with widths of up to 2' traverse the area. These cracks are vertical or very steeply dipping and reach from the surface to at least the top of the warm unconfined aquifer described below. This is evidenced by the discharge of warm, moist air from many of these cracks. The cracks trend parallel to the major structures and lineaments of the Lower East Rift Zone.

1.4.2 The zone below the unsaturated surface rock consists of an unconfined aquifer which contains relatively fresh ground water with varying degrees of natural contamination from the underlying geothermal system. This zone is approximately 1400' thick with the water surface elevation controlled by sea level according to the Ghyben-Herzberg model. The unconfined aquifer surface in the project area is approximately 7' above mean sea level. Based on that model, the thickness of the low salinity lens is therefore about 280'. This constitutes the USDW. The salinity of the underlying water will probably approach that of sea water. The temperature of this zone ranges from 95 to 130 deg. F in the project area and tends to be nearly isothermal throughout the entire interval indication good vertical mixing.

1.4.3 The interval from 1400’ below sea level to 2400’ below sea level is characterized by an extremely steep thermal gradient in the range of 30 deg. F / 100’ or more. The steep temperature gradient is characteristic of conductive heat transfer and indicates the zone has essentially zero vertical permeability. The zone appears to be an effective aquitard separating the high temperature geothermal fluid below from the low temperature unconfined aquifer overlying it. Locally the aquitard exhibits natural leakage as in the area of MW-2 and GTW-III where anomalously high shallow ground water temperatures and salinities are observed.

1.4.4 Between the depth interval 2400’ and 4300’ below sea level, the temperature profile indicates the existence of a transition zone which consists of alternating permeable and impermeable strata. Within this zone are two more alternating zones of high thermal gradients and isothermal intervals. The high average thermal gradient through this zone indicates that vertical fluid circulation is very limited.

1.4.5 Below a depth of 4300’ below sea level, the temperature profile becomes nearly isothermal. This intervals within the geothermal reservoir in which significant vertical movement of fluid is taking place at temperatures above 620 deg. F.

The casing program planned for the production and injection wells calls for cemented casing to reach from ground surface to a depth below 3400’ below sea level. This allows the casing to be anchored securely within the transition zone described in 1.4.4 and to fully isolate the geothermal reservoir from the shallow aquifer with a cemented interval through the aquitard. Within the shallow aquifer, two cemented casing strings are installed. Three cemented strings pass through the top of the shallow aquifer and the unsaturated zone. The production and injection casing programs are designed to prevent leakage of geothermal fluid from the wellbore into the shallow aquifer above a depth of 1400’ below sea level. The CMP discussed below provides the methods and procedures to detect any leakage.

2. Production and injection well casing monitoring program

2.1 Pressure testing during drilling.

Each well is completed with three casing strings cemented to the surface. Immediately upon completion of cementing each string of casing and prior to drilling out the cement shoe, the casing is pressure tested. 30CFR Section 250.55 requires as test of 70% of the casing minimal internal yield pressure or as otherwise approved or required by the District Supervisor. After drilling out the shoe, 30 CFR Section 250.427 requires a pressure integrity test below the surface casing or liner and all intermediate casings or liner. You must test to either the formation leak-off pressure or to an equivalent drilling fluid weight if identified in an approved APD. For PGV, the equivalent drilling fluid weight specified in our drilling programs is the 0.65 psi/ft mud pressure gradient. This is designed to stay below the leak-off pressure in order to avoid weakening the formation. PGV uses the terminology “shoe test” or just simply a “Formation Integrity Test” (FIT). A leak off test (LOT) is different than the FIT, as the LOT tests formation until failure, while the FIT tests the formation up to a predetermined pressure before formation failure. The FIT is the preferred term for wells tests in geothermal fields. The FIT is not a “leak off test” unless it fails and there is leak off. The FIT procedure is performed after the casing has been cemented and the cement drilled out a few feet below the casing shoe. Pressure is applied to the cement and formation below the casing shoe at a pressure gradient that is below any likely fracture pressure gradient. This assures the integrity of the formation and cement at the shoe. During subsequent operations, injection pressure is limited to the same pressure, which ensure that injectate will not go up behind the casing to shallower depths where the fracture pressure is lower or where protected aquifers might be located. PGV does not establish a specific fracture pressure for the basalt formations, because injection pressures during operations are kept well below fracture pressures. Establishing a fracture pressure gradient is generally not necessary in geothermal areas where the formation fluids are at hydrostatic pressure gradient, over-pressured zones do not exist, and high mud weights are not used.

2.2 Monitoring during injection testing

Upon completion of each well an injection test may be performed to give an initial indication of reservoir permeability. The injection test consists of pumping cool fresh water into the wellbore at several controlled rates while monitoring downhole and wellhead pressure. Pressure temperature logs are also run during the test. These logs can be used to locate leaks in the casing by noting a sudden rise in temperature with depth within the casing string. Also a temperature reversal within the casing string that remains after injection is stopped may be indicative of leakage.

2.2.1 Injectivity testing procedure

- Keep constant pumping rates during the entire test.
- Pump at 1/3 maximum pump rate while setting up.
- Run open ended drillpipe into well close to the injection zone and set in pipe rams.
- Rig up slick line unit on drillpipe with a safety valve and lubricator.
- Run sinker bar to maximum reachable depth. Continue pumping at 1/3 max pump rate.
- Run high temperature Kuster PT tool to 10 feet above sinker bar set down depth.
- Pull up to middle of lost circulation zones.
- Wait for 30 minutes.
- Increase pump rate to 2/3 maximum pump rate and pump for 1 hour.
- Increase pump rate to maximum pump rate and pump for 1 hour.
- Stop pumping and wait for 1 hour to record pressure drop off.
- Run PT tool in to 10 feet above sinker bar set down depth, pull PT out of hole at 100 ft/min.

An estimated injectivity index can be calculated into gallons per psi by dividing the maximum flow rate by drop off pressure.

2.3 Monitoring during routine injection

Once annually tests and surveys are conducted on each injection well to verify mechanical integrity of the injection casing and the hangdown liner. Pressure temperature surveys are taken to include a flowing well profile, pressure drop off and static conditions. The resulting pressure and temperature profiles are used to confirm all the injected fluid is exiting at the shoe with no inter formational flows behind the casing. Yearly surveys are kept on file and cross referenced to previous years to verify if any changing or abnormal conditions arise, indicating a loss of integrity of the casing. All testing is sent to an offsite Hydro geologic Service for review. Upon review a report of each well's condition is generated and submitted to agencies including, DLNR, Hawaii Department of Health, and Federal EPA.

2.4 Monitoring of injection liners

Continuous monitoring is performed by purging the annular space between the injection casing and the hangdown liner. Purge pressure and flow rate will be monitored for any change indicative of a casing leak. Leakage in the casing will cause a drop in annular nitrogen pressure. Pressure on the annular space is kept to a calculated pressure to maintain a fluid level below 2000'. Maintaining calculated pressure to depress the fluid level to 2000' insures that injectate will not leak out of the hang down casing, rather nitrogen will leak into any possibly casing leak. Once annually tests and surveys are also conducted to verify mechanical integrity of the casing and hangdown liner.

2.4.1 An annual pump down test is performed to depress the fluid level to 3000'. Surface pressure on the annulus and hangdown liner are monitored and recorded for 5 hours with initial readings every 10 minutes for the first hour, followed by 30 minute readings for 4 hours. The maximum allowable leak off rate is 10% during the testing period.

2.4.2 An additional test using an Echometer is performed during the pump down test to verify fluid level in the annulas is at 3000'

2.4.3 Logging tools are run into the injection well to the maximum depth or a predetermined depth below 3000'. A pressure temperature survey is taken with the well flowing under normal conditions. The well is then shut in with the PT tool below 3000' to record pressure drop off and an initial static profile. A second PT is completed 12 hours after the well has been shut in to identify fluid levels in the wellbore, a pressure profile and temperature build up. This data will identify any abnormal conditions such as fluid communication outside the casing or unusual thermal recovery after injection is stopped.

2.4.4 Additional testing such as a camera run or a caliper survey to check for integrity can also be completed to obtain further information if more testing is deemed necessary or desired.

Appendix E

Chemical and Physical Analysis Plan for Injectate Testing

UIC Permit R9UIC-HI5-FY16-1R

EPA will accept analyses and reports as required under Hawaii Department of Health Permit No. UH-1529.

B. MONITORING AND REPORTING CONDITIONS:

1. Injectant and Injection Well Monitoring

(a) Injectant samples, measurements, and analyses taken or conducted as required by this permit shall be valid and representative of the volume and nature of the injectant. Pursuant to the monitoring and reporting conditions of this permit, detailed records of the operation of the injection wells shall be kept by the permittee. When applicable, records shall include at a minimum the following information:

(1) Type of injectant;
(2) Quantity of injectant;
(3) The method of injection;
(4) Injection pressure;
(5) The rate of injection;
(6) The operational status of the injection well;
(7) The exact date and time of the measurement or sampling;
(8) The person(s) who performed the measurement or sampling;
(9) The dates the analyses were performed;
(10) The person(s) who performed the analyses;
(11) The analytical techniques or methods used;
(12) The results of all required analyses and permit limits; and
(13) Chain of Custody.

(b) A daily record of the injectant quantity (gpd) being discharged into each injection well shall be kept. Injectant quantity recordings shall be continuously made through a direct measurement of the wastestream or by a method approved by the Director. A per month summary giving the daily amounts of injectant for each well shall be submitted **every month** to the Department.

A continuous recording of the injection pressure (psig) and annular pressure at the well head shall be kept. Pressure recordings shall be documented on a graphical chart, such as a strip chart or circular chart, or log that shows the relationship between pressure and elapse time. A per-month summary giving the daily injection and annular pressures for each well shall be submitted **every month** to the Department. The annular pressures shall be compared against the calculated required pressure to maintain the proper depth of the nitrogen/water interface.

A daily record of the injectant temperature being discharged into each injection well shall be maintained. Injectant temperature recordings shall be continuously monitored and recorded. A per-month summary giving the daily average injection temperature for each well shall be submitted **every month** to the Department.

The use of injection supplemental water discharged into the injection wells shall be recorded. The recording shall be directly and continuously made to measure the flow of supplemental water. A per-month summary giving the daily amounts of supplemental water used shall be submitted **every month** to the Department.

Chemical additions being used for corrosion, scale, and biofouling control shall be recorded. The record shall account for the daily, weekly, and monthly consumptive amounts of each chemical. A per-month summary giving the monthly consumptive amount of each chemical shall be submitted **every month** to the Department.

(c) Representative grab samples (three types: Types I, III, and IV) of the injectant shall be collected from a collection point to be established by the permittee and approved by the Director. The permittee shall collect and analyze the samples and report the analytical results according to the conditions and the Monitoring and Reporting Schedule of this permit. The collection and analysis of the samples shall be conducted by a laboratory acceptable to the Director. If the laboratory is unable to perform the sample collection, the Director may allow the permittee to collect the sample under the direction of the laboratory.

All samples shall be collected, transported, preserved, stored, documented, analyzed, and reported in accordance with EPA or EPA equivalent methods or standards, and all such activities shall be performed properly and satisfactorily in order to produce valid samples and analytical results. The falsification, fabrication, tampering, or improper handling and management of the samples, chain-of-custody form, or analytical results shall be a violation of this permit.

Methods of analysis shall be as stated herein or approved by the Director. The frequency of sample collection and the type of analyses are as described:

Type I Sample:

(1) Type I sample shall be collected and analyzed at least **once every two months**. A monitoring and reporting schedule is attached that outlines the schedule of analyses and reportings.

(2) Type I sample shall be analyzed for the test parameters listed in **Table No. 2**.

(3) Type I sample shall be collected between the hours of 9 a.m. and 3 p.m.

(4) The analytical results (Type I) shall be submitted to the Department and a copy shall be kept on file at the facility. Analytical results are due within 60 days from the sampling date.

TABLE NO. 2
TEST PARAMETERS FOR TYPE I SAMPLE

Parameter	EPA Method	TCLP Related Action Level (mg/l)
Arsenic (As)	6010/206	5.0
Barium (Ba)	6010/208	100.0
Boron (B)	200	
Cadmium (Cd)	6010/213	1.0
Copper (Cu)	6010/220	
Iron (Fe)	6010/236	
Lead (Pb)	6010/239	5.0
Lithium (Li)	6010/7430	
Magnesium (Mg)	6010/242	
Manganese (Mn)	6010/243	
Mercury (Hg)	7470/245	0.2
Nickel (Ni)	6010/200	
Potassium (K)	6010/258	
Selenium (Se)	6010/270	1.0
Silver (Ag)	6010/272	5.0
Sodium (Na)	6010/273	
Vanadium (V)	6010/286	
Zinc (Zn)	6010/289	
Bromide	320	
Bicarbonate (HCC03)	310	
Carbonate (C03)	310	
Chloride	325	
Fluoride	340	
Nitrate (as N)	352	
Nitrite (as N)	354	
Silica, Dissolved (as Si02)	370	
Sulfate (S04)	375	
Total Sulfur (S)	various	

Total Alkalinity	310	
Total Dissolved Solids (TDS)	160.1	
Total Suspended Solids (TSS)	160.2	
Oil and Grease	1664	
Specific Conductance	120	
Field pH	150.1	≤ 2 or ≥ 12.5
Field Temperature	170	

Gas Parameter
Ammonia (NH3)
Argon (Ar)
Carbon Dioxide (CO2)
Hydrogen (H2)
Hydrogen Sulfide (H2S)
Methane (CH4)
Nitrogen (N2)
Oxygen (O2)
Radon
N-Pentane

All methods listed are EPA or EPA equivalent, unless otherwise noted.

Type III Sample:

(1) Type III sample shall be collected and analyzed at least once every six months in conjunction with Type I sample. A monitoring and reporting schedule is attached that outlines the schedule of analyses and reportings.

(2) Type III sample shall be analyzed for Ignitability, Corrosivity, Reactivity, and Method 1311: Toxicity Characteristic Leaching Procedure (TCLP) as described in 40 CFR, Part 261, Appendix II. Refer to **Table No. 3** which lists the test parameters for which the analysis shall be conducted under Method 1311. Regulatory levels of the chemical parameters are listed for reference.

(3) Type III samples shall be collected between the hours of 9 a.m. and 3 p.m.

(4) The analytical results (Type III) shall be submitted to the Department and a copy shall be kept on file at the facility. Analytical results are due within 60 days from the sampling date.

TABLE NO. 3
TEST PARAMETERS FOR TYPE III SAMPLE

Parameter	Regulatory Level	EPA Method
Ignitability	As described in 40 CFR (2012), Part 261.21	
Corrositvity	As described in 40 CFR (2012), Part 261.22	
Reactivity	As described in 40 CFR (2112), Part 26.23	
Inorganics:		Method 1311 (TCLP), with appropriate methods of analyses contained in SW-846
arsenic	5.0	
barium	100.0	
cadmium	1.0	
chromium	5.0	
lead	5.0	
mercury	0.2	
selenium	1.0	
silver	5.0	
Organics:		
benzene	0.5	
carbon tetrachloride	0.5	
chlorobenzene	100.0	
chloroform	6.0	
o-cresol	200.0	
m-cresol	200.0	
p-cresol	200.0	
1.4-dichlorobenzene	7.5	
1,2-dichloroethane	0.5	
1,1-dichloroethylene	0.7	
2.4-dinitrotoluene	0.13	
hexachlorobenzene	0.13	
hexachloro-1.3-butadiene	0.5	
hexachloroethane	3.0	
methyl ethyl ketone	200.0	
nitrobenzene	2.0	
pyridine	5.0	
tetrachloroethylene	0.7	
trichloroethylene	0.5	

2,4,5-trichlorophenol	400.0	
2,4,6-trichlorophenol	2.0	
vinyl chloride	0.2	

Type IV Sample:

(1) Type IV sample shall be collected and analyzed at least once every six months in conjunction with Type I and III sample. A monitoring and reporting schedule is attached that outlines the schedule of analyses and reportings.

(2) Type IV sample shall be analyzed for volatile organic compounds as described in 40 CFR, Part 136, Appendix A, Method 624. Refer to **Table No. 4** which lists the test parameters and the analytical methods.

(3) Type IV sample shall be collected between the hours of 9 a.m. and 3 p.m.

(4) The analytical results (Type IV) shall be submitted to the Department and a copy shall be kept on file at the facility. Analytical results are due within 60 days from the sampling date.

TABLE NO. 4
TEST PARAMETERS FOR TYPE IV SAMPLE

Parameter	EPA Method		TCLP Related Action Level (mg/l)
Volatile Organics	524/ 624/ 8240/ 8260		
Acetone			
Benzene			0.5
Bromodichloromethane			
Bromoform			
Bromomethane			
Carbon Tetrachloride			0.5
Chlorobenzene			100.0
Chloroethane			
2-Chloroethylvinyl ether			
Chloroform			6.0
Chloromethane			
Dibromochloromethane			
1,2-Dichlorobenzene			
Volatile Organics	524 /624/ 8240/ 8260		
1,3-Dichlorobenzene			
1,4-Dichlorobenzene			7.5
1,1-Dichloroethane			
1,2-Dichloroethane			0.5
1,1-Dichloroethylene			0.7
Trans-1, 2-Dichloroethene			
1,2-Dichloropropane			
cis-1,3-Dichloropropene			
trans-1,3-Dichloropropene			
Ethyl benzene			
Methylene chloride			

Methyl Ethyl Ketone			200.0
1,1,2,2-Tetrachloroethane			
Tetrachloroethene			
Toluene			
1,1,1-Trichloroethane			
1,1,2-Trichloroethane			
Trichloroethene			
Trichlorofluoromethane			
Vinyl Chloride			
Xylene			
Semi-Volatile Organics			
o-cresol			200.0
m-cresol	8270		200.0
p-cresol			200.0
hexachlorobenzene			0.13
Semi-Volatile Organics			
2,4-dinitrotoluene			0.13
hexachloro-1,3-butadiene			0.5
hexachloroethane			3.0
nitrobenzene	8270		2.0
pyridine			5.0
2,4.5-trichlorophenol			400.0
2.4,6-trichlorophenol			2.0

(d) The collection of Type III and Type IV samples shall be witnessed by DOH personnel unless a waiver to this condition is granted by the Director. The permittee shall notify the DOH at least seven (7) days prior to the date of sample collection for this phase of analysis. Any Type III and Type IV samples that are collected without the acknowledgment and inspection by DOH personnel, unless waived by the Director, will not serve to comply with the monitoring and reporting conditions of this permit.

(e) Every exceeding of a Regulatory Level concentration shall prompt an immediate (within five days from the time of knowledge of the initial analytical results) resampling for and reanalysis of the particular exceeding test parameter. If a TCLP-related action level is

exceeded, the reanalysis shall be conducted by using Method 1311: TCLP as described in 40 CFR, Part 261, Appendix II. If a TCLP regulatory level is exceeded, the reanalysis shall be conducted by using the same method.

The permittee shall immediately notify the DOH of every exceeding and shall submit the original and follow-up analytical results. The DOH may impose additional conditions.

(f) A periodic recorded inspection of the injection well system at least once every week shall be conducted by the permittee. The inspection shall include the recordation of the operational status of the injection well system to detect any deterioration of the injection well system and associated operations that might lead to an injection well failure, and provide the opportunity to correct any occurrence of prohibited discharge activity. The person conducting the periodic inspection shall be knowledgeable of what is unlawful disposal of chemical compounds, petroleum products and other hazardous substances into the injection well. If such activities are encountered, the permittee shall take immediate action to alleviate, correct, clean up, and record such disposal incidents. The recorded inspection including any disposal incidents shall be kept at the facility and be made available for inspection by DOH personnel.

(g) A periodic status report shall be completed at least once every 3 months regarding the condition and performance of the injection well system. The status report shall be made by a professional consultant, engineer, or geologist proficient in injection well performance. The status report shall document the condition and performance of the injection well system in accordance with the DOH's guidelines for an injection well status report. Field inspections and observations for the status report shall be performed at least during the last month of the 3-month monitoring period. A Monitoring and Reporting Schedule is attached that designates the last months of the monitoring periods. The status report shall be submitted to the DOH for review within one month after the end of the designated monitoring period.

(h) Under applicable conditions, the Director shall have the right to order and direct the permittee to collect and analyze special or unscheduled samples of the injectant or substance in the injection well, or to perform injection well performance or mechanical integrity assessments. Applicable conditions consist of, but are not limited to, accidental discharges, malicious discharges, and undefined discharges into the injection well, as well as indications that the injection well may be under performance or mechanical integrity deterioration. The permittee is required to maintain records of the sample collection, analysis, and assessment in conformance with Part B.1.(a) of this permit.

(i) Summary reports, results of scheduled chemical analyses, inspection reports, mechanical integrity reports, or hydrologic monitoring reports shall be submitted to the Department within 60 days after the end of the designated monitoring period for which the submittal applies. Submittals taking longer than 60 days are noncompliant with the 60 day time limit unless a time extension is granted by the Director based on circumstances for the delay.

APPENDIX B

PUNA GEOTHERMAL VENTURE
PROGRAM FOR MECHANICAL INTEGRITY TESTING AND MONITORING OF INJECTION WELLS
July 29, 1996

1. INTRODUCTION

1.1 Background

Pursuant to Underground Injection Control (UIC) Permit No. HI596002, the U.S. Environmental Protection Agency requires that Puna Geothermal Venture (PGV) comply with this Testing and Monitoring Program (TMP) for injection wells. Monitoring and testing provisions in this TMP are similar in most respects to those in the "Casing Monitoring Program," April 26, 1993 version, which is referenced by title in PGV's current UIC Permit No. UH-1529. **(The Casing Monitoring Program related to Hawaii UIC Permit No. UH-1529 was originally dated 11/21/1991 and amended later dated 4/26/1993.)** It is anticipated that this same TMP will be approved and adopted by the Hawaii Department of Health as a replacement for the 1993 "Casing Monitoring Program." Revisions to testing and monitoring provisions in the 1993 "Casing Monitoring Program" have been made as a result of a joint review of PGV's injection well monitoring and testing involving EPA, BLM (as advisor to EPA), HDOH and PGV. The purpose of these revisions is to better accomplish the goal of protecting the groundwater aquifer under the PGV project site, which is considered to be a USDW. The principle changes in the monitoring and testing procedures are as follows:

- As described in Section 3.1 of this TMP for wells in injection service, the annulus nitrogen pressure will be maintained to keep the nitrogen/water interface at a depth of at least 2000 ft.

The 1993 CMP requires that the nitrogen/water interface be maintained "more than half way down the annulus." Based on a nominal casing depth of 4000 ft., the two criteria are effectively the same.

- In accordance with Section 3.2.1, the annual casing pressure test of each well will be done by depressing the water level to 3000 ft. with nitrogen while the well is on injection. Annulus pressure drop exceeding 10% in five hours will be considered indicative of a leak requiring diagnosis and repair.

  The 1993 CMP specifies that the pressure test be done by depressing the water level to the shoe of the 9-5/8-inch casing with nitrogen (while, by practical necessity, the well is shut in.). An annulus pressure drop exceeding 8% in 30 minutes was considered indicative of a leak requiring diagnosis and repair. The principle difference is the increase in length of the test period from 30 minutes to five hours, which makes the nitrogen pressure test equivalent to a 30-minute test with water.

1.2 Purpose

The purpose of this TMP is to specify the observations, tests, drilling operations and , if necessary, remedial actions required to insure that the mechanical integrity of injection well casing and cement is maintained through the drilling, testing and operation of PGV wells. The cemented and hung casing strings that are used in the PGV wells are designed to prevent contamination of any underground source of drinking water (USDW) by injected fluids. Contamination of the USDW's might occur if the casing strings are breached due to corrosion or mechanical failure or if there is a failure of the cement to seal the casing/borehole annulus between the casing shoe and the lowermost USDW. The testing and monitoring program described below is designed to detect and diagnose a loss of mechanical integrity in the casing or cement.

Remedial actions required to restore mechanical integrity are also described.

1.3 Scope

This TMP covers all injection wells on the 500-acre PGV site.

2. TESTING DURING DRILLING AND COMPLETION

2.1 Pressure Testing During Drilling

Each injection well is completed with three casing strings (not including the 30-inch conductor pipe) cemented to the surface (Figure 1). Upon completion of cementing each casing string and prior to drilling out the cement shoe, the casing well be pressure tested. The DLNR will be notified at least 24 hours before each test for the opportunity to witness it. The test will consist of pressurizing the casing with water or drilling mud to a specified test pressure and monitoring the pressure for 30 minutes with the well shut-in. The minimum casing test pressure shall be approximately one-third of the internal yield pressure rating, provided that the test pressure shall not be less than 600 psig nor greater than 2500 psig. In cases where combination strings or liners are involved, the above test pressures shall apply to the lowest pressure-rated casing. The pressure drop during the 30-minute period shall not exceed 10% of the test pressure.

In the event of a pressure loss exceeding the above criterion, one or more of the following diagnostic methods will be used to locate the leak:

- Temperature log while injecting
- Shut-in temperature survey
- Casing inspection logs with multi-arm caliper and/or magnetic inspection tools
- Pressure testing with a packer(s) on drillpipe
- Other applicable methods

After identification of the point of leakage, a cement squeeze job will be performed and the casing retested.

After a successful pressure test of each casing string, drilling will proceed to a point at least one foot below the casing shoe, and a pressure leak-off test will be performed to test the integrity of the annular cement. Each test will be performed at a pressure approaching the fracturing pressure of the exposed formation. If there is excessive leak-off, a squeeze cement job will be performed, the cement will be drilled out and the test will be repeated. Drilling will not proceed until an effective cement seal is established in the casing/borehole annulus above the casing shoe. In some situations, such as the case where there is natural formation permeability immediately below the casing shoe, it may not be practical to prove cement integrity with the pressure test described above. As an alternative, a standard water shutoff test (WSO) may be done above the shoe, or shut-in temperature surveys may be run.

2.2 Logs and Surveys During Injection Testing

Upon completion of drilling and prior to installation of the hangdown liner, a water injection test may be performed, if needed, to obtain a preliminary evaluation of the well. During such a test, one or more of the following logs or surveys may be run:

- TPS or T/P logs through the open hole and cased intervals with the well on injection; or

- Shut-in temperature survey(s) before and/or after injection.

If any of these logs or surveys indicates a loss of mechanical integrity, the problem will be diagnosed, and repair procedures will be performed in accordance with Section 2.3.

2.3 Casing Repair

Once a loss of mechanical integrity is identified and approximately located, casing repair procedures will be initiated. These procedures may include any or all of the following activities:

2.3.1 Shut in well and run magnetic and multi-arm casing inspection logging tools to locate the leak and to evaluate the casing condition.

2.3.2 Rig up workover rig on well. Run packer(s) on drillpipe and pressure test to confirm suspected leaking interval.

2.3.3 Execute cement squeeze job to seal casing leak or stop interzonal flows behind casing.

2.3.4 Perform casing pressure test and other diagnostic tests as necessary to confirm success of the remedial work. If good, move rig off well and return well to injection service.

2.3.5 In the event of major casing failure, a cemented liner may be installed through the damaged interval.

2.3.6 Prior to drilling out the liner shoe, the liner will be pressure tested as described in Section 2.1.

2.3.7 If mechanical integrity cannot be restored satisfactorily, the well will be plugged and abandoned.

3. MONITORING AND TESTING AFTER WELL IS PLACED IN SERVICE

3.1 Continuous Monitoring During Routine Injection Operations

During routine injection well operations, including brief periods when well(s) may be temporarily out of service, the following conditions will be maintained:

3.1.1 A continuous recording of the following parameters will be maintained for each well:

* Injection wellhead pressure,
* Annulus (nitrogen) pressure, and
* Injection flow rate.

These parameters shall be recorded on a graphical chart which shows their relationship to elapsed time. Plant operators will take daily readings at each well.

3.1.2 The annular space between the hangdown liner and cemented casing will be pressurized with nitrogen, and the pressure will be monitored and recorded in accordance with Section 3..1. above. The annulus will be repressurized with nitrogen as necessary to maintain the nitrogen/water interface at a depth of 2000 ft KB (1975 ft below ground level) or deeper. some loss of nitrogen pressure is normal, and occasional repressurization will be required. If the rate of nitrogen pressure decline is such that it is impractical to maintain the required minimum pressure, it will be considered indicative of a leak requiring diagnosis and repair.

3.2 Annual Testing

Once annually, tests and surveys will be conducted to verify mechanical integrity of the hangdown liner. The casing and hangdown liner will be tested for leaks by one of the following procedures, or a combination thereof.

3.2.1 Perform a pump-down test on the annulus between the hangdown liner and the cemented casing. The test will be done with the well on injection at normal operating flow rate and wellhead pressure, or higher.

or

3.2.2 If the hangdown liner is pulled, the casing may be pressure tested above a bridge plug or packer set near the shoe following the basic procedure outlined in Section 2.1. Integrity of the hangdown liner may be verified by inspection on the surface, by a pressure test (with nitrogen) after it is run in the hole, or by a TPS log with the well on injection.

Integrity of the cement (external mechanical integrity) will be checked during each workover by one or more of the following procedures:

3.2.3 One or more shut-in static temperature surveys will be run. Shut-in time will be at least 12 hours, or longer if necessary to obtain meaningful results.

or

3.2.4 Other logs or surveys may be run, at the discretion of PGV, if static temperature surveys are not definitive.

3.3 Restoration of Mechanical Integrity or Abandonment

In the event that the diagnostic procedures indicate a loss of mechanical integrity, remedial or abandonment procedures will be carried out as specified in Section 2.3.

Appendix F

Well Testing and Logging

UIC Permit R9UIC-HI5-FY16-1R

Both the production and injection wells are subjected to various logging and testing procedures, both during and after completion. The tests ensure the integrity of the casing and cement, and help define the location of the production and injection zones. Testing may be performed by the rig, or by an independent contractor. Depending on the test, contractors may include international wellfield firms such as Schlumberger, Halliburton, Baker Atlas, Well Analysis Corporation and Roke Technologies Ltd.

Testing methods can include:

- CALIPER LOG - checks inside casing diameter to detect corrosion, scale, washouts, parted casing.
- ULTRASONIC LOGS- determines the internal casing diameter and thickness, and potential internal and external metal loss.
- ELECTROMAGNETIC (EM) LOGS - detects overall metal loss. Can discriminate internal and external metal loss and holes, but can be hard to interpret in the presence of two strings of casing or external hardware such as centralizers.
- RADIOACTIVE (RA) TRACER SURVEYS - detects leaks in injection well casing. A slug of iodine 131 is injected into the wellbore and a gamma ray detector is then lowered that can detect small amounts of fluid leaving the wellbore. Fluid flow behind pipe can also be detected. Periodic RA surveys are used to demonstrate the mechanical integrity of injection wells.
- CEMENT BOND LOGS - determines the integrity and density of the cement behind the casing. The test is often unreliable in geothermal wells because of the cements used, and tooling designed for oil and gas wells where the maximum diameter is smaller than geothermal wells.
- STATIC PRESSURE AND TEMPERATURE SURVEY - measures reservoir pressure and temperature with depth. Can identify casing leaks, and hotter and cooler zones within the reservoir. Can also be used to detect injection fluid going to unauthorized depths in geothermal wells. When the cool injection fluid goes down the wellbore it cools the formation a short distance away from the well and when injection stops the wellbore heats up slowly. The cooling penetrates further out in permeable areas in the formation, so when injection stops the wellbore does not heat up as much in the injection zones. A series of static temperature surveys is run and external well integrity is assured by temperatures increasing with time above the casing shoe.
- FLOWING PRESSURE AND TEMPERATURE SURVEYS – identifies production zones and cold water infiltration zones.
- FLOWING SPINNER SURVEY - Identifies production zones and zones of production losses.

- PRESSURE TRANSIENT ANALYSIS - Measures reservoir permeability and skin factor – can quantify near wellbore blockage.
- CASING CALIPER SURVEY - Identifies holes in casing, internal metal loss to corrosion or wear, collapsed casing, and scale buildup.
- ULTRA-SONIC CASING INSPECTION - Identifies holes or corrosion in casing, internal and external metal loss, and material behind pipe (cement, water or gas).
- VIDEO SURVEY - Requires clear water or air.
- SHOE TEST – tests the integrity of the casing by pressurizing the well and measuring the leaking rate.
- FORMATION INTEGRITY TEST – tests the integrity of the formation and casing cement by pressurizing the casing and measuring the leakage rate.
- TANDEM PACKER TESTS - this type of test might be used to identify the precise location of a casing leak. If a leak is indicated by pressure datat, a spinner-temperature log may first be used to identify the leak area. A tandem packer assembly can be used to isolate the zone and measure fluid flow.

PGV uses the terminology "shoe test" or just simply a "Formation Integrity Test" (FIT). A leak off test (LOT) is different than the FIT, as the LOT tests formation until failure, while the FIT tests the formation up to a predetermined pressure before formation failure.

The FIT is the preferred term for wells tests in geothermal fields. The FIT is not a "leak off test" unless it fails and there is leak off. The FIT procedure is performed after the casing has been cemented and the cement drilled out a few feet below the casing shoe. Pressure is applied to the cement and formation below the casing shoe at a pressure gradient that is below any likely fracture pressure gradient. This assures the integrity of the formation and cement at the shoe. During subsequent operations, injection pressure is limited to the same pressure, which ensure that injectate will not go up behind the casing to shallower depths where the fracture pressure is lower or where protected aquifers might be located. PGV does not establish a specific fracture pressure for the basalt formations, because injection pressures during operations are kept well below fracture pressures. Establishing a fracture pressure gradient is generally not necessary in geothermal areas where the formation fluids are at hydrostatic pressure gradient, over-pressured zones do not exist, and high mud weights are not used.

The FIT provides a conservative limit to injection pressure. Higher injection pressures would be possible if the actual fracture pressure was measured by a step rate test, but such high pressures are generally not necessary in geothermal fields due to high permeabilities in the production/ injection fracture zones, and are not desired due to the high cost of pumping injectate into the wells at high pressure. Although the FIT does not measure fracture pressure, it does ensure that injection pressures will stay below the fracture pressure. Therefore FIT's provide a safety margin above the 30 CFR subpart D method.

If the casing shoe is set in a high-permeability fracture within the geothermal reservoir, it may be difficult to get a successful FIT. In this case, the FIT test is not necessary because injection into the geothermal reservoir below the casing shoe is acceptable. However, it is still necessary to ensure that injection is not going up behind the casing. If this situation occurs, it is necessary to perform a survey that can detect flow behind the casing such as the Quad Neutron, RA Tracer Survey, Water Flow Log, Thermal Decay Time Tool, etc. These types of surveys are standard industry practice for determining external well integrity. See attached articles or website references for more information.

Quad Neutron Test: this test can determine the formation Porosity including clay free porosity, saturation, clay volume, relative permeability and relative bulk density. This test was used as a basis for our FIT in KS-13 ML-1.

Water Flow Log: determines the direction of water flowing in and around a borehole based on oxygen activation by a radioactive source. The log may also include estimates of the flow volume and the distance from tool to flowing water.

Thermal Decay Time Tool: The thermal decay time log is a record of the rate of capture of thermal neutrons in a formation after it is bombarded with a burst of 14 Mev neutrons. Because chlorine is by far the strongest neutron absorber of the common earth elements, the response of the tool is determined primarily by the chlorine present (as sodium chloride) in the formation water. Like the resistivity log, therefore, the measured response is sensitive to the salinity and amount of formation water present in the pore volume.

A **Water Injection Test** is a rig test design to measure the well's Injectivity Index. A general Ormat procedure is as follows:

The well bottom is tagged using a sinker bar run. Following the tag run, a static pressure and temperature survey was run which determines the static water level. The injection test is then performed at multiple injection rates, while measuring the wellhead pressure in PSIG, and the downhole pressure increased in PSIA. During this injection, a spinner survey may be run to the tag depth, up to the drill pipe, down to tag depth, within the open-hole once again, and then back down. Once the tool is parked at depth, the pump rate is increased while again measuring the wellhead and downhole pressure. The well is then shut in after the injection period to record pressure fall-off. The total injection time and volume are recorded.

The Injectivity Index is calculated by the change in rate divided by the change in pressure using the Horner projected static reservoir pressure. From the pressure fall-off, the Horner projection calculates a static reservoir at the tool depth. The pressure increases and stabilization during both injection rates are then evaluated. The Injectivity Index results are interpreted in GPM/PSI.

Appendix G

Hydrologic Monitoring Program

UIC Permit R9UIC-HI5-FY16-1R

EPA will accept analyses and reports as required under Hawaii Department of Health Permit No. UH-1529.

PUNA GEOTHERMAL VENTURE

HYDROLOGIC MONITORING PROGRAM

December 2005

Sampling Locations: The following wells will be monitored.

Well Name	Elevation (MSL)	Completion Depth (MSL)
MW-1	610	-46
MW-2	588	-2
MW-3 (standby)		

Frequency: Regular sampling shall occur twice a year, once in January and once in July.

Water Level Measurements: Prior to bailing or pumping the well and sampling, water level measurements will be taken and recorded. The permittee can use an Echo Meter or similar device, or an electronic direct contact detection probe with a calibrated cable/tape for direct measurement at the top of the well casing. Calibrated cable/tape length shall be sufficient to measure water levels in the deepest wells. The metering device shall be equipped with an audible signal and light to indicate water level contact.

Quality Assurance/Quality Control: Quality assurance/quality control procedures will be in compliance with standards of practice for similar programs relative to the acquisition, reduction, verification, and validation of the site data. At each location, standardized equipment cleaning will be conducted prior to obtaining each sample.

Prior to ground water sampling, the well will be bailed or pumped at least three times the wellbore volume.

All samples will be taken and field analyses conducted in accordance with standard protocols approved by the EPA. An EPA or State of Hawaii certified laboratory will be used to conduct the analyses for samples submitted. Samples will be transferred from the sampling device directly to appropriately prepared containers supplied by the laboratory. Samples will be labeled, stored and transported in a chilled state in insulated containers to the laboratory.

In the analyses, detection limits will be used that are below maximum contaminant levels. If they are not, the sampling and analyses will be repeated using the proper detection limits.

The contractor will provide a copy of their Quality Assurance program to DOH and EPA for review and approval.

Physical and Chemical Parameters: Field analyses will include:

- pH
- temperature
- conductivity
- salinity
- chloride concentration
- water level

These measurements will be obtained by using calibrated instruments specifically designed to directly measure these physical and chemical parameters within the operational constraints

dictated by site conditions.

The inorganic (Type I) and organic (Type II and IV) constituents that are to be sampled for are specified in Appendix H.

Reporting: Sampling results and measurements will be submitted during the February following the January sampling, and the August following the July sampling. Original laboratory reports will be included with a cover letter. Reporting units shall be specified. The laboratory shall not use text descriptions, such as "Below Regulatory Limits" or "BRL", in its reporting, but rather, the actual numerical results will be reported. If the actual numerical results are not reported, the sampling and analysis will be redone until numerical results are reported.

Further Monitoring: If leakage of the injectate into the USDW is suspected, the ground water sampling may be modified. Depending on the situation, this could include sampling from Malama Ki and GTW-III, sampling for certain analytes and more frequent sampling.

Appendix H

Chemical Additives

UIC Permit R9UIC-HI5-FY16-1R

Note: Some of these generic products may not be currently used but are approved for use if needed.

Appendix H- Chemical Additives

Product Function	Active Chemical Ingredient	Maximum Injection Concentration(ppm)
Corrosion Inhibitor/Oxygen Scavenger	Sodium Sulfite Salt (10% solution)	15
Corrosion Inhibitor	Filming Amine (<30% solution)	30
Corrosion Inhibitor	Filming Amine Chloride Salt (<30% solution)	30
Corrosion Inhibitor	Filming Amine Acid (<30% solution)	30
Corrosion Inhibitor	Soya Amine Poly (<30% solution)	30
Anti-Scalant/pH adjustor	Sulfuric Acid	3
Anti-Scalant	Phosphonate (<30% solution)	15
pH adjustor and H2S Abator	Sodium Hydroxide	3
Microbiocide	Isothiazoline	1
Barrier Oil	Lubricant Oil	1

Appendix I

Plugging and Abandonment Plans

UIC Permit R9UIC-HI5-FY16-1R

OMB No. 2040-0042 Approval Expires 4/30/2022

United States Environmental Protection Agency

WELL REWORK RECORD, PLUGGING AND ABANDONMENT PLAN, OR PLUGGING AND ABANDONMENT AFFIDAVIT

Name and Address, Phone Number and/or Email of Permittee

Puna Geothermal Venture
14-3860 Kapoho Pahoa Road, Pahoa, HI 96778
Jordan Hara jhara@ormat.com 808-896-8551

Permit or EPA ID Number	API Number	Full Well Name
HI596002		Kapoho State (KS) 1A

State	County
Hawaii	Hawaii

Locate well in two directions from nearest lines of quarter section and drilling unit

Surface Location

Latitude: N 19° 28' 37.3"

Longitude: W 154° 53' 23.9"

____ 1/4 of ____ 1/4 of Section ____ Township ____ Range ____

____ ft. from (N/S) ____ Line of quarter section

____ ft. from (E/W) ____ Line of quarter section.

Well Class	Timing of Action (pick one)	Type of Action (pick one)
☐ Class I	☑ Notice Prior to Work	☐ Well Rework
☐ Class II	Date Expected to Commence: TBD	☑ Plugging and Abandonment
☐ Class III	☐ Report After Work	☐ Conversion to a Non-Injection Well
☑ Class V	Date Work Ended:	

Provide a narrative description of the work planned to be performed, or that was performed. Use additional pages as necessary. See instructions.

Plug and Abandonment Plan.

1. Move in suitable rig and associated equipment.
2. Install BOPE suitable for maximum expected pressures.
3. Remove any tubing or hang-down liner.
4. Fill high permeability injection zone with rocks, gravel and sand.
5. Place 200 linear feet of 15 ppg geothermal cement on top of sand. Wait on cement, tag cement, and place more cement if necessary for 200 foot cement plug.
6. Fill hole with 9 ppg bentonite mud from top of cement to next casing shoe.
7. Place 200 linear feet of 15 ppg geothermal cement across each casing shoe with 9 ppg bentonite mud between cement plugs.
8. Place 15 ppg geothermal cement from 170 feet to surface.
9. Remove BOPE.
10. Cut off casing below casing head.
11. Weld plate on casing with well name and date.
12. Rig down.

Certification

I certify under the penalty of law that I have personally examined and am familiar with the information submitted in this document and all attachments and that, based on my inquiry of those individuals immediately responsible for obtaining the information, I believe that the information is true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment. (Ref. 40 CFR § 144.32)

Name and Official Title *(Please type or print)*	Signature	Date Signed
Jordan Hara, Plant Manager	Jordan L Hara	1-16-2020

OMB No. 2040-0042 Approval Expires 4/30/2022

United States Environmental Protection Agency

WELL REWORK RECORD, PLUGGING AND ABANDONMENT PLAN, OR PLUGGING AND ABANDONMENT AFFIDAVIT

Name and Address, Phone Number and/or Email of Permittee

Puna Geothermal Venture
14-3860 Kapoho Pahoa Road, Pahoa, HI 96778
Jordan Hara jhara@ormat.com 808-896-8551

Permit or EPA ID Number	API Number	Full Well Name
HI596002		Kapoho State (KS) 3

State	County
Hawaii	Hawaii

Locate well in two directions from nearest lines of quarter section and drilling unit

Surface Location

Latitude: N 19° 28' 31.4"

Longitude: W 154° 53' 29.3"

___ 1/4 of ___ 1/4 of Section ___ Township ___ Range ___

___ ft. from (N/S) ___ Line of quarter section

___ ft. from (E/W) ___ Line of quarter section.

Well Class	Timing of Action (pick one)	Type of Action (pick one)
☐ Class I ☐ Class II ☐ Class III ☑ Class V	☑ Notice Prior to Work Date Expected to Commence: TBD ☐ Report After Work Date Work Ended:	☐ Well Rework ☑ Plugging and Abandonment ☐ Conversion to a Non-Injection Well

Provide a narrative description of the work planned to be performed, or that was performed. Use additional pages as necessary. See instructions.

Plug and Abandonment Plan.

1. Move in suitable rig and associated equipment.
2. Install BOPE suitable for maximum expected pressures.
3. Remove any tubing or hang-down liner.
4. Fill high permeability injection zone with rocks, gravel and sand.
5. Place 200 linear feet of 15 ppg geothermal cement on top of sand. Wait on cement, tag cement, and place more cement if necessary for 200 foot cement plug.
6. Fill hole with 9 ppg bentonite mud from top of cement to next casing shoe.
7. Place 200 linear feet of 15 ppg geothermal cement across each casing shoe with 9 ppg bentonite mud between cement plugs.
8. Place 15 ppg geothermal cement from 170 feet to surface.
9. Remove BOPE.
10. Cut off casing below casing head.
11. Weld plate on casing with well name and date.
12. Rig down.

Certification

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Name and Official Title *(Please type or print)*	Signature	Date Signed
Jordan Hara, Plant Manager	Jordan Hara	1-16-2020

OMB No. 2040-0042 Approval Expires 4/30/2022

United States Environmental Protection Agency

WELL REWORK RECORD, PLUGGING AND ABANDONMENT PLAN, OR PLUGGING AND ABANDONMENT AFFIDAVIT

Name and Address, Phone Number and/or Email of Permittee

Puna Geothermal Venture
14-3860 Kapoho Pahoa Road, Pahoa, HI 96778
Jordan Hara jhara@ormat.com 808-896-8551

Permit or EPA ID Number	API Number	Full Well Name
HI596002		Kapoho State (KS) 11

State	County
Hawaii	Hawaii

Locate well in two directions from nearest lines of quarter section and drilling unit

Surface Location

[ ] 1/4 of [ ] 1/4 of Section [ ] Township [ ] Range [ ]

[ ] ft. from (N/S) [ ] Line of quarter section

[ ] ft. from (E/W) [ ] Line of quarter section.

Latitude N 19° 28' 37.1"

Longitude W 154° 53' 27.4"

Well Class	Timing of Action (pick one)	Type of Action (pick one)
[ ] Class I	[✔] Notice Prior to Work	[ ] Well Rework
[ ] Class II	Date Expected to Commence TBD	[✔] Plugging and Abandonment
[ ] Class III	[ ] Report After Work	[ ] Conversion to a Non-Injection Well
[✔] Class V	Date Work Ended	

Provide a narrative description of the work planned to be performed, or that was performed. Use additional pages as necessary. See instructions.

Plug and Abandonment Plan.

1. Move in suitable rig and associated equipment.
2. Install BOPE suitable for maximum expected pressures.
3. Remove any tubing or hang-down liner.
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5. Place 200 linear feet of 15 ppg geothermal cement on top of sand. Wait on cement, tag cement, and place more cement if necessary for 200 foot cement plug.
6. Fill hole with 9 ppg bentonite mud from top of cement to next casing shoe.
7. Place 200 linear feet of 15 ppg geothermal cement across each casing shoe with 9 ppg bentonite mud between cement plugs.
8. Place 15 ppg geothermal cement from 170 feet to surface.
9. Remove BOPE.
10. Cut off casing below casing head.
11. Weld plate on casing with well name and date.
12. Rig down.

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Name and Official Title *(Please type or print)*	Signature	Date Signed
Jordan Hara, Plant Manager	Jordan L Hara	1-16-2020

OMB No. 2040-0042 Approval Expires 4/30/2022

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WELL REWORK RECORD, PLUGGING AND ABANDONMENT PLAN, OR PLUGGING AND ABANDONMENT AFFIDAVIT

Name and Address, Phone Number and/or Email of Permittee

Puna Geothermal Venture
14-3860 Kapoho Pahoa Road, Pahoa, HI 96778
Jordan Hara jhara@ormat.com 808-896-8551

Permit or EPA ID Number	API Number	Full Well Name
HI596002		Kapoho State (KS) 13

State	County
Hawaii	Hawaii

Locate well in two directions from nearest lines of quarter section and drilling unit

Surface Location

[ ] 1/4 of [ ] 1/4 of Section [ ] Township [ ] Range [ ]

[ ] ft. from (N/S) [ ] Line of quarter section

[ ] ft. from (E/W) [ ] Line of quarter section.

Latitude N 19° 28' 38.5"

Longitude W 154° 53' 24.7"

Well Class	Timing of Action (pick one)	Type of Action (pick one)
[ ] Class I	[✓] Notice Prior to Work	[ ] Well Rework
[ ] Class II	Date Expected to Commence TBD	[✓] Plugging and Abandonment
[ ] Class III	[ ] Report After Work	[ ] Conversion to a Non-Injection Well
[✓] Class V	Date Work Ended	

Provide a narrative description of the work planned to be performed, or that was performed. Use additional pages as necessary. See instructions.

Plug and Abandonment Plan.

1. Move in suitable rig and associated equipment.
2. Install BOPE suitable for maximum expected pressures.
3. Remove any tubing or hang-down liner.
4. Fill high permeability injection zone with rocks, gravel and sand.
5. Place 200 linear feet of 15 ppg geothermal cement on top of sand. Wait on cement, tag cement, and place more cement if necessary for 200 foot cement plug.
6. Fill hole with 9 ppg bentonite mud from top of cement to next casing shoe.
7. Place 200 linear feet of 15 ppg geothermal cement across each casing shoe with 9 ppg bentonite mud between cement plugs.
8. Place 15 ppg geothermal cement from 170 feet to surface.
9. Remove BOPE.
10. Cut off casing below casing head.
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12. Rig down.

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Name and Official Title *(Please type or print)*	Signature	Date Signed
Jordan Hara, Plant Manager	Jordan J. Hara	1-16-2020

OMB No. 2040-0042 Approval Expires 4/30/2022

United States Environmental Protection Agency

WELL REWORK RECORD, PLUGGING AND ABANDONMENT PLAN, OR PLUGGING AND ABANDONMENT AFFIDAVIT

Name and Address, Phone Number and/or Email of Permittee

Puna Geothermal Venture
14-3860 Kapoho Pahoa Road, Pahoa, HI 96778
Jordan Hara jhara@ormat.com 808-896-8551

Permit or EPA ID Number	API Number	Full Well Name
HI596002		Kapoho State (KS) 15

State	County
Hawaii	Hawaii

Locate well in two directions from nearest lines of quarter section and drilling unit

Surface Location

Latitude: N 19° 28' 44.7"

Longitude: W 154° 53' 12.7"

___ 1/4 of ___ 1/4 of Section ___ Township ___ Range ___

___ ft. from (N/S) ___ Line of quarter section

___ ft. from (E/W) ___ Line of quarter section.

Well Class	Timing of Action (pick one)	Type of Action (pick one)
☐ Class I ☐ Class II ☐ Class III ☑ Class V	☑ Notice Prior to Work Date Expected to Commence: TBD ☐ Report After Work Date Work Ended:	☐ Well Rework ☑ Plugging and Abandonment ☐ Conversion to a Non-Injection Well

Provide a narrative description of the work planned to be performed, or that was performed. Use additional pages as necessary. See instructions.

Plug and Abandonment Plan.

1. Move in suitable rig and associated equipment.
2. Install BOPE suitable for maximum expected pressures.
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7. Place 200 linear feet of 15 ppg geothermal cement across each casing shoe with 9 ppg bentonite mud between cement plugs.
8. Place 15 ppg geothermal cement from 170 feet to surface.
9. Remove BOPE.
10. Cut off casing below casing head.
11. Weld plate on casing with well name and date.
12. Rig down.

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Name and Official Title *(Please type or print)*	Signature	Date Signed
Jordan Hara, Plant Manager	Jordan L Hara	1-16-2020

OMB No. 2040-0042 Approval Expires 4/30/2022

United States Environmental Protection Agency

WELL REWORK RECORD, PLUGGING AND ABANDONMENT PLAN, OR PLUGGING AND ABANDONMENT AFFIDAVIT

Name and Address, Phone Number and/or Email of Permittee

Puna Geothermal Venture
14-3860 Kapoho Pahoa Road, Pahoa, HI 96778
Jordan Hara jhara@ormat.com 808-896-8551

Permit or EPA ID Number	API Number	Full Well Name
HI596002		Kapoho State (KS) 17

State	County
Hawaii	Hawaii

Locate well in two directions from nearest lines of quarter section and drilling unit

Surface Location

Latitude: N 19° 28' 36.478"

Longitude: W 154° 53' 27.599"

[ ] 1/4 of [ ] 1/4 of Section [ ] Township [ ] Range [ ]

[ ] ft. from (N/S) [ ] Line of quarter section

[ ] ft. from (E/W) [ ] Line of quarter section.

Well Class	Timing of Action (pick one)	Type of Action (pick one)
[ ] Class I	[✓] Notice Prior to Work	[ ] Well Rework
[ ] Class II	Date Expected to Commence: TBD	[✓] Plugging and Abandonment
[ ] Class III	[ ] Report After Work	[ ] Conversion to a Non-Injection Well
[✓] Class V	Date Work Ended:	

Provide a narrative description of the work planned to be performed, or that was performed. Use additional pages as necessary. See instructions.

Plug and Abandonment Plan.

1. Move in suitable rig and associated equipment.
2. Install BOPE suitable for maximum expected pressures.
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7. Place 200 linear feet of 15 ppg geothermal cement across each casing shoe with 9 ppg bentonite mud between cement plugs.
8. Place 15 ppg geothermal cement from 170 feet to surface.
9. Remove BOPE.
10. Cut off casing below casing head.
11. Weld plate on casing with well name and date.
12. Rig down.

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Name and Official Title *(Please type or print)*	Signature	Date Signed
Jordan Hara, Plant Manager	Jordan L Hara	1-16-2020

OMB No. 2040-0042 Approval Expires 4/30/2022

United States Environmental Protection Agency

WELL REWORK RECORD, PLUGGING AND ABANDONMENT PLAN, OR PLUGGING AND ABANDONMENT AFFIDAVIT

Name and Address, Phone Number and/or Email of Permittee

Puna Geothermal Venture
14-3860 Kapoho Pahoa Road, Pahoa, HI 96778
Jordan Hara jhara@ormat.com 808-896-8551

Permit or EPA ID Number	API Number	Full Well Name
HI596002		Kapoho State (KS) 18

State	County
Hawaii	Hawaii

Locate well in two directions from nearest lines of quarter section and drilling unit

Latitude: N 19° 28' 32.087"

Longitude: W 154° 53' 27.651"

Surface Location

___ 1/4 of ___ 1/4 of Section ___ Township ___ Range ___

___ ft. from (N/S) ___ Line of quarter section

___ ft. from (E/W) ___ Line of quarter section.

Well Class	Timing of Action (pick one)	Type of Action (pick one)
☐ Class I	☑ Notice Prior to Work	☐ Well Rework
☐ Class II	Date Expected to Commence: TBD	☑ Plugging and Abandonment
☐ Class III	☐ Report After Work	☐ Conversion to a Non-Injection Well
☑ Class V	Date Work Ended:	

Provide a narrative description of the work planned to be performed, or that was performed. Use additional pages as necessary. See instructions.

Plug and Abandonment Plan.

1. Move in suitable rig and associated equipment.
2. Install BOPE suitable for maximum expected pressures.
3. Remove any tubing or hang-down liner.
4. Fill high permeability injection zone with rocks, gravel and sand.
5. Place 200 linear feet of 15 ppg geothermal cement on top of sand. Wait on cement, tag cement, and place more cement if necessary for 200 foot cement plug.
6. Fill hole with 9 ppg bentonite mud from top of cement to next casing shoe.
7. Place 200 linear feet of 15 ppg geothermal cement across each casing shoe with 9 ppg bentonite mud between cement plugs.
8. Place 15 ppg geothermal cement from 170 feet to surface.
9. Remove BOPE.
10. Cut off casing below casing head.
11. Weld plate on casing with well name and date.
12. Rig down.

Certification

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Name and Official Title *(Please type or print)*	Signature	Date Signed
Jordan Hara, Plant Manager	Jordan L Hara	1-16-2020

OMB No. 2040-0042 Approval Expires 4/30/2022

United States Environmental Protection Agency

WELL REWORK RECORD, PLUGGING AND ABANDONMENT PLAN, OR PLUGGING AND ABANDONMENT AFFIDAVIT

Name and Address, Phone Number and/or Email of Permittee

Puna Geothermal Venture
14-3860 Kapoho Pahoa Road, Pahoa, HI 96778
Jordan Hara jhara@ormat.com 808-896-8551

Permit or EPA ID Number	API Number	Full Well Name
HI596002		Kapoho State (KS) 19

State	County
Hawaii	Hawaii

Locate well in two directions from nearest lines of quarter section and drilling unit

Surface Location

____ 1/4 of ____ 1/4 of Section ____ Township ____ Range ____

____ ft. from (N/S) ____ Line of quarter section

____ ft. from (E/W) ____ Line of quarter section.

Latitude TBD

Longitude TBD

Well Class	Timing of Action (pick one)	Type of Action (pick one)
☐ Class I ☐ Class II ☐ Class III ☑ Class V	☑ Notice Prior to Work Date Expected to Commence TBD ☐ Report After Work Date Work Ended	☐ Well Rework ☑ Plugging and Abandonment ☐ Conversion to a Non-Injection Well

Provide a narrative description of the work planned to be performed, or that was performed. Use additional pages as necessary. See instructions.

Plug and Abandonment Plan.

1. Move in suitable rig and associated equipment.
2. Install BOPE suitable for maximum expected pressures.
3. Remove any tubing or hang-down liner.
4. Fill high permeability injection zone with rocks, gravel and sand.
5. Place 200 linear feet of 15 ppg geothermal cement on top of sand. Wait on cement, tag cement, and place more cement if necessary for 200 foot cement plug.
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7. Place 200 linear feet of 15 ppg geothermal cement across each casing shoe with 9 ppg bentonite mud between cement plugs.
8. Place 15 ppg geothermal cement from 170 feet to surface.
9. Remove BOPE.
10. Cut off casing below casing head.
11. Weld plate on casing with well name and date.
12. Rig down.

Certification

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Name and Official Title *(Please type or print)*	Signature	Date Signed
Jordan Hara, Plant Manager	Jordan L Hara	1-16-2020

OMB No. 2040-0042 Approval Expires 4/30/2022

United States Environmental Protection Agency

WELL REWORK RECORD, PLUGGING AND ABANDONMENT PLAN, OR PLUGGING AND ABANDONMENT AFFIDAVIT

Name and Address, Phone Number and/or Email of Permittee

Puna Geothermal Venture
14-3860 Kapoho Pahoa Road, Pahoa, HI 96778
Jordan Hara jhara@ormat.com 808-896-8551

Permit or EPA ID Number	API Number	Full Well Name
HI596002		Kapoho State (KS) 20

State	County
Hawaii	Hawaii

Locate well in two directions from nearest lines of quarter section and drilling unit

Surface Location

____ 1/4 of ____ 1/4 of Section ____ Township ____ Range ____

____ ft. from (N/S) ____ Line of quarter section

____ ft. from (E/W) ____ Line of quarter section.

Latitude TBD

Longitude TBD

Well Class	Timing of Action (pick one)	Type of Action (pick one)
☐ Class I	☑ Notice Prior to Work	☐ Well Rework
☐ Class II	Date Expected to Commence TBD	☑ Plugging and Abandonment
☐ Class III	☐ Report After Work	☐ Conversion to a Non-Injection Well
☑ Class V	Date Work Ended	

Provide a narrative description of the work planned to be performed, or that was performed. Use additional pages as necessary. See instructions.

Plug and Abandonment Plan.

1. Move in suitable rig and associated equipment.
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8. Place 15 ppg geothermal cement from 170 feet to surface.
9. Remove BOPE.
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12. Rig down.

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Name and Official Title *(Please type or print)*	Signature	Date Signed
Jordan Hara, Plant Manager	Jordan L Hara	4-6-2020

OMB No. 2040-0042 Approval Expires 4/30/2022

United States Environmental Protection Agency

EPA WELL REWORK RECORD, PLUGGING AND ABANDONMENT PLAN, OR PLUGGING AND ABANDONMENT AFFIDAVIT

Name and Address, Phone Number and/or Email of Permittee

Puna Geothermal Venture
14-3860 Kapoho Pahoa Road, Pahoa, HI 96778
Jordan Hara jhara@ormat.com 808-896-8551

Permit or EPA ID Number	API Number	Full Well Name
HI596002		Kapoho State (KS) 21

State	County
Hawaii	Hawaii

Locate well in two directions from nearest lines of quarter section and drilling unit

Surface Location

____ 1/4 of ____ 1/4 of Section ____ Township ____ Range ____

____ ft. from (N/S) ____ Line of quarter section

____ ft. from (E/W) ____ Line of quarter section.

Latitude TBD

Longitude TBD

Well Class	Timing of Action (pick one)	Type of Action (pick one)
☐ Class I ☐ Class II ☐ Class III ☑ Class V	☑ Notice Prior to Work Date Expected to Commence TBD ☐ Report After Work Date Work Ended	☐ Well Rework ☑ Plugging and Abandonment ☐ Conversion to a Non-Injection Well

Provide a narrative description of the work planned to be performed, or that was performed. Use additional pages as necessary. See instructions.

Plug and Abandonment Plan.

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Name and Official Title *(Please type or print)*	Signature	Date Signed
Jordan Hara, Plant Manager	Jordan L Hara	1-16-2020

OMB No. 2040-0042 Approval Expires 4/30/2022

United States Environmental Protection Agency

EPA

WELL REWORK RECORD, PLUGGING AND ABANDONMENT PLAN, OR PLUGGING AND ABANDONMENT AFFIDAVIT

Name and Address, Phone Number and/or Email of Permittee

Puna Geothermal Venture
14-3860 Kapoho Pahoa Road, Pahoa, HI 96778
Jordan Hara jhara@ormat.com 808-896-8551

Permit or EPA ID Number	API Number	Full Well Name
HI596002		Kapoho State (KS) 22

State	County
Hawaii	Hawaii

Locate well in two directions from nearest lines of quarter section and drilling unit

Latitude: TBD

Longitude: TBD

Surface Location

___ 1/4 of ___ 1/4 of Section ___ Township ___ Range ___

___ ft. from (N/S) ___ Line of quarter section

___ ft. from (E/W) ___ Line of quarter section.

Well Class	Timing of Action (pick one)	Type of Action (pick one)
☐ Class I	☑ Notice Prior to Work	☐ Well Rework
☐ Class II	Date Expected to Commence: TBD	☑ Plugging and Abandonment
☐ Class III	☐ Report After Work	☐ Conversion to a Non-Injection Well
☑ Class V	Date Work Ended:	

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Name and Official Title *(Please type or print)*	Signature	Date Signed
Jordan Hara, Plant Manager	Jordan F. Hara	1-16-2020

OMB No. 2040-0042 Approval Expires 4/30/2022

United States Environmental Protection Agency

WELL REWORK RECORD, PLUGGING AND ABANDONMENT PLAN, OR PLUGGING AND ABANDONMENT AFFIDAVIT

Name and Address, Phone Number and/or Email of Permittee

Puna Geothermal Venture
14-3860 Kapoho Pahoa Road, Pahoa, HI 96778
Jordan Hara jhara@ormat.com 808-896-8551

Permit or EPA ID Number	API Number	Full Well Name
HI596002		Kapoho State (KS) 23

State	County
Hawaii	Hawaii

Locate well in two directions from nearest lines of quarter section and drilling unit

Latitude: TBD

Longitude: TBD

Surface Location

____ 1/4 of ____ 1/4 of Section ____ Township ____ Range ____

____ ft. from (N/S) ____ Line of quarter section

____ ft. from (E/W) ____ Line of quarter section.

Well Class	Timing of Action (pick one)	Type of Action (pick one)
☐ Class I ☐ Class II ☐ Class III ☑ Class V	☑ Notice Prior to Work Date Expected to Commence: TBD ☐ Report After Work Date Work Ended:	☐ Well Rework ☑ Plugging and Abandonment ☐ Conversion to a Non-Injection Well

Provide a narrative description of the work planned to be performed, or that was performed. Use additional pages as necessary. See instructions.

Plug and Abandonment Plan.

1. Move in suitable rig and associated equipment.
2. Install BOPE suitable for maximum expected pressures.
3. Remove any tubing or hang-down liner.
4. Fill high permeability injection zone with rocks, gravel and sand.
5. Place 200 linear feet of 15 ppg geothermal cement on top of sand. Wait on cement, tag cement, and place more cement if necessary for 200 foot cement plug.
6. Fill hole with 9 ppg bentonite mud from top of cement to next casing shoe.
7. Place 200 linear feet of 15 ppg geothermal cement across each casing shoe with 9 ppg bentonite mud between cement plugs.
8. Place 15 ppg geothermal cement from 170 feet to surface.
9. Remove BOPE.
10. Cut off casing below casing head.
11. Weld plate on casing with well name and date.
12. Rig down.

Certification

I certify under the penalty of law that I have personally examined and am familiar with the information submitted in this document and all attachments and that, based on my inquiry of those individuals immediately responsible for obtaining the information, I believe that the information is true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment. (Ref. 40 CFR § 144.32)

Name and Official Title *(Please type or print)*	Signature	Date Signed
Jordan Hara, Plant Manager	Jordan L Hara	1-16-2020

OMB No. 2040-0042 Approval Expires 4/30/2022

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14-3860 Kapoho Pahoa Road, Pahoa, HI 96778
Jordan Hara jhara@ormat.com 808-896-8551

Permit or EPA ID Number	API Number	Full Well Name
HI596002		Kapoho State (KS) 24

State	County
Hawaii	Hawaii

Locate well in two directions from nearest lines of quarter section and drilling unit

Surface Location

_____ 1/4 of _____ 1/4 of Section _____ Township _____ Range _____

Latitude TBD

Longitude TBD

_____ ft. from (N/S) _____ Line of quarter section

_____ ft. from (E/W) _____ Line of quarter section.

Well Class	Timing of Action (pick one)	Type of Action (pick one)
☐ Class I ☐ Class II ☐ Class III ☑ Class V	☑ Notice Prior to Work Date Expected to Commence TBD ☐ Report After Work Date Work Ended	☐ Well Rework ☑ Plugging and Abandonment ☐ Conversion to a Non-Injection Well

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6. Fill hole with 9 ppg bentonite mud from top of cement to next casing shoe.
7. Place 200 linear feet of 15 ppg geothermal cement across each casing shoe with 9 ppg bentonite mud between cement plugs.
8. Place 15 ppg geothermal cement from 170 feet to surface.
9. Remove BOPE.
10. Cut off casing below casing head.
11. Weld plate on casing with well name and date.
12. Rig down.

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Jordan Hara, Plant Manager	Jordan L Hara	1-16-2020

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Puna Geothermal Venture
14-3860 Kapoho Pahoa Road, Pahoa, HI 96778
Jordan Hara jhara@ormat.com 808-896-8551

Permit or EPA ID Number	API Number	Full Well Name
HI596002		Kapoho State (KS) 25

State	County
Hawaii	Hawaii

Locate well in two directions from nearest lines of quarter section and drilling unit

Latitude: TBD

Longitude: TBD

Surface Location

1/4 of 1/4 of Section Township Range

ft. from (N/S) Line of quarter section

ft. from (E/W) Line of quarter section.

Well Class	Timing of Action (pick one)	Type of Action (pick one)
☐ Class I ☐ Class II ☐ Class III ☑ Class V	☑ Notice Prior to Work Date Expected to Commence: TBD ☐ Report After Work Date Work Ended:	☐ Well Rework ☑ Plugging and Abandonment ☐ Conversion to a Non-Injection Well

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7. Place 200 linear feet of 15 ppg geothermal cement across each casing shoe with 9 ppg bentonite mud between cement plugs.
8. Place 15 ppg geothermal cement from 170 feet to surface.
9. Remove BOPE.
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Name and Official Title *(Please type or print)*	Signature	Date Signed
Jordan Hara, Plant Manager	Jordan L Hara	1-16-2020

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Name and Address, Phone Number and/or Email of Permittee

Puna Geothermal Venture
14-3860 Kapoho Pahoa Road, Pahoa, HI 96778
Jordan Hara jhara@ormat.com 808-896-8551

Permit or EPA ID Number	API Number	Full Well Name
HI596002		Kapoho State (KS) 26

State	County
Hawaii	Hawaii

Locate well in two directions from nearest lines of quarter section and drilling unit

Surface Location

Latitude TBD

Longitude TBD

1/4 of 1/4 of Section Township Range

ft. from (N/S) Line of quarter section

ft. from (E/W) Line of quarter section.

Well Class	Timing of Action (pick one)	Type of Action (pick one)
☐ Class I ☐ Class II ☐ Class III ☑ Class V	☑ Notice Prior to Work Date Expected to Commence TBD ☐ Report After Work Date Work Ended	☐ Well Rework ☑ Plugging and Abandonment ☐ Conversion to a Non-Injection Well

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Name and Official Title *(Please type or print)*	Signature	Date Signed
Jordan Hara, Plant Manager	Jordan L Hara	4/16-2020

OMB No. 2040-0042 Approval Expires 4/30/2022

United States Environmental Protection Agency

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Name and Address, Phone Number and/or Email of Permittee

Puna Geothermal Venture
14-3860 Kapoho Pahoa Road, Pahoa, HI 96778
Jordan Hara jhara@ormat.com 808-896-8551

Permit or EPA ID Number	API Number	Full Well Name
HI596002		Kapoho State (KS) 27

State	County
Hawaii	Hawaii

Locate well in two directions from nearest lines of quarter section and drilling unit

Surface Location

____ 1/4 of ____ 1/4 of Section ____ Township ____ Range ____

____ ft. from (N/S) ____ Line of quarter section

____ ft. from (E/W) ____ Line of quarter section.

Latitude TBD

Longitude TBD

Well Class	Timing of Action (pick one)	Type of Action (pick one)
☐ Class I ☐ Class II ☐ Class III ☑ Class V	☑ Notice Prior to Work Date Expected to Commence TBD ☐ Report After Work Date Work Ended	☐ Well Rework ☑ Plugging and Abandonment ☐ Conversion to a Non-Injection Well

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Name and Official Title *(Please type or print)*	Signature	Date Signed
Jordan Hara, Plant Manager	Jordan L Hara	1-16-2020

Appendix J

EPA Reporting Forms

UIC Permit R9UIC-HI5-FY16-1R

OMB No. 2040-0042 Approval Expires 4/30/2022

United States Environmental Protection Agency

WELL REWORK RECORD, PLUGGING AND ABANDONMENT PLAN, OR PLUGGING AND ABANDONMENT AFFIDAVIT

Name and Address, Phone Number and/or Email of Permittee

Permit or EPA ID Number	API Number	Full Well Name

State	County

Locate well in two directions from nearest lines of quarter section and drilling unit

Latitude

Longitude

Surface Location

1/4 of 1/4 of Section Township Range

ft. from (N/S) Line of quarter section

ft. from (E/W) Line of quarter section.

Well Class	Timing of Action (pick one)	Type of Action (pick one)
☐ Class I ☐ Class II ☐ Class III ☐ Class V	☐ Notice Prior to Work Date Expected to Commence ☐ Report After Work Date Work Ended	☐ Well Rework ☐ Plugging and Abandonment ☐ Conversion to a Non-Injection Well

Provide a narrative description of the work planned to be performed, or that was performed. Use additional pages as necessary. See instructions.

Certification

I certify under the penalty of law that I have personally examined and am familiar with the information submitted in this document and all attachments and that, based on my inquiry of those individuals immediately responsible for obtaining the information, I believe that the information is true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibliity of fine and imprisonment. (Ref. 40 CFR § 144.32)

Name and Official Title *(Please type or print)*	Signature	Date Signed

INSTRUCTIONS FOR FORM 7520-19

This form replaces forms 7520-12 and 7520-14. Use this form only when work is planned or has occurred that affects the well's construction or operation as an injection well, including work on the casing, tubing or packer (or for shallow Class V wells, the subsurface fluid emplacement network). Use one form per injection well. While reports or other information developed by contractors or service companies may be attached, this form must be signed by a responsible entity as described at 40 CFR 144.32. Note: operators closing Class V wells should use Form 7520-17.

NAME, ADDRESS, PHONE AND/OR EMAIL OF PERMITTEE: Enter the name and street address, city/town, state, and ZIP code of the permittee. Also provide an email address (if available) and/or a phone number.

PERMIT OR EPA ID NUMBER: Enter the well identification number or permit number assigned to the well by the EPA or the permitting authority.

API NUMBER: Enter the number assigned by the local jurisdiction (usually a State Oil and Gas Agency) using the American Petroleum Institute standard numbering system.

FULL WELL NAME: Enter the full name of the well or project.

Enter the **STATE** and **COUNTY** where the well is located. For States that do not have counties, use the name of that State's equivalent jurisdiction at a more local level.

WELL LOCATION: Fill in the complete township, range, and section to the nearest quarter-quarter section. A township is north or south of the baseline, and a range is east or west of the principal meridian (e.g., T12N, R34W). Also include the distance, in feet, from the nearest north or south line and nearest east or west line of the quarter-section. Also, enter the **latitude** and **longitude** of the well in decimal degrees, to five or six places if possible; be sure to include a negative sign for the longitude of a well in the Western Hemisphere and a negative sign for the latitude of a well in the Southern Hemisphere.

Enter the **WELL CLASS,** i.e., the class of injection well as defined in 40 CFR 144.6.

TIMING OF THE ACTION: Check ***Notice prior to work*** if the activity has not yet occurred (i.e., is planned). Check ***Report after work*** if the activity described has already occurred. As appropriate, include the date the activity is expected to start or the date the activity was completed. (Note this may not be available, e.g., for a plugging plan submitted with a permit application.)

TYPE OF ACTION: Check the appropriate box to describe the kind of activity being reported. Check ***Well Rework*** for work that was/will be performed on the well after it has already been in operation as an injection well. Check ***Plugging and Abandonment*** to report on plans for or descriptions of final closure/plugging after use as an injection well. Check ***Conversion to a Non-Injection Well*** if the well is to be converted to something other than an injection well.

Provide a **NARRATIVE DESCRIPTION** of the work planned to be performed, or that was performed. The narrative should include a description of the main procedures planned or that occurred during the work activity. A service company report, daily report, or similar document may be attached if it includes all the requested information and is clear and legible.

For well reworks, include the following information: The reason for the well rework; depths of activity; type of activity; changes to injection well configuration, well casing, or cement behind casing; any plug added to the well and its depth; any newly drilled interval and its depth; method(s) to demonstrate that the well has mechanical integrity (as applicable); and any deviations from the approved rework plan (as applicable).

For a well plugging plan, include the following information: Reason for the well plugging; number of plugs placed, and their depths; materials used as plugs (e.g., cast iron bridge plug, cement, cement retainer); method to set plugs; and wait-on-cement times, if any. Also provide one or more cost estimates from an independent firm in the business of plugging and abandoning wells to plug the well as described in the plan.

For well plugging affidavit, include the following information: Reason for the well plugging; number of plugs placed, and their depths; materials used as plugs (e.g., cast iron bridge plug, cement, cement retainer); method to set plugs; wait-on-cement times, if any; and any deviations from the approved plugging plan (if applicable).

For conversion to a non-injection well, include the following information: Depths of activity; type of activity; changes to injection well configuration, well casing, or cement behind casing; any plug added to the well and its depth; any newly drilled interval and its depth; depths of new perforations; and method(s) to demonstrate that the well has mechanical integrity (as applicable).

For all of the above activities, include a well sketch depicting the work, results of well tests/logging performed, service company tickets, and any other available information demonstrating how the work was/is to be performed. Also, specify whether depths are below ground surface, relative to Kelly bushing, etc.

CERTIFICATION: This form must be signed and dated by either: a responsible corporate officer for a corporation, by a general partner for a partnership, by the proprietor of a sole proprietorship, or by a principal executive or ranking elected official for a public agency.

PAPERWORK REDUCTION ACT NOTICE: The public reporting and recordkeeping burden for this collection of information is estimated to average between 6.0 and 7.9 hours per response, depending on the injection well class. Burden means the total time, effort, or financial resource expended by persons to generate, maintain, retain, or disclose or provide information to or for a Federal Agency. This includes the time needed to review instructions; develop, acquire, install, and utilize technology and systems for the purposes of collecting, validating, and verifying information, processing and maintaining information, and disclosing and providing information; adjust the existing ways to comply with any previously applicable instructions and requirements; train personnel to be able to respond to the collection of information; search data sources; complete and review the collection of information; and, transmit or otherwise disclose the information. An agency may not conduct or sponsor, and a person is not required to respond to, a collection of information unless it displays a currently valid OMB control number. Send comments on the Agency's need for this information, the accuracy of the provided burden estimates, and any suggested methods for minimizing respondent burden, including the use of automated collection techniques to Director, Collection Strategies Division, U.S. Environmental Protection Agency (2822), 1200 Pennsylvania Ave., NW., Washington, D.C. 20460. Include the OMB control number in any correspondence. Do not send the completed forms to this address.