Final Report
Caldwell Ranch Exploration and Confirmation Project, Northwest Geysers, CA
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CHAPTER 1: Summary

The project area is the site of former Central California Power Agency (CCPA) No.1 power plant and steam field which were abandoned and razed in 1999-2000 primarily for economic reasons (Figure 1). The purpose of the Caldwell Ranch Exploration and Confirmation Project was to drill, test, and confirm the present economic viability of the undeveloped geothermal reservoir in the 870 acre Caldwell Ranch area of the Northwest Geysers that included the CCPA No.1 steam field.

All of the drilling, logging, and sampling challenges were met.

- Three abandoned wells, Prati 5, Prati 14 and Prati 38 were re-opened and recompleted to nominal depths of 10,000 feet in 2010. Two of the wells required sidetracking.
- The flow tests indicated Prati 5 Sidetrack 1 (P-5 St1), Prati 14 (P-14) and Prati 38 Sidetrack 2 (P-38 St2) were collectively capable of initially producing an equivalent of 12 megawatts (MWe) of steam using a conversion rate of 19,000 pounds of steam/hour (KPH) per megawatt/hour.
- Both downhole and surface geochemical samples were collected and analyzed. The geochemical analyses show that the current geochemical conditions in the present reservoir are notably different than the pre-1996 geothermal reservoir. The NCG concentrations from P-5 St1 and P-38 St2 are significantly lower than when the original wells were produced in the late 1980's and into the middle 1990's.
- A core was retrieved from P-5 St1 from a depth of 9940 feet with measured rock temperatures exceeding 650 °F (>345 °C). The core was from the high temperature (up to 750 °F, or 400 °C) reservoir (HTR) known to underlie a cooler Normal Temperature Reservoir (NTR) about 465 °F, or 240 °C. The collection of core was difficult because the physical properties of the rock and high temperatures in the HTR.

The innovative combination of isotopic analyses of the rocks, and fluids collected from the wells in addition to the static and flowing log interpretation was designed to better understand the hydrothermal reservoir volume and thermal structure. The isotopic analyses have allowed Calpine to determine that:

- The reservoir fluids and rocks in the Caldwell Ranch Project area are geochemically different than the fluids and rocks in the adjacent Enhanced Geothermal Demonstration area (Figure 2).
- The injection of treated wastewater from the Santa Rosa Geysers Recharge Project has significantly lowered the concentration of NCG (e.g., carbon dioxide).

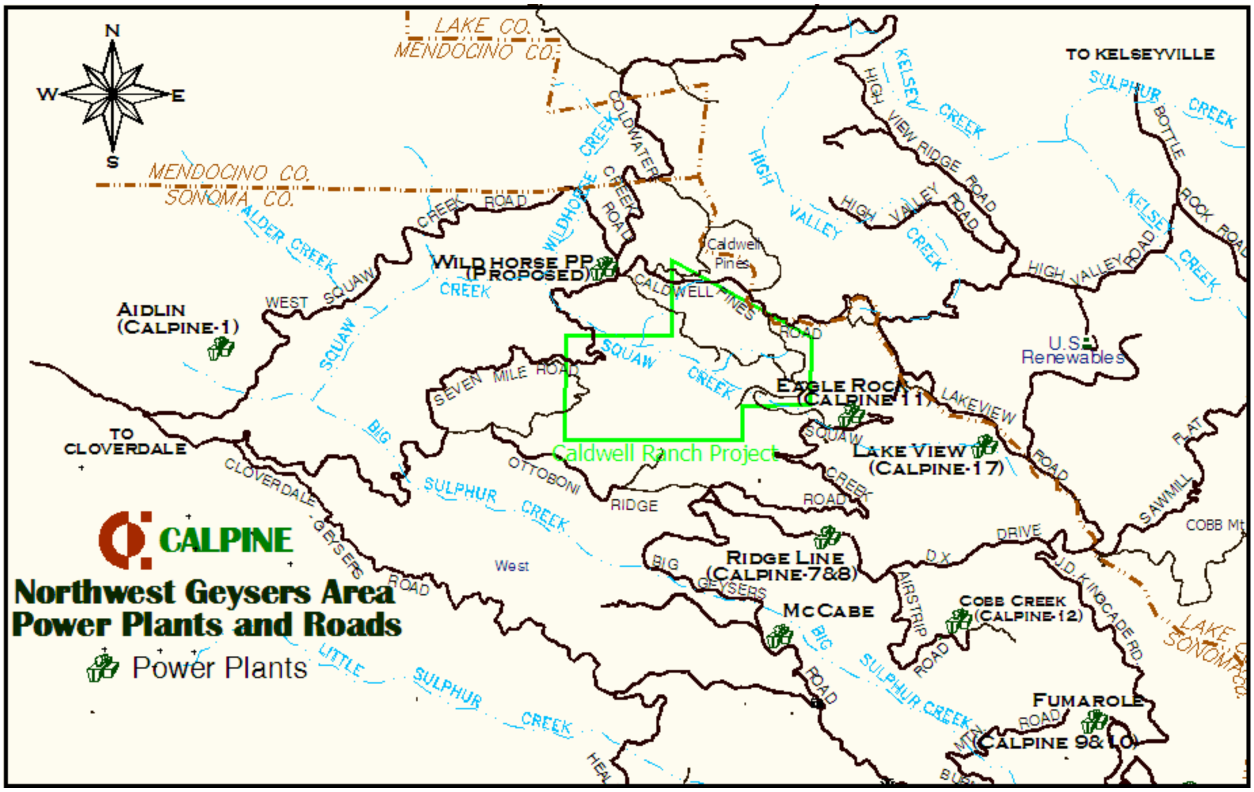
Calpine's goal was to determine the feasibility of developing a new sustainable steam supply to existing Unit 11 power plant, or the proposed Wild Horse Power Plant. Re-development of the Caldwell Ranch Project area was originally seen as dependent on current NCG concentrations, and Calpine's ability to mitigate NCG concentration levels.

Since 2011, Calpine produced steam from P-5 St1 and P-14 to the Unit 11 power plant. The actual steam production from these wells and the calculated pipeline interference if P-38 St2 were connected to a power plant confirms that the three project wells are capable of producing 11.4MWe. The significant decrease in NCG allows more efficient use of the steam at existing Geysers power plants.

Background

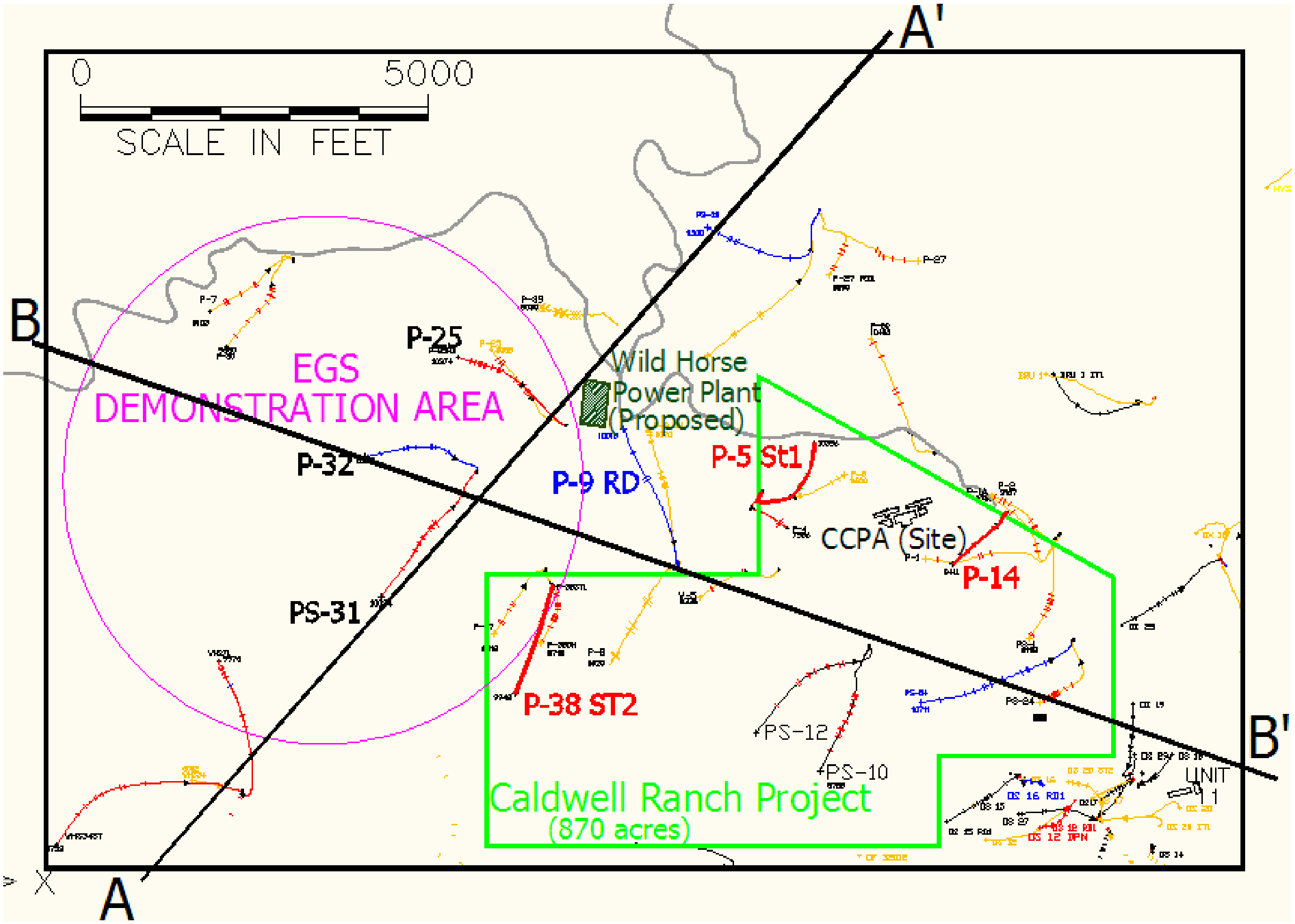
The Caldwell Ranch Exploration and Confirmation Project is in the northwest part of The Geysers, Sonoma County, CA. Figure 1 shows its location relative to nearby Calpine power plants (Unit 11, Units 7 & 8, and Aidlin). Figure 2 shows the Caldwell Ranch project wells and the nearby EGS Demonstration area. The photograph in Figure 3 shows the undeveloped Caldwell Ranch project acreage in 2010, with the Aidlin power plant visible in the distance about 3.5 miles west of, and behind, the P-5 St1 during a short test following the completion of the well ("rig flow test").

Figure 1: Location Map



Caldwell Ranch Exploration and Confirmation Project and Nearby Power Plants.

Figure 2: Caldwell Ranch Project Wells and Nearby EGS Demonstration Area



Location of the Caldwell Ranch Exploration and Confirmation Project. The whole-rock oxygen-18 concentration sections A-A' and B-B' shown above are in Appendix VII.

The Caldwell Ranch Exploration and Confirmation Project is located within the confines of the former CCPA No.1 steam field. The steam field and power plant were operated from 1988 to 1996 but were shut-in in July 1996 because of severe reservoir pressure declines, an insufficient water supply to supplement condensate injection, falling energy prices, relatively high NCG values, and an over-sized electrical generator that rendered the CCPA No.1 Power Plant (130 MWe) uneconomic to operate. The CCPA No. 1 power plant, steam field wells and pipelines were abandoned and razed in 2000. Calpine acquired the Caldwell Ranch leases in 2004.

Figure 3: Initial Prati 5 St1 Rig Flow Test

Caldwell Ranch Exploration and Confirmation project area in the foreground and the Aidlin power plant in the distance about 3.5 miles to the west.
Photo Credit: Calpine

Before drilling and testing the Caldwell Ranch Exploration and Confirmation project in 2010 and 2011, Calpine began injecting water from the Santa Rosa Geysers Recharge Project (SRGRP) into the project area beginning in late 2007 after re-opening, sidetracking and completing the Prati 9 well for injection. The SRGRP water is highly treated wastewater brought 42 miles from Santa Rosa. Contracts are in place with Santa Rosa for the delivery of injection water which will sustain both the proposed redevelopment of the Caldwell Ranch steam field and surrounding steam fields.

The only injection during the operation of the CCPA No. 1 steam field before June 1996 was steam condensate from the CCPA No.1 cooling towers. The steam condensate from the CCPA No.1 was highly enriched in the oxygen-18 and deuterium isotopes compared to the local meteoric water, including the water from the SRGRP. Therefore the large differences in oxygen-

18 and deuterium values in the native steam and meteoric water allow us to use these isotopes as natural tracers (see Figure 5).

P-9 well was “un-abandoned” (i.e., reopened) in late 2007 by Calpine and the well bore was kicked off from the original wellbore at a depth of 4800′. This redrill was through the reservoir section and remained within several hundred feet of the original well bore yet failed to find any of the eight steam entries encountered by the original well between 7200′ and 7900′ depth in 1983. High temperature zone steam entries below 8900′ in the redrill of P-9 did not correlate with those in the original well bore. Water entries in the redrilled interval were isotopically similar to the steam produced during the years of CCPA production.

The lack of steam entries in the upper portion of the redrill of P-9 raised concerns for the viability of the resource in the Caldwell Ranch area. Consequently, new drilling and reservoir characterization were required to establish that the upper “normal” temperature reservoir (NTR) was still economically viable.

Observations and Conclusions

1. The Caldwell Ranch project successfully tested and confirmed that the three project wells are capable of supplying about 11.4MWe to the proposed nearby Wild Horse Power Plant.
2. The injection of highly treated wastewater (or, “meteoric water”) into the steam reservoir has decreased the concentration of gases mixed with the reservoir steam from the range of 2 to 4 wt% to about 1 wt% in the Caldwell Ranch project area.
3. Reservoir modeling shows the Caldwell Ranch area and the adjacent Enhanced Geothermal System (EGS) Demonstration wells are capable of supplying enough steam for 40 to 45 MWe of sustainable electrical generation.
4. Construction of the proposed Wild Horse Power Plant is now solely dependent upon obtaining a Power Purchase Agreement which will yield an adequate return on investment.

Recommendations and Lessons Learned

In retrospect, there is nothing that Calpine proposed to do in its application to the U.S. DOE and Statement of Project Objectives (SOPO) which Calpine would not do, or do differently, in the future. Calpine’s efforts were successful and exceeded the original expectations of confirming and producing new steam reserves in the Caldwell Ranch Exploration and Confirmation Project area.

Calpine staff was pleasantly surprised to learn that the injection of SRGRP water into the Caldwell Ranch project area was very effective in lowering the carbon dioxide component of the gases mixed with the reservoir steam by about 65 percent in both P-5 St1 and P-38 St2. However Calpine staff was disappointed to learn that SRGRP injection seemingly lowered the hydrogen sulfide component of the of the gases mixed with the reservoir steam by only 7 to 18 percent in these two wells, and may not have lowered the highly variable concentrations of chloride. The SRGRP water injection did not substantially affect the concentration of gases mixed with the reservoir steam in Prati 14. The lesson here is that different gas components are scrubbed differently by IDS depending upon the gas species, chemical reaction kinetics between the IDS, gas species in the native steam, and the source of the gases.

Calpine recommends isotopic analyses of the geothermal reservoir rock, in combination with temperature logs, be used to determine the three-dimensional volume of any geothermal reservoir. Equally important, this technological combination is useful in defining the portions of old, cold geothermal reservoirs where there is little or no potential for reservoir development despite indications from some geophysical methods which may indicate geothermal reservoir features such as clay zones.

CHAPTER 2:
Well Drilling and Completion

The re-opening, and sidetracking of P-38 began on November 3, 2010. P-38 St2 was completed on January 12, 2011, to a total depth of 9942′. A core was attempted but not retrieved due to adverse temperature conditions. Cores from the hot Geysers reservoir taken while air drilling are often less than successful. High temperatures often damage the coring bit causing the core barrel to jam and for the core to become fragmented and fall out of the core catcher/ The well schematic for the re-opened, sidetrack, and re-completed P-38 St2 is in Appendix A.

The re-opening of P-14 was started on January 13, 2011, and completed to a total depth of 9412′ on February 10, 2011. The well could not be deepened nor could a core be obtained because the cement retainer below the abandonment plug fell to the bottom of P-14 while re-opening the well and could not be removed. The cement retainer therefore blocked all attempts to deepen P-14 with the consequence that no new drilling samples or cores could be collected. The well schematic for the re-opened and re-completed P-14 well is in Appendix A.

The re-opening of P-5 St1 began on February 21, 2011. P-5 St1 was completed on April 25, 2011 to a total depth of 10,396′. Five feet of core were retrieved from depths between 9940′ and 9945′. The well schematic for the re-opened, sidetrack, and re-completed P-5 St1 well is in Appendix A Photographs of the core are in Figure 7 and Figure 8.

Figure 4 below, shows P-5 St1 flowing 107 KPH on April 23, 2010, while the production liner was being installed "hot" (i.e., while steam was flowing from the well). The reason for installing a liner "hot" is to avoid "killing" the well with a large volume of water with the risk of the unstable and unprotected formation in the well bore collapsing into the yet unlined well. The production liners in P-14 and P-38 St2 were also run "hot" for the same reason as P-5 St1. The isochronal tests followed the well completions more than two months after the wells were completed and shut-in to allow time for the formation to heat up following the drilling.

Figure 4: P-5 St-1 Flowing Steam While Installing Production Liner

Photo Credit: Calpine

The drill cuttings from P-5 St1 and P-38 St2 were shipped to the geothermal laboratory warehouse of the Energy Geoscience Institute (EGI) in Salt Lake City, UT for long-term storage. The samples are available for use by qualified investigators. All of the cuttings and core acquired during the development of the CCPA No.1 steam field during the 1980's and early 1990's (including the Caldwell Ranch project area) are also stored and indexed at the EGI warehouse facility.

All of the drilling related data including daily drilling reports, drilling and casing program, well history, lithology ("mud") log, bit records, lost circulation amounts and depths were sent to the National Geothermal Data Base (NGDB), and the California Division of Oil, Gas and Geothermal Resources (CA DOGGR) where the data are open-filed and available to the public.

CHAPTER 3:
Well Testing and Reservoir Characterization

3.1 Isochronal Flow Testing

Three-day, isochronal flow tests were conducted to estimate the stabilized flow rates from P-5 St1, P-14 and P-38 St2. The flow tests were done at least two months after each well was completed to allow an adequate period of time for the well to heat up after being disturbed by the drilling activities. As detailed below, these wells were collectively estimated to be capable of producing an equivalent of 12 megawatts of electrical power from a generator using an assumed rate of 19,000 pounds of steam/hour per megawatt/hour (MWe).

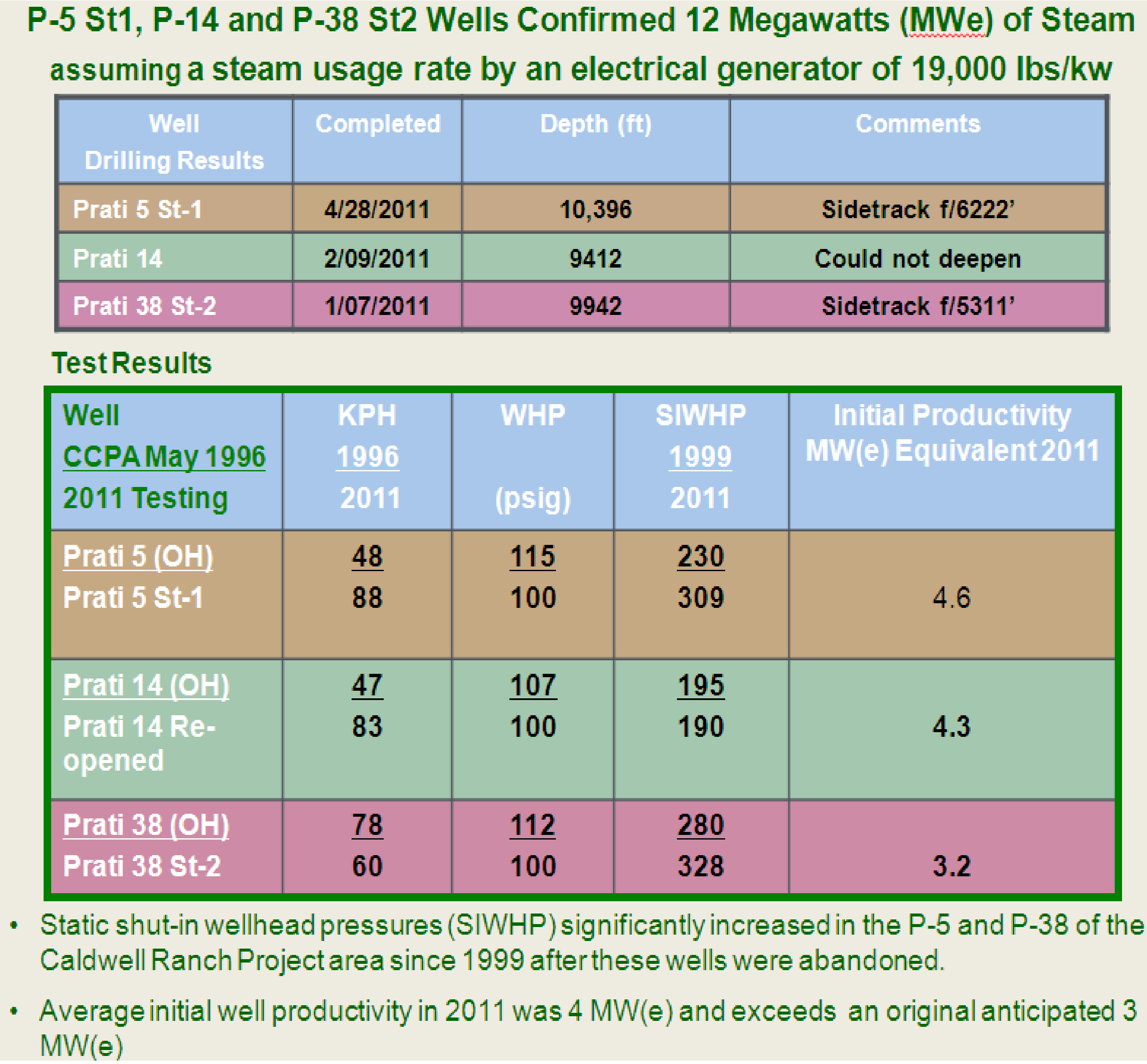
The results and analyses of these flow tests were prepared by Dr. Keshav Goyal of Calpine. Each report is included in its entirety in Appendix B.

A three and one-half day isochronal flow test of P-5 St1 was conducted from August 22 to August 25, 2011, subsequent to installing the production liner on April 25, 2011. The test showed the initial calculated flow rate of P-5 St1 was 88 kilo pounds per hour ("KPH") or 88,000 pounds per hour with a wellhead pressure normalized to 100 pounds per square inch gauge (PSIG), or about 4.6 MWe (assuming a conservative steam to electrical megawatt conversion rate of 19,000 pounds steam/hour per MWe at the proposed Wild Horse Power Plant). The measured static shut-in wellhead pressure (SIWHP) was 309 PSIG. The permeability thickness product ("kH") is calculated to be 64,330 millidarcy-feet (md-ft). The detailed isochronal flow test report is in Appendix B

Isochronal flow testing of Prati 14 was completed on April 14, 2011. The detailed isochronal flow test report is in Appendix B. The flow test showed the *initial* calculated flow rate is 83 KPH with a normalized wellhead pressure of 100 PSIG, or about 4.3 MWe (assuming a conservative steam to electrical megawatt conversion rate of 19,000 pounds per MWe). The shut-in wellhead pressure (SIWHP) was 190 PSIG. The kH is calculated to be 320,000 md-ft. The increase in steam flow deliverability from 47 KPH in 1996, to 83 KPH in 2011, shown in Table 1 is attributed to the liner which Calpine installed into the original well bore after re-opening it and cleaning out the well to bottom. The original wellbore may have been bridged between 6800′ and 7000′ depth during the operation of the CCPA steam field. A bridge is indicated by a decline curve analysis made in 1993 from which the calculated kH was only 13,600 md-ft compared to the kH of 320,000 md-ft calculated from the 2011 isochronal flow test data.

Isochronal flow testing of P-38 St2 was completed on March 17, 2011. The detailed isochronal flow test report is in Appendix B. The flow test showed an *initial* calculated flow rate of 60 KPH with a wellhead pressure of 100 PSIG, or about 3.2 MWe (assuming a steam to megawatt conversion rate of 19,000 pounds per MWe). The SIWHP was 328 PSIG. The kH is calculated to be 78,000 md-ft.

Table 1: Isochronal Testing Results



P-5 St1, P-14 and P-38 St2 Wells Confirmed 12 Megawatts (MWe) of Steam assuming a steam usage rate by an electrical generator of 19,000 lbs/kw

Well Drilling Results	Completed	Depth (ft)	Comments
Prati 5 St-1	4/28/2011	10,396	Sidetrack f/6222’
Prati 14	2/09/2011	9412	Could not deepen
Prati 38 St-2	1/07/2011	9942	Sidetrack f/5311’

Test Results

Well CCPA May 1996 2011 Testing	KPH 1996 2011	WHP (psig)	SIWHP 1999 2011	Initial Productivity MW(e) Equivalent 2011
Prati 5 (OH) Prati 5 St-1	48 88	115 100	230 309	4.6
Prati 14 (OH) Prati 14 Re-opened	47 83	107 100	195 190	4.3
Prati 38 (OH) Prati 38 St-2	78 60	112 100	280 328	3.2

- Static shut-in wellhead pressures (SIWHP) significantly increased in the P-5 and P-38 of the Caldwell Ranch Project area since 1999 after these wells were abandoned.
- Average initial well productivity in 2011 was 4 MW(e) and exceeds an original anticipated 3 MW(e)

Collectively, the isochronal flow tests indicated *approximately* 12 MWe of steam would be *initially* produced from the U.S. DOE Caldwell Ranch project wells, P-5 St1, P-14 and P-38 St2 if and when the proposed Wild Horse Power Plant is constructed in proximity to the project wells. The location of the Wild Horse Power Plant relative to the Caldwell Ranch project area is shown in Figure 1.

3.2 Well Logging

Pressure, temperature and spinner logs were run into the Caldwell Ranch project wells under both static and flowing conditions. These logs are plotted and discussed in Appendix C.

The most interesting part of the pressure-temperature spinner (PTS) log from P-5 St1 is at the very bottom. The temperature increases steadily to the depth of the deepest recorded steam entry at 9847′. At that point the temperature peaks at 597 °F (314 °C), then decreases to 560 °F (293 °C) from 9975′ to 10,274′. This is extraordinary temperature behavior in a wellbore bottoming over 2000′ into the high temperature (>500 °F (>260 °C) reservoir (HTR). Even with the temperature drop of 37 °F (23 °C), the superheat at 10,274 is 149 °F (93 °C). The spinner rotation (RPM) increases precisely with temperature decreases at three depths below the deepest steam entry recorded while drilling P-5 St1. This establishes that these are steam entries with a component of injection-derived steam as discussed in section 3.3.1. Because no steam entries were recorded in the well while drilling below 9847′, it seems likely that new steam entries have formed, resulting from injection into P-9. This may be the first indication that new steam entries can be formed from injection into the HTR. Based on the studies of microseismic events in the EGS Demonstration area, the new steam entries in P-5 St-1 may be a result of thermal contraction and shear reactivation.

The PTS plot of P-38 St2 while it was flowing, the pressure-temperature (PT) survey while it was static and the maximum-reading thermometer (MRT) temperatures made while drilling, all converge toward a temperature above 600 °F (315 °C) in the HTR at the bottom of the well. The top of the HTR is near 8000′ depth. Both the MRT measurements and the static PT logs survey indicate a conductive temperature gradient in the HTR of about 8 °F /100′ in the lower 1,000′ of the well.

The PT logs of P-14 show that the well is completed in the NTR. The temperatures are very close to the typical, convective reservoir temperature of about 465 °F (241 °C).

3.3 Well Geochemistry

3.3.1 Fluid Geochemistry

Calpine began injecting water from the SRGRP into the project area beginning in November 2007 after re-opening, redrilling and re-completing P-9. Therefore, before the drilling and testing of the Caldwell Exploration and Confirmation project in 2010 and 2011 the area had already received three years of SRGRP water injection. The large differences in oxygen-18 (^{18}O) and deuterium (D)concentrations in the native steam and SRGRP (see Figure 5) allow the use of these isotopes as natural tracers.

Table 2 below shows the geochemical analyses of surface and subsurface samples collected from the Caldwell Ranch project wells, as well as the geochemical analyses for the project wells when they were last operated as part of the CCPA No.1 steam field before its closure in 1996.

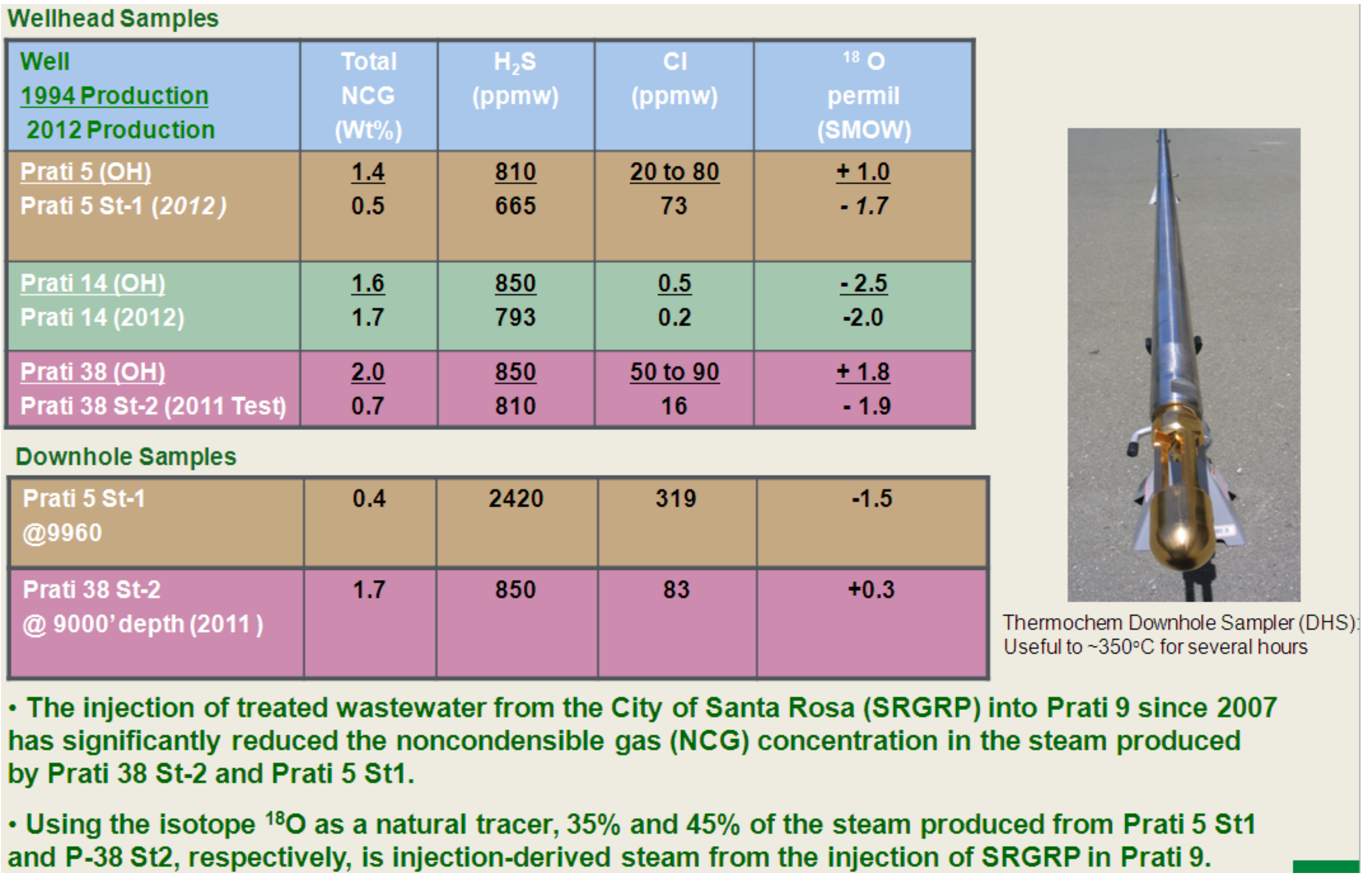
All of the analytical isotopic results are presented in the del notation, δ; as parts per thousand (per mil, or $^{o}/oo$) deviation of isotopic rations $^{18}O/^{16}O$ or D/H, relative to Standard Mean Ocean Water (SMOW). Using ^{18}O as an example:

$$\delta^{18}O = \left(\frac{^{18}O/^{16}O \text{ unknown}}{^{18}O/^{16}O \text{ SMOW}} - 1\right) \times 10^{3}\ ^{o}/oo$$

The reproducibility of SMU analyses from the internal standardization of the laboratory is about $\pm$ 1 $^{o}/oo$ for δD and $\pm$ 0.2 $^{o}/oo$ for $\delta^{18}O$.

The NCG concentration in the steam condensate from P-5 St1 was about 0.5 wt% with 665 ppmw hydrogen sulfide (H_2S) and 73 ppmw chloride (Cl) when the well was first produced in 2012. When P-5 was last produced in 1996, the NCG concentration in the native steam was 1.4 wt% with 810 ppmw H_2S. Subsurface (downhole) geochemical samples were successfully collected in August 2011 from depths of 8800′ and 9700′ in the HTR using the Thermochem downhole sampler (see Table 2). The results of the downhole sampling show that the NCG concentration of the HTR steam is 0.4 wt% with 2420 ppmw H_2S and 319 ppmw Cl. The decreases in $\delta^{18}O$ values at the well head from +1 per mil to -1.7 per mil (SMOW), and in the subsurface at 9960′ to -1.5 per mil, indicate to us that the high original NCG concentrations in the native steam of the HTR are being flushed by IDS from the SRGRP water injection at P-9. However because the Cl and H_2S in the HTR may be from a magmatic source, the Cl may not be abated because IDS may not saturate the HTR, and the availability of oxygen may not be sufficient to oxidize the H_2S compared to the mitigation of the total NCG concentration.

Table 2: Geochemical Composition of Steam at Wellhead and in Subsurface.



Wellhead Samples

Well 1994 Production 2012 Production	Total NCG (Wt%)	H_2S (ppmw)	Cl (ppmw)	^{18}O permil (SMOW)
Prati 5 (OH) Prati 5 St-1 (*2012*)	1.4 0.5	810 665	20 to 80 73	+ 1.0 *- 1.7*
Prati 14 (OH) Prati 14 (2012)	1.6 1.7	850 793	0.5 0.2	- 2.5 -2.0
Prati 38 (OH) Prati 38 St-2 (2011 Test)	2.0 0.7	850 810	50 to 90 16	+ 1.8 - 1.9

Downhole Samples

Prati 5 St-1 @9960	0.4	2420	319	-1.5
Prati 38 St-2 @ 9000' depth (2011)	1.7	850	83	+0.3

Thermochem Downhole Sampler (DHS):
Useful to ~350°C for several hours

- **The injection of treated wastewater from the City of Santa Rosa (SRGRP) into Prati 9 since 2007 has significantly reduced the noncondensible gas (NCG) concentration in the steam produced by Prati 38 St-2 and Prati 5 St1.**
- **Using the isotope ^{18}O as a natural tracer, 35% and 45% of the steam produced from Prati 5 St1 and P-38 St2, respectively, is injection-derived steam from the injection of SRGRP in Prati 9.**

Fluid Analyses of Surface and Subsurface Geochemical Samples

As seen in Table 2, the fluid geochemistry in P-14 is not significantly different in 2012, then when it was last produced in 1996.

The NCG in the steam condensate from P-38 St2 was about 0.7 wt% with 810 ppmw H_2S and 16 ppmw chloride (Cl) when the well was flow tested in 2011. Downhole geochemical samples were successfully collected in August 2011 from depths of 9000′ in the HTR. The results of the downhole sampling show that the NCG concentration of steam in the HTR is 1.7 wt% with 850 ppmw H_2S and 83 ppmw Cl. The downhole $\delta^{18}O$ value is +0.3 per mil in the HTR compared to -1.9 per mil (SMOW) at the well head which indicates the HTR is less flushed by IDS than the NTR.

The NCG in the steam condensate from P-5 St1 was about 0.5 wt% with 665 ppmw H_2S and 73 ppmw chloride (Cl) when the well was flow tested in 2012. Downhole geochemical samples were successfully collected during the flow test from depths of 9950′ in the HTR. The results of the downhole sampling show that the NCG concentration of steam in the HTR is 0.4 wt% with 2420 ppmw H_2S and 319 ppmw Cl. The downhole $\delta^{18}O$ value is -1.5 per mil in the HTR compared to -1.7 per mil at the well head which indicates both the NTR (about 465 °F (241 °C)) and the HTR are well-flushed by IDS. However, the degree of reaction of H2S with IDS relative to the large reduction of NCG is relatively low and Cl is not typically affected by IDS in other parts of the Geysers reservoir. The differences in the relative degree of IDS flushing may be due to the different sources of the fluid components and their reaction to IDS. The very high concentrations of H_2S and Cl sampled near the bottom of P-5 St1 apparently are present because there is a significant magmatic gas component in the HTR.

Three maps showing the concentration of NCG in the Caldwell Ranch project and vicinity are presented in Appendix E: (1) the years before November 2011 when injection of SRGRP in Prati 9 began; (2) 2010-2011 after the Caldwell Ranch project wells were drilled and tested; and (3) after injection into P-32 had begun in the EGS Demonstration project. These maps show a very large decrease in NCG concentration from 2008 and 2012 following the injection of SRGRP water into the Caldwell Ranch and EGS Demonstration project areas, indicating generation and production of SRGRP IDS.

Large diameter steam pipelines from P-5 St1 and P-14 were constructed to the existing Calpine Unit 11 power plant. P-14 began production to Unit 11 in October 2011. P-5 St1 began steam production to Unit 11 In January 2012 through a separate pipeline. Calpine later collected additional geochemical steam samples from P-14 and the P-5 St1 wells in March, June and September 2012. The NCG in P-14 and P-5 St1 steam increased from 14,849 ppmw (1.48 wt%) to 15,728 ppmw (1.57 wt%), and from 3369 ppmw (0.33 wt%) to 4849 ppmw (0.48 wt%), respectively, between the first sampling of these wells and September 2012 . The NCG increased from P-5 St1 after it went into production but, is relatively small compared to the 80 percent decrease in NCG concentration when this well was operated from 1989 to 1996 by CCPA No.1 with the NCG concentration in the range of 2.0 wt%.

The relationship between meteoric water flushing and whole-rock oxygen isotope values was integrated into the understanding of the relationship between the high temperature reservoir and noncondensable gas concentration throughout the Northwest Geysers (Walters and Beall, 2002). The authors write:

> *"Gunderson (1991) noted the lack of meteoric water flushing in the Northwest Geysers also resulted in lower calculated water to rock ratios. Walters and others (1996) enlarged on the "meteoric flushing" model to further refine the geochemical evolution of the Northwest Geysers. They described an area of the Northwest Geysers* (specifically the Caldwell Ranch Project Area and EGS Demonstration Area)…*in which extremely high NCG concentrations (up to 7 wt %) and isotopically heavy (^{18}O) reservoir metagraywacke indicate a lack of flushing by meteoric water*."

The native steam from P-5 and P-38 had $\delta^{18}O$ values of +1 per mil and δD values of about -43 per mil when these wells were originally flow tested in the 1980's, and later produced to the CCPA No.1 power plant until its closure in 1996. The $\delta^{18}O$ values in steam produced from P-5 St1 and P-38 St2 in 2012 have decreased from about of +1 per mil in 1996 to -1.7 and -1.9 per mil, respectively, in 2012. The δD values of about -43 per mil in 1996 have increased slightly to about -41 per mil in 2012. These changes in $\delta^{18}O$ and δD values are attributed to the injection of SRGRP water into P-9. The SRGRP water has $\delta^{18}O$ values of -6 per mil and δD values of -38 per mil which are similar to the local meteoric waters close to the Caldwell Ranch project area. The $\delta^{18}O$ and δD values of local meteoric water, SRGRP water, the original steam produced from the Northwest Geysers, and the steam now produced from the Caldwell Ranch project are plotted on a mixing-line graph in Figure 5.

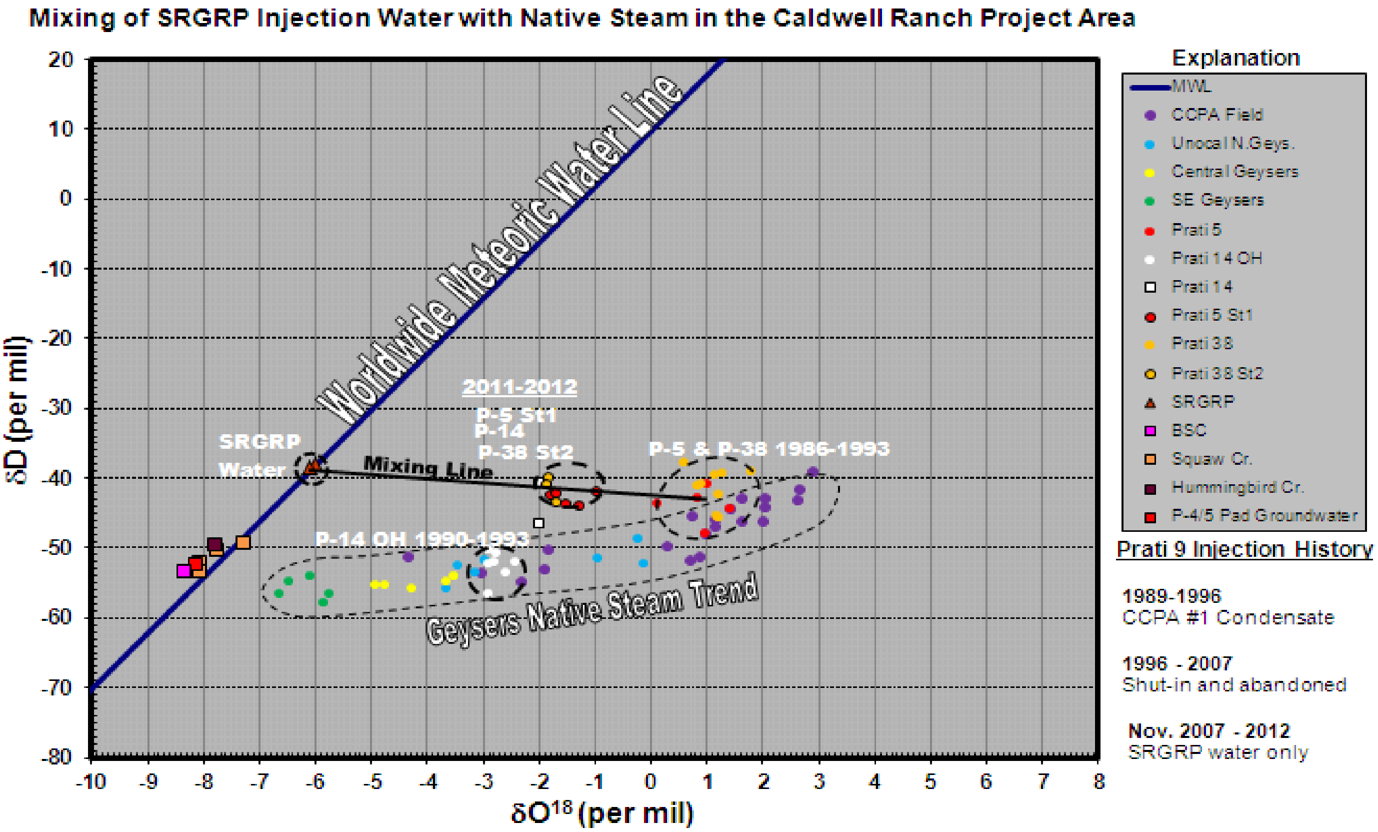
The mixing-line in Figure 5 indicates that about 35 percent of the steam from P-5 St1 is now derived from the SRGRP water injected into Prati 9, and about 45 percent of the steam from P-38 St2 is injection-derived steam (IDS). Therefore it is evident that the IDS from SRGRP water injected into P-9 has flushed the reservoir since treated wastewater injection began in November 2007.

In contrast to the $\delta^{18}O$ values in P-5 St1 and P-38 St2, the $\delta^{18}O$ values in P-14 steam are not changed much since 1993; from about -2.7 per mil from 1990 to 1993, to about -2.0 per mil in 2011 and 2012 (see Figure 5). In contrast to the relatively unchanged P-14 $\delta^{18}O$ values in 2011 and 2012 in steam condensate, the δD values in P-14 have increased from about -53 per mil between 1990 and 1993 to about -44 per mil in 2011 and 2012. These data suggest that there is a mixture of IDS from SRGRP and Unit 11 condensate water being produced at P-14.

The early (1977-1985) $\delta^{18}O$ values in steam condensate throughout the western half of the Caldwell Ranch project and EGS Demonstration Area ranged from 0 per mil to +3 per mil. These $\delta^{18}O$ values are indicative that the native steam in these areas was not significantly influenced by meteoric water. Various geochemical and fluid inclusion studies have concluded the early steam in these areas was from connate water (sea water trapped in the metagraywacke and argillite reservoir rocks) from the Mesozoic (about 150 million years ago). The $\delta^{18}O$ values in Standard Mean Ocean Water (SMOW) have not varied significantly from 0 per mil for the last 150 million years.

Three maps for the Caldwell Ranch project area and vicinity are presented in Appendix F: (1) "early" (1977-1985) $\delta^{18}O$ values; (2) $\delta^{18}O$ values in the Caldwell Ranch project area acquired in 2010 and early 2011 from recently re-opened and recompleted wells; and (3) $\delta^{18}O$ values acquired in 2012 after the EGS Demonstration injection well, Prati 32, began injecting SRGRP water. These maps show that the $\delta^{18}O$ values of steam from the western half of the Caldwell Ranch project area and the southeastern part of the EGS Demonstration project area has been progressively, and substantially, reduced by the injection of SRGRP water: from 0 to +2 per mil **before** 2008, to -1 to -4 per mil in 2012.

Figure 5: Changes to isotopic composition of native steam by injection of meteoric water.



2011 Prati -38 St2 steam flow (tests) = ~45% injection-derived steam from SRGRP water injected at Prati 9.

2012 Prati -5 St1 steam production= ~35% injection-derived steam from SRGRP water injected at Prati 9.

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3.3.2 Whole-Rock Isotopic Geochemistry

The geothermal reservoir rock in the northwestern portion of the Caldwell Ranch Project is only weakly exchanged with meteoric water and is characteristic of the margins of the Geysers hydrothermal reservoir (Walters and Beall, 2002, Gunderson, 1991b). Here the integrated $\delta^{18}O$ values close to the P-5 St1 and P-38 St2 well bores are depleted, from +12 per mil and greater in the cap rock, to +10 per mil. In the southeastern portion of Caldwell Ranch Project and in the area of P-14, the $\delta^{18}O$ values in the typical Geysers reservoir are progressively depleted to the southeast from +12 per mil and greater in the cap rock, to almost +5 per mil. (see: Figure 6, right half).

Northwest of, and adjacent to, the Caldwell Ranch Project area, an Enhanced Geothermal System (EGS) was created in the EGS Demonstration area (Figure 2). As shown on the left side of Figure 6 below, the $\delta^{18}O$ values in the biotite hornfels within the HTR are as unexchanged by meteoric water between depths of 8400′ to 11,000′, as the cap rock to the NTR (≥ +12 per mil).

Moore and Gunderson (1996) wrote:

> *"With increasing depth, and towards the center of the* (Geysers steam) *field, the* $\delta^{18}O$ *values become progressively more depleted. Between +610 m and sea level, the lowest* $\delta^{18}O$ *values are found toward the southeastern end of the field above the shallowest part of the felsite* (granitic) *intrusion. At greater depths, this isotopic low is shifted northward, defining an elongate northwest-southeast area that is more centrally located with the steam field. … The lowest* $\delta^{18}O$ *values which range from +4 to +7 per mil, occur within the hornfels. With increasing depths and proximity to the intrusive contact, the* $\delta^{18}O$ *values of the hornfels increase to +8 to +10 per mil and then remain fairly constant within the pluton itself."*

Gunderson (1991b) showed that integrated water/rock ratios (mass) range from 0.1 in the Northwest Geysers to 2 in the central Geysers.

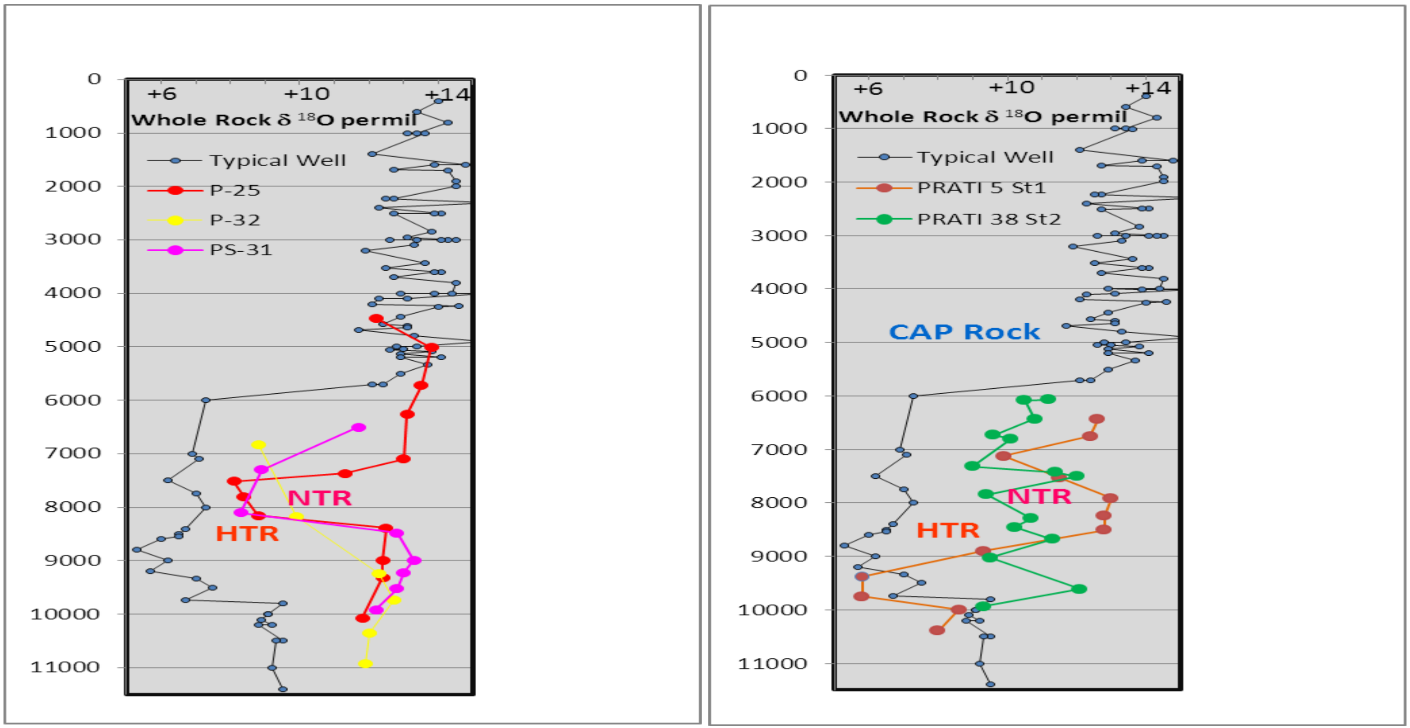
Calpine's detailed analysis of the $\delta^{18}O$ values for the northwestern portion of the Caldwell Ranch area, represented by P-5 St1 and P-38 St2, indicates the integrated water/rock ratios are in the range of 0.05 to 0.2. These ratios are in the same range of values found by Gunderson (1991) to characterize the weakly exchanged and marginal hydrothermal system developed around the margins of The Geysers.

In the southeastern portion of the Caldwell Ranch project represented by the P-14 well, the integrated water/rock ratios range from 0.2 to 1.0 and characterize the typical Geysers hydrothermal reservoir.

In the adjacent EGS Demonstration area to the northwest of the Caldwell Ranch project area, the biotite hornfels below the weakly developed hydrothermal NTR of Prati 25 (P-25), Prati 32 (P-32) and Prati State 31 (PS-31) is unexchanged with meteoric water and therefore is classified as hot dry rock (Figure 6).

The water/rock ratios were calculated with four assumptions: (1) the unexchanged cap rocks to the Geysers hydrothermal reservoir have whole-rock $\delta^{18}O$ values of +12 per mil or greater; (2) 0 per mil connate water originally occupied the pores of the metagraywacke reservoir rock; (3) the meteoric water which isotopically depleted the reservoir rock was -7 per mil; and (4) the water/rock exchange occurred between 650 to 750 °F (350 to 400 °C).

Figure 6: Comparison plots of whole-rock δ^{18}O values



Whole-rock δ^{18}O values for the Northwest Geysers are plotted versus depth. The graph on the left is for the EGS Demonstration area wells. The graph on the right is for the Caldwell Ranch project wells. Data for Prati 14 are not available. However, the “Typical Well” plot likely represents the whole-rock δ^{18}O values that might be anticipated from Prati 14.

The whole-rock δ^{18}O values in the Caldwell Ranch project and surrounding areas are plotted as isotopic cross-sections in Appendix G. The sections also show the top of steam, the top of the high temperature reservoir, and faults, shown in Figure 9a, which create hydraulic discontinuities. The northwestern portion of the Caldwell Ranch area, and southeastern portion of the project area are in separate reservoir compartments defined by faults which create hydraulic discontinuities shown on Figure 9a. To the northwest of the project area, the isotopic whole-rock oxygen-18 values indicate the HTR in the EGS Demonstration Area is hot dry rock which is as unexchanged with meteoric water as the reservoir cap rock. The southern portion of the project area southwest of the Caldwell Ranch Fault is well-exchanged with meteoric water and is characteristic of the hydrothermal reservoir found throughout the Geysers steam fields.

3.4 Well Geology

Figure 9b is a geologic map showing detailed geologic mapping and Quaternary faults which extend to reservoir depth and create hydraulic discontinuities. Whole-rock isotopic zoning contrasts (Appendix G), together with steep NCG concentration gradients (Appendix E), are also coincident with the hydraulic discontinuities across the Caldwell Ranch Fault, Alder Creek Fault, Mercuryville Fault, Ridgeline Fault, and an Un-named Fault. These Quaternary faults serve to loosely “compartmentalize” the Caldwell Ranch project into two segregated parts, as well as segregating the Caldwell Ranch Project from the EGS Demonstration project.

The northeast-trending Caldwell Ranch Fault appears to create a hydraulic pressure discontinuity which segregates the southeastern portion of the project area (nearest to Unit 11 where P-14 is drilled) from the northwestern portion of the project area where P-5 St1 and P-38 St2 are drilled. In the portion of the Caldwell Ranch project reservoir where P-14 is drilled, the concentration of NCG ranges from 1 to 2 wt% NCG. In the portion of the Caldwell Ranch project reservoir where P-5 St1 and P-38 St2 are drilled, the NCG concentration ranged from 2 to 4 wt% when these wells were originally drilled in the early 1980's. When the CCPA steam field was being developed in the 1980's, there was a static pressure differential of about 50 PSIG across the Caldwell Ranch Fault. In 2010, the pressure differential across the Caldwell Ranch Fault is about 30 PSIG.

During the course of the Caldwell Ranch project, a second northeast-trending fault (labeled "Un-Named Fault" in Figure 9a) was identified. This minor fault or shear zone creates a hydraulic discontinuity with a differential pressure of up to 90 PSIG and segregates the P-5 St1 and P-38 St2 wells from the EGS Demonstration Project area where the NCG concentration of the steam ranged from 5 to 7.5 wt% when these wells were first tested in the early 1980's.

3.4.1 Lithologic Findings

The geology for the re-opened and re-completed P-5 St1, P-14 and P-38 St2 wells are graphically summarized in Appendix D. The lithologic sections of the new well bore penetrations in P-5 and P-38 incorporate the logging of the upper portions of the original well bores.

Unstable, tectonic mixtures or sheared rocks ("mélange") and lost circulation zones are behind cemented casing and slotted production liners were installed in all of the three re-opened and recompleted Caldwell Ranch Project wells. The mélange unit near 7000' depth containing serpentine in P-14 is the most likely cause of a bridge postulated in the original, unlined well bore when this well was operated by CCPA No.1.

Two-phase water and steam entries overlie the current steam reservoir and are shown on the lithologic logs for each of the project wells in Appendix D. These zones may have decreased in depth since the original wells were drilled due to decreases of drops (200 – 300 psi) in reservoir pressure.

In P-5 St1 and P-38 St2 wells, the top of the HTR (>500 °F (261°C)) is near 8000' and associated with hornfelsic metagraywacke. Neither hornfelsic metagraywacke nor high temperatures were observed in P-14 which is typical of the NTR in the Northwest Geysers where maximum temperatures are about 465 °F (241 °C).

3.4.2 Findings from Laboratory Studies of Drill Core and Cuttings

The core retrieved from P-5 St1 in the HTR between depths of 9940' and 9945' (Figure 7 and 8) was comprehensively tested and analyzed by TerraTek in Salt Lake City. Fourteen core plugs were taken from the core for laboratory analyses. Arrangements were also made for TerraTek to cut a suite of specialized core plugs for testing and analysis by Lawrence Berkeley National Laboratory. Figure 8 shows that numerous core plugs were taken. The TerraTek laboratory analysis shows the core from P-5 St1 is biotite hornfels with very low permeability and low porosity. Following the testing of the P-5 core at TerraTek, additional petrographic thin sections were made in March 2012 to study the fluid inclusions in vein minerals in the core. The salinity of the hydrothermal fluids which formed the vein minerals is high with salinities up to 44 wt% sodium chloride (NaCl) with crystals of halite and sylvite.

Drill cuttings samples were sent to TerraTek for comprehensive petrographic analysis to compare the hornfelsic graywacke in the HTR of P-38 St2 to P-5 St1. This was conducted to determine if the laboratory test results for P-5 St1 well might be applied to P-38 St2 for reservoir modeling purposes. The results of the petrographic examination showed that the drill cuttings from P-38 St2 are biotite hornfels with pervasive albite replacement of the clay mineral matrix. A report titled, "Petrologic Evaluation of Selected Well Cuttings from Well P-38 St2, Geysers Geothermal Field, CA" dated October 2011 was prepared by TerraTek. This report was included in Calpine's submittal to the NGDB.

Figure 7: Prati 5 St1 Core

Relict sedimentary structures are seen in the biotite hornfels.

Figure 8: Core Plugs from P-5 St1 Core

Multiple core plugs were taken for laboratory tests.

The results from the petrographic analyses for the P-38 St2 drill cuttings and the P-5 St1 core were compiled and compared to other cores from the hornfelsic graywacke from the Northwest Geysers in: Lutz, S. and others, New Insights into the High-Temperature Reservoir, Northwest Geysers, 2012, Geothermal Resources Council Transactions, v. 36. A detailed abstract of this paper is quoted in part below:

> *"The P-5 St1 core (9940-9945 ft) represents one of the few windows into the hornfelsic metagraywacke HTR. Analysis of core samples indicates that the original illitic matrix of the laminated silty to sandy hornfelsic metagraywacke has been converted to biotite, actinolite, and calcium-rich plagioclase. High-temperature magmatic-hydrothermal veins cut the metagraywacke matrix and are composed of actinolite, biotite, clinopyroxene, quartz, albite, pyrrhotite, and tourmaline. Elemental analyses indicate that the vein albite has a pure sodic composition, and bleached selvages on the veins are composed of calcic feldspar. Fluid inclusions trapped in vein quartz from the P-5 St1 core are vapor-rich and multiple daughter phases include halite and sylvite. Vapor-dominated fluid inclusions dominate and indicate that boiling has occurred in the HTR reservoir and that highly saline fluids were present during formation of the veins.*
>
> *The high temperature minerals that only occur as veins in the P-5 St1 core occur throughout the matrix of the hornfelsic metagraywacke in well cuttings from P-38 St2 (8250-9900 ft). In contrast to P-5 St1, the secondary plagioclase in the matrix of the hornfelsic metagraywacke in P-38 St2 is dominantly sodic (albite composition), and the rock appears to have undergone more extensive sodium metasomatism than in P-5*

> *St1. P-38 St2 apparently has had greater volumes of saline hydrothermal brine, perhaps originating as connate water, moving through the rock matrix than in P-5 St1. Sodium metasomatism has caused extensive albite cementation of the rock matrix.*
>
> *Basic core properties (density, porosity, and permeability) and scratch testing of the P-5 St1 core confirm the low matrix permeabilities and high rock strengths in the hornfelsic metagraywacke in the high temperature reservoir. Analyses of the P-5 St1 core samples indicate less than 1 percent porosity and 90 microdarcy gas permeability in unfractured samples. Scratch test results at ambient conditions indicate very high rock strengths, with unconfined compressive strength estimates of up to 56,000 psi (390 MPa) for the hornfelsic metagraywacke lithologies. Actual in-situ rock strengths and mechanical properties within the HTR are not known; and the rocks are sufficiently hot (400 °C) to behave in a ductile manner at these depths. However, a steam-bearing fracture near 11,000 feet was encountered while drilling P-32 and the injection of cool water into the HTR as part of the EGS Demonstration apparently has promoted brittle failure to depths 1 km below the bottom of the P-32 well."*

In summary, the metagraywacke near the postulated Recent granite which underlies the HTR in the Caldwell Ranch and EGS Demonstration areas has been thermally recrystallized to a biotite hornfels ("hornfels") and bears no mechanical resemblance of the original sedimentary graywacke and argillite sequences which are directly analogous to sandstone and shale, respectively. The only resemblance of the hornfels to its sedimentary past is the relict bedding structures seen in Figure 7. The porosity, permeability and compressive strength of the biotite hornfels are similar to a granite rather than a rock of sedimentary origin.

The laboratory reports for the P-5 St1 hornfelsic reservoir rock were compared to the cores taken in 1986 from the original P-5 and P-38 wells. Core plugs from the original P-5 and P-38 core had helium porosities in the range of 0.8 to 1.3 percent and 0.9 to 3.1 percent, respectively, whereas twelve core plugs from the hornfels in P-5 St1 have an average porosity of 0.9 percent with a range of 0.6 to 1.8 percent .

The core analyses, geochemistry, isotopic chemistry of the fluids and rock from P-5 St1 and P-38 St2, together with the previous data collected in Phase 1 of the Caldwell Ranch projects are summarized in an invited abstract for a presentation to the American Geophysical Union during its 2012 Fall Meeting (December 7 -11) in San Francisco titled, Evolution of an active magmatic-geothermal system at The Geysers, California" by Joseph N. Moore (Energy & Geoscience Institute) and Mark Walters (Calpine Corp). The abstract is quoted below and includes parenthetical comments which put the Caldwell Ranch project area in perspective with the overall Geysers area.

> *"The Geysers geothermal system initially developed* (in the southeast and central portion of The Geysers steam field) *at 1.1 to 1.2 Ma in response to the intrusion of a hypabyssal granitic pluton exceeding 100 km^2 in area. The geothermal system, which is developed in Mesozoic metagraywacke and the underlying granite* (locally known as the Geysers felsite)*, is currently vapor-dominated and produces only dry steam. Mineralogic, fluid inclusion and isotopic data demonstrate the current vapor-dominated regime evolved from a liquid-dominated system. Within 600 m of the pluton* (felsite)*, the rocks were altered to a biotite hornfels that is cut by veins of tourmaline + biotite + actinolite + clinopyroxene + albitic plagioclase. Fluid inclusions trapped in the vein minerals* (found in hornfels core samples from the OF27A-2 well adjacent to, and south of, the Caldwell Ranch project area) *record maximum homogenization temperatures near 380 °C and salinities up to 44 wt% NaCl equivalents. With increasing*

> *distance from the pluton, the veins are characterized by actinolite + epidote, epidote + chlorite, and finally calcite. Quartz and adularia are commonly observed in these veins. Fluid inclusions trapped at a distance of 1750 m from the intrusion record temperatures up to 305 °C and salinities of 5 wt% NaCl equivalent. Whole-rock oxygen isotope data indicates the metagraywacke and granitic reservoir rocks were isotopically exchanged with meteoric water during the liquid dominated phase of the system.*
>
> *The transition from liquid- to vapor-dominated conditions occurred at 0.25 to 0.28 Ma* (million years absolute)*, based on 40Ar/39Ar spectrum dating of adularia. As the liquids boiled off, bladed calcite, chalcedony, quartz and adularia were deposited. Vapor-rich inclusions dominate the fluid inclusion populations of many samples. Low salinity liquid-rich fluid inclusions (0.0 – 0.4 wt% NaCl), interpreted to consist primarily of steam condensate, suggest that widespread boiling and vapor-dominated convection cells had formed in the upper part of the present-day reservoir by the time temperatures had dropped to approximately 250° - 265°C. Subsequent inflow of relatively cool marginal meteoric waters resulted in the deposition of calcite and the formation of low permeability seals around the reservoir.*
>
> *The present vapor-dominated system at The Geysers consists of two distinct, hydraulically connected steam reservoirs. The upper, normal vapor-dominated reservoir is found throughout the field. Temperatures within this reservoir are isothermal and close to 240°C. The lower high temperature reservoir occurs within the biotite hornfels in the northern half of the field* (including the Caldwell Ranch project area*). Measured temperatures follow a conductive gradient* (10 °F /100') in the EGS Demonstration area) *and range from about 240 °C to 400 °C. Pressures are vaporstatic in both reservoirs.*
>
> *The high temperature reservoir in the Northwest Geysers is the youngest part of the system. Here newly formed biotite hornfels is being heated by a recent magmatic intrusion interpreted* (by the US Geological Survey) *to have been emplaced between 5,000 and 10,000 ybp. This portion of the deep Northwest reservoir* (the EGS Demonstration and Caldwell Ranch Project areas*) is characterized by low permeabilities and the highest measured temperatures and 3He/4He ratios (~7-9.6Ra* (Relative ratio absolute)) *encountered in the field. In contrast to other parts of the system, the biotite hornfels in the* (EGS Demonstration Area) *of the Northwest Geysers has not been isotopically exchanged with meteoric water."*

In short, the reservoir and thermal history of the Caldwell Ranch Project area and EGS Demonstration Area are substantially different.

3.4.3 Structural Geology Findings

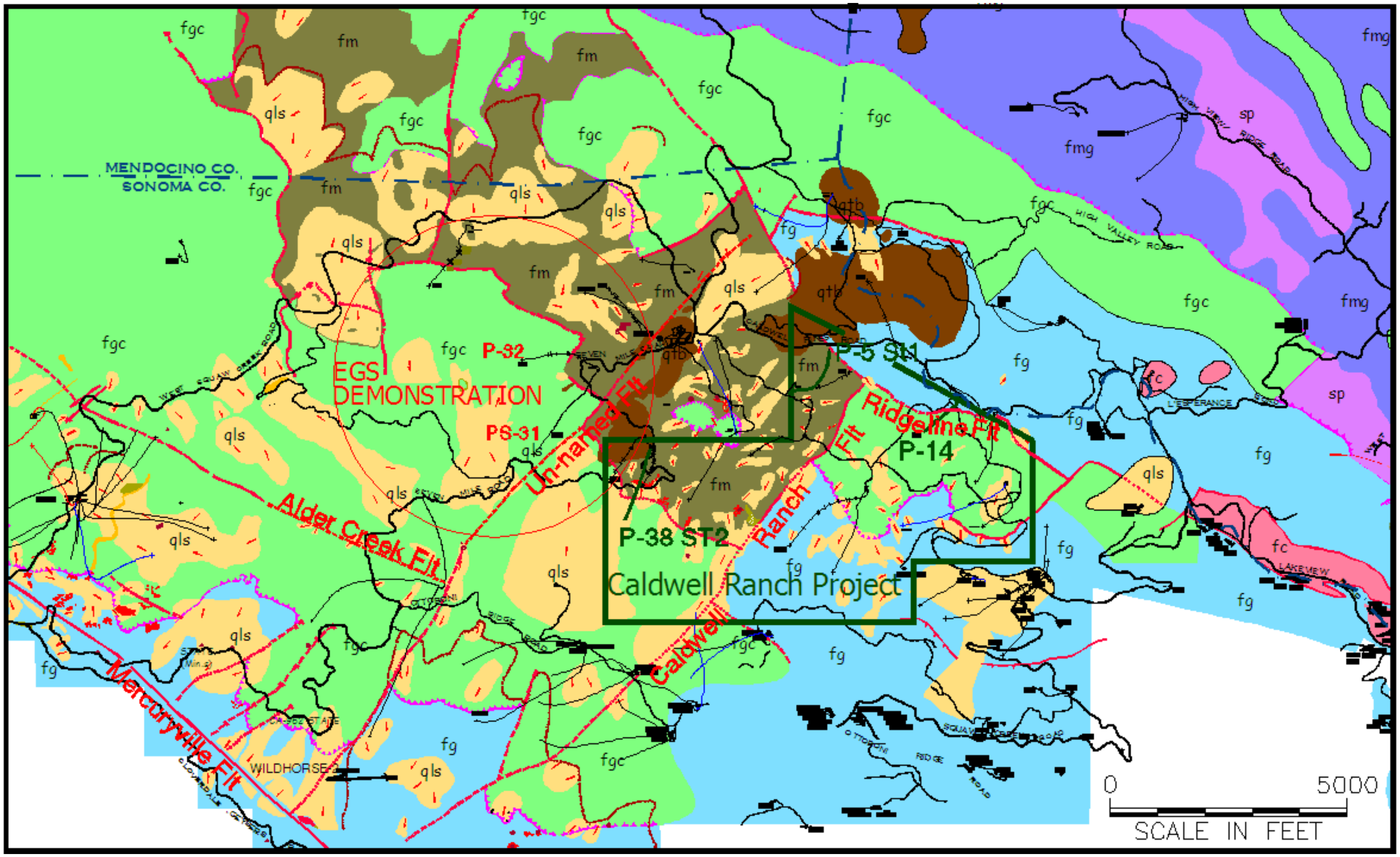
The report for the isochronal test from March 14 to 17, 2011 of P-38 St2 states that **"**P-38 St2 was not found to be in pressure communication with the nearby wells Prati State 31 (PS-31) and Prati 32 (P-32)". (See Appendix B for P-38 St2 for isochronal flow report.)

An unpublished progress report (Garcia, 2012) presented at the Geothermal Resources Council Reservoir Engineering Workshop in Reno, Nevada on September 28, 2012, shows there was no pressure response at P-38 St2 (green line on Figure 10 graph) during injection at P-32 beginning in October 2011. However, P-25 and PS- 31 in the EGS Demonstration Area show a clear pressure increase in response to P-32 injection. An un-named fault (yellow dashed line) was also attributed to the hydraulic discontinuity shown on the graph in Figure 10.

Although it is relatively rare that mapped surface faults and shear zones extend downward into the reservoir at the Geysers, the Un-named Fault apparently extends downward into the reservoir and is the probable cause of the hydraulic discontinuity between the Caldwell Ranch project area and the EGS Demonstration project.

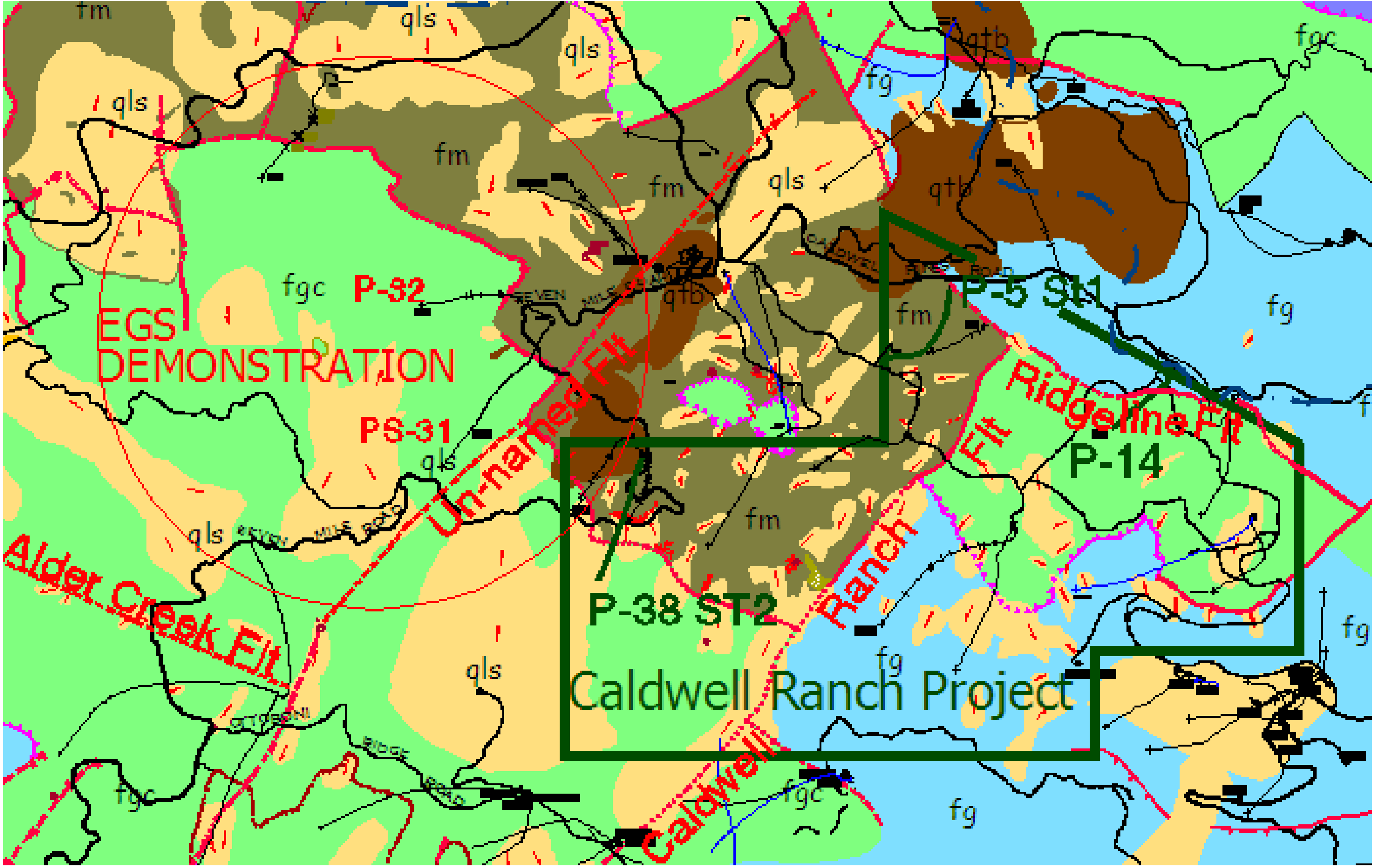
Five Quaternary surface faults mapped on the basis of lithologic discontinuities divide the Northwest Geysers reservoir into compartments separated by hydraulic discontinuities. These are the Mercuryville, Alder Creek, Ridgeline, Un-named and Caldwell Ranch faults which are labeled on the surface geologic map in Figure 9a. These faults are also posted on the contoured NCG maps and oxygen-18 values for the NW Geysers steam condensate maps.

Figure 9a: Surface Geologic Map of Project and Surrounding Area



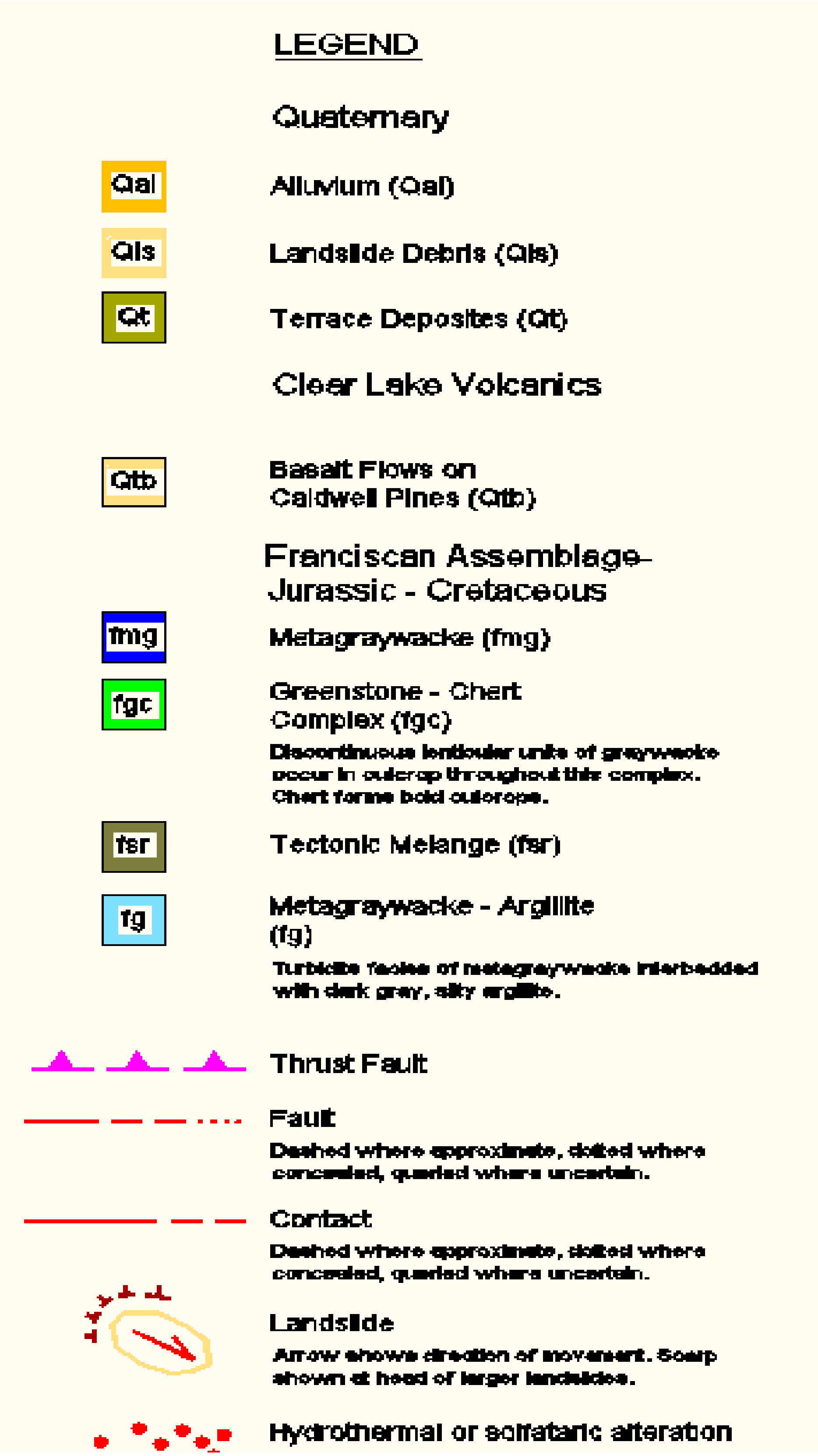
Surface faults which are coincident with hydraulic discontinuities in the reservoir are labeled in red. The hydraulic discontinuity between the EGS Demonstration Area and Caldwell Ranch project pictured in Figure 10 with the yellow dashed line is attributed to the Un-named Fault shown above. See Figure 9c for Geologic Map Legend

Figure 9b: Detailed Geologic Map of Project Area



See Figure 9c for Geologic Map Legend

Figure 9c: Geologic Map Legend



LEGEND

Quaternary

Qal	Alluvium (Qal)
Qls	Landslide Debris (Qls)
Qt	Terrace Deposites (Qt)

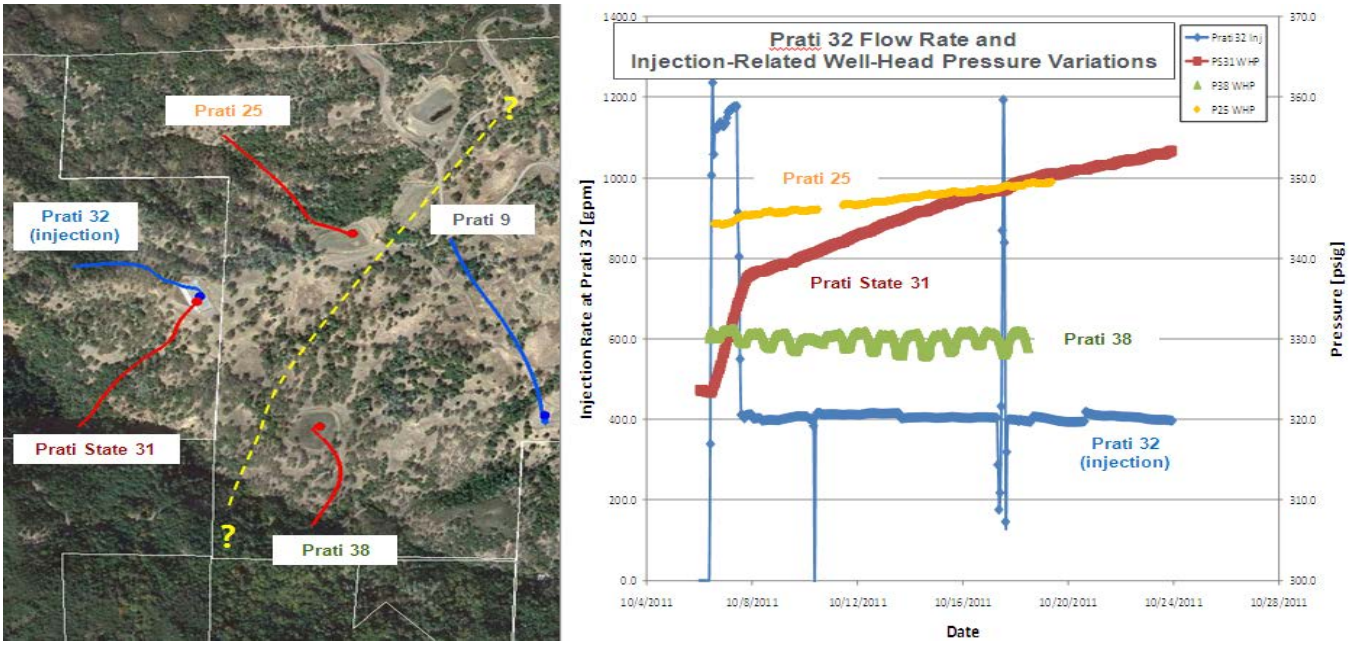
Clear Lake Volcanics

Qtb	Basalt Flows on Caldwell Pines (Qtb)

Franciscan Assemblage-Jurassic - Cretaceous

fmg	Metagraywacke (fmg)
fgc	Greenstone - Chert Complex (fgc) Discontinuous lenticular units of graywacke occur in outcrop throughout this complex. Chert forms bold outcrops.
fsr	Tectonic Melange (fsr)
fg	Metagraywacke - Argillite (fg) Turbidite facies of metagraywacke interbedded with dark grey, silty argillite.
▲ ▲ ▲	Thrust Fault
—— — — · · · ·	Fault Dashed where approximate, dotted where concealed, queried where uncertain.
——— — —	Contact Dashed where approximate, dotted where concealed, queried where uncertain.
	Landslide Arrow shows direction of movement. Scarp shown at head of larger landslides.
● ● ● ● ● ●	Hydrothermal or solfataric alteration

Figure 10: Location of Hydraulic Discontinuity in Reservoir.



Shut-in static wellhead pressure measurements at P-25, Prati State 31 and P-38 St2 during the injection of SRGRP water at P-32. The yellow dashed line in the photograph coincides with a mapped surface fault published in 1991 and a hydraulic discontinuity in the reservoir. The pressure graph for P 38 St2 shows an “oscillating” pressure because the transducer of the data logger was not corrected for diurnal temperature variations.

CHAPTER 4:
Reservoir Confirmation and Assessment of Reservoir Productivity

P-14 went on line to the Unit 11 power plant on October 18, 2011 with an initial flow rate of 82 KPH at 86 PSIG. A subsequent flow rate of 80 KPH at 89 PSIG was measured on January 25, 2012. This compares very well to the pre-production, isochronal flow test results of April 14, 2011 in which a flow rate of 83 KPH at 100 PSIG was calculated.

P-5 St1 went on line to the Unit 11 power plant on January 11, 2012 with an initial flow rate of 78 KPH at 78 PSIG. This compares fairly well to the pre-production isochronal flow test results of August 25, 2011, in which a calculated flow rate of 88 KPH at 100 PSIG was estimated. However by April 2012, the steam flow had increased to 97 KPH at 111 PSIG with an accompanying temperature increase from 348 ^{o}F (176 ^{o}C) to 433 ^{o}F (223 ^{o}C) since January 2012.

The steam production and electrical generation from P-5 St1 and P-14 are given in Table.

After P-5 St1 and P-14 initially started flowing steam to Calpine’s existing Unit 11 power plant, Calpine sent a memorandum to the Energy Commission as an interim step in completing Task 2.4 and Task 2.5 of the Energy Commission Work Agreement for PIR 10-10-060 (Appendix II). This memorandum is based on the increases in megawatt production at Units 11 when P-5 St1 and P-14 went online. An estimate of the increase in Unit 11 power plant output when P-38 St2 comes on line was made using Calpine's TAPS pipeline simulator. Only 1.7 MW megawatts at Units 11 might be attributable to P-38 St2 when it comes on line to Unit 11 as planned because of 50 percent pipeline losses caused by the 15,000′ distance between P-38St2 wellhead and Unit 11 power plant. However, if PS-38 St2 were instead flowed to the proposed Wild Horse Power Plant about 3000 feet from the P-38 St2wellhead, it is anticipated this well would produce about 3.4 MWe. The relatively large difference of producing P-38 St2 to the Wild Horse Power Plant occurs because this proposed generator would be about 12,000 feet closer to P-38 St2 than Unit 11.

As shown in Table 3, the average total production from P-5 St1 and P-14 at Unit 11 is 8 MWe. As discussed above, P-38 St2 might produce 3.4 MW(e) at the proposed Wild Horse power plant which brings the total of available steam which might be produced to the Wild Horse Power Plant to 11.4 to MW(e). This total compares very well to the 12 MW(e) estimated from the isochronal tests discussed previously and substantially confirms the isochronal testing results.

The steam reserves for this Project are reported in electrical units (MWe). However, the Caldwell Ranch project reserves are actually steam (measured in thousands of pounds per hour) which vary with the well's operating pressure. A well's operating pressure is affected by both the pipeline design (distance and diameter to the power plant) and the power plant's electrical generating system. The effect of pipeline design on pressure loss is well known and can be readily estimated, and is a function of the well's steam velocity squared. However, when the Project's steam is piped to an existing, on-line generating system, there are three salient effects on the power plant's electrical generation load: 1) the operating pressure increases as electrical load increases (and this leads to a decrease in offset well production also known as offset well suppression), 2) the steam conversion rate changes as measured by pounds per kilowatt hour, and 3) the back-pressure of the plant changes due to steam thermodynamics and steam impurities. The collective term for the net-effect of this new steam on the electrical load of the power plant is the pipeline interference factor. At The Geysers, pipeline interference will always reduce a new steam well's net effect on the electrical load of the power plant. For example, the actual generation from P-5 St1 and P14 is a combined 8 MWe. However, when including the pipeline interference factor, the incremental reserves from these wells to Unit 11 is actually 5.7 MWe, or 29 percent (1 - 5.7/8). It is important to plan on pipeline interference for a new well as this has significant influence on Project economics.

Table 3: MW produced at Calpine Unit 11 due to P5-St1 and P-14 steam production.

Prati 5 Production Year 1: January 2012 through October 2012					Prati 14 Production Year 1: October 2011 through September 2012			
PDATE	Klbm	Unit 11 Steam Usage Rate Klbm/GMWh	KGMWh		PDATE	Klbm	Unit 11 Steam Usage Rate Klbm/GMWh	KGMWh
Jan-12	37,603	16.3	2.3		Oct-11	24,917	17.9	1.4
Feb-12	53,153	16.3	3.3		Nov-11	57,241	17.5	3.3
Mar-12	62,808	16.3	3.9		Dec-11	56,846	17.0	3.3
Apr-12	66,646	16.4	4.1		Jan-12	57,206	16.3	3.5
May-12	67,743	16.5	4.1		Feb-12	54,829	16.3	3.4
Jun-12	62,086	16.6	3.7		Mar-12	56,096	16.3	3.4
Jul-12	64,830	16.9	3.8		Apr-12	56,490	16.4	3.5
Aug-12	50,302	17.0	3.0		May-12	55,731	16.5	3.4
Sep-12	45,255	16.2	2.8		Jun-12	55,471	16.6	3.3
Oct-12	46,157	16.6	2.8		Jul-12	55,182	16.9	3.3
		Total =	33.7		Aug-12	54,942	17.0	3.2
					Sep-12	55,440	16.2	3.4
							Total =	38.4
	4.78 MW(e) Average Generation					3.20	MW(e) Average Generation	

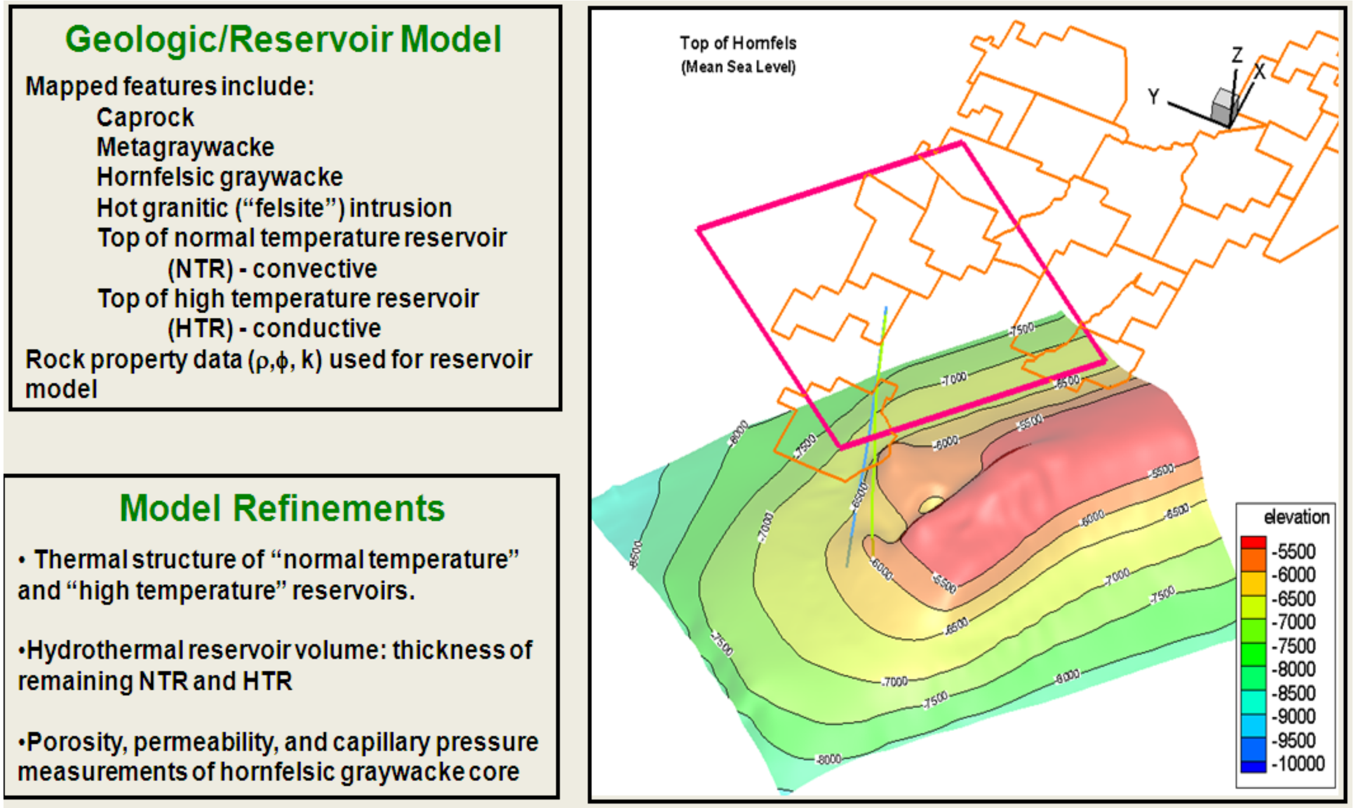
Description of Terms Used in this Table

Pdate = Production Date
Klbm = Kilo pounds mass
Klbm/h = Kilo pounds mass per hour
GMWh = Gross megawatt hours
KGMWh = Kilo gross megawatt hours
MW (e) = Megawatt (electric)

CHAPTER 5:
Reservoir Modeling

Calpine developed an integrated reservoir model (Figure 22) in cooperation with Lawrence Berkeley National Laboratory (LBNL) that includes reservoir boundaries, lithologic surfaces, the normal temperature (NTR) and high temperature reservoir (HTR), and rock properties including porosity and permeability during Phase 1 of the Caldwell Ranch Exploration and Confirmation project. This model was updated with information and data collected during Phase 2 of the Caldwell Ranch project which will inform the future re-development activities of the geothermal leases within the Caldwell Ranch Project area.

Figure 11: Calpine Geologic Reservoir Model of Northwest Geysers



Geologic/Reservoir Model

Mapped features include:
- Caprock
- Metagraywacke
- Hornfelsic graywacke
- Hot granitic ("felsite") intrusion
- Top of normal temperature reservoir (NTR) - convective
- Top of high temperature reservoir (HTR) - conductive

Rock property data (ρ,ϕ, k) used for reservoir model

Model Refinements

- Thermal structure of "normal temperature" and "high temperature" reservoirs.
- Hydrothermal reservoir volume: thickness of remaining NTR and HTR
- Porosity, permeability, and capillary pressure measurements of hornfelsic graywacke core

The geologic/reservoir model area covers most of the Northwest Geysers including the Caldwell Ranch project. Here the hornfelsic graywacke surface is shown. Other geologic surfaces include the metagraywacke reservoir rock, the top of the NTR and HTR reservoirs and their respective reservoir volumes, and rock properties. The blue line between the surface shown in the red rectangle, and the hornfels below, locates Prati State 31 (also shown in Figure 1b) which is west of the Caldwell Ranch project area.

5.1 Innovative Technology

Although the use of whole-rock isotopes for geothermal exploration is not new (Taylor, 1967), and the zoning of whole-rock isotopes has had limited use in exploring geothermal systems around the world, this project takes the innovative step of combining whole-rock isotope analyses with temperature logs to define the three-dimensional (3-D) hydrothermal reservoir volume in the Caldwell Ranch project area as well as the hot dry rock system in the EGS Demonstration Area (Moore and Walters, 2012, Lutz and others, 2012, and Borgia and others, 2013).

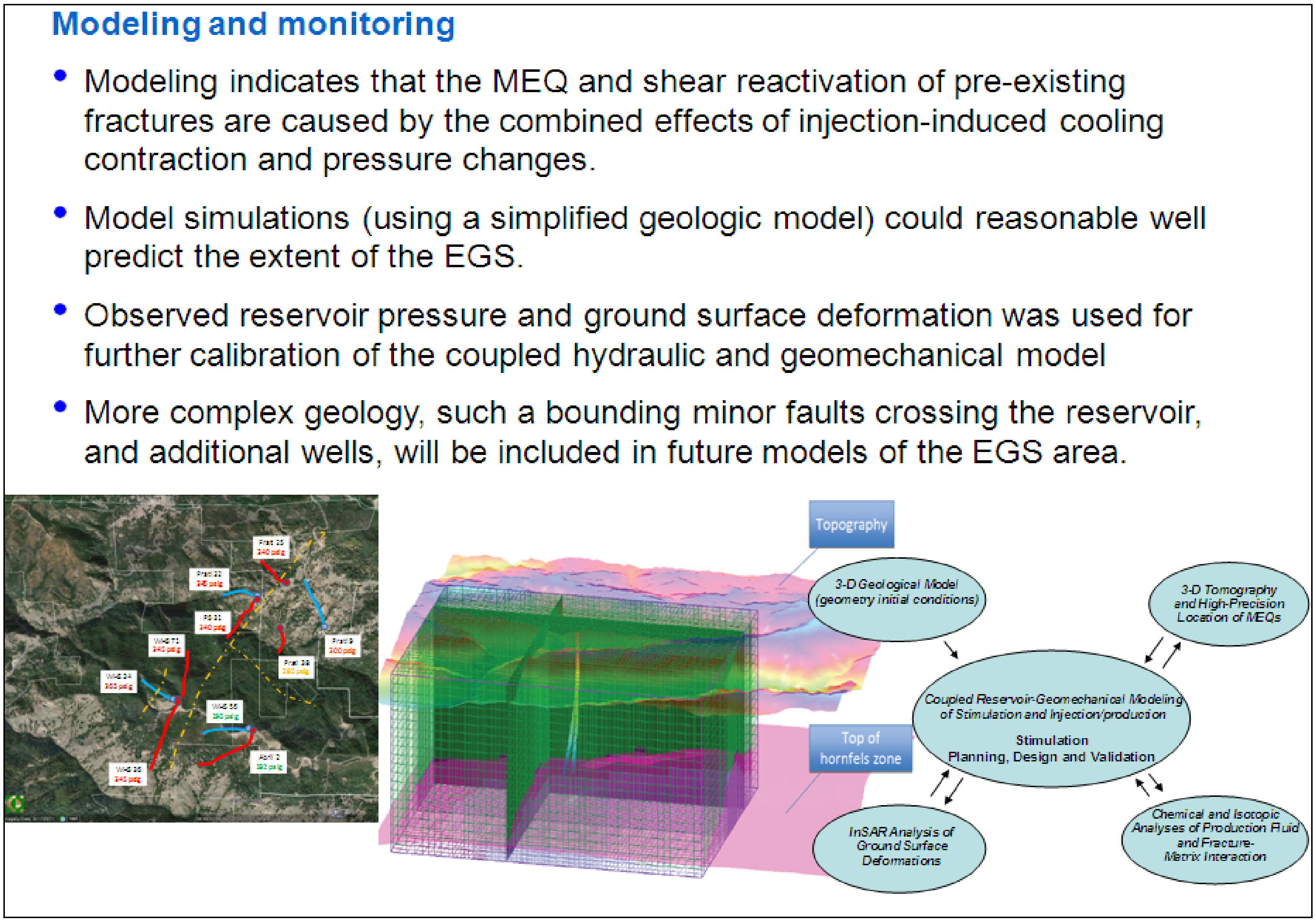
Just as a hydrothermal ore deposition requires more than the nearby presence of a hot magma, a viable geothermal resource requires more than a heat source. Hot geothermal exploratory wells have been drilled in the Geysers-Clear Lake Known Geothermal Resource Area (KGRA) where temperatures were adequate for geothermal production but fluids and/or permeability were not adequate. Isotopic analyses of produced fluids and the whole-rock formation samples associated with them allow us to interpret the origin of geothermal fluids and, even more important, indicate whether or not an exchange of oxygen-18 isotope between water and rock has occurred. As in hydrothermal ore deposits, the degree of rock alteration by meteoric water known as "ground preparation" is also important to the development of hydrothermal geothermal systems. Therefore the viability of a geothermal resource requires a meteoric water source and rocks which have exchanged oxygen-18 with the meteoric water (Craig, 1963). Calpine believes the isotopic methods and technology used for exploring this project are universally applicable to hydrothermal reservoirs and substantially lower the risk of developing a geothermal reservoir which might lack a sufficient hydrothermal reservoir volume to sustain production at an electrical generator.

The isotopic sections in Appendix G which are mapped as A-A′ and B-B′ graphically show the extent and thickness of the hydrothermal and hot dry rock reservoir. Additionally, there is brief discussion of each whole-rock isotopic section. The isotopic sections show that the reservoir in the western half of the Caldwell Ranch project is a weakly developed hydrothermal system whereas the eastern half of the project area is typical of the well-developed hydrothermal system found throughout the core of The Geysers steam field.

5.2 LBNL Geomechanical Modeling

A geomechanical model is under development by the LBNL for the EGS Demonstration area and includes the northwest portion of the Caldwell Ranch project. The Un-Named Fault is being incorporated into this EGS model to define the location of the hydraulic discontinuity between the P-38 St2 well and the EGS Demonstration wells. The Un-Named Fault is a minor fault and part of the complex geology which crosses the EGS Demonstration area. It and the simplified geologic model shown in Figure 11 are included in the bulleted items shown in Figure 12 below.

Figure 12: Elements of LBNL Geomechanical Modeling in the EGS and Caldwell Ranch Project Areas.



Modeling and monitoring

- Modeling indicates that the MEQ and shear reactivation of pre-existing fractures are caused by the combined effects of injection-induced cooling contraction and pressure changes.
- Model simulations (using a simplified geologic model) could reasonable well predict the extent of the EGS.
- Observed reservoir pressure and ground surface deformation was used for further calibration of the coupled hydraulic and geomechanical model
- More complex geology, such a bounding minor faults crossing the reservoir, and additional wells, will be included in future models of the EGS area.

Geomechanical model for EGS Demonstration Project and Caldwell Ranch Project areas presented at Geothermal Resources Council Workshop September 29, 2012, Reno, NV.

Dr. Julio Garcia of Calpine continues to work with Dr. Jonny Rutqvist and others at LBNL to revise and update both the LBNL geomechanical model and Calpine's reservoir model for the EGS Demonstration project. As shown in Figure 12, the data from the Caldwell Ranch project are being incorporated into the geomechanical model which is anticipated to be complete in 2013. An update on LBNL's geomechanical reservoir model will be presented to the 2013 European Geophysical Union meeting (Borgia and others, 2013).

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GLOSSARY OF ACRONYMS

Acronym/Abbreviation	Original Term
"	Inch
′	Feet
°C	Degrees Celsius
°F	Degrees Fahrenheit
^{18}O	Oxygen-18 isotope
bbl	Barrel
bph	Barrels per hour
Calpine	Geysers Power Company, LLC
CCPA	Central California Power Agency
Cl	Chloride
DHS	Downhole sampler
DOGGR	Division of Oil, Gas and Geothermal Resources
DP	Differential pressure
EGI	Energy Geoscience Institute
EGS	Enhanced Geothermal System
Energy Commission	California Energy Commission
Fpm	Feet per minute
FTEs	Full time equivalents
GTP	Geothermal Technologies Program
H_2S	Hydrogen sulfide
HCl	Hydrochloric acid
hornfels	Biotite hornfels
HTR	High temperature reservoir
HTZ	High temperature zone
IDS	Injection-derived steam
KGMWh	Kilo (thousands) gross megawatt hours
KGRA	Known Geothermal Resource Area designated by USGS
kH	Permeability thickness product
Klbm	Kilo (thousands) pounds mass
KPH	Kilo pounds per hour
LBNL	Lawrence Berkeley National Laboratory
Ma	Millions of years, absolute
md-ft	Millidarcy-feet
mil	thousand
MPa	Megapascal, a unit of pressure equal to one million newtons per square meter
MRT	Maximum reading thermometer
MW	Megawatt
MWe	Megawatts, electric
N_2	Nitrogen
NCG	Noncondensable gas (includes carbon dioxide and hydrogen sulfide)
NCGC	Noncondensable gas concentration
NGDB	National Geothermal Data Base

NH_3	Ammonia
NH_4Cl	Ammonium chloride
NTR	Normal temperature reservoir
NW Geysers	Northwest Geysers
OH	Hydroxide
P*	Maximum shut-in wellhead pressure
P-25	Prati 25
P-32	Prati 32
P-38 St2	Prati 38 Sidetrack 2
P-5	Prati 5
P-5 St1	Prati 5 Sidetrack 1
P-9	Prati 9
PI	Calpine Production Information System
PIER	Public Interest Energy Research
PPA	Power Purchase Agreement
Ppmw	Parts per million by weight
PS-31	Prati State 31
psi	Pounds per square inch
PSIG	Pound-force per square inch gauge
PT	Pressure-Temperature
PTS	Pressure-temperature-spinner log
Ra	Present atmospheric ratio of 3He/4He (He = helium)
RPM	Revolutions per minute
SH	Superheat
SIWHP	Shut-in wellhead pressure
SMOW	Standard Mean Ocean Water
SOPO	Statement of Proposed Objectives
SRGRP	Santa Rosa Geysers Recharge Project
St	Sidetrack
TAPS	Tetrad and PIPES Simulator
TD	Total depth
TNCG	Total noncondensable gas
TOS	Top of steam
U.S. DOE	United States Department of Energy
USGS	United States Geological Survey
WHP	Wellhead pressure
WHT	Wellhead temperature
Wt%	Weight as a percentage of the total
ybp	Years before present
$\delta^{18}O$	Concentration of ^{18}O relative to SMOW in del notation
δ D (18)	Concentration of deuterium ("D") relative to SMOW in del notation

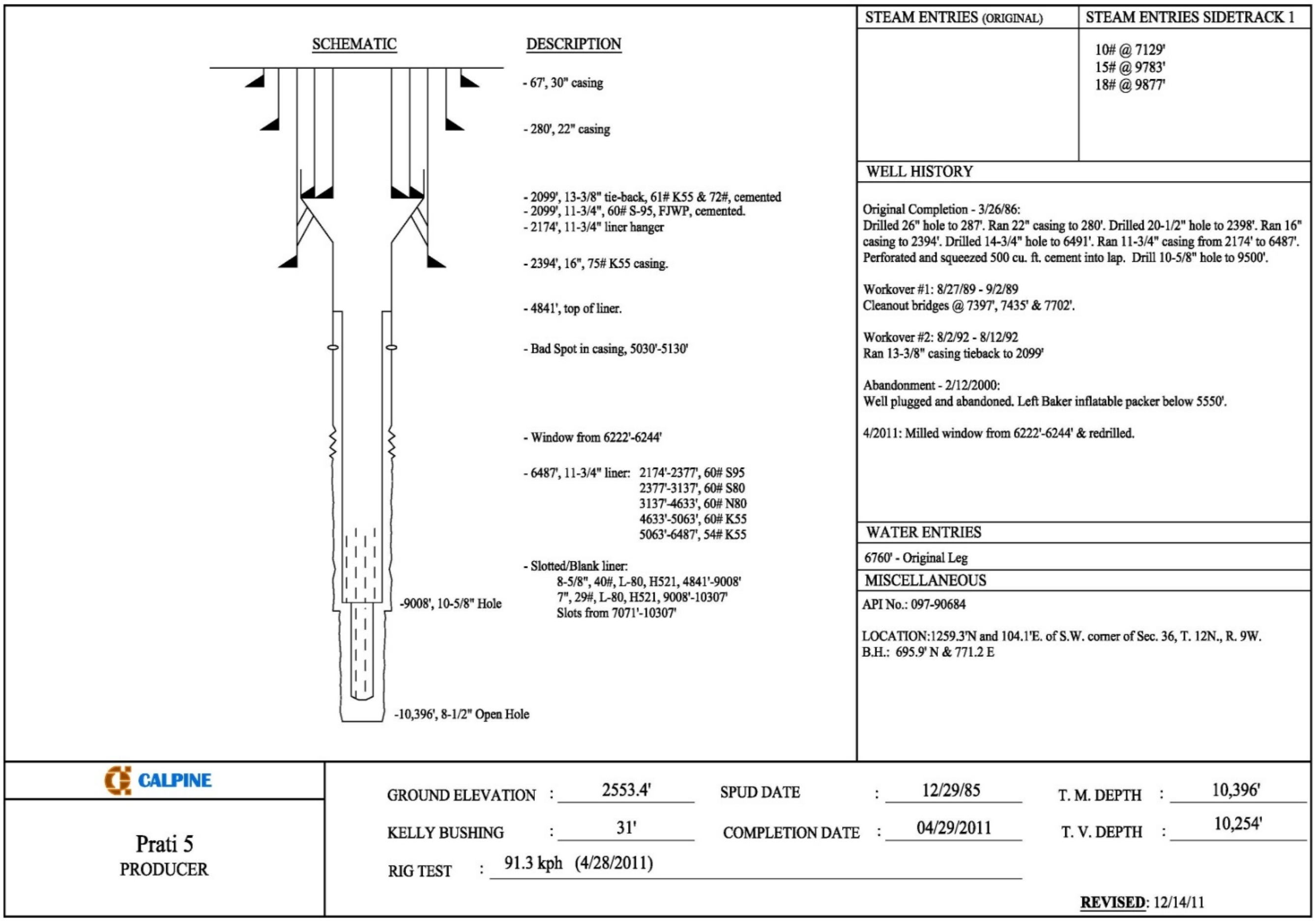
APPENDIX A

WELL COMPLETION SCHEMATICS

Prati 5 St1

Prati 14

Prati 38 St2



SCHEMATIC

DESCRIPTION

- 67', 30" casing
- 280', 22" casing
- 2099', 13-3/8" tie-back, 61# K55 & 72#, cemented
- 2099', 11-3/4", 60# S-95, FJWP, cemented.
- 2174', 11-3/4" liner hanger
- 2394', 16", 75# K55 casing.
- 4841', top of liner.
- Bad Spot in casing, 5030'-5130'
- Window from 6222'-6244'
- 6487', 11-3/4" liner: 2174'-2377', 60# S95
  - 2377'-3137', 60# S80
  - 3137'-4633', 60# N80
  - 4633'-5063', 60# K55
  - 5063'-6487', 54# K55
- Slotted/Blank liner:
  - 8-5/8", 40#, L-80, H521, 4841'-9008'
  - 7", 29#, L-80, H521, 9008'-10307'
  - Slots from 7071'-10307'

-9008', 10-5/8" Hole

-10,396', 8-1/2" Open Hole

STEAM ENTRIES (ORIGINAL)	STEAM ENTRIES SIDETRACK 1
	10# @ 7129' 15# @ 9783' 18# @ 9877'

WELL HISTORY

Original Completion - 3/26/86:
Drilled 26" hole to 287'. Ran 22" casing to 280'. Drilled 20-1/2" hole to 2398'. Ran 16" casing to 2394'. Drilled 14-3/4" hole to 6491'. Ran 11-3/4" casing from 2174' to 6487'. Perforated and squeezed 500 cu. ft. cement into lap. Drill 10-5/8" hole to 9500'.

Workover #1: 8/27/89 - 9/2/89
Cleanout bridges @ 7397', 7435' & 7702'.

Workover #2: 8/2/92 - 8/12/92
Ran 13-3/8" casing tieback to 2099'

Abandonment - 2/12/2000:
Well plugged and abandoned. Left Baker inflatable packer below 5550'.

4/2011: Milled window from 6222'-6244' & redrilled.

WATER ENTRIES

6760' - Original Leg

MISCELLANEOUS

API No.: 097-90684

LOCATION:1259.3'N and 104.1'E. of S.W. corner of Sec. 36, T. 12N., R. 9W.
B.H.: 695.9' N & 771.2 E

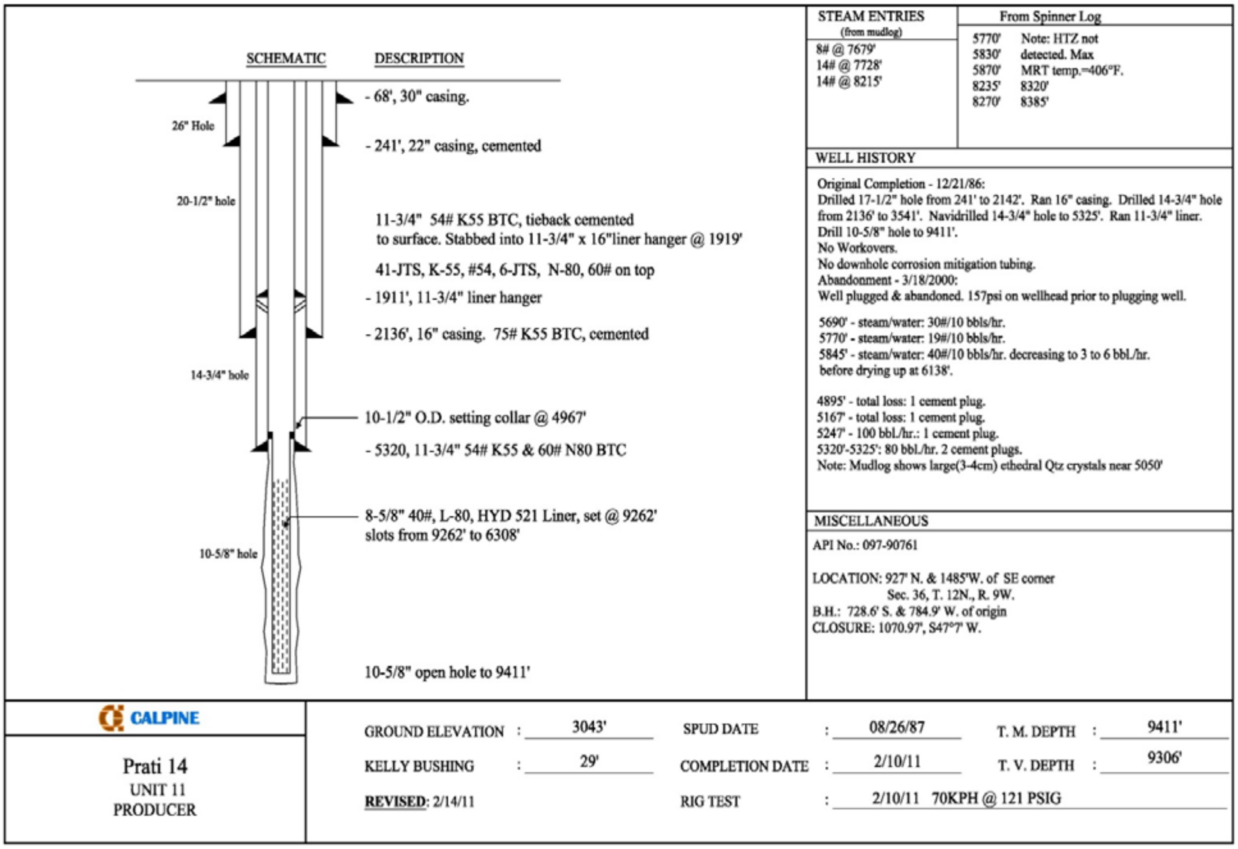
CALPINE

Prati 5
PRODUCER

GROUND ELEVATION : 2553.4'
SPUD DATE : 12/29/85
T. M. DEPTH : 10,396'
KELLY BUSHING : 31'
COMPLETION DATE : 04/29/2011
T. V. DEPTH : 10,254'
RIG TEST : 91.3 kph (4/28/2011)

REVISED: 12/14/11

Prati 5 Well Schematic shown after sidetracking and recompletion as Prati 5 Sidetrack1.



DESCRIPTION

- 68', 30" casing.

- 241', 22" casing, cemented

11-3/4" 54# K55 BTC, tieback cemented
to surface. Stabbed into 11-3/4" x 16"liner hanger @ 1919'

41-JTS, K-55, #54, 6-JTS, N-80, 60# on top

- 1911', 11-3/4" liner hanger

- 2136', 16" casing. 75# K55 BTC, cemented

10-1/2" O.D. setting collar @ 4967'

- 5320, 11-3/4" 54# K55 & 60# N80 BTC

8-5/8" 40#, L-80, HYD 521 Liner, set @ 9262'
slots from 9262' to 6308'

10-5/8" open hole to 9411'

STEAM ENTRIES (from mudlog)	From Spinner Log	
8# @ 7679'	5770'	Note: HTZ not
14# @ 7728'	5830'	detected. Max
14# @ 8215'	5870'	MRT temp.=406°F.
	8235'	8320'
	8270'	8385'

WELL HISTORY

Original Completion - 12/21/86:
Drilled 17-1/2" hole from 241' to 2142'. Ran 16" casing. Drilled 14-3/4" hole from 2136' to 3541'. Navidrilled 14-3/4" hole to 5325'. Ran 11-3/4" liner.
Drill 10-5/8" hole to 9411'.
No Workovers.
No downhole corrosion mitigation tubing.
Abandonment - 3/18/2000:
Well plugged & abandoned. 157psi on wellhead prior to plugging well.

5690' - steam/water: 30#/10 bbls/hr.
5770' - steam/water: 19#/10 bbls/hr.
5845' - steam/water: 40#/10 bbls/hr. decreasing to 3 to 6 bbl./hr.
before drying up at 6138'.

4895' - total loss: 1 cement plug.
5167' - total loss: 1 cement plug.
5247' - 100 bbl./hr.: 1 cement plug.
5320'-5325': 80 bbl./hr. 2 cement plugs.
Note: Mudlog shows large(3-4cm) ethedral Qtz crystals near 5050'

MISCELLANEOUS

API No.: 097-90761

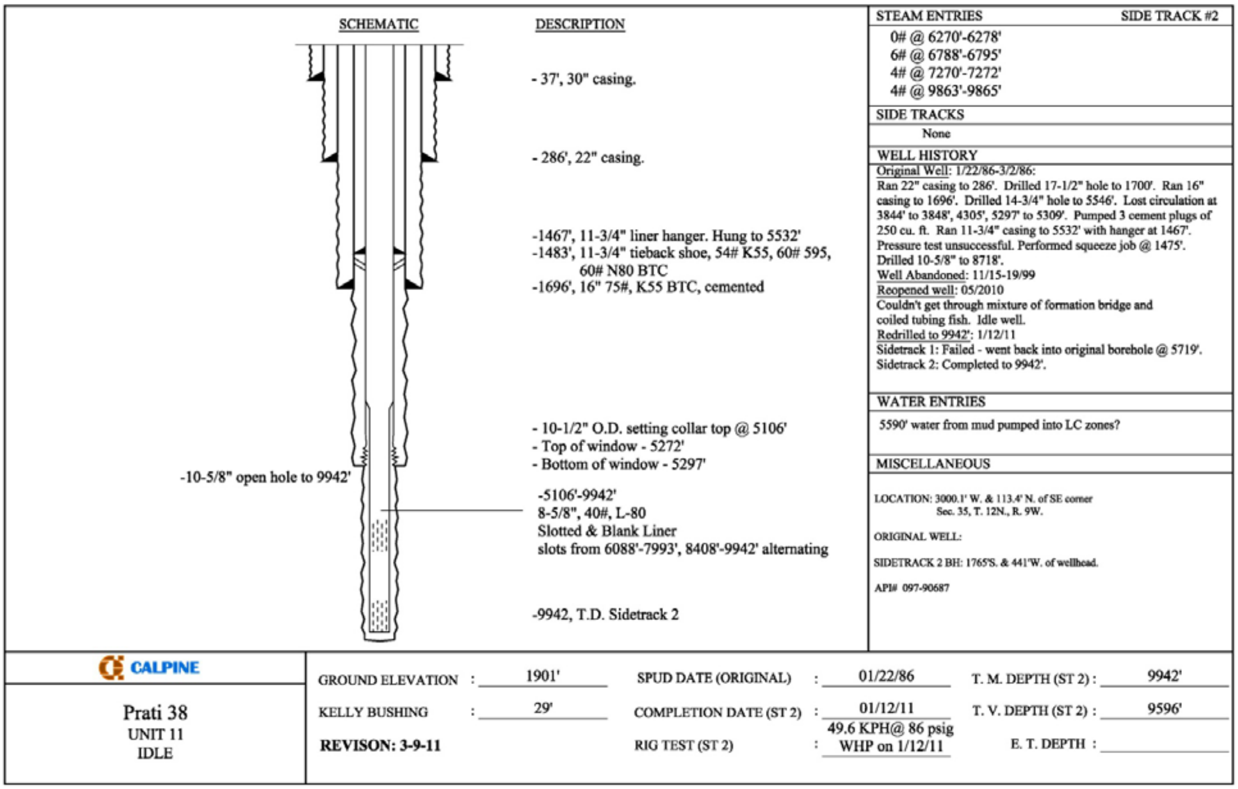
LOCATION: 927' N. & 1485'W. of SE corner
Sec. 36, T. 12N., R. 9W.
B.H.: 728.6' S. & 784.9' W. of origin
CLOSURE: 1070.97', S47°7' W.

CALPINE

Prati 14
UNIT 11
PRODUCER

GROUND ELEVATION :	3043'	SPUD DATE :	08/26/87	T. M. DEPTH :	9411'
KELLY BUSHING :	29'	COMPLETION DATE :	2/10/11	T. V. DEPTH :	9306'
REVISED: 2/14/11		RIG TEST :	2/10/11 70KPH @ 121 PSIG		

Prati 14 after re-opening and re-completion.



SCHEMATIC

DESCRIPTION

- 37', 30" casing.

- 286', 22" casing.

-1467', 11-3/4" liner hanger. Hung to 5532'
-1483', 11-3/4" tieback shoe, 54# K55, 60# 595, 60# N80 BTC
-1696', 16" 75#, K55 BTC, cemented

- 10-1/2" O.D. setting collar top @ 5106'
- Top of window - 5272'
- Bottom of window - 5297'

-10-5/8" open hole to 9942'

-5106'-9942'
8-5/8", 40#, L-80
Slotted & Blank Liner
slots from 6088'-7993', 8408'-9942' alternating

-9942, T.D. Sidetrack 2

STEAM ENTRIES — SIDE TRACK #2

0# @ 6270'-6278'
6# @ 6788'-6795'
4# @ 7270'-7272'
4# @ 9863'-9865'

SIDE TRACKS

None

WELL HISTORY

Original Well: 1/22/86-3/2/86:
Ran 22" casing to 286'. Drilled 17-1/2" hole to 1700'. Ran 16" casing to 1696'. Drilled 14-3/4" hole to 5546'. Lost circulation at 3844' to 3848', 4305', 5297' to 5309'. Pumped 3 cement plugs of 250 cu. ft. Ran 11-3/4" casing to 5532' with hanger at 1467'. Pressure test unsuccessful. Performed squeeze job @ 1475'. Drilled 10-5/8" to 8718'.
Well Abandoned: 11/15-19/99
Reopened well: 05/2010
Couldn't get through mixture of formation bridge and coiled tubing fish. Idle well.
Redrilled to 9942': 1/12/11
Sidetrack 1: Failed - went back into original borehole @ 5719'.
Sidetrack 2: Completed to 9942'.

WATER ENTRIES

5590' water from mud pumped into LC zones?

MISCELLANEOUS

LOCATION: 3000.1' W. & 113.4' N. of SE corner
Sec. 35, T. 12N., R. 9W.

ORIGINAL WELL:

SIDETRACK 2 BH: 1765'S. & 441'W. of wellhead.

API# 097-90687

CALPINE

Prati 38
UNIT 11
IDLE

GROUND ELEVATION : 1901'
KELLY BUSHING : 29'
REVISON: 3-9-11

SPUD DATE (ORIGINAL) : 01/22/86
COMPLETION DATE (ST 2) : 01/12/11
RIG TEST (ST 2) : 49.6 KPH@ 86 psig WHP on 1/12/11

T. M. DEPTH (ST 2) : 9942'
T. V. DEPTH (ST 2) : 9596'
E. T. DEPTH :

Prati 38 Well Schematic shown after sidetracking and recompletion as Prati 38 Sidetrack 2.

APPENDIX B

WELL TESTING

Isochronal Testing

Prati 5 St1

Prati 14

Prati 38 St2

Memorandum to John Hingtgen of the CA Energy Commission

Energy Commission ARRA Grant: Data Integration, Data Validation, and Resource Assessment

Prati-5 St1: Isochronal Test August 22 to 25, 2011

SUMMARY

Prati-5st1 (P-5 St1) was isochronally tested using an 8″ orifice during 8/22-25/11 as shown in Figure 2. A chronology of events for P-5st1 is presented in Table 1. This well produced 85 kph of superheated steam at a WHP and WHT of 120 psig and 372°F respectively at the end of the 24 hour flow period on 8/25/11. An analysis of this isochronal test provided an exponent "n" of 0.545 as presented in Figure 3. The steam flow of P-5st1, normalized at 100 psig WHP, is calculated to be 88 kph. This flow rate is close to the 91 kph estimated from the wet test on 4/29/11 as given in Table 1. Shut-in WHP data of P-5st1 collected from 5/4 to 6/23/11 is shown in Figure 4. Data from Tecton's data logger, presented in this figure, shows that P-5st1 achieved a maximum WHP of 311 psig during 5/19 to 6/9/11. A shut-in WHP (P*) of 309.4 psig was estimated using a Horner Plot based on the post isochronal pressure buildup shown in Figure 5. This value is close to 311 psig of Figure 4. A kh value of 64,330 md-ft was estimated for this well using the slope from the Horner plot in Figure 5. P-5st1 was found to be in good pressure communication with Prati-4. Prati-4 WHP dropped by 4.5 psi during the 30+ hour flow of P-5st1 on 8/24-25/11as shown in Figure 6.

DISCUSSION

P-5st1 was completed on 4/29/2011 to a TD of 10,396′. A schematic of this well is shown in Figure 1. An 11-3/4″ tieback casing was installed and cemented from surface to 2,099′ after cleaning out two top cement plugs. Packer and coiled tubing fell in the hole during subsequent drilling operation. Some of the fish was recovered. However, high hook loads were encountered during milling of the 1-1/4″ coiled tubing in the open hole below the casing shoe at 6,487′bacause of the tubing caught between the mill and the wellbore. This led to the side tracking of this well.

A side track was drilled by cutting a 25′ window from 6,219′ to 6,244′ in the existing 11-3/4″ liner. Thereafter, a 10-5/8″ open hole was drilled to 9,008′. The hole size was reduced to 8-1/2″ from 9,008′ to 10,396′ (TD). A 5′ core was retrieved from 9,940′ to 9,945′. A combination of 8-5/8″ and 7″ slotted/ blank liner was installed from 4,841′ to 10, 307′ as shown in Figure 1. A wet test, conducted on 4/29/11 at TD, indicated steam flow rate of 91 kph as presented in Table 1.

A static P/T survey was run in to P-5st1 on 8/9/11 from surface to 7,190′ at 50 feet per minute (fpm) due to an obstruction encountered at 7,190′. A maximum temperature and pressure of 504°F and 339 psig were measured at a depth of 7,170′. Subsequently the temperature dropped to 437°F (339 psig) at a depth of 7,120′ due to cooler steam entry at 7,129′. The obstruction consisting of silica scale was cleaned out on 8/15/11 by a bridge busting tool and venting.

A P/T/S survey was run on 8/23/11 from surface to 10,274′ when the well was flowing 83 kph at 142 psig WHP. At bottom (10,274′), a temperature and pressure of 558°F and 279 psig were recorded. A maximum temperature of 597°F was recorded at 9,847′ (depth of the deepest steam entry) along with a pressure of 275 psig (J.J. Beall e-mail of 8/24/11).

The isochronal test of P-5st1 started on 8/22/11 with an orifice of 8″ ID and choke of 3.5″. The well produced saturated steam for 8 hours from 11 am to 7 pm. The choke size was changed to 4″ and 4.5″ on subsequent days. The data of the entire test is graphically shown in Figure 2. Duplicate readings for pressure, temperature and the DP point were taken using Calpine and Tecton instruments. These readings were quite close to each other as shown in this figure, suggesting all instruments worked well. The pressure and flow rate data at the end of three 8-hour tests are plotted in Figure 3. The slope of the line in this figure provides a value of 0.545 for the exponent "n". At the end of 24 hours flow, P-5st1 produced 85 kph of superheated steam at 120 psig and 372°F as given in Table 1. This is equivalent to a steam flow rate of 88 kph normalized at 100 psig.

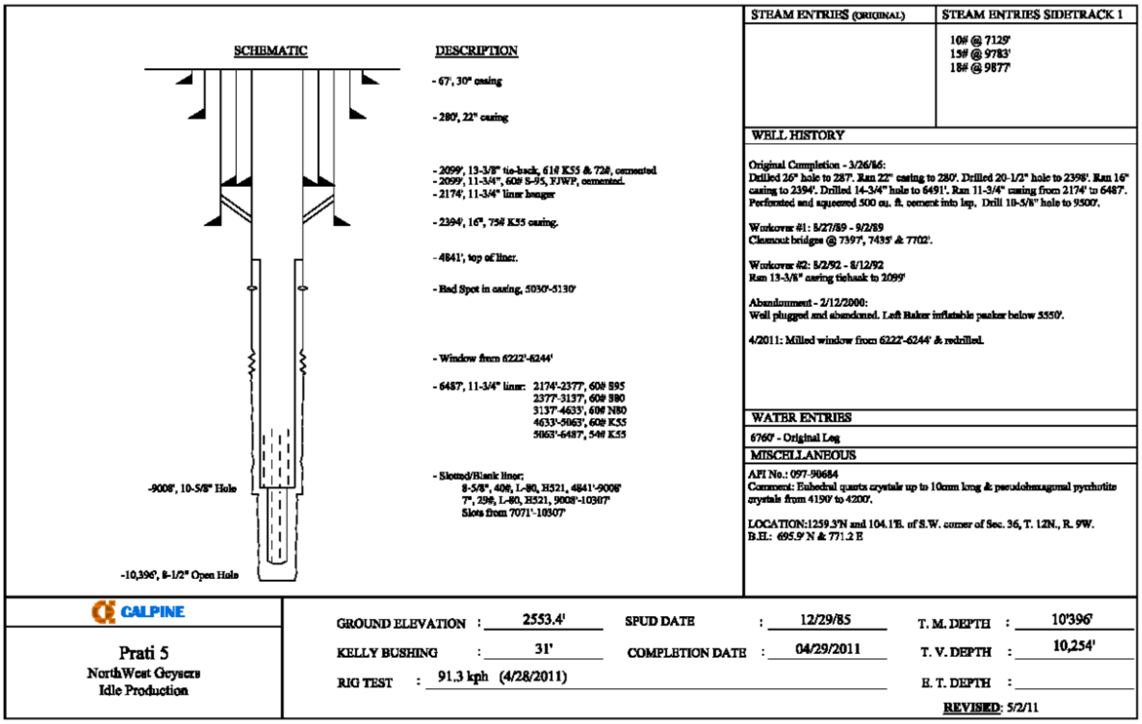
Shut-in WHP (SIWHP) data from two data loggers (Tecton and Calpine) were collected from 5/4 to 6/23/11 as shown in Figure 4. This figure shows that the Tecton data logger had relatively stable WHP readings and that P-5st1reached a maximum WHP of 311 psig.

A shut-in WHP (P*) of 309.4 psig was estimated using a Horner Plot based on the post isochronal pressure buildup data as shown in Figure 5. This value is close to 311 psig shown in Figure 4. A kh value of 64,330 md-ft was estimated for this well using the slope from the Horner plot (Figure 5).

Pressure interference data were collected for the nearby well Prati-4. P-5st1 was found to be in good pressure communication with Prati-4 as shown in Figure 6. Prati-4 displayed a drop of 4.5 psi during the 30+ hour flow on 8/24-25/11.

Table 1: Prati-5St1 Testing Chronology

				Elevation	2553.4	Patm =	13.42		
Date	**Flow Rate kph**	**WHP psig**	**WHT F**	**Comments**	**Sat Temp °F**	**Normalized Flow (kph) at 100 psig**	**SH °F**	**DP psid**	**Enthalpy Btu/lbm**
3/15/2011	41.6	125.0	352.9	Rig test (3"choke) at TD 9,500 ft from 12:05 to 16:05 hrs. Wet Test = 36.9 kph	352.2		0.7		1,193.7
				MaxSIWHP = 279.8 psig. Due coiled tubing problems, plugged old hole & drilled					
4/29/2011				St1. Completed to TD = 10,396'. WT = 91.3 kph after liner (8-5/8" & 7") from 4841 to					
				10,307'. SIWHP ~311 psig based on SIWHP from 5/4/11 to 6/9/11					
8/9/2011				Ran static P/T survey from surface to 7,200'. Bridge at 7,190' from wet steam at					
				7,129'.Maximum temperature & pressure 504F and 339 psig at 7,170'. Temp drops					
				to 437 F at 7,120' due to cooler wet entry at 7,129'.					
8/15/2011				Removed the bridge at 7,190' by bridge busting tool and venting.					
8/19/2011				Ran casing caliper log from 4775' to surface.					
8/22/2011	77.1	172.0	378.2	Day-1, Iso. test (11 am - 7 pm). Orifice = 8", choke = 3.5", SIWHP = 306.5 psig	375.5		2.7	2.557	1,199.6
8/23/2011	83.0	141.9	370.3	Day-2, Iso. test (11 am - 7 pm). Orifice = 8", choke = 4", SIWHP = 304.3 psig	361.2		9.1	3.564	1,200.9
				Ran P/T/S from surface to 10,274' (558F & 279 psig). Max at 9,847' (597F & 275					
				psig- steam entry per spinner). Collected 2 downhole samples from 12:20 pm to					
				7:45 pm 9,700' (sample#1) & 8,800' (sample#2).					
8/24/2011	85.3	119.9	372.2	Day-3, Iso. test (11 am - 11 am). Orifice = 8", choke = 4.5", SIWHP = 302.6 psig	349.3		23.0	4.472	1,206.6
8/25/2011	85.1	120.3	394.3	Day-4, 5:45 pm shut-in. n= 0.545, kh =64,330 md-ft	349.5	**87.7**	44.9	4.579	1,219.2



DESCRIPTION

- 67', 30" casing
- 280', 22" casing
- 2099', 13-3/8" tie-back, 61# K55 & 72#, cemented
- 2099', 11-3/4", 60# S-95, FJWP, cemented.
- 2174', 11-3/4" liner hanger
- 2394', 16", 75# K55 casing.
- 4841', top of liner.
- Bad Spot in casing, 5030'-5130'
- Window from 6222'-6244'
- 6487', 11-3/4" liner: 2174'-2377', 60# S95
  2377'-3137', 60# S80
  3137'-4633', 60# N80
  4633'-5063', 60# K55
  5063'-6487', 54# K55
- Slotted/Blank liner;
  8-5/8", 40#, L-80, H521, 4841'-9008'
  7", 29#, L-80, H521, 9008'-10307'
  Slots from 7071'-10307'

STEAM ENTRIES (ORIGINAL)	STEAM ENTRIES SIDETRACK 1
	10# @ 7129' 15# @ 9783' 18# @ 9877'

WELL HISTORY

Original Completion - 3/26/86:
Drilled 26" hole to 287'. Ran 22" casing to 280'. Drilled 20-1/2" hole to 2398'. Ran 16" casing to 2394'. Drilled 14-3/4" hole to 6491'. Ran 11-3/4" casing from 2174' to 6487'. Perforated and squeezed 500 cu. ft. cement into lap. Drill 10-5/8" hole to 9500'.

Workover #1: 8/27/89 - 9/2/89
Cleanout bridges @ 7397', 7435' & 7702'.

Workover #2: 8/2/92 - 8/12/92
Ran 13-3/8" casing tieback to 2099'

Abandonment - 2/12/2000:
Well plugged and abandoned. Left Baker inflatable packer below 5550'.

4/2011: Milled window from 6222'-6244' & redrilled.

WATER ENTRIES

6760' - Original Log

MISCELLANEOUS

API No.: 097-90684
Comment: Euhedral quartz crystals up to 10mm long & pseudohexagonal pyrrhotite crystals from 4190' to 4200'.

LOCATION:1259.3'N and 104.1'E. of S.W. corner of Sec. 36, T. 12N., R. 9W.
B.H.: 695.9' N & 771.2 E

CALPINE

Prati 5
NorthWest Geysers
Idle Production

GROUND ELEVATION : 2553.4'
KELLY BUSHING : 31'
RIG TEST : 91.3 kph (4/28/2011)
SPUD DATE : 12/29/85
COMPLETION DATE : 04/29/2011
T. M. DEPTH : 10'396'
T. V. DEPTH : 10,254'
E. T. DEPTH :

REVISED: 5/2/11

Figure 1: Schematic of Prati-5st1

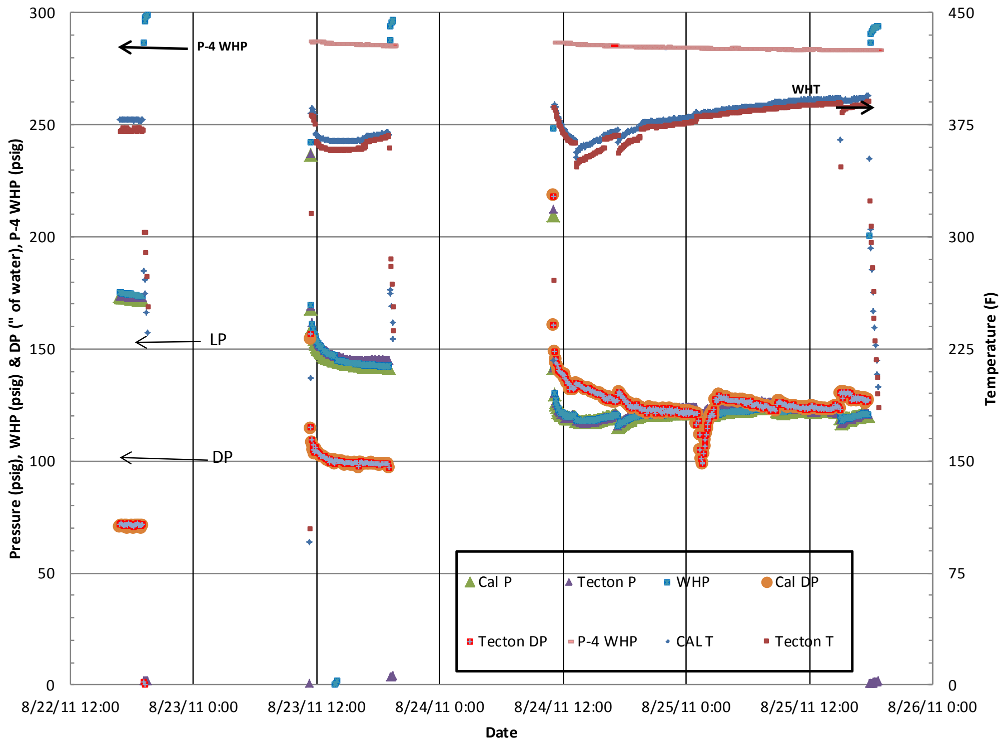


Figure 2: Prati-5 st1 Isochronal test

Figure 3: Prati-5st1 Isochronal Test (8/22-24/11)

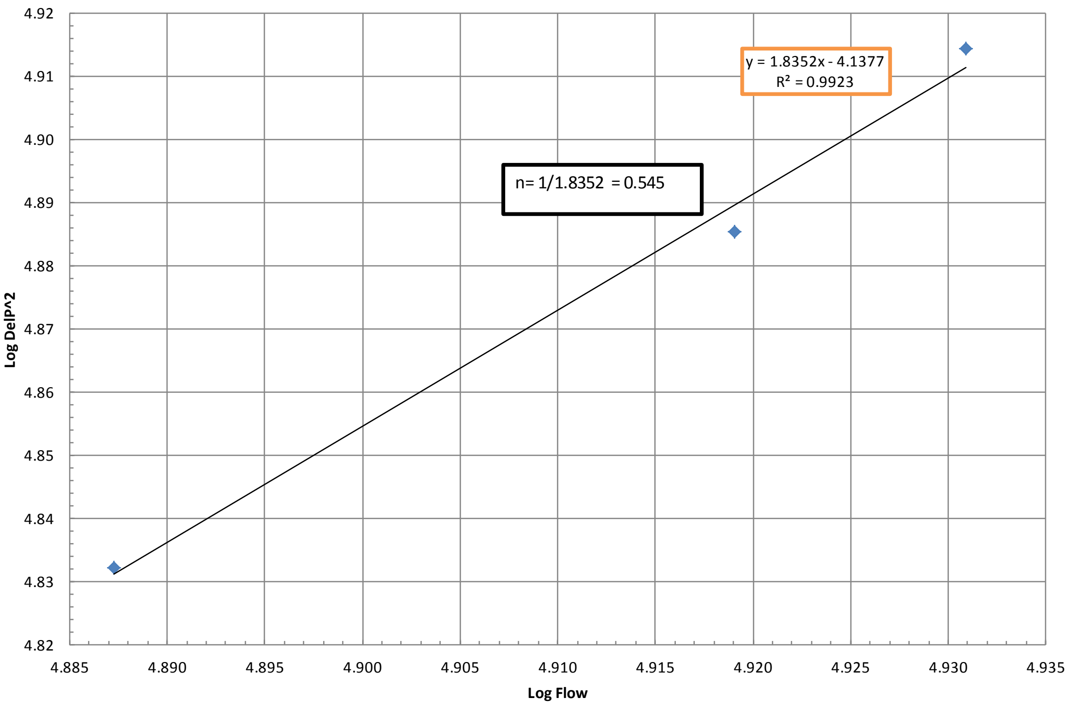


Figure 4: Prati-5 SIWHP 5/4 to 6/23/11

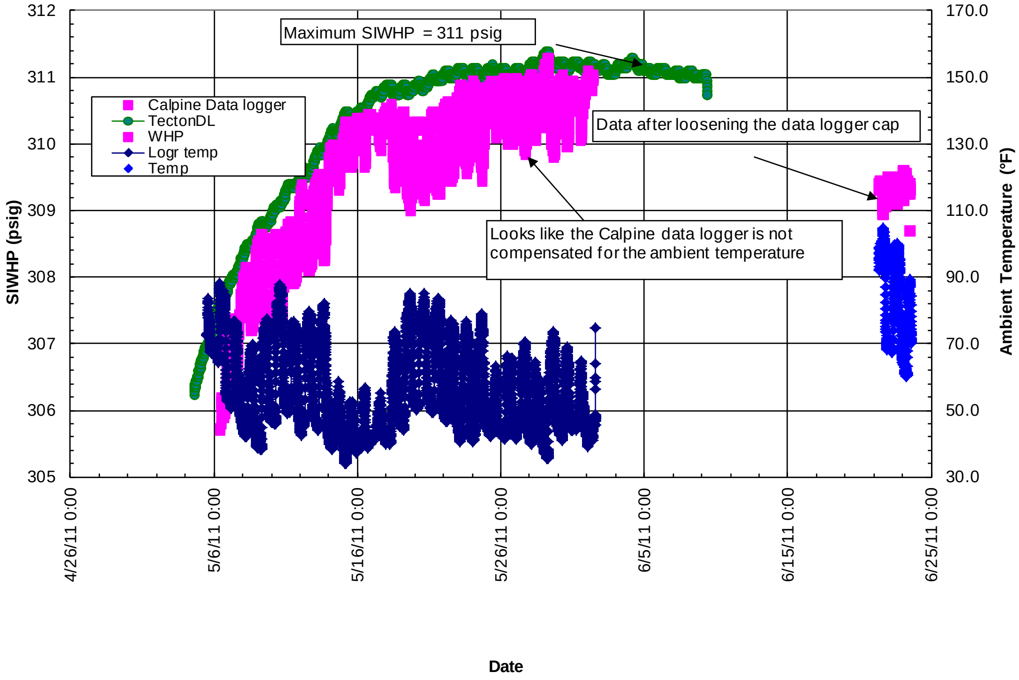
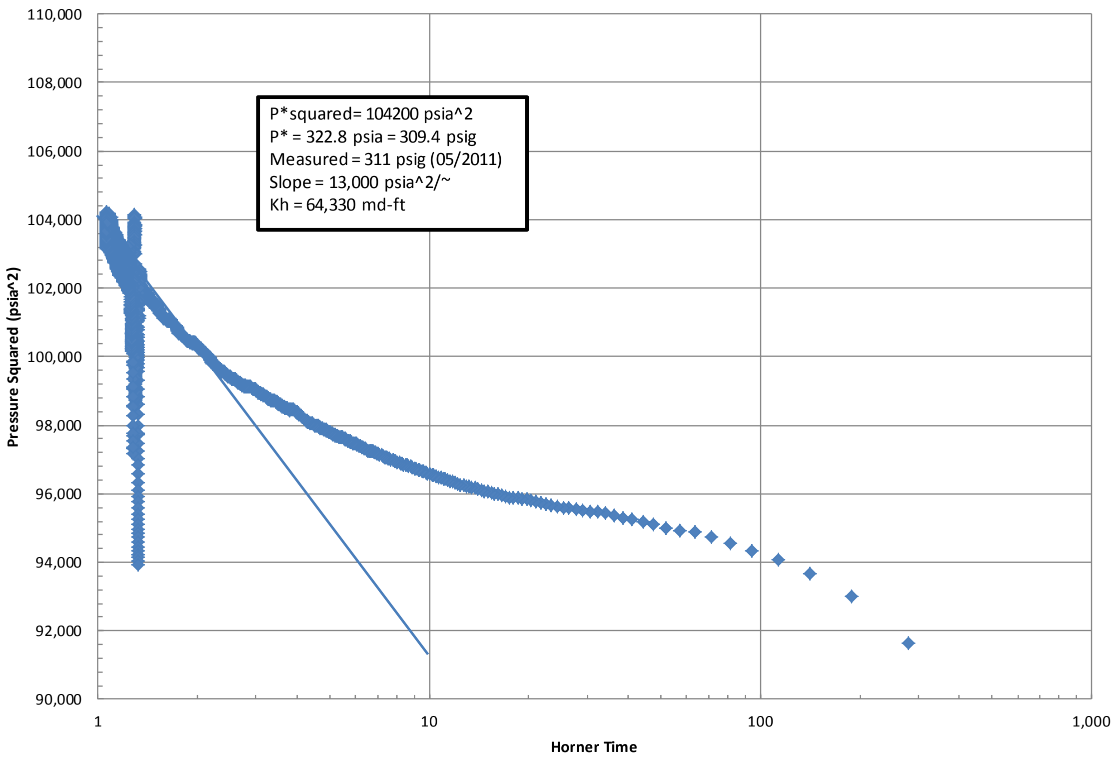


Fig 5: Pressure Buildup after the Isochronal Test



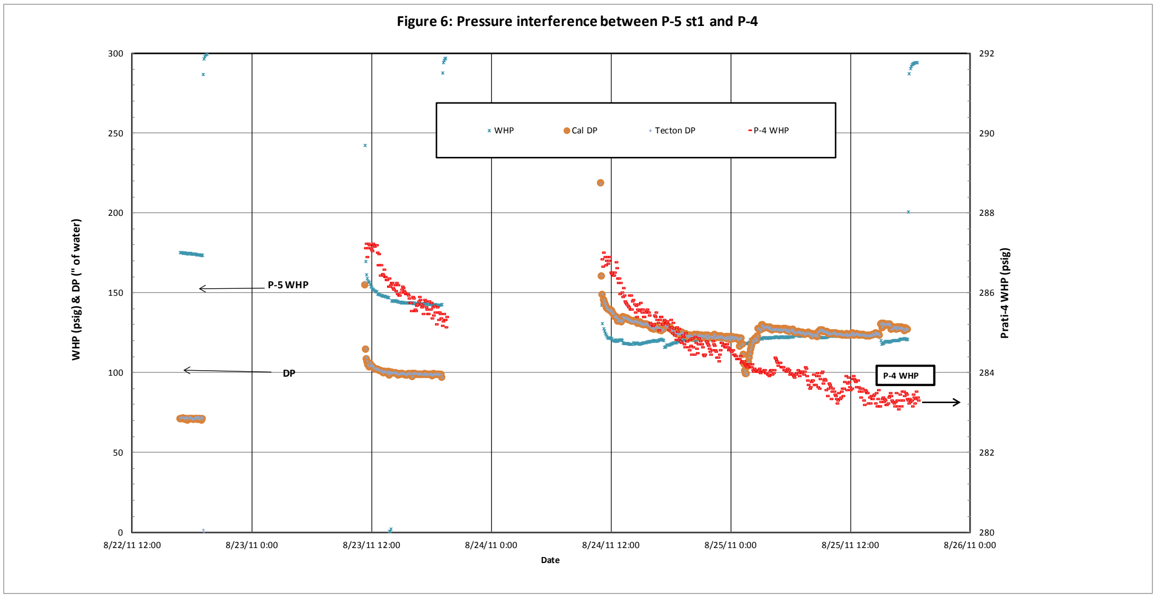


Figure 6: Pressure interference between P-5 st1 and P-4

Prati-14: Isochronal Test April 11 to 14, 2011

SUMMARY

Prati-14 was isochronally tested using an 8″ orifice during 4/11-14/2011 as shown in Figure 2. A chronology of events for P-14 is presented in Table 1. This well flowed 81 kph of saturated steam at a WHP and WHT of 105 psig and 341°F, respectively, at the end of the 24 hour flow period on 4/14/11. An analysis of this isochronal test provided an exponent "n" of 0.5104 as presented in Figure 3. The steam flow of P-14, normalized at 100 psig WHP, is calculated to be 83 kph. This flow rate is 6 kph higher than 77 kph calculated on 2/10/11 from the choke test (Table 1). WHP data of Prati-14 collected from 3/11 to 4/7/11 is shown in Figure 4. A shut-in WHP (P*) of 186 psig was estimated using a Horner Plot based on the post isochronal pressure buildup data as shown in Figure 5. The pressure buildup after 2 hour test on 4/21/11, provides a P* value of 184 psig as presented in Figure 6. These both P* values are close to 181 psig measured on 4/13/11, the third day of the isochronal test. For Calpine's purpose, a P* of 186 psig is a reasonable value to use. A kh value of 320,000 md ft was estimated for this well using the slope from the Horner plot (Figure 5). Prati-4 (P-4) shut-in WHP data are shown in Figure 4. These data were collected using two data loggers: one from Calpine and the other from Tecton. The pressure behavior of P-4 during the isochronal test is similar to that before and after the test. In addition, WHP has a cyclic fluctuation of 2 psi or more. Therefore, pressure interference, if any, between P-14 and P-4 is not apparent in Figure 4.

DISCUSSION

P-14 was completed on 2/10/2011 to a TD of 9,411′. A schematic of this well is shown in Figure 1. Two top cement plugs were cleaned out and an 11-3/4″ tie back was run and cemented from surface to top of the receptacle at 1911′ with a 7′ stinger. Cleaned out the third cement plug from 4,824′ to 5,148′ and drilled the EZSV packer at 5,148′. Cleaned out to bottom with a 10-5/8″ bit. Ran 8-5/8″ blank/ slotted liner from 4967′ to 9,262′. A wet test indicated a steam flow of 59.5 kph on 2/10/11 as given in Table 1. P-14 produced 70 kph at 121 psig per 4″ choke test conducted on 2/10/11. This is equivalent to a flow rate of 77 kph normalized at 100 psig WHP (Table 1).

Subsequent to completion, shut-in WHP (SIWHP) data were collected during 2/10-25/11. A Horner plot of these data suggest a P* value of 190 psig. This P* was higher than the shut-in pressure of 181 psig measured on 2/11/11.

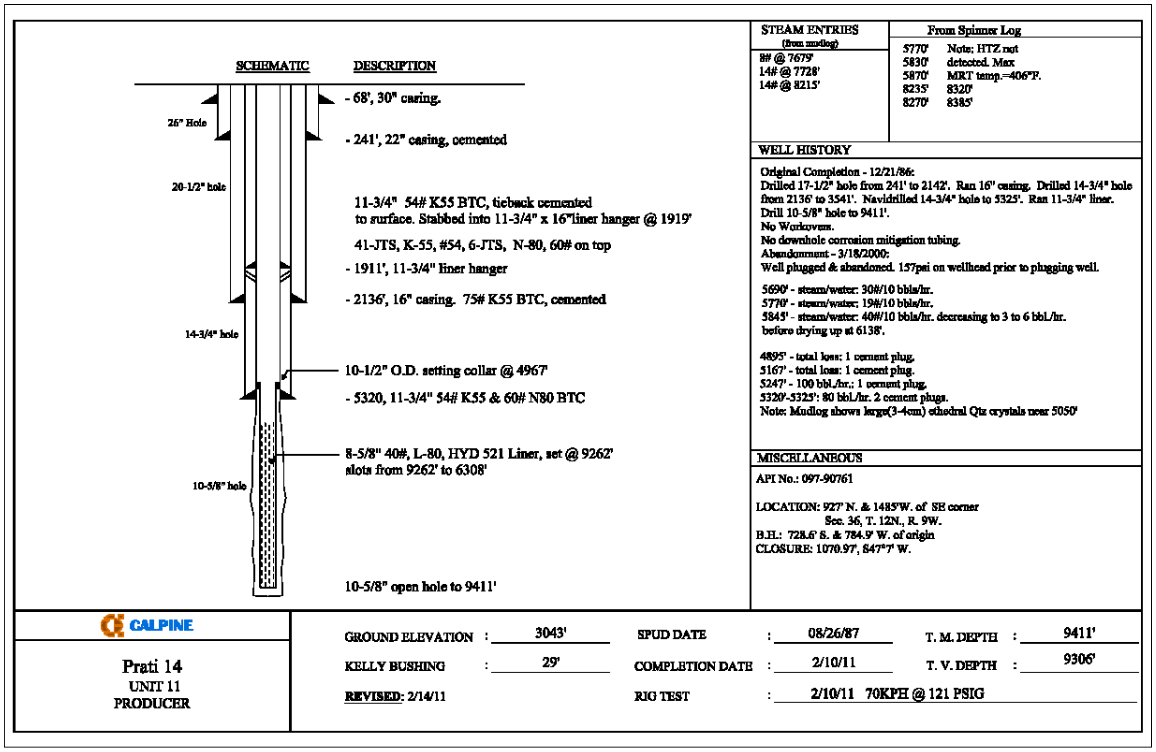
A static P/T survey was run on 4/7/11. Maximum downhole temperature and pressure of 476°F and 214 psig were measured at a depth of 9,100′. WHP data of Prati-14 collected from 4/7 to 5/4/11 are shown in Figure 4. This figure contains the WHP data before, during and after the isochronal test. The WHP trend in this figure shows a continuous decrease after the test, mostly due to heat loss to the formation. The pressure buildup data after the isochronal test and after a short 2 hour test are reproduced on a Horner plot presented in Figures 5 and 6. This plot suggests a P* value (maximum shut-in WHP) of 186 and 184 psig respectively. Calpine uses a value of 186 psig for Calpine’s calculations.

The isochronal test of P-14 started on 4/11/11 with an orifice of 8″ ID and choke of 3.5″. The well produced saturated steam for 8 hours from 9 am to 5 pm. The choke size was changed to 4″ and 4.5″ on subsequent days. The data of the entire test is graphically shown in Figure 2. Duplicate readings for pressure, temperature and the DP point were taken using Calpine and Tecton transmitters. These readings were quite close as shown in this figure, suggesting all instruments worked well. The pressure and flow rate data at the end of three 8-hour tests are plotted in Figure 3. The slope of the line in this figure provides a value of 0.5104 for the exponent “n”. At the end of 24 hours flow, Prati-14 produced 81 kph of saturated steam at 105 psig and 341°F as given in Table 1. This is equivalent to 83 kph normalized at 100 psig.

Pressure interference data were collected for the nearby well P-4 using two (Calpine and Tecton) data loggers. SIWHP data for P-4 from both loggers are shown in Figure 4 along with the WHP data of P-14. The time duration of the isochronal test and the short 2 hour test is also indicated in this figure. There is no indication of any pressure communication between P-14 and P-4 per Figure 4. P-4 WHP exhibits a cyclic trend with amplitude of 2 psi or more.

Table 1: Prati-14 Testing Chronology

Date	Flow Rate kph	WHP psig	WHT F	Comments	Sat Temp °F	Normalized Flow (kph) at 100 psig	SH °F	DP psid	Enthalpy Btu/lbm
				Elevation	3043	Patm =	13.18		
2/10/2011	69.9	121.1	349.7	Rig test (4"choke) at a TD of 9,411ft from 6:10 to 10:20 am. SIWHP = 181.2 psig	349.8	77.5	-0.1		321.5
2/10/2011				Completed to 9,411' (TD). Wet test = 59.5 kph					
2/11/2011				SIWHP = 180.8 psig, P* = 190.3 psig					
4/7/2011				Ran a static P/T log. Max temp & P = 476°F & 214 psig at 9100'					
4/11/2011	62.2	137.0	359.7	Iso. test. Day =1 (9 am to 5 pm), Orifice = 8", choke = 3.5", SIWHP = 176.3 psig	358.5		1.2	2.028	1,195.3
4/12/2011	73.7	121.4	351.5	Day =2, (10:30 am to 6:30 pm) Orifice = 8", choke = 4", SIWHP = 179.8 psig	350.0		1.5	3.183	1,193.7
4/13/2011	82.5	107.2	341.8	Day =3, 24 hrs (10:30 am to 10:30 am), choke = 4.5", SIWHP = 180.7 psig	341.5		0.3	4.458	1,191.0
4/14/2011	81.2	105.3	340.7	At the end of 24 hrs flow. "n" = 0.5104	340.3	83.2	0.4	4.390	1,190.8
4/21/2011	81.9	107.9	343.6	Tested again from 9:25 am to 11:30 am thru 8" orifice and 4.5" choke	341.9		1.7	4.379	1,191.9
				P*= 186 psig based on PBU data during 4/14-21/11. Kh= 320,000 md-ft					



SCHEMATIC **DESCRIPTION**

- 68', 30" casing.
- 241', 22" casing, cemented

11-3/4" 54# K55 BTC, tieback cemented
to surface. Stabbed into 11-3/4" x 16"liner hanger @ 1919'

41-JTS, K-55, #54, 6-JTS, N-80, 60# on top

- 1911', 11-3/4" liner hanger
- 2136', 16" casing. 75# K55 BTC, cemented

10-1/2" O.D. setting collar @ 4967'

- 5320, 11-3/4" 54# K55 & 60# N80 BTC

8-5/8" 40#, L-80, HYD 521 Liner, set @ 9262'
slots from 9262' to 6308'

10-5/8" open hole to 9411'

STEAM ENTRIES
(from mudlog)

8# @ 7679'
14# @ 7728'
14# @ 8215'

From Spinner Log

5770' Note: HTZ not
5830' detected. Max
5870' MRT temp.=406°F.
8235' 8320'
8270' 8385'

WELL HISTORY

Original Completion - 12/21/86:
Drilled 17-1/2" hole from 241' to 2142'. Ran 16" casing. Drilled 14-3/4" hole from 2136' to 3541'. Navidrilled 14-3/4" hole to 5325'. Ran 11-3/4" liner.
Drill 10-5/8" hole to 9411'.
No Workovers.
No downhole corrosion mitigation tubing.
Abandonment - 3/18/2000:
Well plugged & abandoned. 157psi on wellhead prior to plugging well.

5690' - steam/water: 30#/10 bbls/hr.
5770' - steam/water; 19#/10 bbls/hr.
5845' - steam/water: 40#/10 bbls/hr. decreasing to 3 to 6 bbl./hr.
before drying up at 6138'.

4895' - total loss; 1 cement plug.
5167' - total loss: 1 cement plug.
5247' - 100 bbl./hr.; 1 cement plug.
5320'-5325': 80 bbl./hr. 2 cement plugs.
Note: Mudlog shows large(3-4cm) ethedral Qtz crystals near 5050'

MISCELLANEOUS

API No.: 097-90761

LOCATION: 927' N. & 1485'W. of SE corner
Sec. 36, T. 12N., R. 9W.
B.H.: 728.6' S. & 784.9' W. of origin
CLOSURE: 1070.97', S47°7' W.

CALPINE

Prati 14
UNIT 11
PRODUCER

GROUND ELEVATION : 3043'
KELLY BUSHING : 29'
REVISED: 2/14/11
SPUD DATE : 08/26/87
COMPLETION DATE : 2/10/11
RIG TEST : 2/10/11 70KPH @ 121 PSIG
T. M. DEPTH : 9411'
T. V. DEPTH : 9306'

Figure 1: Schematic of Prati-14

Figure 2: Prati-14 Isochronal Test: 4/11-14/11

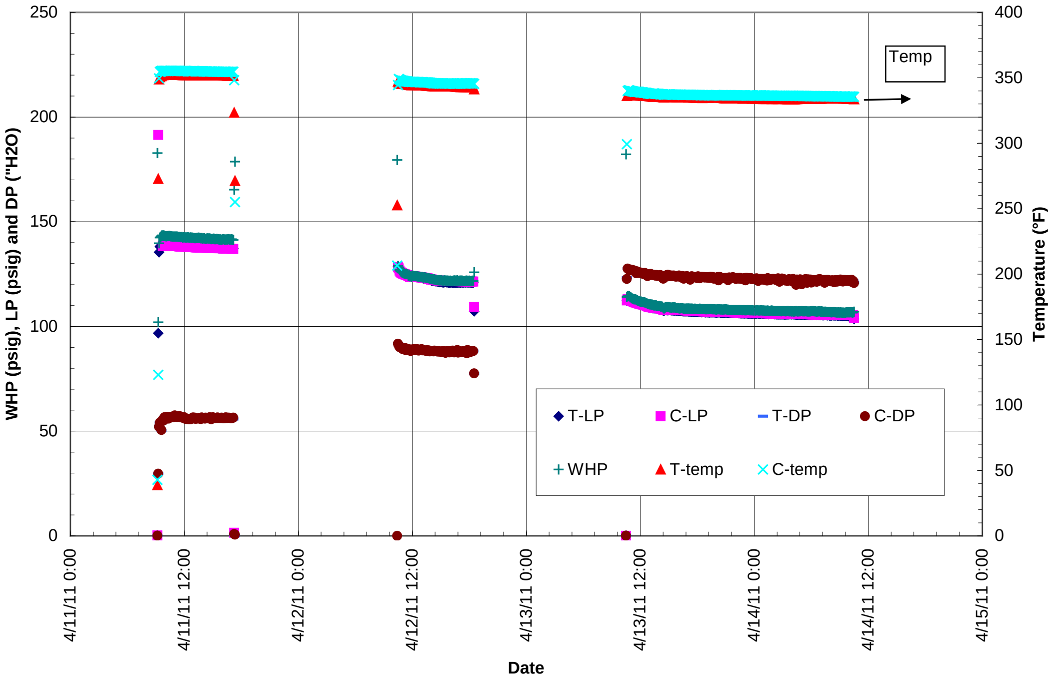


Figure 3: P-14 Isochronal Test

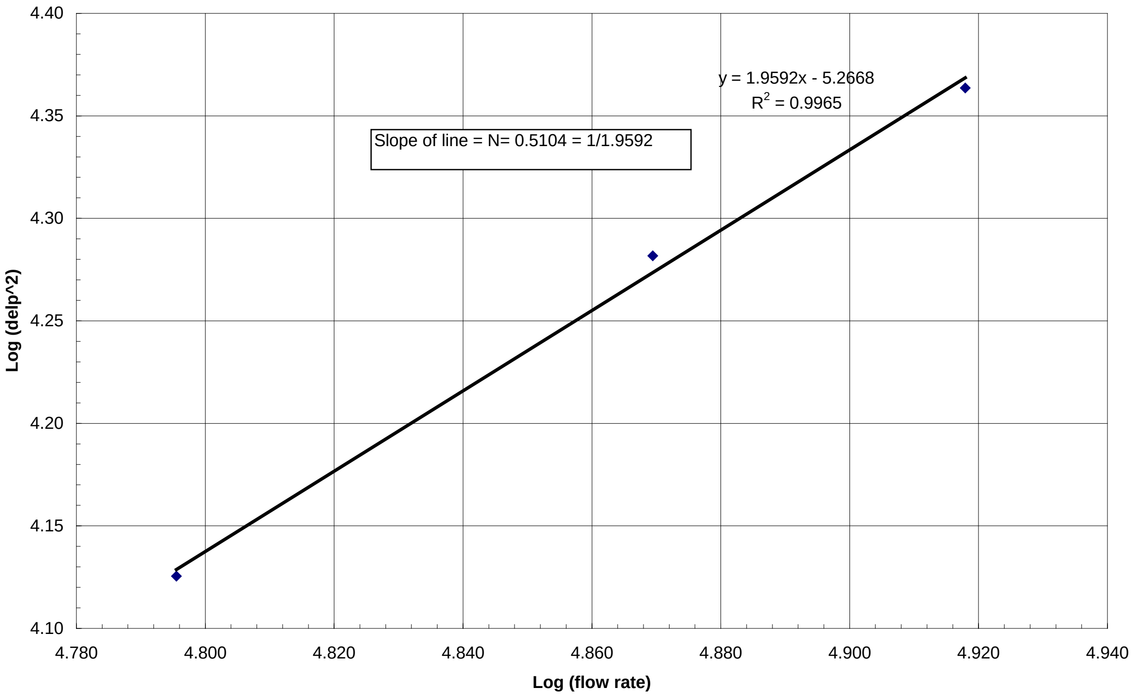
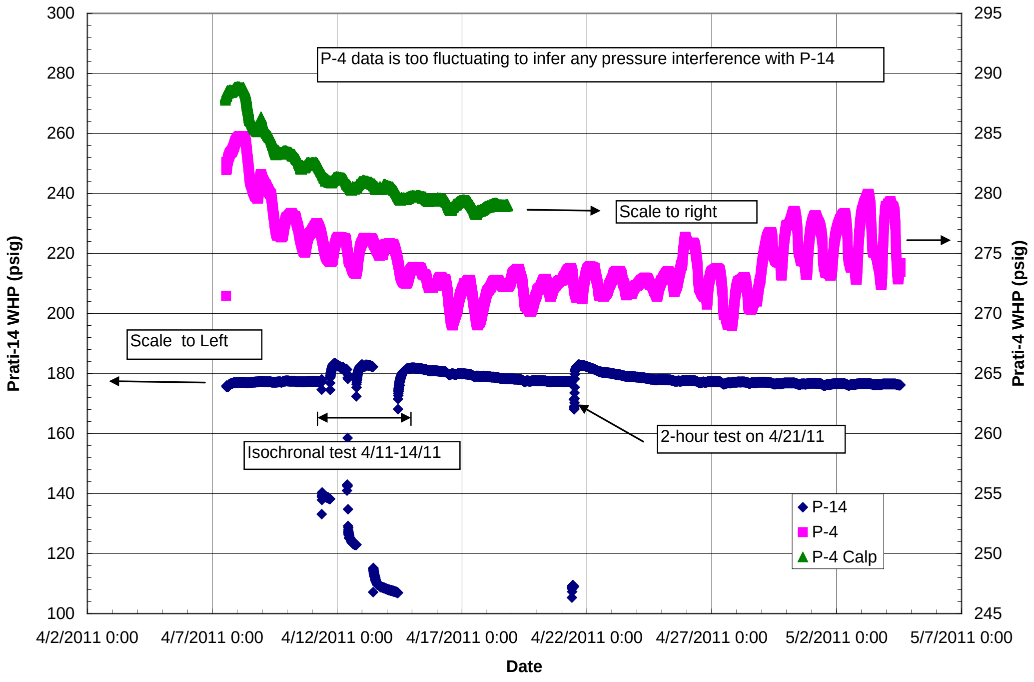


Figure 4: WHP of Prati-14 and Prati-4


P-4 data is too fluctuating to infer any pressure interference with P-14

Scale to right

Scale to Left

Isochronal test 4/11-14/11

2-hour test on 4/21/11

Figure 5: Horner Plot Prati-14 after Isochronal test in 4/11

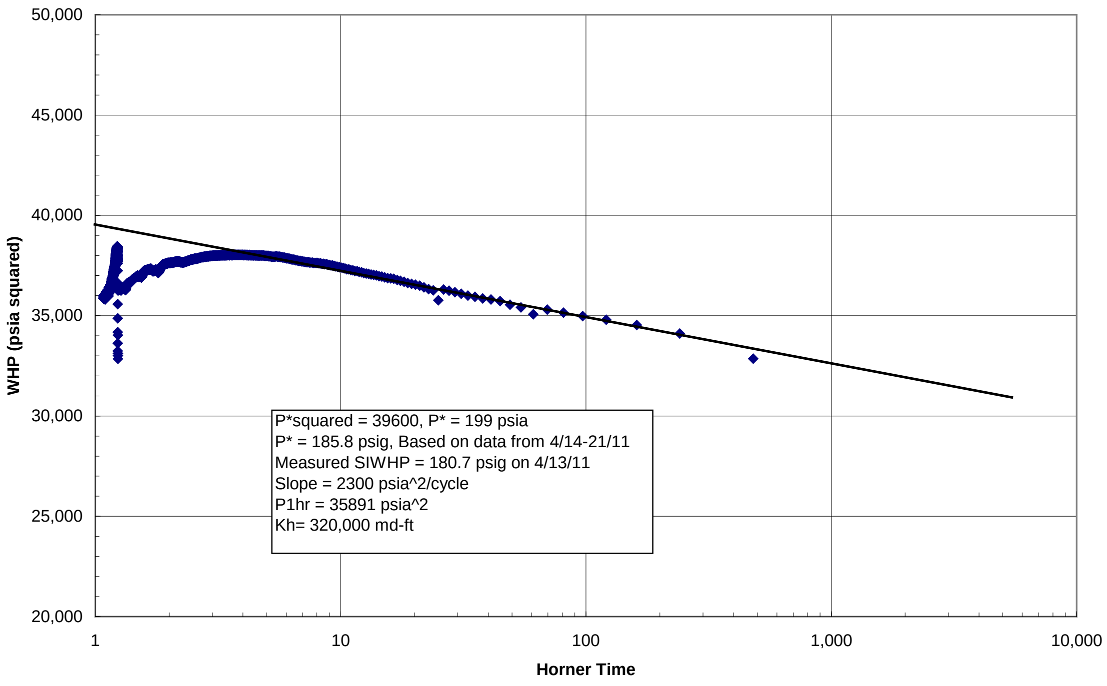
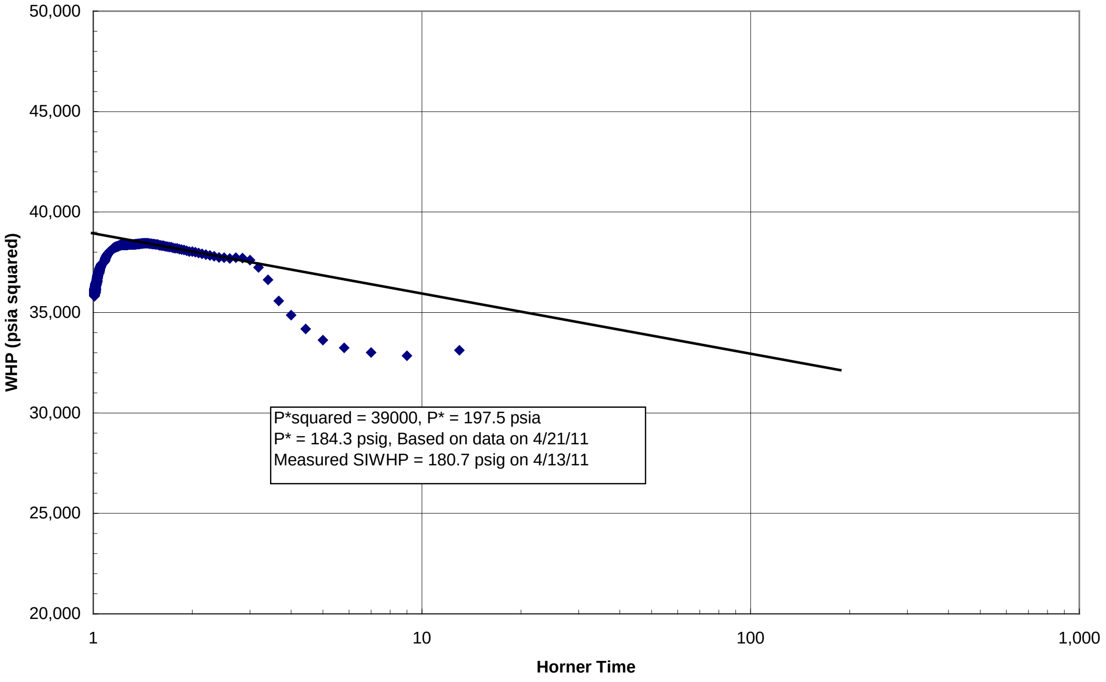

P*squared = 39600, P* = 199 psia
P* = 185.8 psig, Based on data from 4/14-21/11
Measured SIWHP = 180.7 psig on 4/13/11
Slope = 2300 psia^2/cycle
P1hr = 35891 psia^2
Kh= 320,000 md-ft

Figure 6: Horner Plot Prati-14 after short test on 4/21/11



Prati-38 St2: Isochronal Test March 14 to 17, 2011

SUMMARY

Prati 38 Sidetrack 2 (P-38 St2) was isochronally tested using a 5.9″ orifice during 3/14-17/11 as shown in Figure 2. A chronology of events for P-38st2 is presented in Table 1. This well flowed 57 kph of saturated steam at a WHP and WHT of 125 psig and 353°F respectively at the end of 24 hour flow period on 3/17/11. An analysis of this isochronal test provided an exponent "n" of 0.6645 as presented in Figure 3. The steam flow of P-38st2 normalized at 100 psig WHP is calculated to be 60 kph. This flow rate is 6 kph higher than 54 kph calculated on 1/10/11 from the choke test as given in Table 1. WHP data of Prati-38st2 collected from 3/11 to 4/7/11 is shown in Figure 4. A shut-in WHP (P*) of 328 psig was estimated using a Horner Plot based on the post isochronal pressure buildup data as shown in Figure 5. This value is close to 327 psig measured on 3/15/11, the second day of the isochronal test. A kh value of 78,000 md ft was estimated for this well using the slope from the Horner plot (Figure 5). P-38st2 was **not** found to be in pressure communication with any of two nearby wells Prati State 31 (PS-31) and Prati 32 (P-32) as indicated in figures 6 and 7 respectively. A comparison of the PI and logger data for PS-31 and P-32, shown in Figure 6, suggests that PI data were quite fluctuating and, therefore, not reliable during the isochronal test.

DISCUSSION

P-38st2 was completed on January 12, 2011 to a TD of 9,942′. A schematic of this well is shown in Figure 1. A side track was drilled by cutting a 25′ window from 5272′ to 5,297′ in the existing

11-3/4″ liner. Thereafter a 10-5/8″ open hole was drilled to TD (9,942′). An 8-5/8″ slotted/ blank liner was installed from 5106′ to TD as shown in Figure 1. A rig test, conducted on 1/10/11 at TD, using a 4" choke provided 55 kph of flow at a WHP of 86 psig & WHT of 329°F. This is equivalent to a flow rate of 54 kph normalized at 100 psig WHP (Table 1). A wet test on 1/12/11 indicated a flow of 50 kph also presented in Table 1.

A Horner plot of the SIWHP data of P-38st2, collected during January 11 to 17, 2011, is shown in Figure 8. A P* value of 323 psig was obtained from this plot. This P* was higher than the shut-in pressure of 312 psig measured on 1/16/11. Subsequent to the isochronal test in March 2011, a P* value of 328 psig and a SIWHP of 327 psig (measured on 3/15/11) were achieved (Figure 5). An improvement in the SIWHP suggests that the isochronal test helped clean the well.

A static P/T survey was run on 3/7/11. Downhole temperature of 460°F and 583°F were measured at depths of 9135′ and 9600′ respectively. A P/T/S survey was run on 3/17/11 from surface to 9530′ at 50 feet per minute (fpm). Maximum temperature and pressure of 609°F and 237 psig were measured at 9530′.

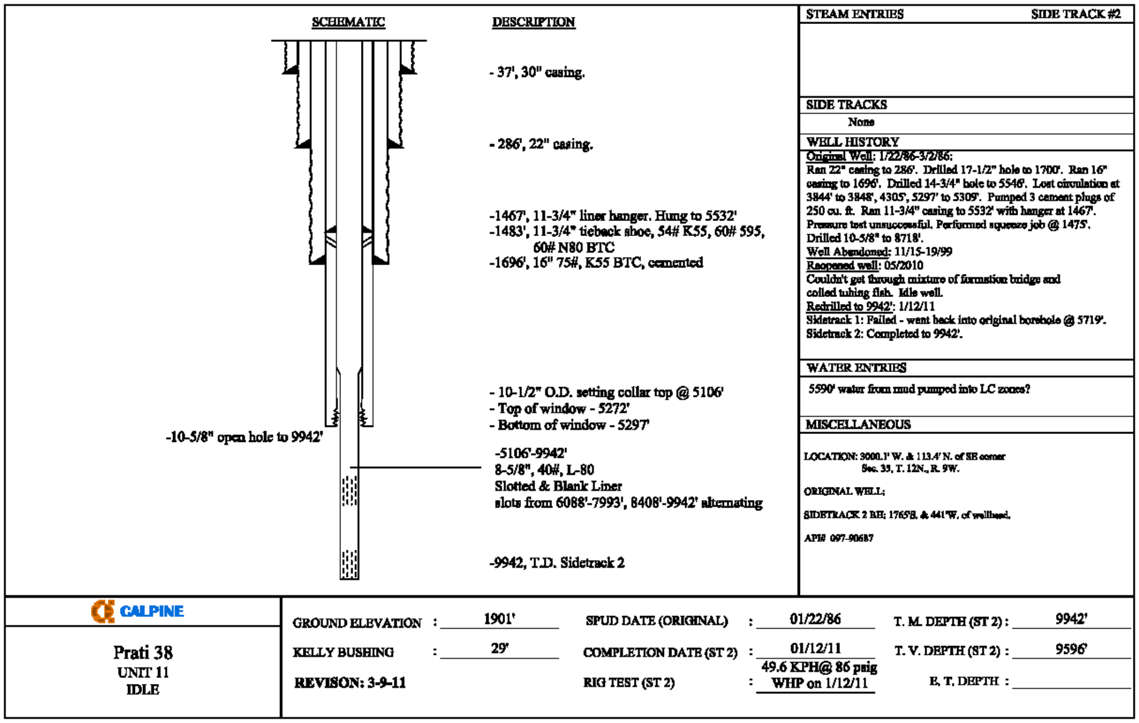
WHP data of Prati-38st2 collected from 3/11 to 4/7/11 are shown in Figure 4. This figure contains the WHP data before, during and after the isochronal test. The WHP trend in this figure shows a continuous decrease after the test, mostly due to heat loss to the formation. The pressure buildup data after the isochronal test are reproduced on a Horner plot presented in Figure 5. This plot suggests a P* value (maximum shut-in WHP) of 328 psig as mentioned earlier.

The isochronal test of P-38st2 started on 3/14/11 with an orifice of 5.9″ ID and choke of 2.5″. The well produced saturated steam for 8 hours from 9 am to 5 pm. The choke size was changed to 3″ and 3.5″ on subsequent days. The data of the entire test is graphically shown in Figure 2. Duplicate readings for pressure, temperature and the DP point were taken using Calpine and Tecton transmitters. These readings were quite close as shown in this figure, suggesting all instruments worked well. The pressure and flow rate data at the end of three 8-hour tests are plotted in Figure 3. The slope of the line in this figure provides a value of 0.6645 for the exponent “n”. At the end of 24 hours flow, Prati-38st2 produced 57 kph of saturated steam at 125 psig and 353°F as given in Table 1. This is equivalent to 60 kph normalized at 100 psig.

Pressure interference data were collected for the nearby wells PS-31 and P-32. Both wells are hooked to the PI system. For data comparison, a Tecton data logger was also installed at PS-31. SIWHP data for both of these wells are shown in Figures 6 and 7. The time duration of the isochronal test is also indicated on these figures. These figures suggest that PS-31 and P-32 do not communicate with Prati-38st2. Figure 6 also shows unstable PI data during the test and not good enough for any interpretation. However, the data from the logger is stable and reliable as evident in Figures 6 and 7.

Table 1: Prati-38ST2 Testing Chronology

				Elevation	1901	Patm =	13.7		
Date	**Flow Rate** **kph**	**WHP** **psig**	**WHT** **F**	**Comments**	**Sat Temp** **°F**	**Normalized Flow (kph) at 100 psig**	**SH** **°F**	**DP** **psid**	**Enthalpy** **Btu/lbm**
1/10/2011	54.7	86.2	328.8	Rig test (4"choke) at 9,942 ft from 6:37 to 10:55 am	327.8	53.5	1.0		1,188.1
1/12/2011				Completed to 9,942' (TD). Wet test = 49.6 kph					
1/16/2011				P* = 323 psig and SIWHP = 312 psig on 1/16/2011		53.5			
3/7/2011				Ran static P/T survey. Measured 460°F at 9135' and 583°F at 9600'					
3/11/2011				Ran static P/T but could not go thru the hanger at approx 6000'.					
3/14/2011	46.8	210.6	393.7	Iso. test (9 am - 5 pm). SIWHP (8:10 am) = 324.8 psig. Orifice = 5.9", choke = 2.5"	391.6		2.1	2.820	1,201.8
3/15/2011	55.0	169.2	376.3	Day -2, (9:45 am - 6 pm). SIWHP (8:55 am) = 326.9 psig. Choke = 3". Ran P/T/S	374.4		1.9	4.796	1,198.8
				but tool failed at 1471' at Temp = 405°F and 211 psig.					
3/16/2011	60.1	133.3	356.8	Day -3, (9:30 am - 9:30 am- 24 hrs). SIWHP (9:10 am) = 325.7 psig. Choke = 3.5"	356.9		0.0	7.155	329.0
3/17/2011	57.2	125.1	352.9	Ran P/T/S log to approx 9,900'. "n" = 0.6645, P* (PBU) = 328 psig, kh= 78,000 md-ft	352.4	59.7	0.5	6.854	1,193.5



STEAM ENTRIES SIDE TRACK #2

SIDE TRACKS

None

WELL HISTORY

Original Well: 1/22/86-3/2/86:
Ran 22" casing to 286'. Drilled 17-1/2" hole to 1700'. Ran 16" casing to 1696'. Drilled 14-3/4" hole to 5546'. Lost circulation at 3844' to 3848', 4305', 5297' to 5309'. Pumped 3 cement plugs of 250 cu. ft. Ran 11-3/4" casing to 5532' with hanger at 1467'. Pressure test unsuccessful. Performed squeeze job @ 1475'. Drilled 10-5/8" to 8718'.
Well Abandoned: 11/15-19/99
Reopened well: 05/2010
Couldn't get through mixture of formation bridge and coiled tubing fish. Idle well.
Redrilled to 9942': 1/12/11
Sidetrack 1: Failed - went back into original borehole @ 5719'.
Sidetrack 2: Completed to 9942'.

WATER ENTRIES

5590' water from mud pumped into LC zones?

MISCELLANEOUS

LOCATION: 3000.1' W. & 113.4' N. of SE corner
Sec. 33, T. 12N., R. 9W.

ORIGINAL WELL;

SIDETRACK 2 BH; 1765'S. & 441'W. of wellhead.

API# 097-90687

Prati 38
UNIT 11
IDLE

GROUND ELEVATION : 1901'
KELLY BUSHING : 29'
REVISON: 3-9-11
SPUD DATE (ORIGINAL) : 01/22/86
COMPLETION DATE (ST 2) : 01/12/11
RIG TEST (ST 2) : 49.6 KPH@ 86 psig WHP on 1/12/11
T. M. DEPTH (ST 2) : 9942'
T. V. DEPTH (ST 2) : 9596'
E. T. DEPTH :

Figure 1: Schematic of Prati-38st2

Figure 2: Prati-38st2 Isochronal Test 3/14 to 3/17/11

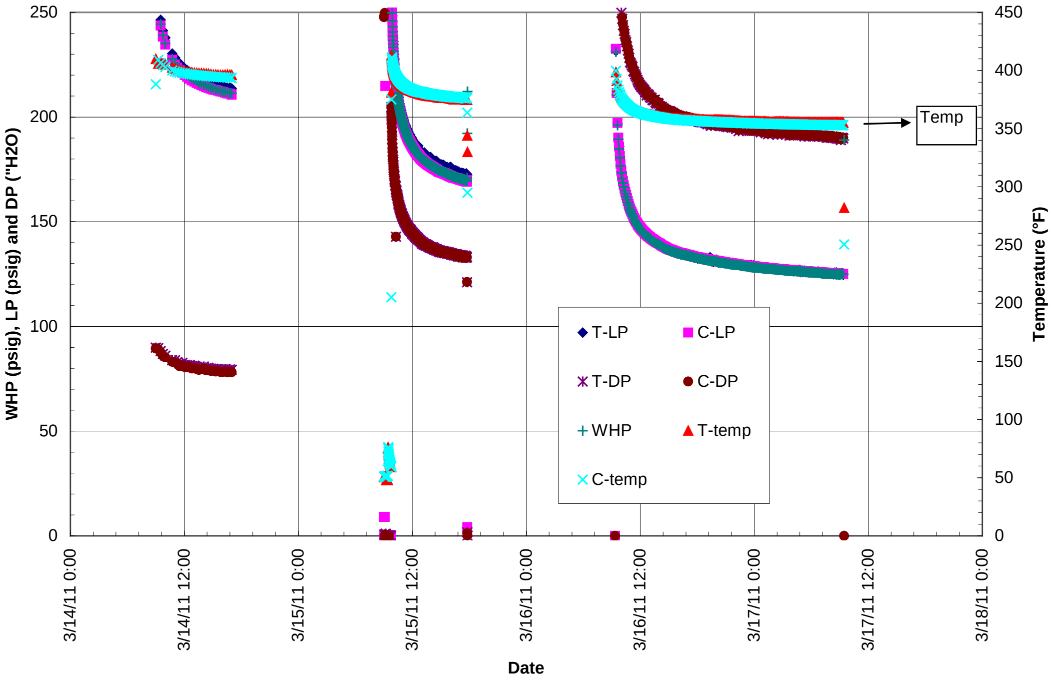


Figure 3: P-38st2 Isochronal Test

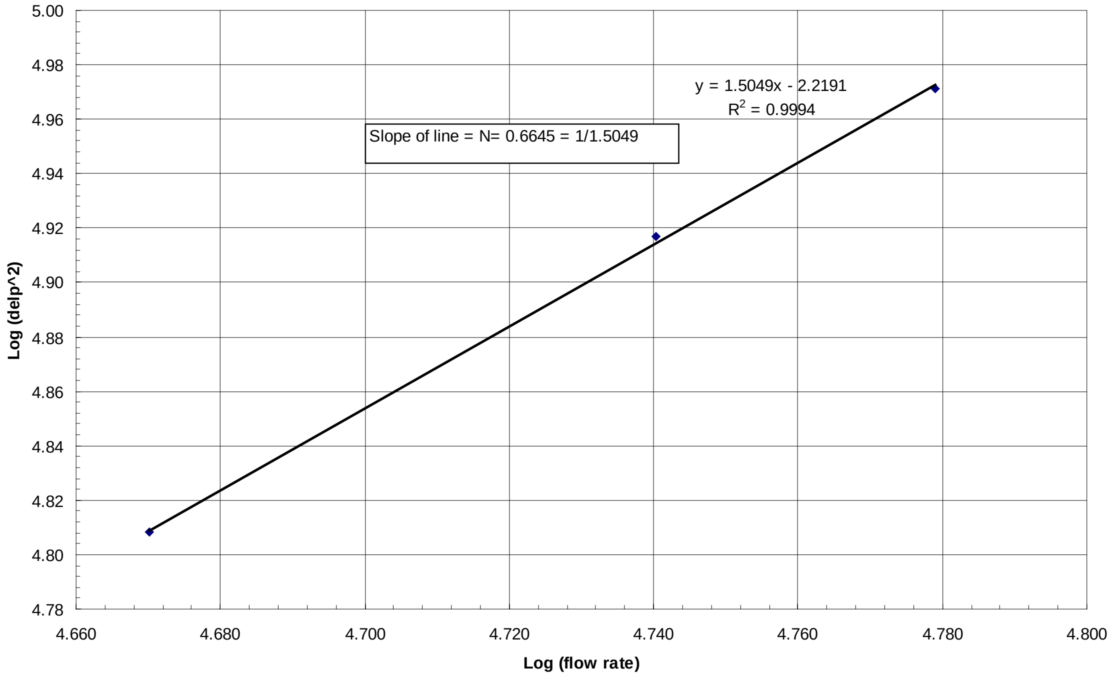
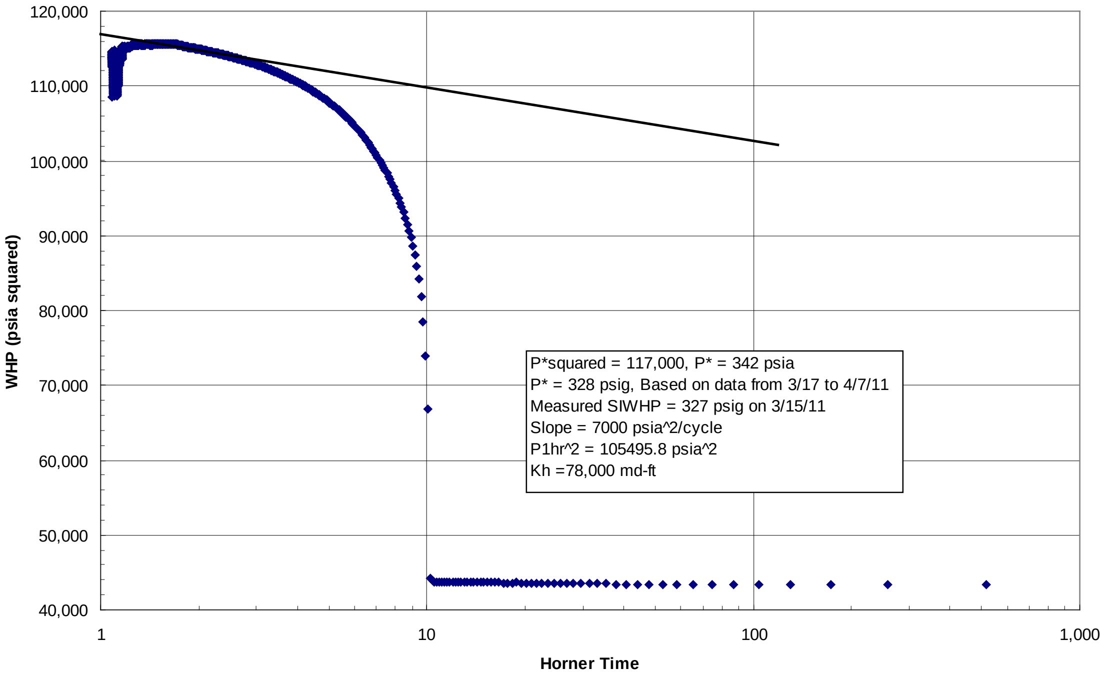
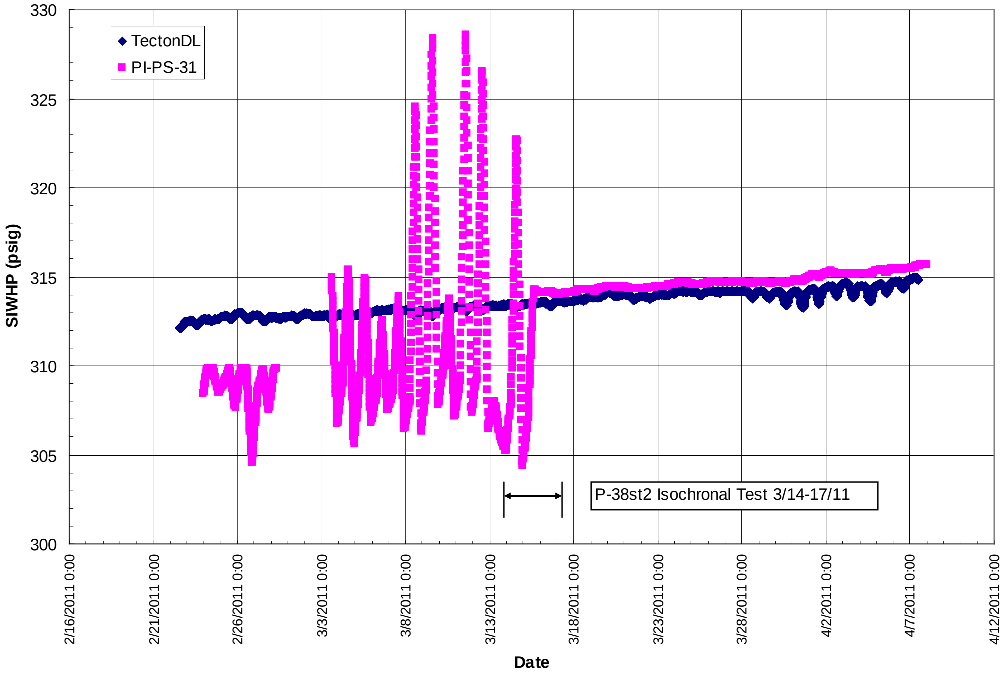


Figure 5: Horner Plot Prati-38RD



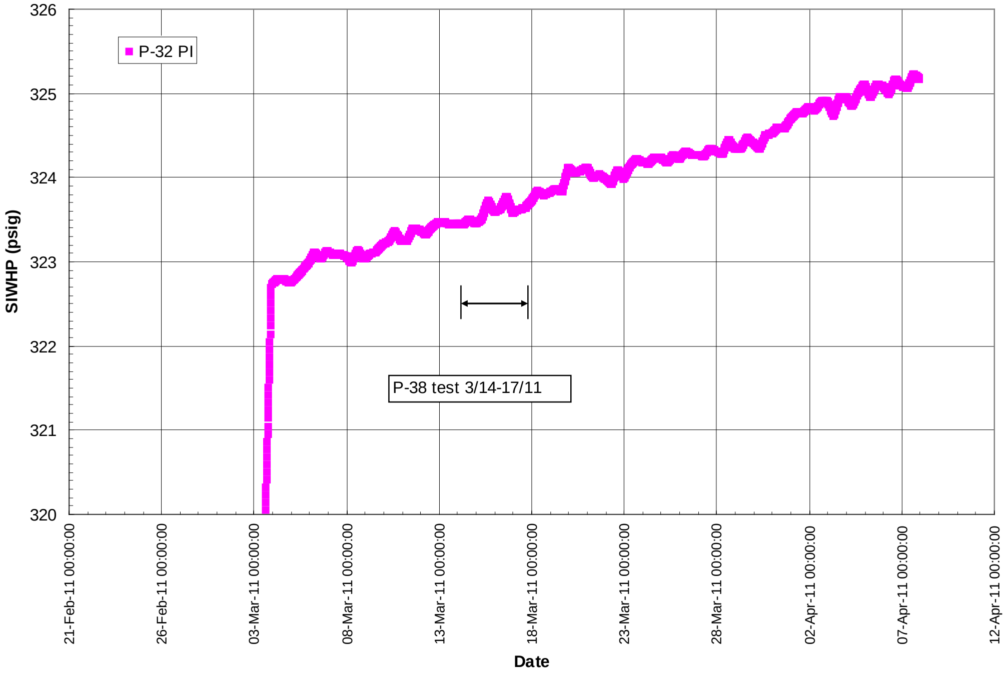
P*squared = 117,000, P* = 342 psia
P* = 328 psig, Based on data from 3/17 to 4/7/11
Measured SIWHP = 327 psig on 3/15/11
Slope = 7000 psia^2/cycle
P1hr^2 = 105495.8 psia^2
Kh =78,000 md-ft

Figure 6: SIWHP of PS-31 from 2/22 to 4/7/11



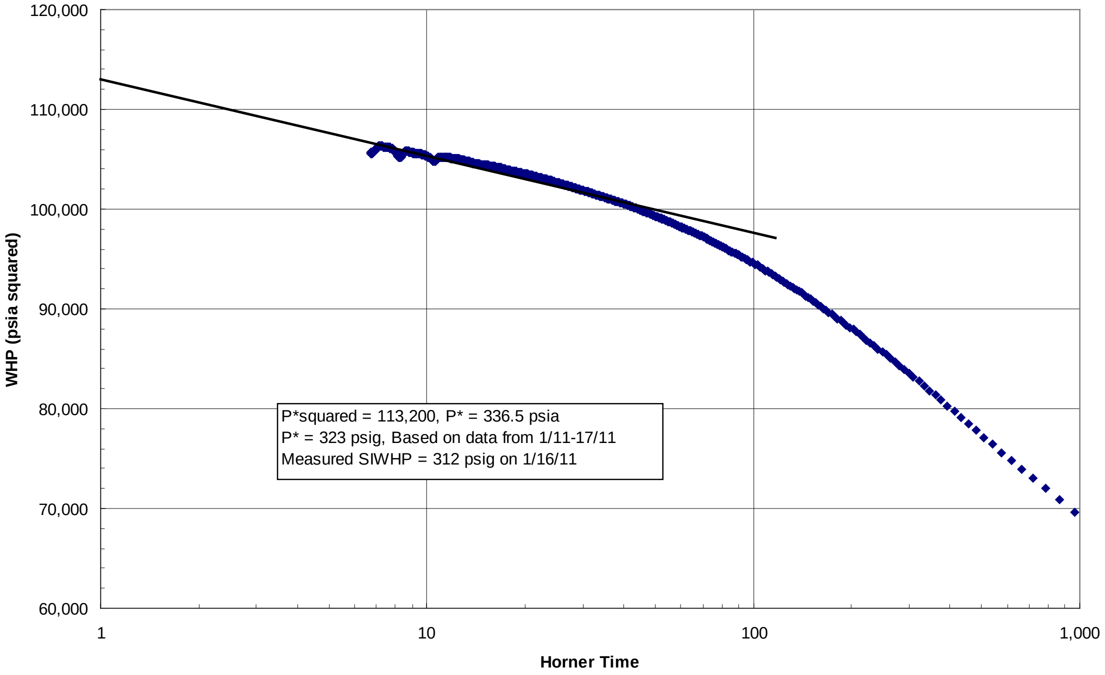
P-38st2 Isochronal Test 3/14-17/11

Figure 7: SIWHP of Prati-32 from 3/4 to 4/7/11



P-38 test 3/14-17/11

Figure 8: Horner Plot Prati-38RD



P*squared = 113,200, P* = 336.5 psia
P* = 323 psig, Based on data from 1/11-17/11
Measured SIWHP = 312 psig on 1/16/11

CALPINE CORPORATION
MEMORANDUM

To: John Hingtgen, California Energy Commission

From: Mark Walters, Sarah Pistone, Julio Garcia; Calpine Corp.

Subject: **CEC ARRA Grant: Data Integration, Data Validation, and Resource Assessment**

This memo is offered in fulfillment of Tasks 2.4 and 2.5 in the CEC ARRA Grant (Work Statement for PIR-10-10-060):

- **Task 2.4 – Data Integration and Validation:** Interpret test data, integrate well test results with previously collected data, and validate exploration technology/methods.
- **Task 2.5 – Resource Assessment:** Assess reservoir capacity of the Caldwell Ranch Project area for generating electrical power (MW).

Data from the three wells in the Caldwell Ranch Project are summarized in this report: Prati-5 Sidetrack 1 (P5-St1), Prati-14 (P-14), and Prati-38 Sidetrack 2 (P-38 St2). Prati-14 came into production October 18, 2011. P5-St1 came into production January 11, 2012. P-38 St2 is scheduled to come online in early 2013.

Task 2.4 – Data Integration and Validation

Test data were integrated with previous test results and are displayed in Figures 1 through 6. A list of previous surveys and well test data are included in Table 1. Two types of data are included: flowing data and shut-in pressure data. During all flow tests and buildup tests, data were collected using two independent well head pressure recorders ("dataloggers"): one belonging to Calpine and one of Calpine's subcontractors, Tecton Geologic. The duplicate datasets provided validation of pressure data over time. These data collected by Calpine and Tecton Geologic were in agreement for all three wells; although some datasets were noisier than others. The least noisy dataset was chosen for further analysis and calculations and are plotted in Figures 2, 4 and 6.

Flowing Data

Rig Tests were conducted during a nominal 8-hr flow period immediately following completion of each of the Caldwell Ranch project wells. Rig Tests provide a preliminary estimate of a well's performance before stabilization from drilling disturbances. Note that in P-5 St1, a rig test was done before redrilling, so the calculated value is much lower (~45 kph) than the subsequent isochronal test data, which were collected after deepening the P-5 St1 (Figure 1). In P-14 and P-38 St2 rig tests produced calculated flow rates 8-10 kph lower than isochronal data (Figures 3 and 5).

For data collected during isochronal flow tests the relationship between steam flow rates and flowing wellhead pressure is generally a concave-down curve with negative slope, but over small ranges may appear linear. The primary data points used to generate the flowing data trends in Figures 1, 3, and 5 were collected during isochronal flow tests where the wells were opened to flow over a period of 3 days with a slightly larger diameter choke plate each day. The smallest choke plate results in the lowest flow rate and the highest wellhead pressure.

In some cases additional flow tests were performed that provided additional discrete data points. In P-14, a 2-hr flow test was completed a few days after the isochronal test that yielded a data point in very good agreement with previous data (Figure 3). Furthermore, P-14 was brought online October 18, 2011 and provided two new data points that also align well with previous data (Figure 3). Prati-5 came online January 11, 2012 and provided a data point in agreement with isochronal flow test results.

Shut-In Data

After a flow test, the well is typically shut-in and a pressure "build-up test" commences during which pressure increases are collected several days to several weeks (Figures 2, 4, and 6). A Horner Plot analysis of the pressure transient observed during the build-up test was generated from the data set for each well. The Horner Plot relates pressure squared to Horner Time (calculated from the duration of pressure drawdown during the flow test to the elapsed time since shut-in) and predicts the pressure at infinite time (P*). P* is the estimate of initial static reservoir pressure. The Horner plots are not included here, but the initial pressure (P*) is plotted on the shut-in wellhead pressure in Figures 2, 4 and 6.

Results of Shut-in Data Analysis

- There is only one pressure build-up data set for P5-St1 from which a Horner Plot can also be generated. The extrapolated initial pressure for P5-St1 was 309.4 psig.
- In P-14 there are three data sets that all correlate very well. The data from the three tests overlie one another and the predictions for initial static reservoir pressure (184-189 psig) are within a range of about 5 psi.
- In P-38 St2 the wellhead pressure transient varies by 15 psi or more (310-325 psig). The build-up test that began on 1/11/2011 was completed immediately after P-38 St2 reached its total depth. Therefore the pressure support from the reservoir may have been hindered by mud-sealed fractures. It is interpreted that the isochronal flow test of P-38 St2 that preceded the 3/17/2011 build-up test, cleaned-out the well fractures and resulted in higher measured wellhead pressures. Regardless, the initial reservoir pressures (P*) from both datasets (323-328 psig) were extrapolated to within a range of 5 psi.

See Table 1 for details of build-up tests.

Task 2.5 – Resource Assessment

Details about the three new production wells were incorporated into Calpine's field-wide finite element model which uses the Tetrad software and Pipe Simulator software known as "TAPS". This model couples the reservoir with the surface pipe network and may be used to forecast the MW output of each production well at each specific Calpine power plant. Using this model as a tool, the estimated net gain for each of the Caldwell Ranch project wells was an estimated 1-2 MW (Table 3) at Calpine's existing power plants, Units 7 and 8, 11, and 17.

Steam from Caldwell Ranch project wells (P-5 St1 and P-14) is tied into pipelines to existing power plants (Unit 7 and 8, Unit 11, and Unit 17). P-14 came online October 18, 2011 and performed better than calculated by the simulator with an approximate 3.3 MW gain at the Units 11 and 17 power plants. P-5 St1 came online January 11, 2012 with an approximate 2.4 MW gain at the Unit 7 and 8, 11 and 17 power plants. Using the actual net gain from P-5 St1 and P-14 and the simulated net gain from P-38 St2, after P-38 St2 comes online the total MW gain from the three wells at the existing power plants may be 7.4 MW, or more.

Pipeline loss factors will be higher the longer the distance that steam has to travel. The proposed Wild Horse Power Plant (Unit 27) is 7500 to 15,000 feet closer to the P-5 St1 and P-38 St2 than the Unit 11 and Unit 17 power plants, respectively. If P-5 St1 and P-38 St2 were produced to Unit 27, rather than the existing power plants, it is estimated that up to 50 percent more power may be produced from the produced steam. P-14 would not be affected since it is routed through a dedicated pipeline to Unit 17.

TABLE 1

Survey List and Well Data

Well	Test or Survey	Date	Flow Rate (kph)	WHP[1] (psig)
Prati-5 (Sidetrack-1)	Rig Test	3/15/2011	42	125
	Well Rework Completed	4/29/2011	-	-
	3-day Isochronal Flow Test	8/22/2011 to 8/25/2011	77 - 85	120 - 172
	Build-Up Test	8/25/2011 to 9/28/2011	0	309
	Production Started	1/11/2012	80	112
Prati-14	Rig Test	2/10/2011	70	116
	Well Rework Completed	2/10/2011	-	-
	Build-Up Test	2/10/2011 to 2/25/2011	0	189
	3-day Isochronal Flow Test	4/11/2011 to 4/14/2011	62 - 81	105 - 137
	Build-Up Test	4/14/2011 to 4/21/2011	0	187
	2-hr Flow Test	4/21/2011	82	108
	Build-Up Test	4/21/2011 to 5/4/2011	0	184
	Production Started	10/18/2011	89	85
Prati-38 (Sidetrack-2)	Rig Test	1/10/2011	55	86
	Build-Up Test	1/11/2011 to 1/17/2011	0	323
	3-day Isochronal Flow Test	3/14/2011 to 3/17/2011	47 - 60	133 - 211
	Build-Up Test	3/17/2011 to 4/7/2011	0	328

[1] WHP from build-up tests represent maximum static WHP with well shut-in (i.e. FR = 0). All other WHPs represent flowing WHP with corresponding flow rate.

TABLE 2

Power Plant Performance Data

Well	Normalized Flow Rate	MW Gain at Existing Power Plants (U7/8, U11, U17)		
	kph @ 100 psig	Expected MW	Actual Pipe Loss	Actual MW
Prati-5 (Sidetrack-1)	86	1.4	46%	2.4
Prati-14	84	1.2	50%	3.3
Prati-38 (Sidetrack-2)	65	1.7	-	-

Fig. 1

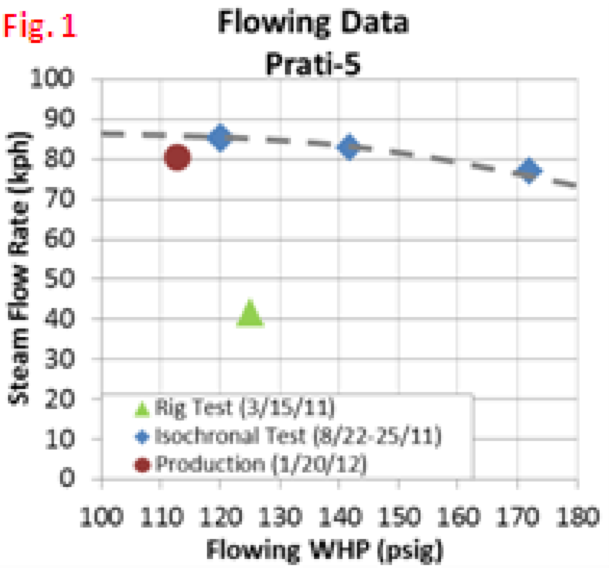


Fig. 2

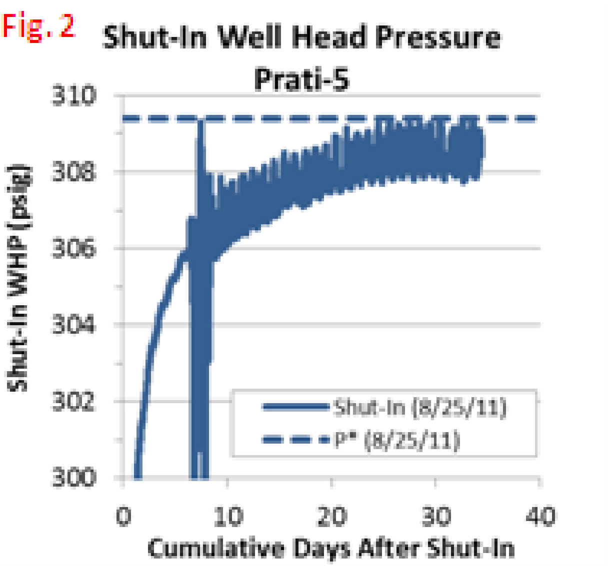


Fig. 3

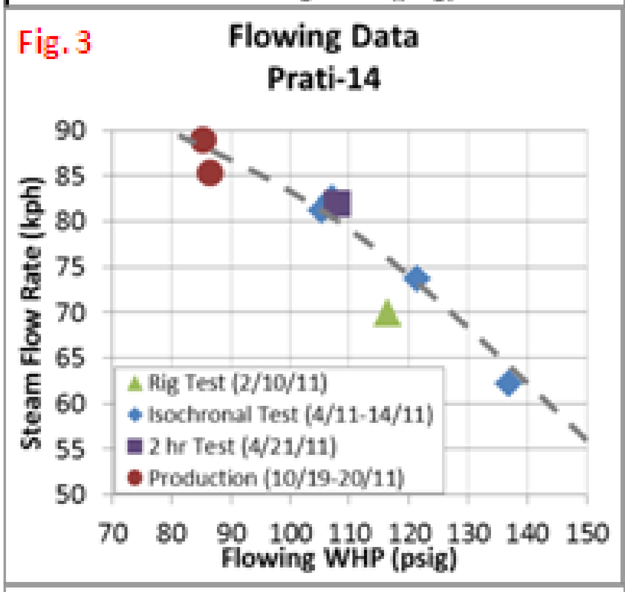


Fig. 4

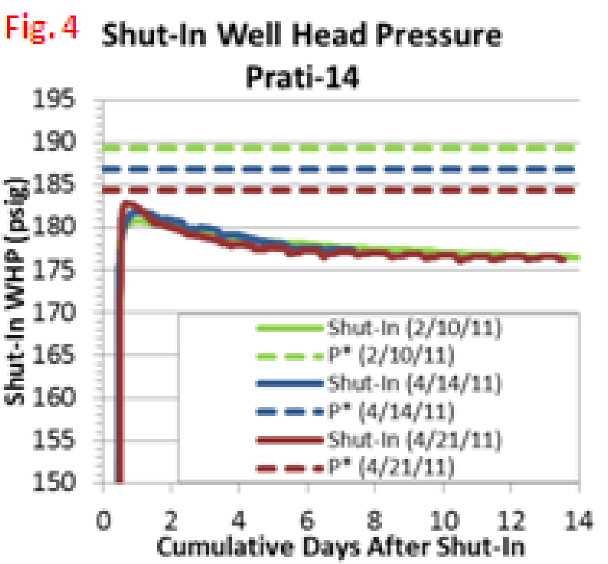


Fig. 5

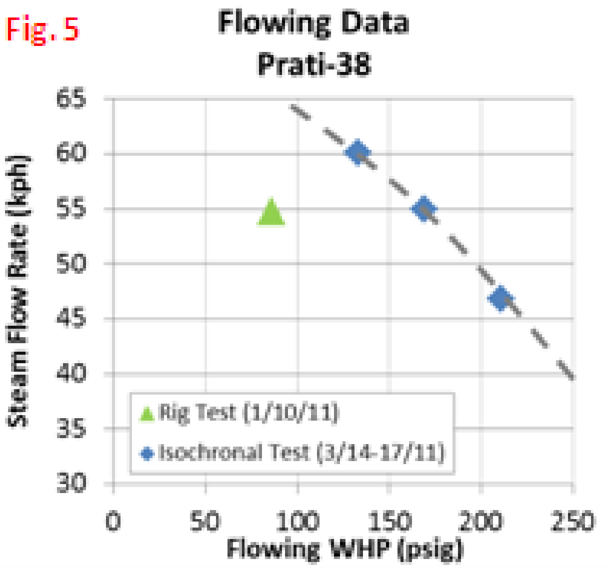
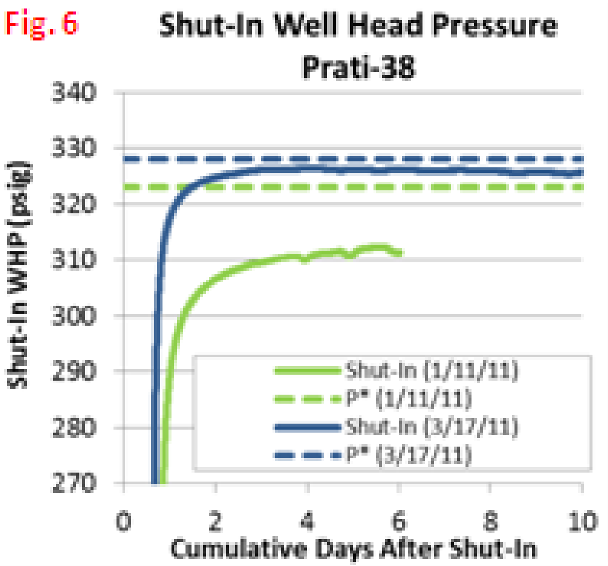


Fig. 6



APPENDIX C

WELL LOGGING

<u>Pressure-Temperature (PT) and Pressure-Temperature Spinner (PTS) logs</u>

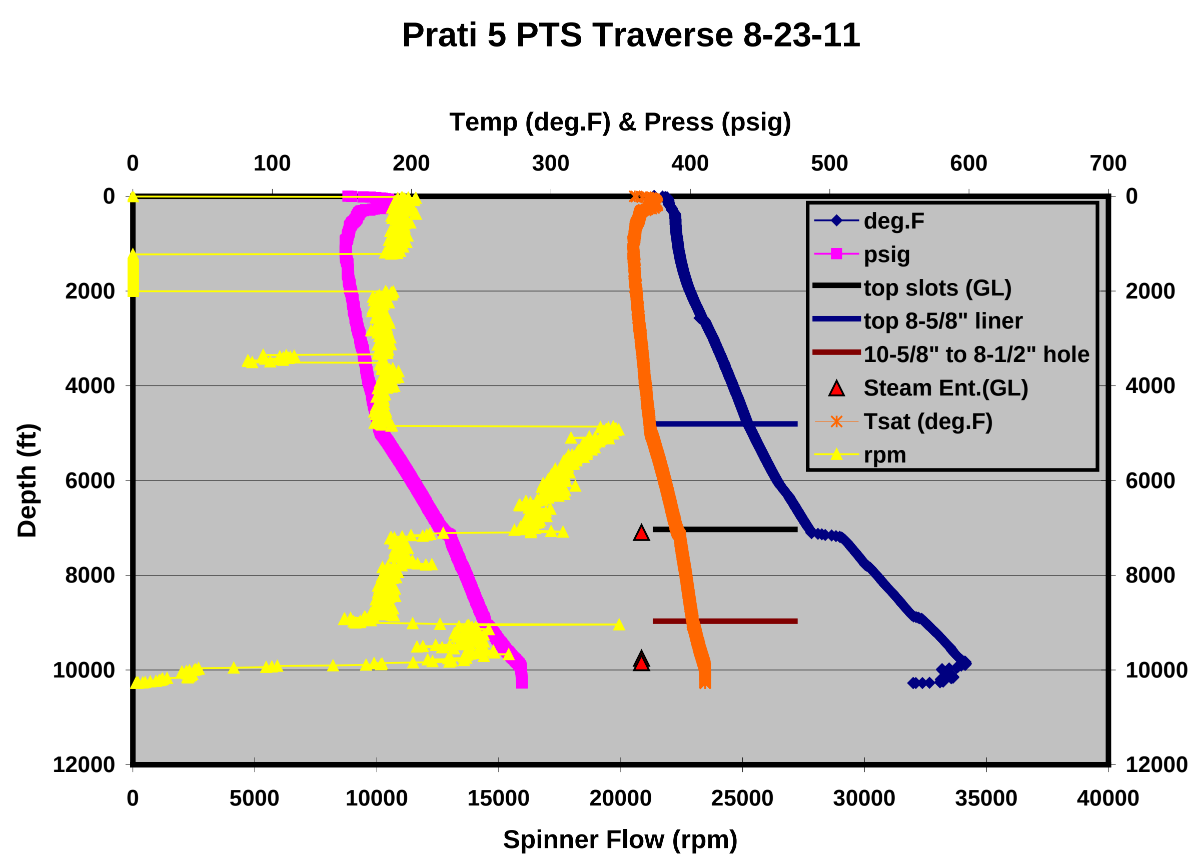
Prati 5 St1

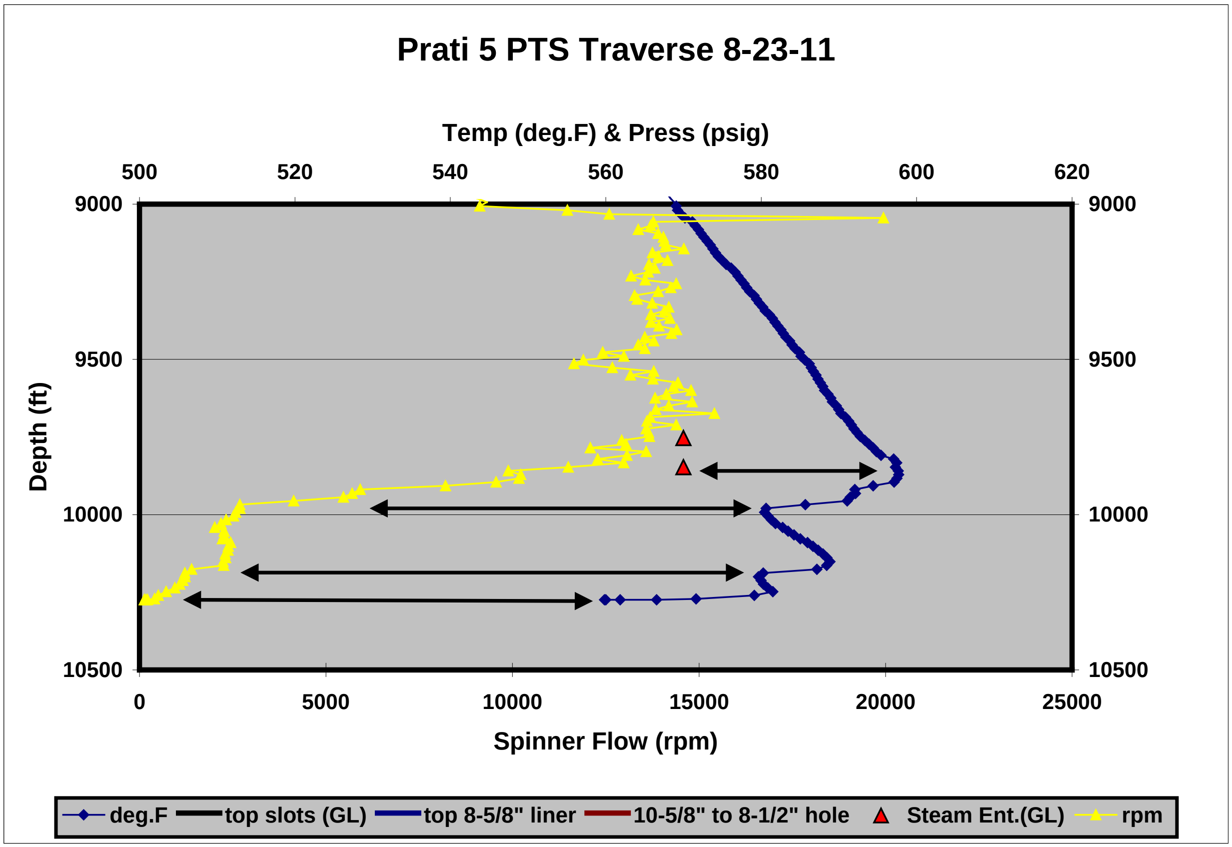
Prati 38 St2

P-5 St1 PTS Log

A pressure-temperature-spinner (PTS) log was made of Prati 5 St1 while flowing on August 23, 2011. The data from the PTS log are graphed below and described in an internal Calpine memo as follows:

> "The data quality from the PTS log appears to be very good. The change in well bore size from 10-5/8" to 8-1/2", the top of the slots and the top of the 8-5/8" liner are all very clearly delineated by sharp discontinuities in the spinner RPM count. The steam entries at 9753 and 9847' (red triangles; corrected from KB to GL) mark the top of a large increase in the spinner RPM count.
>
> The upper steam entry at 7099' is at the top of the slotted section of the 8-5/8" liner. Therefore the effect of the steam entry on the spinner count cannot be determined. The entry was wet, however, which is known from the drilling history and the fact that it deposited a scale bridge in the well that required substantial bridge-busting to remove it last week. Although there is a 95 °F superheated zone immediately above the steam entry, the effect of the entry on the temperature (dark blue line) is a sudden decrease of 24 °F. The gradual increase in spinner RPM count above the depth of the "wet steam" (water and steam) entry may reflect some scale deposition on the casing, decreasing the ID of the liner slightly (the wireline for the PTS tool was reported to have white mineral deposited on it from about this depth). The only interval through which the spinner did not function was from about 2000' to about 1400'. Ammonium bicarbonate scale was encountered in this interval during a caliper run (Some of the scale was retrieved off the tool. Its distinctive odor made its composition obvious.). Some of this scale was apparently stuck in the impeller for a short time.
>
> The most interesting part of this PTS log is the very bottom. Temperature increases steadily to the depth of the deepest recorded steam entry (red triangle, 9847' GL). At that point the temperature peaks at 597 °F then decreases to 560 °F from 9975' to 10,274'. This is extraordinary temperature behavior in a wellbore bottoming over 2000' into the high temperature zone (HTZ). Even with the temperature drop of 37 °F, the superheat at 10,274 is 149 °F. The graph below shows the lower part of the well with the vertical scale expanded. Spinner increases correlate precisely with temperature decreases at three depths (arrows) below the deepest steam entry (red triangle) recorded while drilling P-5 St1. This establishes that these are steam entries with a component of injection-derived steam. Since no steam entries were recorded in the well while drilling below 9847', it seems likely that new steam entries have formed, resulting from injection into Prati 9 and Prati State 29. This may be the first indication that new steam entries can be formed from injection into the HTZ."


Prati 5 PTS Traverse 8-23-11
Temp (deg.F) & Press (psig)
0
100
200
300
400
500
600
700
Depth (ft)
0
2000
4000
6000
8000
10000
12000
deg.F
psig
top slots (GL)
top 8-5/8" liner
10-5/8" to 8-1/2" hole
Steam Ent.(GL)
Tsat (deg.F)
rpm
0
5000
10000
15000
20000
25000
30000
35000
40000
Spinner Flow (rpm)

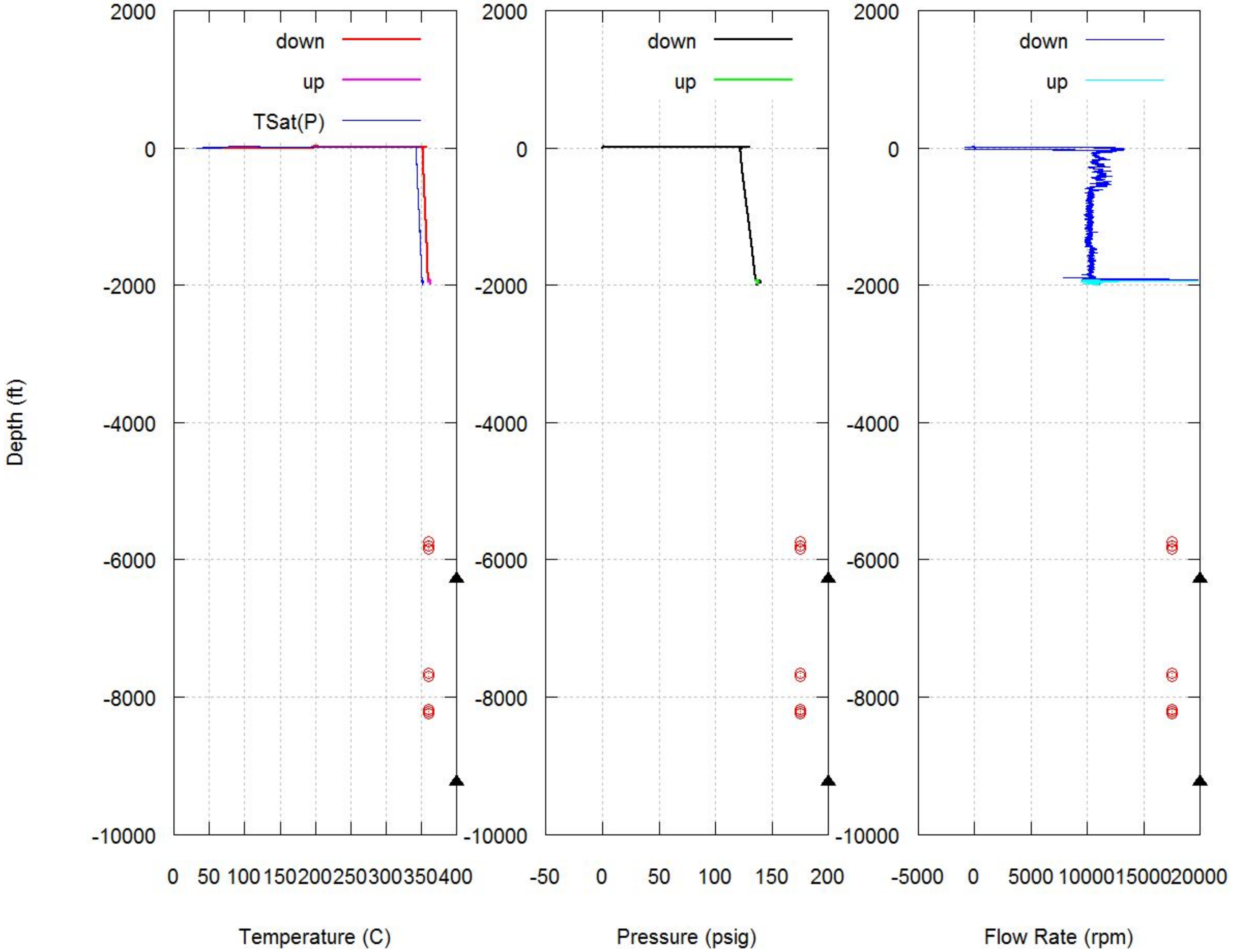


The isotopic section B-B′ in Appendix VII and the table below show the whole-rock ^{18}O values for the hornfels in Prati 5 St1 to range from +13.0 to +5.8 per mil from 8200′ MD at the top of the HTR. The relatively low δ^{18}O values below 9375′ presented in the table below range from +5.8 to +8.0 per mil. Together with the observation from the PTS log that the temperature peaks at 597 ^{o}F then decreases to 560 ^{o}F from 9975′ to 10,274′ may be the first indication that (1) new steam entries can be formed from injection into the HTR and (2) the injection of "light" ^{18}O meteoric SRGRP is actively depleting isotopically "heavy" ^{18}O from the rock.

Well	Depth (M.D.)	$\delta^{18}O$ (SMOW) per mil
ST1	6435'	12.6
ST1	6755'	12.4
ST1	7125'	9.9
ST1	7525'	11.5
ST1	7915'	13.0
ST1	8235'	12.8
ST1	8505'	12.8
ST1	8905'	9.3
ST1	9375'	5.8
ST1	9755'	5.8
ST1	9995'	8.6
ST1	10396'	8.0

Prati 14

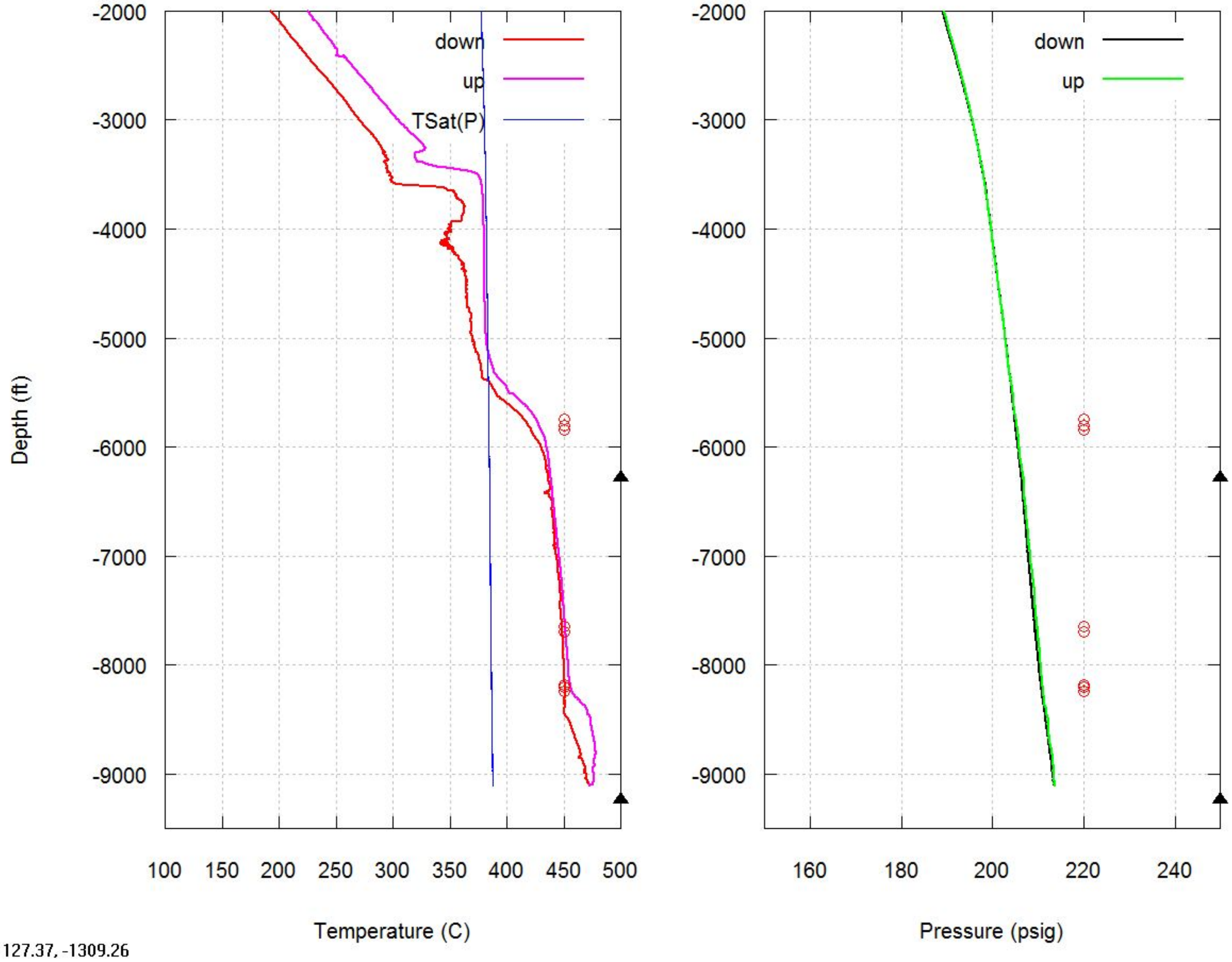
Flowing PTS Log



An obstruction was hit at 1940 feet while running this log. Consequently there is no information of the flowing steam properties below this depth.

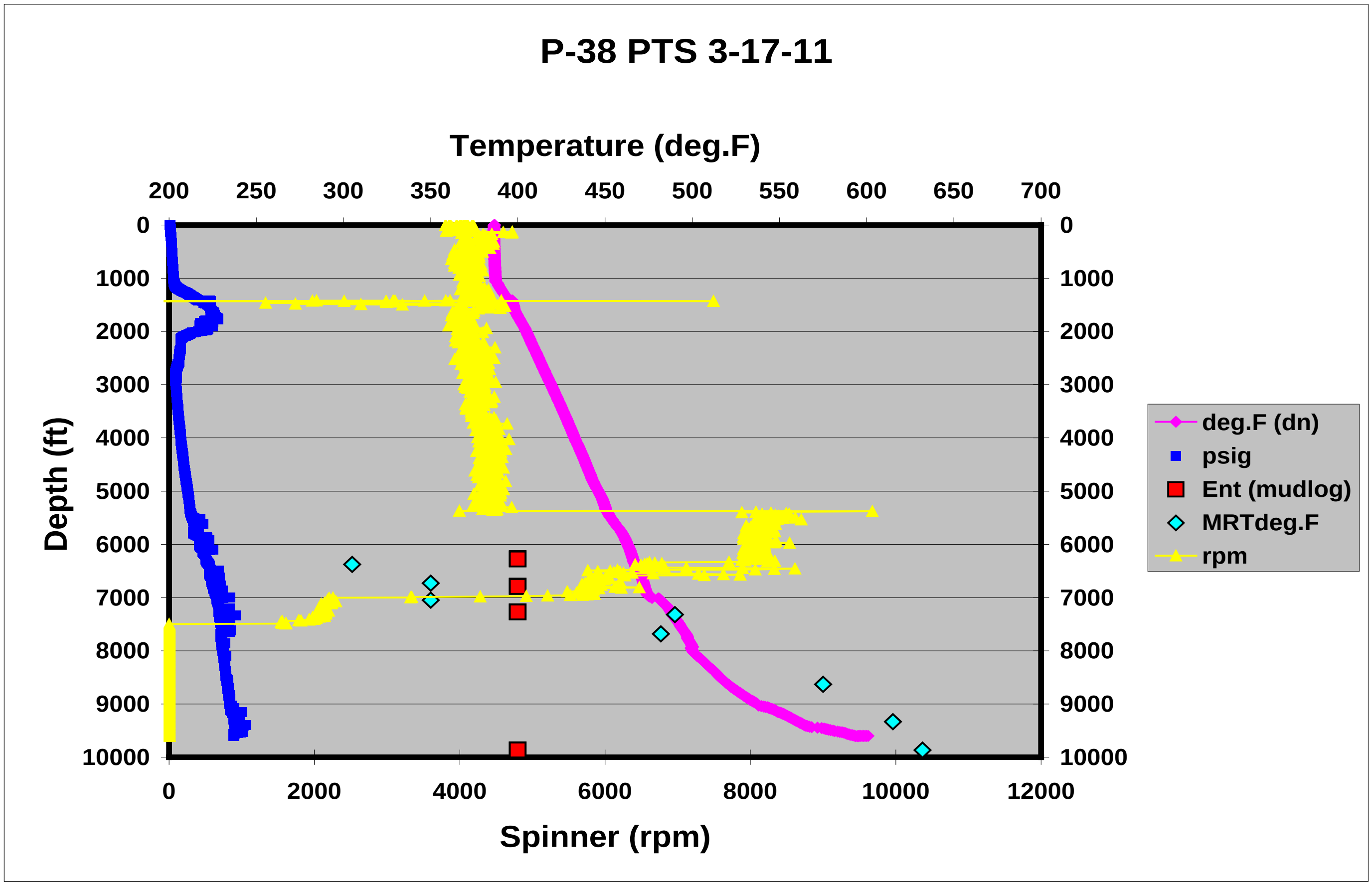
Prati 14

Static PT Log

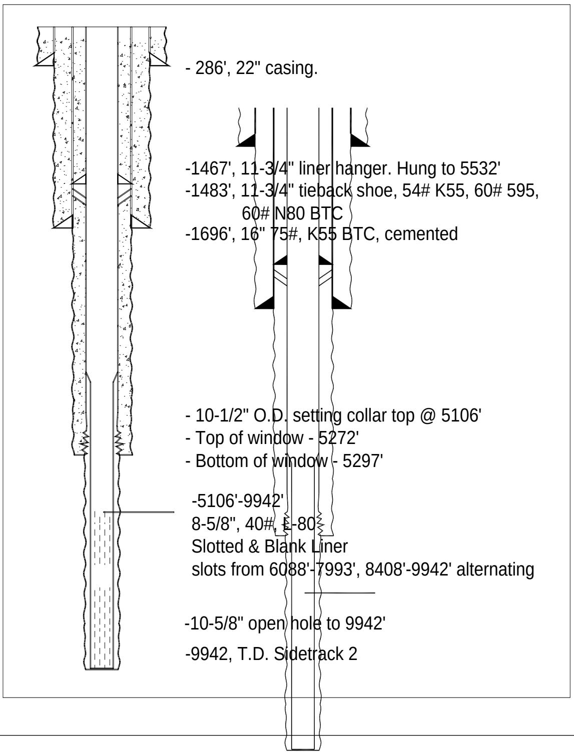


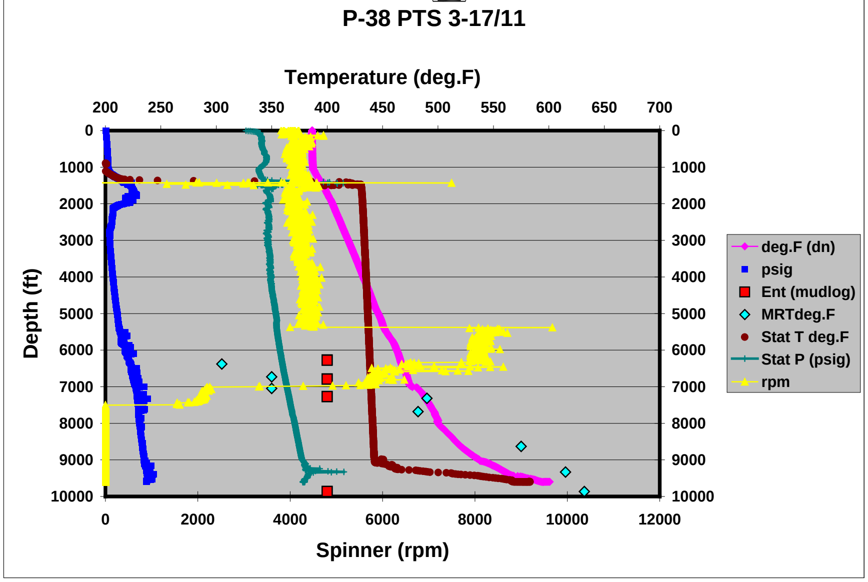
P-38 St2

A PTS log was run into P-38 St2 on March 17, 2011 while the well was flowing and is summarized in the graph below. The temperature and pressure are plotted on the upper x-axis and the spinner on the lower x-axis. The spinner (yellow) suggests that little or no flow comes from the deep "entry" at 9865'. The big increases in the spinner RPM values approximately agree with the locations of the steam entries between 6200 and 7300'(red squares). The bottom of the window in the 11-3/4" casing is at 5297' and coincides closely with a very large decrease in spinner from about 8000 to about 4500 rpm.



At 5297', the spinner is supposed to be traversing 8-5/8" blank liner (see diagram below). This does not make sense, and suggests that the depth indicator is off about 200'. The drop in spinner has to be due to the steam exiting the 8-5/8" into the 11-3/4" casing at 5106'. A 20 psi pressure "bump" (blue line) between about 1200' and 2000' suggests that a valve at the surface may have been partially closed and opened. The MRT temperatures measured during drilling (light blue) converge on the flowing temperature near TD.





The final plot below shows the static log added to this PTS plot. All of the temperatures (static, flowing and MRT) are converging at TD toward a temperature above 600 °F (315 °C). As has come to be the norm apparently, there is evidence in the temperature data of a "stairstep" at about 1400' caused by a slow leak at the wellhead.

Both the maximum-reading thermometer measurements made while drilling and the static temperature and pressure logs plotted in the chart indicate a conductive temperature gradient of about 8 °F (5 °C)/100 ft.

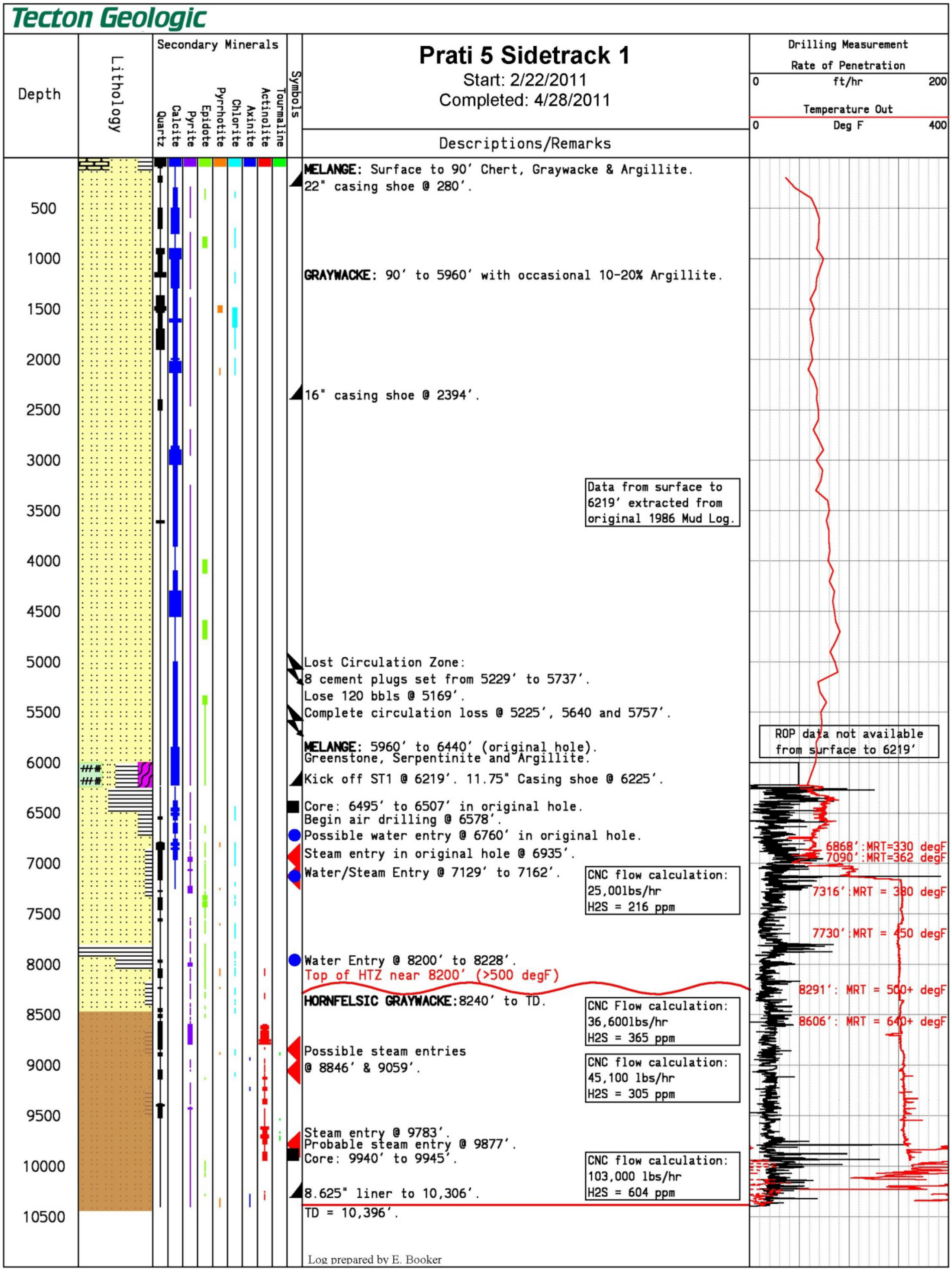
APPENDIX D

WELL GEOLOGIC SUMMARIES

Prati 5 St1

Prati 14

Prati 38 St2



Prati 5 Sidetrack 1

Start: 2/22/2011
Completed: 4/28/2011

MELANGE: Surface to 90' Chert, Graywacke & Argillite.
22" casing shoe @ 280'.

GRAYWACKE: 90' to 5960' with occasional 10-20% Argillite.

16" casing shoe @ 2394'.

Data from surface to 6219' extracted from original 1986 Mud Log.

Lost Circulation Zone:
8 cement plugs set from 5229' to 5737'.
Lose 120 bbls @ 5169'.
Complete circulation loss @ 5225', 5640 and 5757'.

MELANGE: 5960' to 6440' (original hole).
Greenstone, Serpentinite and Argillite.

ROP data not available from surface to 6219'

Kick off ST1 @ 6219'. 11.75" Casing shoe @ 6225'.

Core: 6495' to 6507' in original hole.
Begin air drilling @ 6578'.
Possible water entry @ 6760' in original hole.
Steam entry in original hole @ 6935'.
Water/Steam Entry @ 7129' to 7162'.

CNC flow calculation:
25,001lbs/hr
H2S = 216 ppm

6868':MRT=330 degF
7090':MRT=362 degF
7316':MRT = 380 degF
7730':MRT = 450 degF

Water Entry @ 8200' to 8228'.
Top of HTZ near 8200' (>500 degF)

8291': MRT = 500+ degF

HORNFELSIC GRAYWACKE:8240' to TD.

CNC Flow calculation:
36,600lbs/hr
H2S = 365 ppm

8606': MRT = 640+ degF

Possible steam entries
@ 8846' & 9059'.

CNC flow calculation:
45,100 lbs/hr
H2S = 305 ppm

Steam entry @ 9783'.
Probable steam entry @ 9877'.
Core: 9940' to 9945'.

CNC flow calculation:
103,000 lbs/hr
H2S = 604 ppm

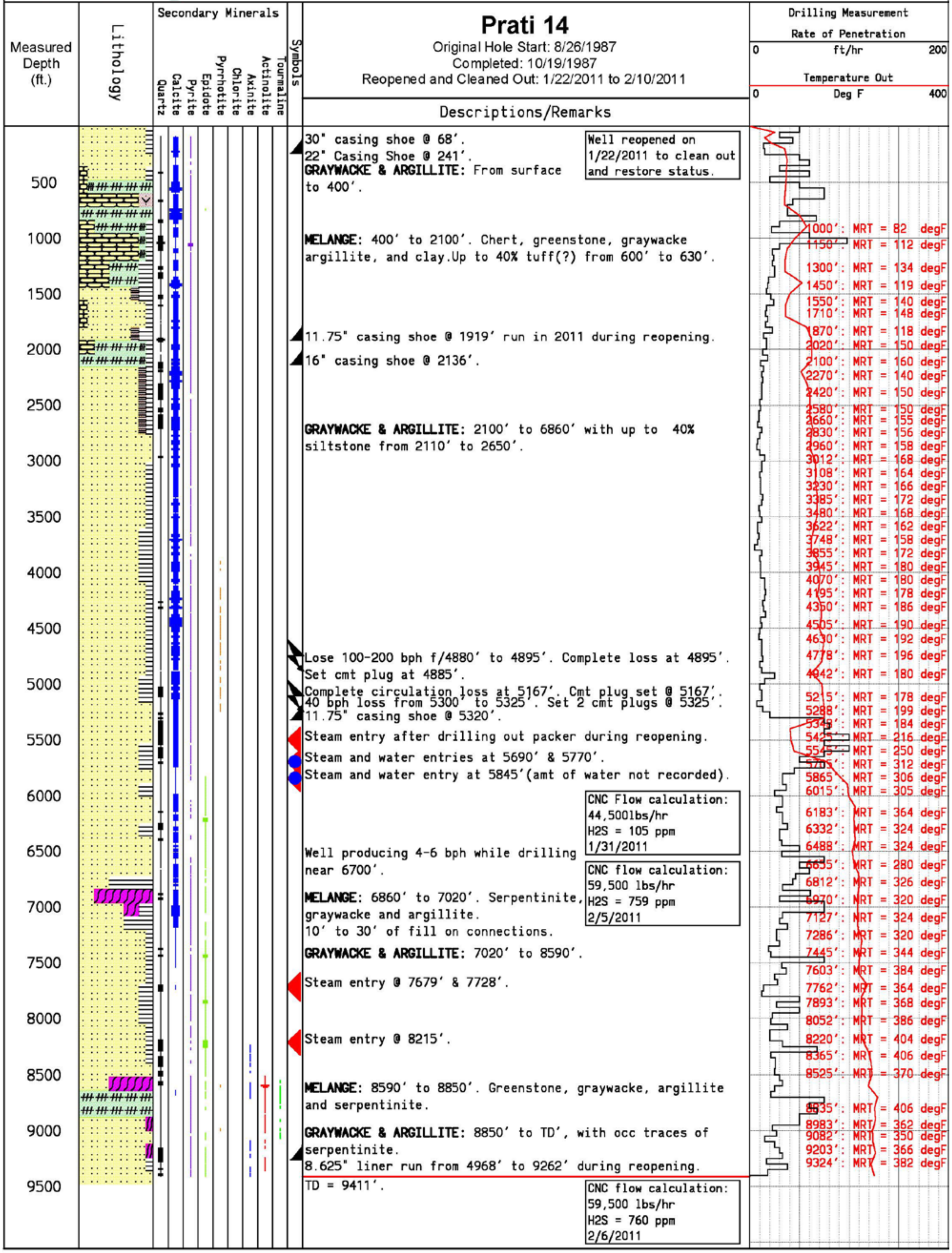
8.625" liner to 10,306'.
TD = 10,396'.

Log prepared by E. Booker

Tecton Geologic

Prati 14

Original Hole Start: 8/26/1987
Completed: 10/19/1987
Reopened and Cleaned Out: 1/22/2011 to 2/10/2011



30" casing shoe @ 68'.
22" Casing Shoe @ 241'.
GRAYWACKE & ARGILLITE: From surface to 400'.

Well reopened on 1/22/2011 to clean out and restore status.

MELANGE: 400' to 2100'. Chert, greenstone, graywacke argillite, and clay.Up to 40% tuff(?) from 600' to 630'.

11.75" casing shoe @ 1919' run in 2011 during reopening.

16" casing shoe @ 2136'.

GRAYWACKE & ARGILLITE: 2100' to 6860' with up to 40% siltstone from 2110' to 2650'.

Lose 100-200 bph f/4880' to 4895'. Complete loss at 4895'. Set cmt plug at 4885'.

Complete circulation loss at 5167'. Cmt plug set @ 5167'.
40 bph loss from 5300' to 5325'. Set 2 cmt plugs @ 5325'.
11.75" casing shoe @ 5320'.

Steam entry after drilling out packer during reopening.

Steam and water entries at 5690' & 5770'.

Steam and water entry at 5845'(amt of water not recorded).

CNC Flow calculation:
44,500lbs/hr
H2S = 105 ppm
1/31/2011

Well producing 4-6 bph while drilling near 6700'.

CNC flow calculation:
59,500 lbs/hr
H2S = 759 ppm
2/5/2011

MELANGE: 6860' to 7020'. Serpentinite, graywacke and argillite.
10' to 30' of fill on connections.

GRAYWACKE & ARGILLITE: 7020' to 8590'.

Steam entry @ 7679' & 7728'.

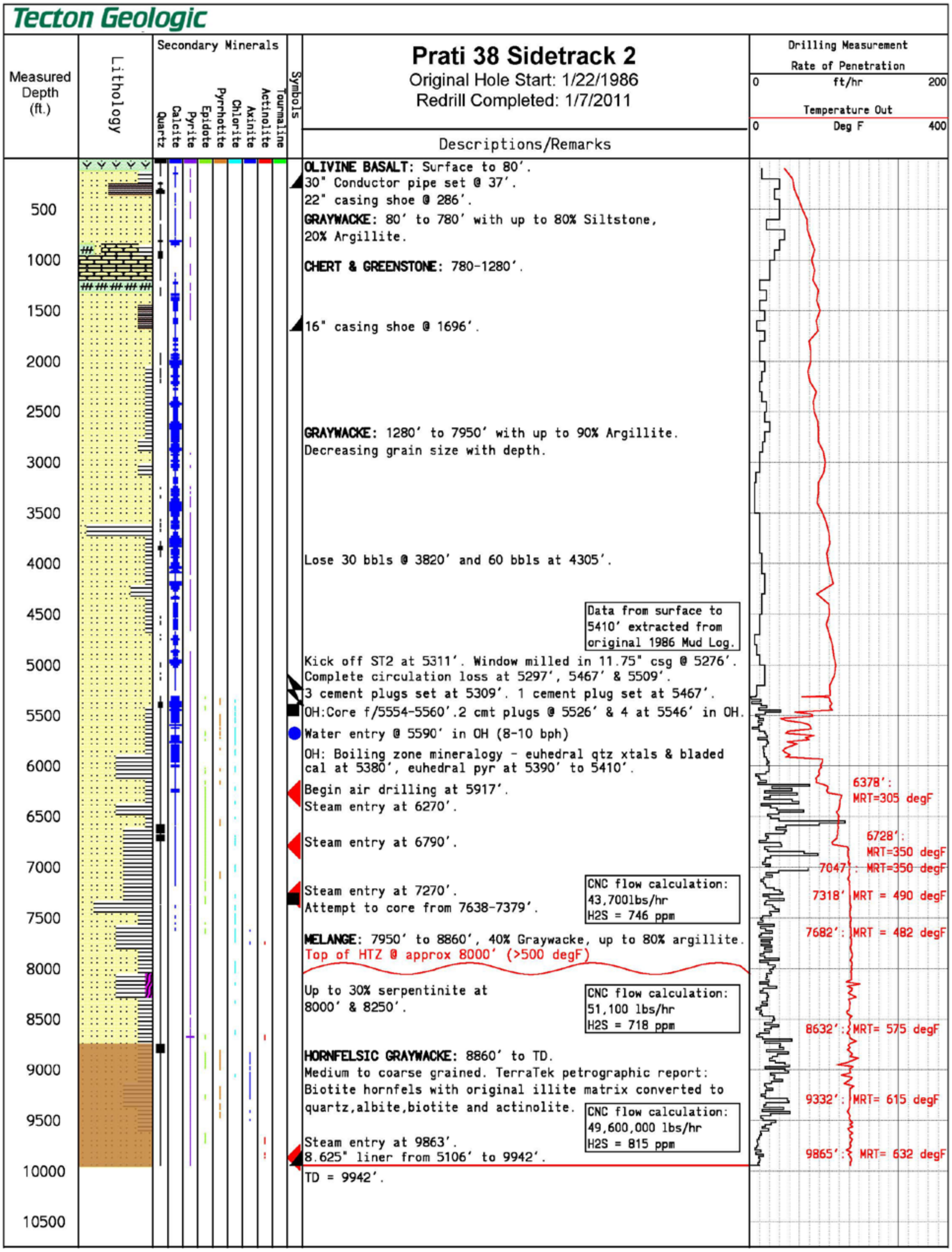
Steam entry @ 8215'.

MELANGE: 8590' to 8850'. Greenstone, graywacke, argillite and serpentinite.

GRAYWACKE & ARGILLITE: 8850' to TD', with occ traces of serpentinite.
8.625" liner run from 4968' to 9262' during reopening.

TD = 9411'.

CNC flow calculation:
59,500 lbs/hr
H2S = 760 ppm
2/6/2011



Prati 38 Sidetrack 2

Original Hole Start: 1/22/1986
Redrill Completed: 1/7/2011

Descriptions/Remarks

OLIVINE BASALT: Surface to 80'.
30" Conductor pipe set @ 37'.
22" casing shoe @ 286'.

GRAYWACKE: 80' to 780' with up to 80% Siltstone, 20% Argillite.

CHERT & GREENSTONE: 780-1280'.

16" casing shoe @ 1696'.

GRAYWACKE: 1280' to 7950' with up to 90% Argillite.
Decreasing grain size with depth.

Lose 30 bbls @ 3820' and 60 bbls at 4305'.

Data from surface to 5410' extracted from original 1986 Mud Log.

Kick off ST2 at 5311'. Window milled in 11.75" csg @ 5276'.
Complete circulation loss at 5297', 5467' & 5509'.
3 cement plugs set at 5309'. 1 cement plug set at 5467'.
OH:Core f/5554-5560'.2 cmt plugs @ 5526' & 4 at 5546' in OH.
Water entry @ 5590' in OH (8-10 bph)
OH: Boiling zone mineralogy - euhedral qtz xtals & bladed cal at 5380', euhedral pyr at 5390' to 5410'.

Begin air drilling at 5917'.
Steam entry at 6270'.

Steam entry at 6790'.

Steam entry at 7270'.
Attempt to core from 7638-7379'.

CNC flow calculation:
43,700lbs/hr
H2S = 746 ppm

MELANGE: 7950' to 8860', 40% Graywacke, up to 80% argillite.
Top of HTZ @ approx 8000' (>500 degF)

Up to 30% serpentinite at 8000' & 8250'.

CNC flow calculation:
51,100 lbs/hr
H2S = 718 ppm

HORNFELSIC GRAYWACKE: 8860' to TD.
Medium to coarse grained. TerraTek petrographic report: Biotite hornfels with original illite matrix converted to quartz,albite,biotite and actinolite.

CNC flow calculation:
49,600,000 lbs/hr
H2S = 815 ppm

Steam entry at 9863'.
8.625" liner from 5106' to 9942'.
TD = 9942'.

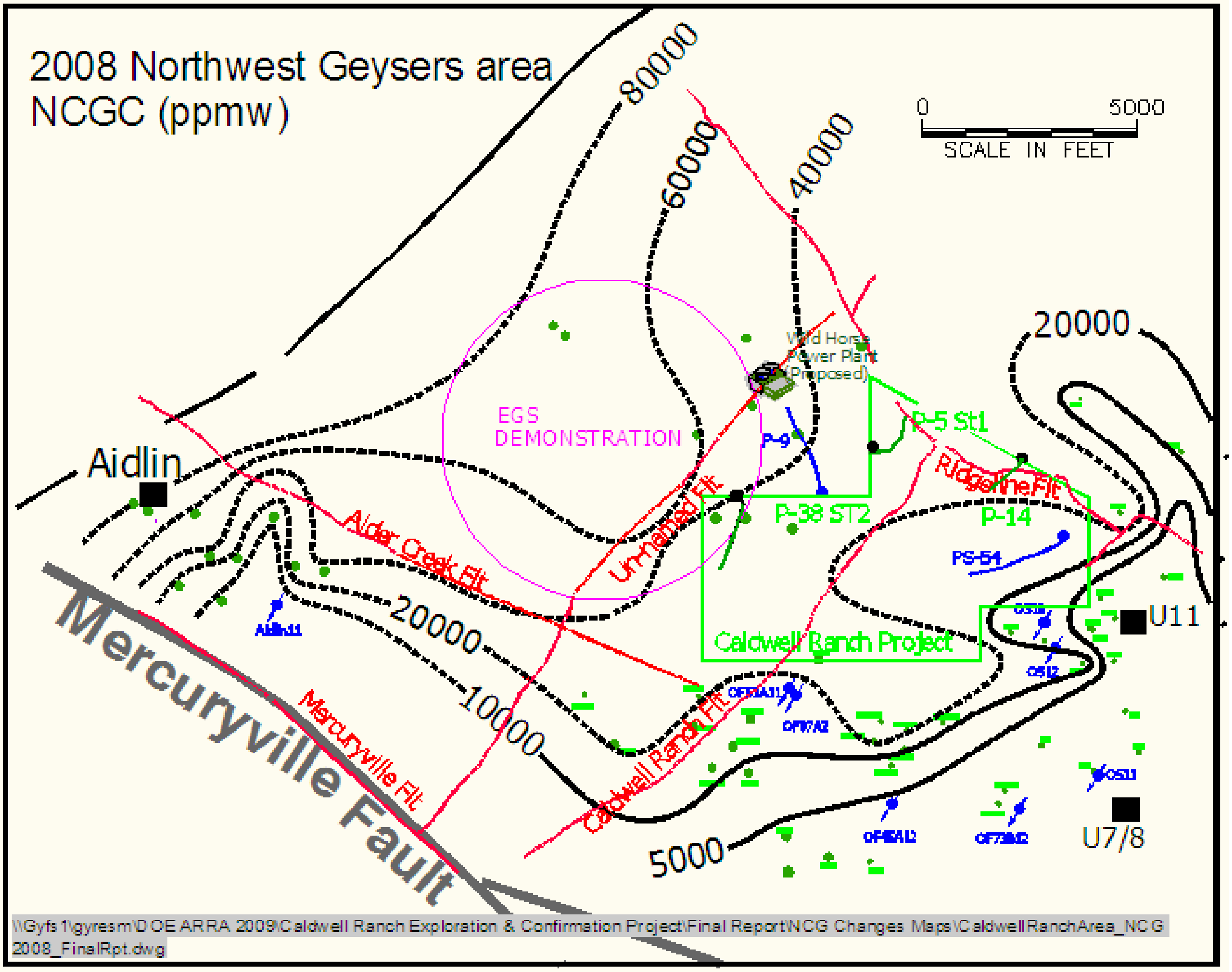
APPENDIX E

TOTAL NONCONDENSABLE GAS CONCENTRATION MAPS

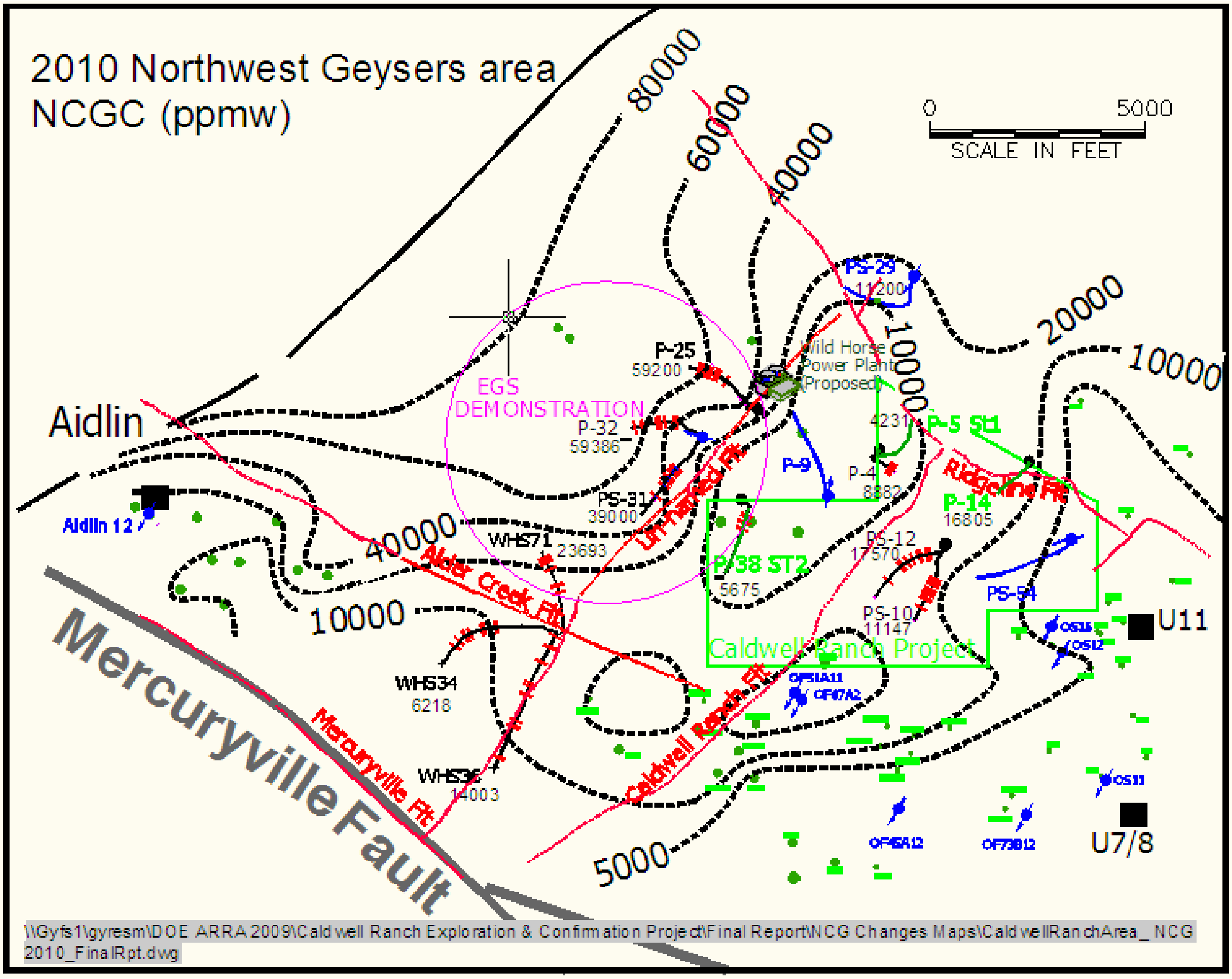
2008 (before Prati 9 injection)

2010 (after Prati 9 injection and re-opening of Caldwell Ranch wells)

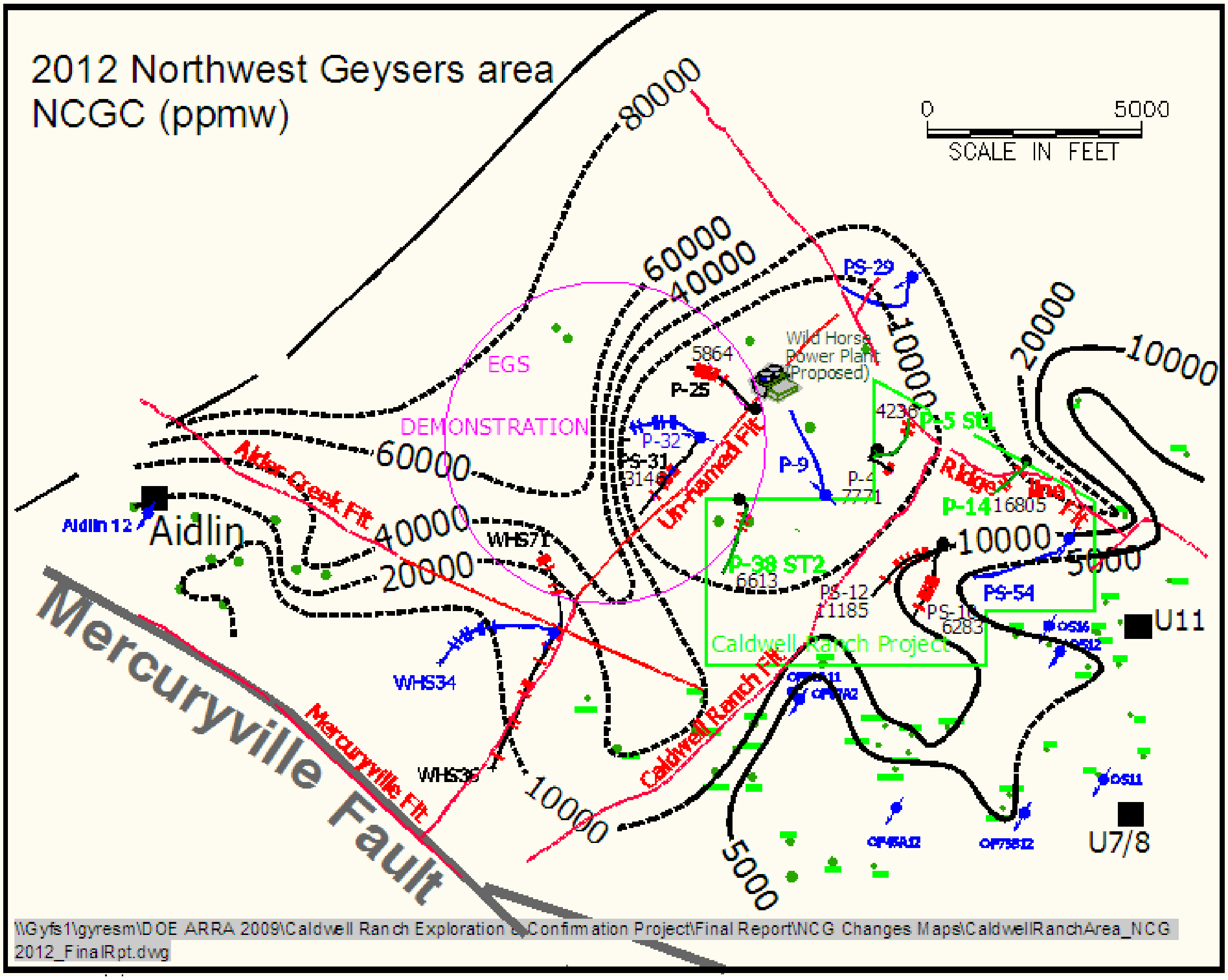
2012 (after production began from P-5 St1 and Prati 38 St2)



The Un-named Fault and the Caldwell Ranch Fault roughly divide the distribution of the noncondensable gas concentrations (NCGC) in the Caldwell Ranch Project into two reservoir compartments. The original gas concentrations between the Un-named Fault and Caldwell Ranch Fault in the northwestern part of the Caldwell Ranch Project area ranged from 20,000 ppmw (2 wt%) to 40,000 ppmw (4 wt%) NCG in the early 1980's until the first injection of meteoric water in 2008. The NCGC values in the southwestern part of the Caldwell Ranch project southwest of the Caldwell Ranch Fault originally ranged from 10,000 ppmw (1 wt%) to 20,000 ppmw (2 wt%) when P-14 and the nearby CCPA steam field wells were drilled in the 1980's and remain essentially the same in 2012.



After the injection of SRGRP water in the northwestern part of the Caldwell Ranch Project began but before the P-5 St12 were drilled and recompleted in late 2010, the original NCG concentrations between the Un-named Fault and Caldwell Ranch Fault were lowered from 20,000 ppmw (2 wt%) to 40,000 ppmw (4 wt%) NCG, to less than 10,000 ppmw (1 wt%). Within this time period, the NCGC values in the southwestern part of the Caldwell Ranch project southwest of the Caldwell Ranch Fault remained essentially the same as the original values, or from 10,000 ppmw (1 wt%) to 20,000 ppmw (2 wt%), even though Prati State 54 (PS-54) had been re-opened and completed as an injection well. To the northwest of the Caldwell Ranch Project in the EGS Demonstration Area, the NCGC ranged from 40,000 ppmw (4 wt%) to about 75,000 ppmw (7.5 wt%).



The NCGC in the EGS Demonstration area was dramatically decreased from a range of 40,000 ppmw (4 wt %) to 60,000 ppmw (6 wt %), to less than 10,000 ppmw (1 wt %), between October 2011 (when the injection of SRGRP water into Prati 32 (P-32) began) and September 2012. As a consequence, the steam from the northwestern portion of the Caldwell Ranch Project and the southwestern part of the EGS Demonstration now contains less than 1 wt% NCG.

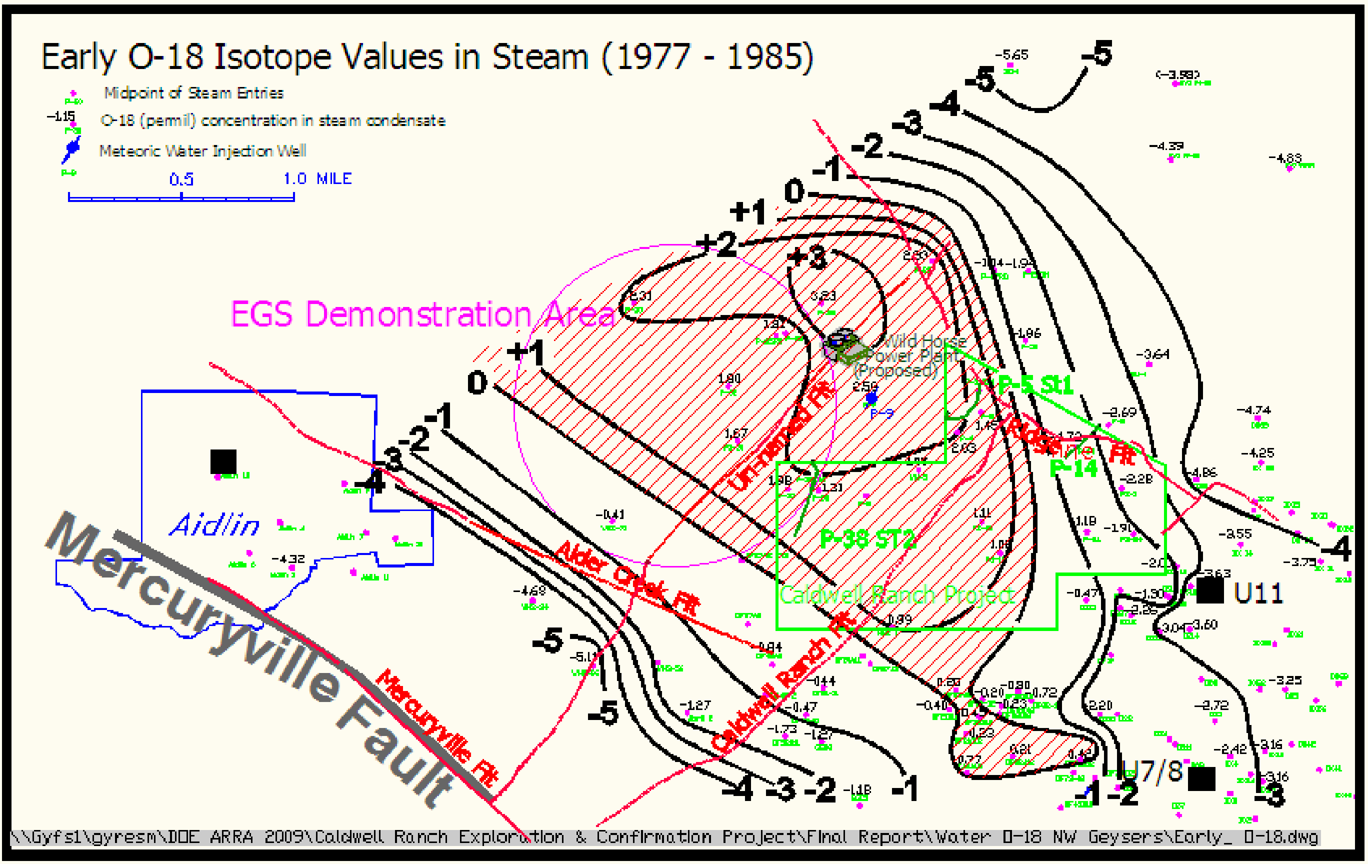
APPENDIX F

OXYGEN-18 VALUES IN NW GEYSERS STEAM CONDENSATE

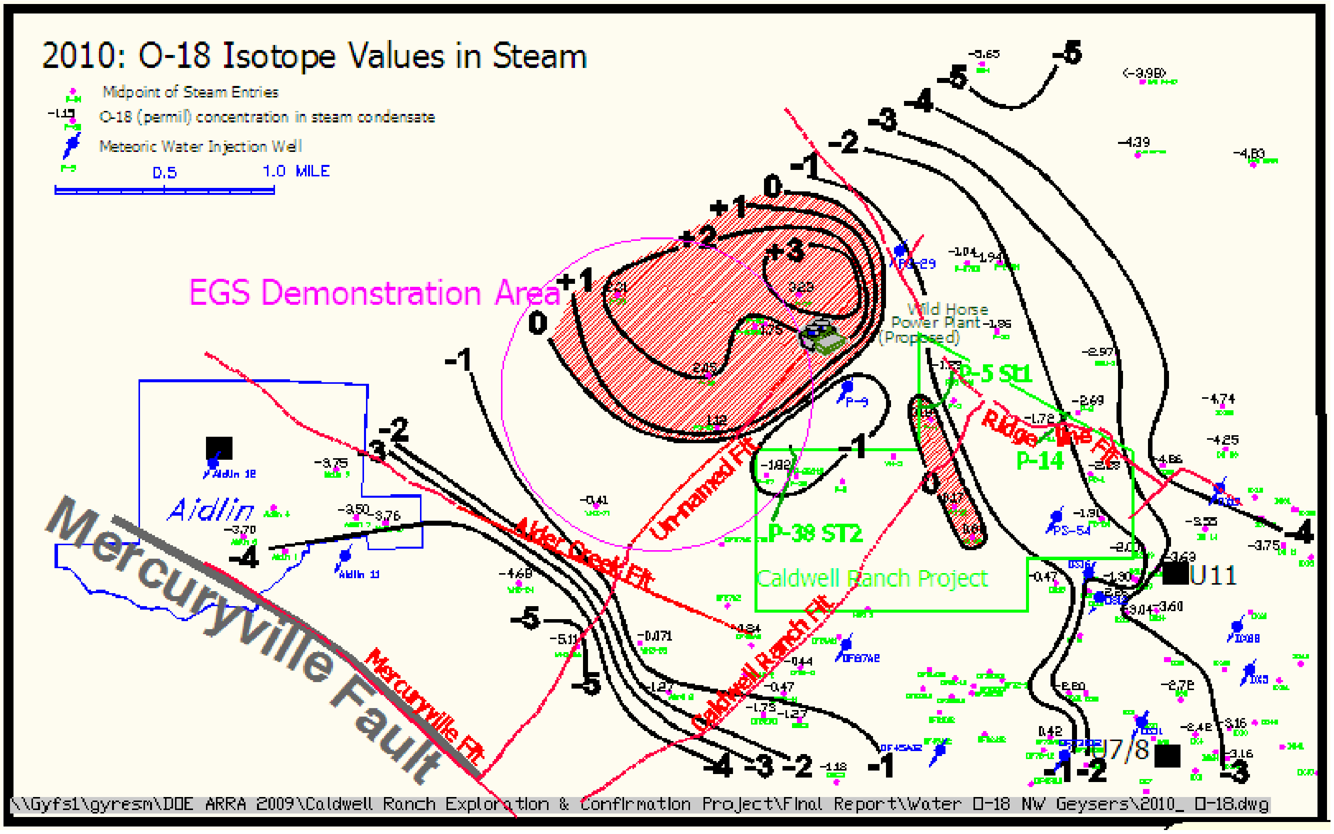
Early Oxygen-18 Values in Steam (1977- 1985) before production or injection

2010: Oxygen-18 Values in Steam (after Prati 9 injection of SRGRP water began)

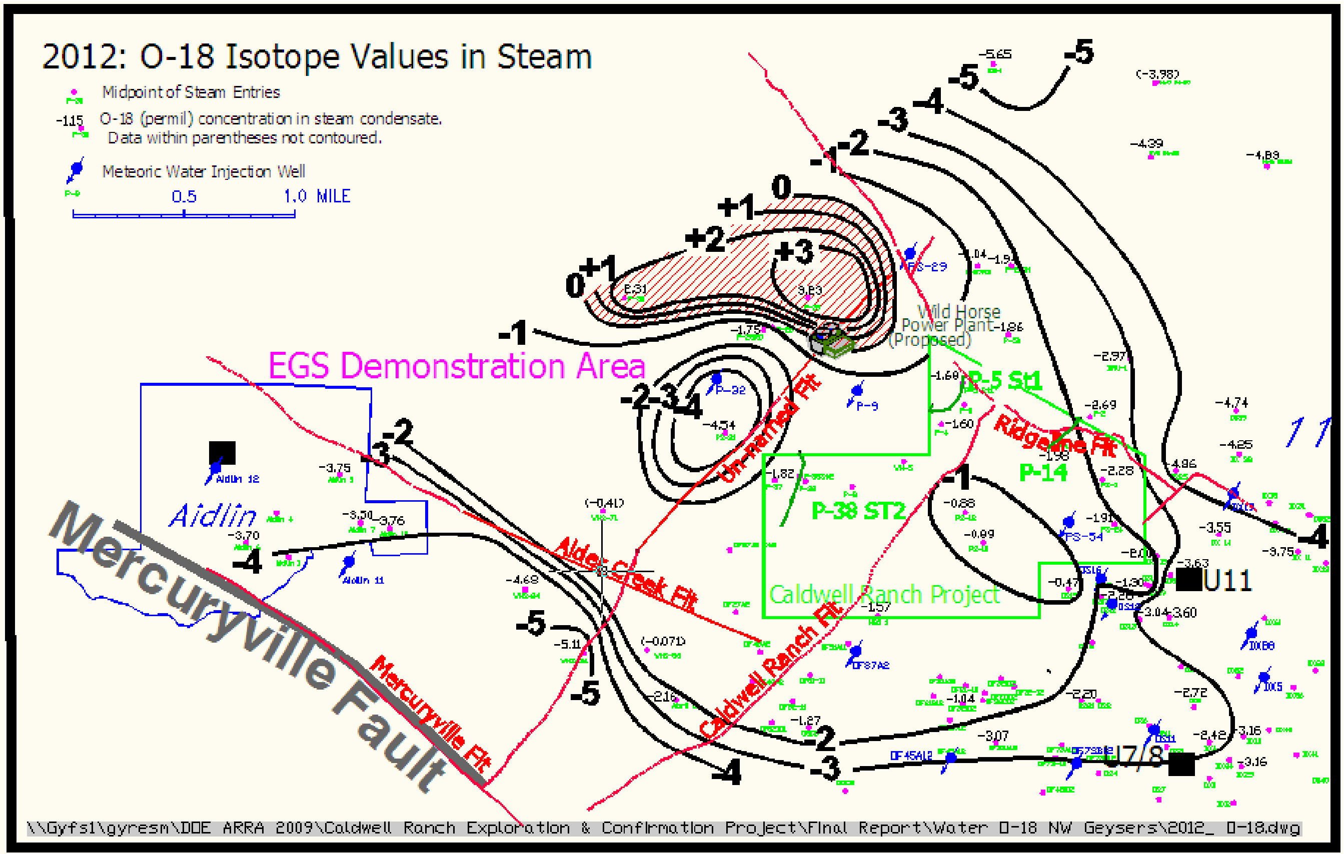
2012: Oxygen-18 Values in Steam (after production from P-5 St1 and Prati 38 St2 began)



The early (1977-1985) $\delta^{18}O$ values in steam condensate throughout the western half of the Caldwell Ranch project and EGS Demonstration Area ranged from 0 per mil to +3 per mil. These $\delta^{18}O$ values are indicative that the native steam in these areas was not significantly influenced by meteoric water. Various geochemical and fluid inclusion studies have concluded the early steam in these areas was from connate water (sea water trapped in the metagraywacke and argillite reservoir rocks) from the Mesozoic (about 150 million years ago). The $\delta^{18}O$ values in Standard Mean Ocean Water (SMOW) have not varied significantly for the last 150 million years.



The early (1977-1985) δ^{18}O values in steam condensate throughout the western half of the Caldwell Ranch project and EGS Demonstration Area ranged from 0 per mil to +3 per mil before the injection of SRGRP water into Prati 9 (P-9) beginning in 2008. By 2010 when P-5 St1 and P-38 St2 were first flow tested, the native steam had been flushed by injection-derived steam (IDS) from SRGRP water and the δ^{18}O values in the steam condensate were in the range of -1 per mil. Note in the figure above that the SRGRP water injection into P-9 did not flush the "heavy" δ^{18}O values ranging from +1 to +3 from the southwestern portion of the EGS Demonstration Area.



By 2012, after the injection of SRGRP water into the EGS Demonstration well, Prati 32 (P-32), began in October 2011, the δ¹⁸O values in steam condensate from Prati State 31 and Prati 25 were substantially reduced from the range of +1 to +2 per mil, to the range of -2 to -4 per mil.

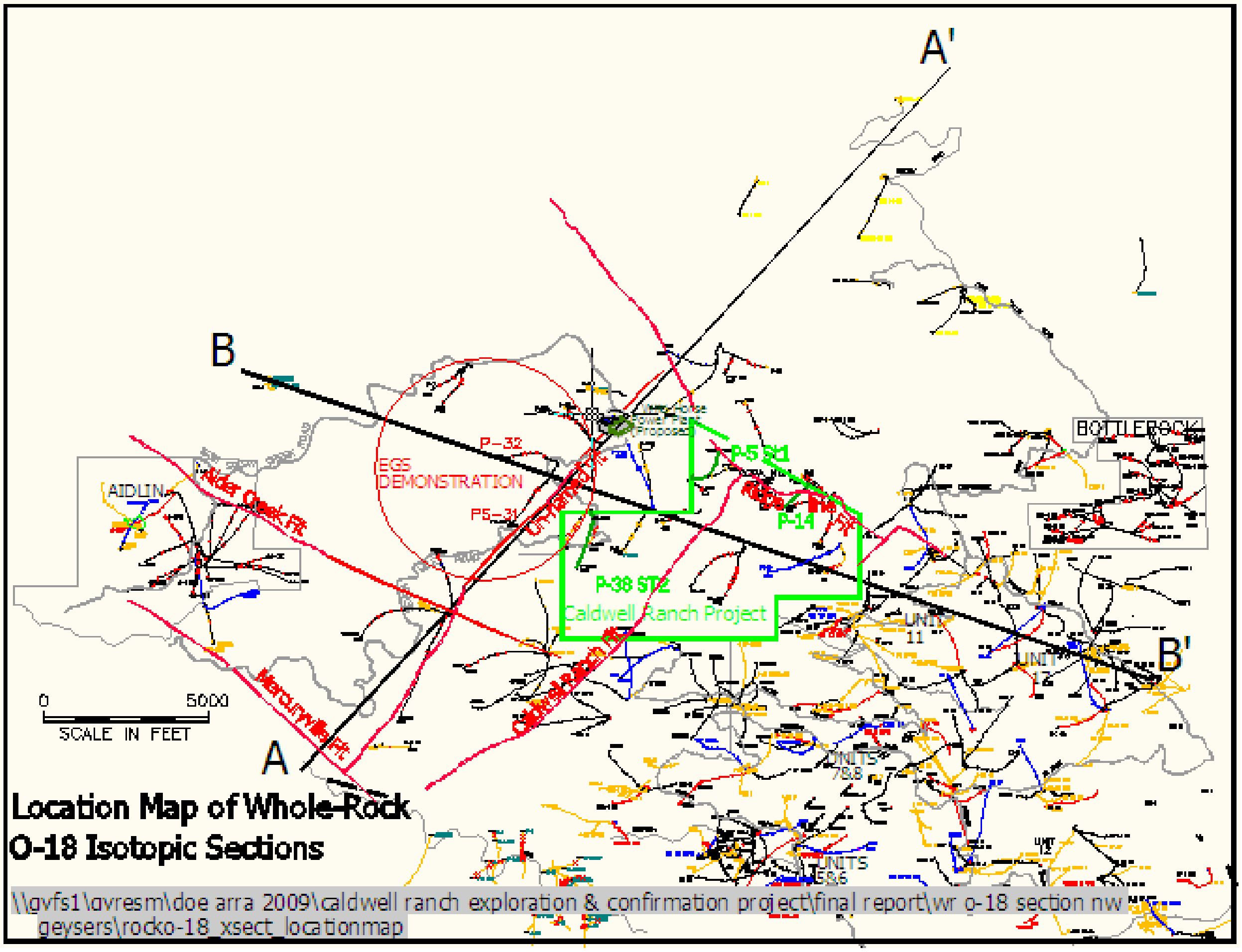
APPENDIX G

WHOLE-ROCK OXYGEN-18 VALUES IN NW GEYSERS

Location Map showing locations of Isotopic Sections

Whole-rock Oxygen-18 Section A-A’

Whole Rock Oxygen-18 Section B-B’



Caldwell Ranch Project

Location Map of Whole-Rock O-18 Isotopic Sections

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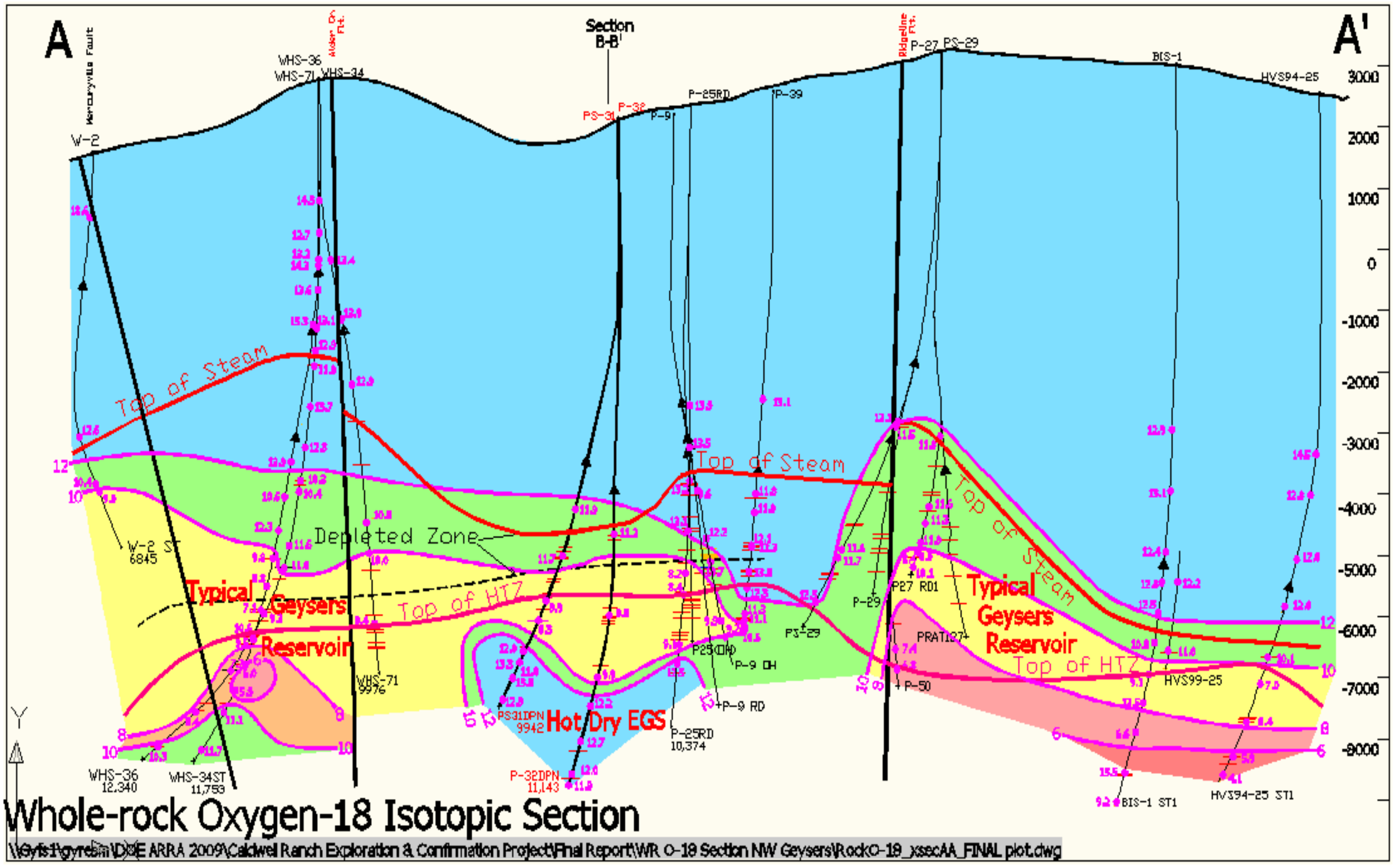

Whole-rock Oxygen-18 Isotopic Section

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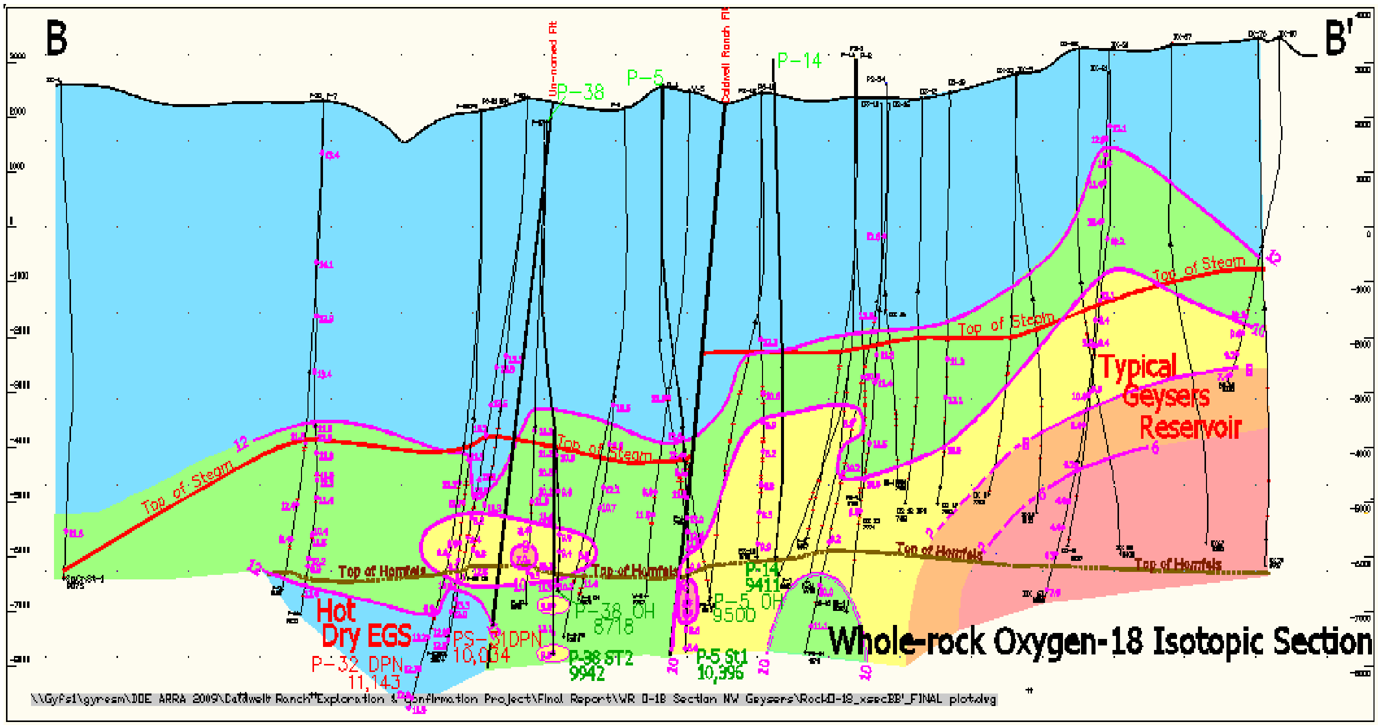
Adjacent to, and northwest of, the Caldwell Ranch Project area, an Enhanced Geothermal System (EGS) has been created in hot dry rock. Here the ^{18}O concentrations in the biotite hornfels are unexchanged by meteoric water. Consequently the cap rock to the normal temperature reservoir has the same range of unexchanged $\delta^{18}O$ values (+12 per mil) as the hot dry basement rocks. East of the EGS Demonstration Area and Ridgeline Fault, including the Prati 27 and High Valley areas, the ^{18}O concentrations in the Geysers metagraywacke reservoir rock are depleted by meteoric water from +12 per mil to +4 per mil. West of the Alder Creek Fault, the ^{18}O concentrations of the metagraywacke reservoir rock are depleted from +12 per mil to +5 per mil.



The geothermal reservoir rock in the northwestern portion of the Caldwell Ranch Project, between the Caldwell Ranch Fault and Un-named Fault, is only weakly exchanged with meteoric water. Here the $\delta^{18}O$ values have been depleted from +12 per mil to +10 per mil. South of the Caldwell Ranch Fault and in the area of P-14, the $\delta^{18}O$ values in the typical Geysers reservoir are progressively depleted to the southeast from +12 per mil to +4 per mil.

Note that the $\delta^{18}O$ values in four samples of drill cuttings from the P-5 St1 and P-38St2 wells have been flushed by meteoric water with the $\delta^{18}O$ values decreasing from about +11 per mil to +9 per mil and less.