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Abstract

The Hawthorne Nevada, deep direct-use geothermal study is a two-year effort funded by the U.S. Department of Energy to determine the techno-economic feasibility of implementing a large-scale, direct-use facility for the Hawthorne Army Depot (HAD) and the public facilities of the city of Hawthorne and Mineral County. The approach links a production side analysis (PSA) and a demand side analysis (DSA) into a whole-system analysis (WSA) to provide an integrated assessment of the resource and the probability of delivering economically viable direct-use energy to Hawthorne.

Hawthorne, Nevada is in the western part of the Basin and Range province and has been the focus of geothermal investigations for over 40 years. Over the last 15 years, several studies completed by the U.S. Navy Geothermal Program Office (GPO) in conjunction with industry professionals quantified the existence of several low temperature geothermal prospects, the most promising of which is called Prospect A. The promise of Prospect A is based on drilling and flow testing that produced ~100 °C water at flow rates of up to 31 l/s (500 gallons per minute). Measured productivity indexes range from 40-85 l/s/MPa, suggesting a warm and productive heat source.

Despite the promise of the resource, uncertainties in its spatial extent and long-term sustainability mean that techno-economic analyses must include probabilities of the sustainability of the resource under different operating scenarios. Here, the PSA is conducted by integrating a wide range of disparate data to estimate lognormal P90, P50, and P10 resource capacities. These capacities are used as input to a thermal-hydrologic (T-H) model to estimate thermal drawdown for each capacity estimate for several different DSA scenarios. Using a systems-based approach, the WSA links the dynamic T-H simulations of the PSA/DSA combinations with the techno-economic model GEOPHIRES to account for both the temporal dynamics and uncertainties in the system to produce probabilistic distributions of several performance metrics including the levelized cost of heat (LCOH) and the return on investment (ROI). This report is the final delivery for the project and documents the study's activities and results.

ACKNOWLEDGMENTS

We would like to thank the Department of Energy Geothermal Technologies Office for funding this project as well as for their guidance and review comments on this work. Our technical reviewer, Paul Schwering also deserves thanks. His insight and comments were a significant addition to the quality of this report. We also want to thank the many people at the HAD, City of Hawthorne, and Mineral County, who showed great interest and enthusiasm in helping us complete this project.

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NOMENCLATURE

Abbreviation	Definition
ASHRAE	American Society of Heating, Refrigeration, and Air conditioning Engineers
BLM	Bureau of Land Management
BTU / MBTU	British Thermal Unit / Million BTU's
COP	Coefficient of Performance
DOE	Department of Energy
DSA	Demand Side Analysis
EBS	Environmental Baseline Study
EIA	Energy Information Agency
gpm	Gallons Per Minute
GPO	Geothermal Programs Office
GTO	Geothermal Technologies Office
GWh / kWh	Giga-Watt hours / kilo-Watt hours
HAD	Hawthorne Army Depot
HVAC	Heating, Ventilation, and Air Conditioning
LCOH	Levelized Cost Of Heat
MT	Metric-Ton (1,000 kilograms)
MWe	Mega-Watt electric
MWth	Mega-Watt thermal
NDEP	Nevada Division of Environmental Protection
NDOM	Nevada Division of Minerals
NEPA	National Environmental Policy Act
NPDES	National Pollutant Discharge Elimination System
NOI	Notice of Intent
O&M	Operations and Maintenance
P&A	Plugged and Abandoned
PE	Power Engineers
PI	Productivity Index
PSA	Production Side Analysis
PSI	Pounds per Square Inch
REC	Record of Environmental Consideration
RMSE	Root Mean Squared Error
ROI	Return On Investment
TDS	Total Dissolved Solids
UIC	Underground Injection Control
WSA	Whole Systems Analysis
XRD	X-ray Diffusion

1. INTRODUCTION

This project develops a multi-disciplinary, three-tiered analysis approach to assess the geothermal resource and determine the feasibility of implementing a large-scale, direct-use facility for the Hawthorne Army Depot (HAD) and the various city and county facilities in Hawthorne, Nevada (Figure 1). This assessment directly targets a geothermal resource recently characterized by the Navy Geothermal Program Office (GPO) as part of a focused exploration and development campaign. The output from this project is a comprehensive techno-economic feasibility assessment that accounts for both the temporal dynamics and uncertainties of the system to produce probabilistic distributions of several performance metrics including the levelized cost of heat (LCOH) and the return on investment (ROI). The intent is to allow decision makers from the City of Hawthorne, Mineral County, and the HAD to select configurations that best meet their priorities and financial capabilities and are thus also the easiest to implement.

The three-tiered analysis approach links a production side analysis (PSA) and a demand side analysis (DSA) into a whole-system analysis (WSA) that provides an integrated assessment of the resource and its ability to provide economically viable direct-use energy to the Hawthorne area. The PSA leverages past work to inform high-resolution sub-surface flow and heat transport modeling to determine the long-term thermal performance as a function of flow rate. The DSA factors in efficiencies and losses from an installed system along with results from the PSA to determine the total heating capacity in terms of square footage. The WSA uses system dynamics theory and advanced modeling capabilities to understand the integrated dynamic behavior and dependencies between the production and demand sides to determine the economic feasibility. This report represents the successful completion of this study and provides a blueprint for direct-use implementation in the Walker Lake Valley. It also serves as a template to efficiently conduct similar types of assessments at other military installations and communities world-wide.

1.1. Location and Research History

The City of Hawthorne, located in the Walker Lake Valley in western Nevada approximately 90 miles southeast of Reno, has a population of approximately 3,200 and serves as the Mineral County seat (Figure 1). Hawthorne houses a local hospital, a K-12 school system, the county courthouse, library, and the sheriff's office. In 1981 the Nevada Department of Energy commissioned a study to create a plan to develop geothermal energy for the City of Hawthorne (GDA, 1981) that estimates the annual heat demand for space heating in the courthouse, hospital, library, and schools to be 10.8×10^9 BTU/yr with a peak of 8.8×10^6 BTU/hr.

Hawthorne is also the location of the 147,000-acre Hawthorne Army Depot (HAD). The HAD currently uses two 500-hp diesel fired boilers that produce steam for district heating of the office buildings and the housing units from September 1st to May 31st each year (273 heating days) (Power Engineers, 2012).

Hawthorne lies in the 60-mile wide Walker Lane tectonic belt. The Walker Lane belt is a north-northwest trending geologic trough between the stable North American continent and the Sierra Nevada micro-plate (Oldow, 2003). It is characterized by northwest striking right-lateral strike-slip faults that run from the San Andreas fault in Southern California up to the eastern slope of the Sierra Nevada range. Walker Lane is the home to many geothermal energy prospects, some of which have been successfully developed (Faulds et al., 2006; Faulds and Hinz, 2015).

The Walker Lake Valley has long been recognized as having geothermal resources that can support large scale district heating (Bohm and Jacobson, 1977a; GDA, 1981; Trexler et al., 1981). Extensive geothermal exploration activities by the GPO (Lazaro et al., 2010; Meade et al., 2011) resulted in drilling 3 moderate to deep wells along the eastern front of the Wassuk Range (Figure 1). Testing of the most promising well, HWAAD-2A, revealed an extensively fractured horizon with a down-hole temperature of 115 °C (239 °F). A flow test performed on HWAAD-2A demonstrated 96 °C (207 °F) fluid flowing at 12.4 l/s (196 gallons per minute - gpm) with a calculated productivity index (PI) of 107 l/s/MPa (9 gpm/psi). Another well, HWAAD-3, which is to the northeast of HWAAD-2A had a measured downhole temperature of 89 °C (192 °F). In addition, elevated groundwater temperatures also occur in several wells drilled to the north of HWAAD-2A and HWAAD-3 wells.

In 2012, Power Engineers Inc. (PE) was commissioned by the GPO to conduct a study (Power Engineers, 2012) evaluating three direct-use heating systems for the HAD. While informative for its intent, the PE study does not include the entire geothermal resource, which extends onto the adjacent city and county land, nor does it include city or county facilities in its proposed direct-use applications. One source that was not included in the PE study that is relevant here is known as the El Capitan well, which was drilled in the early 1980's as a potential geothermal source for a planned resort (Trexler et al., 1981). While the resort never panned out, flow tests revealed that the "El Cap" well produced over 31.5 l/s (500 gpm) of 99 °C (210 °F) water with an estimated PI of 44.2 l/s/MPa (4.83 gpm/psi).

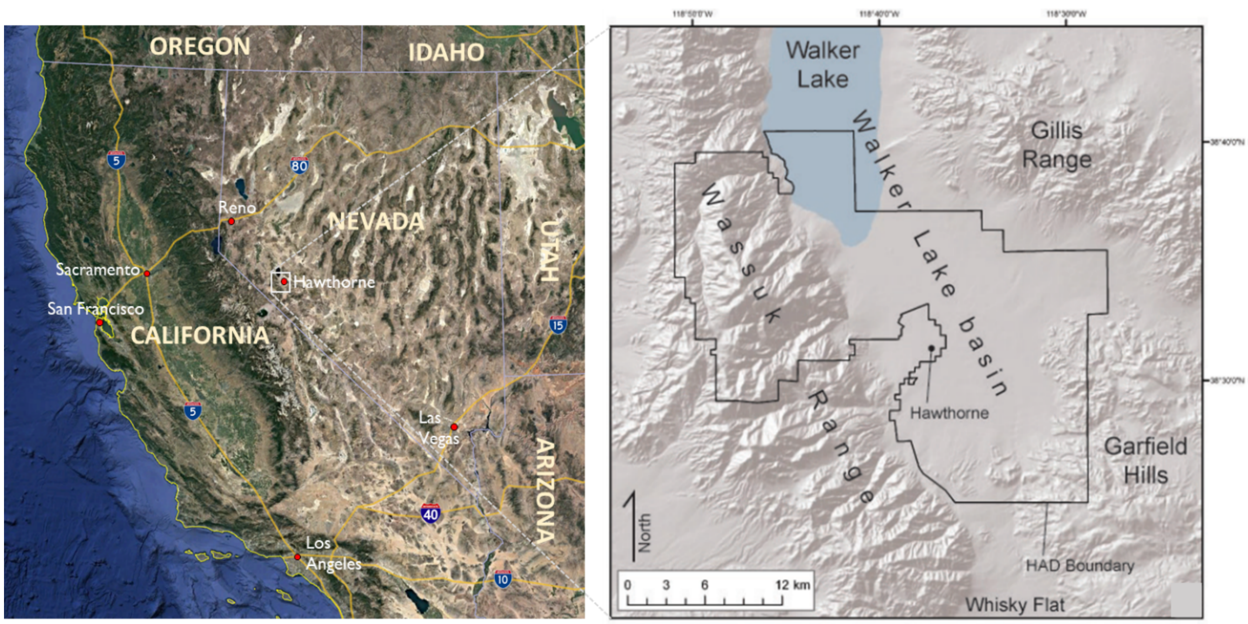

Figure 1 – Location of the study area, (left), the Walker Lake basin, the City of Hawthorne and the HAD (right). The dark outline in the figure on the right represents the boundary of the HAD.

The Navy GPO also supported the development of a 3D geologic model of the Hawthorne region to better understand the mechanism by which elevated water temperatures may occur (Moeck et al., 2010). The modeling combined geologic surface data and sets of geologic cross-sections based on well data to create a 3D stratigraphic representation of the geology (Figure 2). The model clearly shows the releasing bend in the NNW-trending fault system along the Wassuk Range front that is thought to be favorable for geothermal fluid flow.

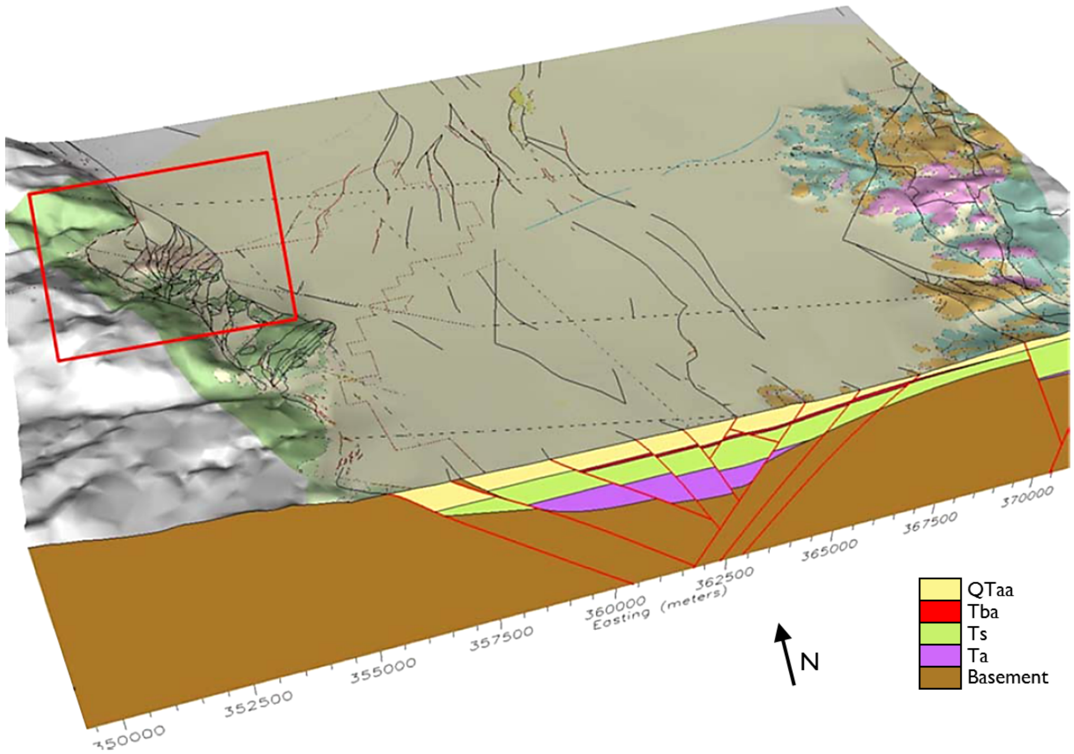

Figure 2 - 3D Geologic model of the Walker Lake Valley Region from (Moeck et al., 2010). The City of Hawthorne is in the lower right hand portion of the red square, which highlights the complex releasing bend along the Wassuk Range front. QTaa = Quaternary alluvial and lacustrine sediments, Tba = Late Tertiary basaltic andesitic lavas, Ts = Late Tertiary fluvial and lacustrine sediments, Ta = Late Tertiary andesite lavas, Basement = Mesozoic volcanics, sediments, and granite.

Further confirming the potential of the Hawthorne area geothermal resource is the DOE funded play fairway analysis study by Faulds et al. (2016), that incorporates local structure modeling, regional scale permeability modeling, and temperature at depth data to evaluate blind geothermal resources in the Great Basin Region. While not the central focus of their study, the Hawthorne area lies within their study area with their results ranking the Hawthorne geothermal resource on the high end of their geothermal potential scale (Figure 3).

These past works are presented in more detail below.

1.2. Scientific Approach

This study develops and utilizes a multi-disciplinary, three-tiered analysis approach to assess the geothermal resource and determine the feasibility of implementing a large-scale, direct-use facility for the Hawthorne Army Depot (HAD) and the various city and county facilities in Hawthorne, Nevada. This assessment directly targets the geothermal resource to produce a comprehensive techno-economic feasibility assessment that accounts for both the temporal dynamics and uncertainties of the system to provide probabilistic distributions of several performance metrics including the levelized cost of heat (LCOH) and the return on investment (ROI). The intent is to allow decision makers from the City of Hawthorne, Mineral County, and the HAD to select configurations that best meet their priorities and

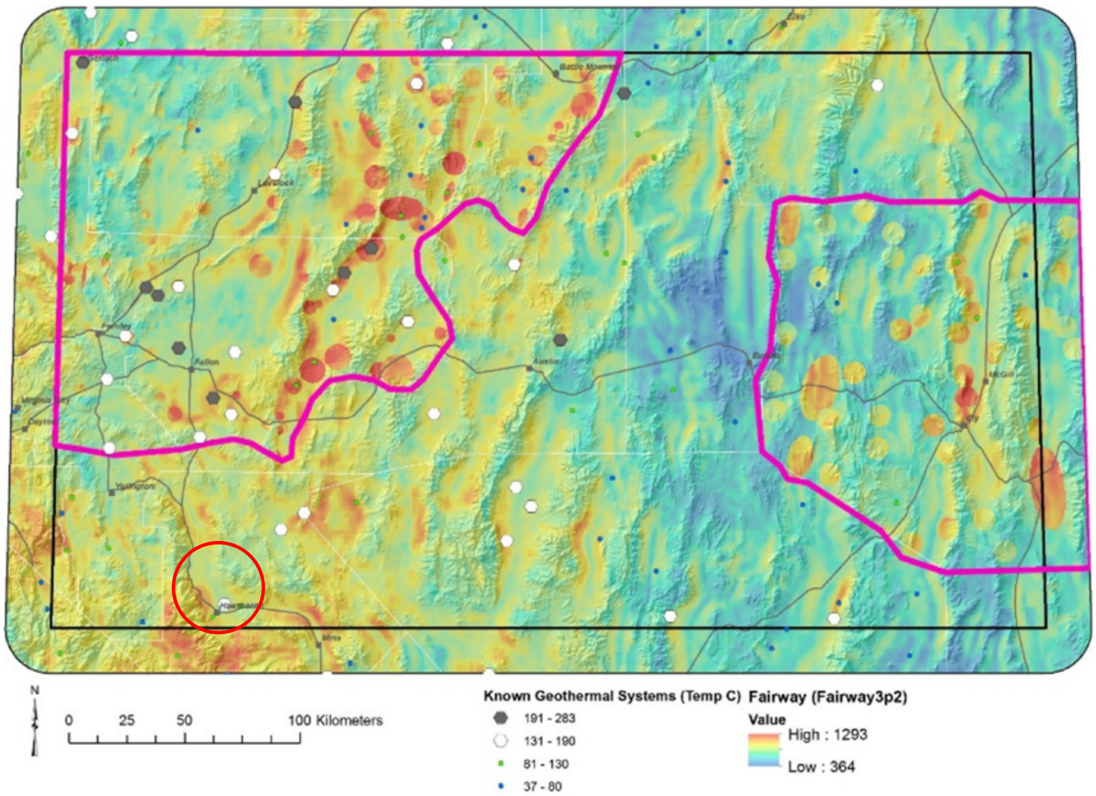

Figure 3 - Preliminary model of the Great Basin "fairway" that incorporates a local structure model, regional scale permeability, and temperature at a depth of 3 km. Reproduced from Faulds et al. (2016). Hawthorne is located in the lower-left of the image circled in red. The purple boundaries are the focused study areas of Faulds et al. (2016). Warmer colors are more favorable for geothermal development.

financial capabilities and are thus also the easiest to implement.

Four, high-level feasibility questions were addressed during the execution of this study:

1. What is the sustainable, heating and cooling potential of the geothermal resource?
2. What are the heating and cooling demand loads of the service area?
3. What is the optimal direct-use configuration to exploit the resource?
4. What are the economics of that configuration?

Despite the considerable amount of past work, there are gaps in the understanding of the hydrogeologic characterization of the resource and its long-term dynamic response under different levels of exploitation that prevented us from directly answering these questions. Thus, to answer the feasibility questions, the following scientific questions were also addressed:

1. What is the extent of the thermal resource?

2. What is the sustainable pumping capacity of the resource?
3. What is the thermal drawdown as a function of pumping rate?
4. What are the dynamics between the rate of geothermal fluid extraction, temperature, and sustainability?
5. How do system uncertainties influence the feasibility estimates?

The integrated three-tiered, PSA, DSA, and WSA approach developed for this project is designed to answer these questions in a systematic and efficient manner. Each analysis is described in more detail below.

1.2.1. Production Side Analysis

Production side analysis (PSA) focuses on evaluating the hydro-geothermal resource to determine the long-term thermal and hydrologic performance of the system as a function of flow rate. This involved four distinct steps; 1) Review and re-process existing data, 2) Update the conceptual model of the sub-surface and the geothermal resource, 3) Conduct a power density analysis to develop probabilistic estimates of the resource extent, and 4) Model the resource to determine thermal drawdown over time.

The main purpose of the PSA is to better understand the sub-surface system and to estimate realistic values of its geological and hydrological characteristics such that the long-term thermal performance of the system can be simulated as a function of the extraction location and rate. The modeling places boundaries on the systems' thermal performance as a function of the uncertainties in the geological and hydrological parameter estimates and allows us to conduct sensitivity analysis by probabilistically varying the model inputs about their range of uncertainty. The results of the uncertainty analysis are propagated through to the WSA (described below) to produce probabilistic estimates of whole-system performance. The PSA also allows us to identify sources of uncertainty that if better understood would narrow the feasibility estimates the most.

1.2.2. Demand Side Analysis

The demand side analysis (DSA) considers the heating and cooling demands of the city, county, and HAD facilities as well as efficiencies and losses associated with extracting, converting, and transporting heat to the end user. The project team worked with facilities managers to understand their current system and gather the necessary data to model the loads. Personnel from the HAD were engaged to update the estimates from the Power Engineers (2012) study. Load modeling is used to predict the amount of square feet that can be heated as a function of mass flow rate and temperature. This in turn is converted into a menu of buildings that can be serviced by the system.

A final piece of the demand side analysis is to build an understanding of the economics of the current and proposed systems. This involves determining operation and maintenance (O&M) and energy costs for the current system so they can be meaningfully compared to the proposed systems.

1.2.3. Whole System Analysis

Whole system analysis (WSA) brings together the production and demand analyses to consider the dynamic integration between the two sides. Unique to geothermal energy is the fact that the total energy produced from a resource is a function of how the resource is stressed, and how the resource is stressed is a function of the demand requirements of the end user. Because the costs of drilling and developing a geothermal well are so high, the goal is to stress the resource enough to get maximum benefit in a manner that is sustainable over the long-term.

The whole system analysis is based on the science of system dynamics (Forrester, 1961) to conduct analyses of the complex dynamics and feedbacks between the production and demand sides. The probabilistic estimates from the PSA and the cost and performance factors from the DSA are used to supply input to the GEOPHIRES geothermal techno-economic simulator (Beckers and McCabe, 2018). For this study, uncertainties in resource extent, well placement, and number of wells are simulated.

2. PRODUCTION SIDE ANALYSIS

2.1. Introduction

The Hawthorne geothermal area is in the Walker Lake basin in the western part of the Great Basin, USA, and has been the focus of geothermal exploration efforts for over 40 years. It contains several blind geothermal systems that were first discovered in the 1940's and 1950s during the drilling of water wells, and has no surface thermal manifestations. Targeted geothermal exploration efforts did not begin until the mid-1970's and have continued sporadically through to the present day. Key exploration activities conducted to date include the drilling and logging of multiple thermal gradient wells and deeper slim-holes, 2 m temperature surveys, gravity, 3D reflection seismic and LiDAR data acquisition, detailed geological and structural studies, and fluid geochemistry sampling from wells in the basin. Previous work identified three known geothermal anomalies (prospects) in the basin; Prospects A, B and C (Hinz et al., 2010) (Figure 4). Downhole temperature logs indicate that these three systems are low-temperature (< 120 °C), and at least two of the three have shallow outflow plumes as observed in temperature logs. With the exception of Prospect A, the locations of geothermal up-flow for these three anomalies are poorly constrained.

The reason the Hawthorne site is the subject of this feasibility study is because of its proven resource potential and long history of exploration, and the opportunity to utilize the geothermal resource for direct-use applications at the Hawthorne Army Depot (HAD) and surrounding community. For the project, Prospect A was prioritized as the potential resource, given its more-comprehensive subsurface dataset (including well-test data), and proximity to the HAD and City of Hawthorne (Figure 4). The PSA evaluated the potential resource capacity of Prospect A in terms of temperature, fluid production rates and reservoir size/volume, through review and integration of the existing geoscientific data for the area, and developed new resource conceptual models at different levels of certainty (but always honoring the data). It was these new resource conceptual models that were used to estimate the potential power capacity for Prospect A.

2.2. Previous Geothermal Exploration

Anomalously warm ground water was first discovered in the Hawthorne area in the 1940's and 1950's on property that belonged to the U.S. Navy, with temperatures ranging from ~16 °C to ~52 °C (Koenig et al., 1981). Several studies in the late 1970's and early 1980's attempted to learn more about the potential geothermal resource and its potential for direct-use applications, including work by Bohm and Jacobson (1977a), Geothermal Development Associates (1981), Robinson and Pugsley (1981), and Koenig et al. (1981). Bohm and Jacobson (1977a) proposed that hot water emerged along faults that transect the basement and alluvium along the Wassuk Range front, and is mixed with cooler water, flowing eastward and northward. The study by Koenig et al. (1981) was comprehensive, and included the acquisition of new data such as water geochemistry, shallow 2-meter temperature surveys, temperature logging of available wells, soil mercury surveys, a gravity survey, low sun-angle photography to assist in identifying recent fault scarps in the basin, and drilling of two new thermal gradient wells (HHT-1 and HHT-2). Around this time (1980), a ~305 m (1,000 ft) deep geothermal well was drilled by a private landowner (El Capitan Club Estates), who hoped to use the geothermal fluids for space heating. The well was named 'El Capitan' and had a maximum measured temperature of 98 °C (210 °F). It was also subjected to pump tests to prove the aquifer transmissivity, as well as geochemical sampling.

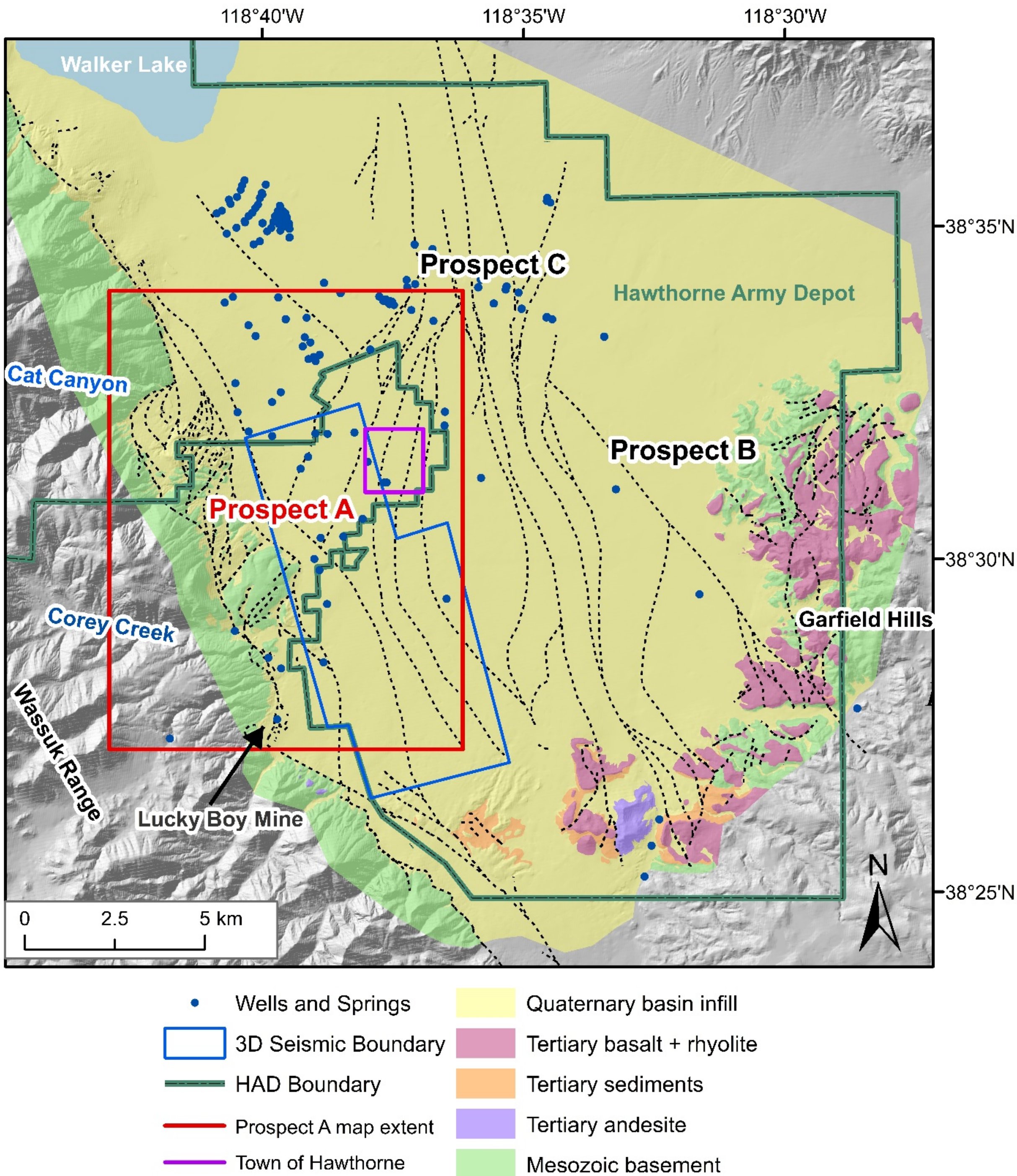

Figure 4 - Semi-transparent geologic map draped over shaded relief image, and key locations mentioned in the text including the approximate area of geothermal anomalies, informally called Prospects A, B and C. Red box corresponds to the map extent of Figures 5 and 11. Faults are represented as dotted black lines.

Koenig et al. (1981) synthesized and interpreted these data from the El Capitan well alongside those collected in their study, and other pre-existing data from the earlier studies. Key findings from this work included the observation that in surface water samples from rivers draining the east side of the Wassuk Range, and in samples from shallow water wells (< 100 m deep), sulfate concentrations increased towards the basin. Additionally, a shallow temperature anomaly was mapped from the 2 m temperature data and test well data, which trended from south to north around the City of Hawthorne area. Deep geothermal fluids were speculated to rise up along permeable faults (in an area of fault intersections near the El Capitan well) and flow out in a northerly-plume hosted in the basin-infilling sediments. A second anomaly was identified just east of the Garfield Hills, but the source or conceptual model of this anomaly was not well constrained.

Continued work by the Navy's Geothermal Program Office (GPO) in the late 1990's and early 2000's to understand the geothermal resource potential of the Hawthorne area included the acquisition of new gravity and magnetic data (Katzenstein et al., 2002). These data were used in conjunction with the existing geochemistry, geological, and geophysical data to develop a conceptual model (cross section) of the geothermal resource on the eastern edge of the Wassuk Range. Key conclusions were similar to earlier interpretations proposed by Bohm and Jacobson (1977a, 1977b), Robinson and Pugsley (1981) and Koenig et al. (1981). Katzenstein et al. (2002) proposed that meteoric water falling on the Wassuk Range percolates down to depths of at least 2,100 m (7,000 ft), is heated, and rises to the surface via faults bounding the eastern edge of the Wassuk Range. Additionally, Katzenstein et al. (2002) recommended the acquisition of a 3D reflection seismic survey to improve the mapping of subsurface structure, and to help site a deep drilling target.

In 2005, the GPO conducted a 3D seismic reflection survey in an attempt to image subsurface fault patterns in a 10 square mile area extending from well HHT-1 to the east of the Lucky Boy Mine (see Figure 4). Ongoing efforts by the Navy GPO culminated in the drilling of multiple wells between 2008 and 2012, including 13 thermal gradient wells (< 200 m deep), three deeper slim holes, one direct-use test hole, and later modifications to two thermal gradient holes (Lazaro et al., 2010; Meade et al., 2011; Blake et al., 2017). The deeper wells were logged, flow tested, and cuttings samples were analyzed using X-ray diffraction (XRD) and petrographic analysis. Additionally, the Navy GPO subcontracted the Great Basin Center for Geothermal Energy to conduct a comprehensive study of the area in 2008-2009. This included detailed geological mapping and structural analysis, developing a 3D geological model of the Walker Lake basin, interpreting the 3D seismic survey, evaluating fluid chemistry, conducting additional 2 m temperature surveys, inversion of gravity data, and evaluation of LiDAR and low sun-angle photography to identify Holocene fault scarps (Bell and Hinz, 2010; Hinz et al., 2010; Kell-Hills et al., 2010; Kratt et al., 2010; Moeck et al., 2010; Penfield et al., 2010; Shoffner et al., 2010). Key findings from this work included identifying an additional thermal anomaly in the basin (bringing the total to three), providing improved delineation of the thermal anomalies via the 2 m data and new temperature logs from the Navy exploration wells, and developing the first 3D structural and geological model of the basin (Figure 2).

2.3. Review of Existing Data

Review and integration of the geological, geochemical and well log data provided new insight into the geothermal system characteristics at Prospect A, and resulted in updates to the previously proposed conceptual model (Ayling et al., 2020). The well temperature and geochemical datasets were the most important for informing the new conceptual model.

2.3.1. Local geology

Prospect A is centered along a 3 km-wide by 12 km-long step-over along the NNW-striking, WNE-dipping Wassuk Range-front fault system (Figures 4 and 5). The step-over consists of two major synthetic range-front fault splays (Faults A and B) bounding an area with numerous NNE- to NE-striking faults. Range-front fault strands A and B both have local 0.5 to 1 km step-overs along-strike, including a nearly ninety-degree bend associated with a step-over near the Ken Maples-1 well. This step-over near the Ken

Maples-1 well is also where the NNE- to NE-striking Hawthorne fault zone projects into the Wassuk Range-front fault zone. The specific linkage or cross-cutting patterns between individual fault strands is not well understood as many fault strands are buried by Late Pleistocene or Holocene alluvium.

Both the range-front fault zone and the Hawthorne fault zone have Late Pleistocene and Holocene fault scarps, indicating relatively active Quaternary fault activity (Bell and Hinz, 2010). Borehole image log analysis and kinematic analysis of fault surface data indicate that the least principal stress extension direction is N47°W and N53°W, respectively (Hinz et al., 2010; Moeck et al., 2010). This stress field orientation could facilitate oblique motion along the Wassuk Range-front fault system and provides a basis for potential enhanced permeability at discrete right step-overs in this fault zone.

The stratigraphic framework defined in the Prospect A area includes only Miocene to present basin-fill sediments and Mesozoic granite. Exposures of these sediments along the fault zones show they are composed of lacustrine sand and silt, pebble conglomerate of fluvial and lacustrine origin, and lesser evaporites and tuffs. The two slim wells, HWAAD-2A and HWAAD-3, both intersect basin-fill sediments and cross-strands of the range-front fault and terminate in Mesozoic granite. From these well records and the 3D seismic data, the late Miocene basaltic andesite pinches out and the middle Miocene andesite is not found this high up in the hanging-wall of the range-front fault system.

2.3.2. Sub-surface temperature data

Two-meter temperature data, downhole temperature logs, and bottom hole temperature measurements were collated from existing data sources. These included data from water wells, temperature gradient holes, and three deeper geothermal exploration wells (HWAAD-2A, HWAAD-3, and 76-19) (Figure 5 and 6). The two deepest wells exhibit temperature profiles that are markedly different from one another: well HWAAD-2A encounters the highest temperatures measured in the Hawthorne area to date, with a 600 m-thick, 115 °C isothermal section at the bottom of the well that is interpreted to reflect fluid upflow. This well is cased and completed in the Mesozoic granite (Figure 3). In contrast, HWAAD-3 exhibits a conductive temperature profile, although it is still elevated compared to the typical regional background for the Basin and Range (~60 °C/km vs ~40 °C/km). Several of the shallower logs have temperature overturns in their upper levels (<200 m depth), suggesting that these wells intersect a thermal outflow plume (Figure 6). There is also a decrease in the temperature of this overturn from south to north, from the vicinity of the El Capitan well, to TGH-1 (Figure 5).

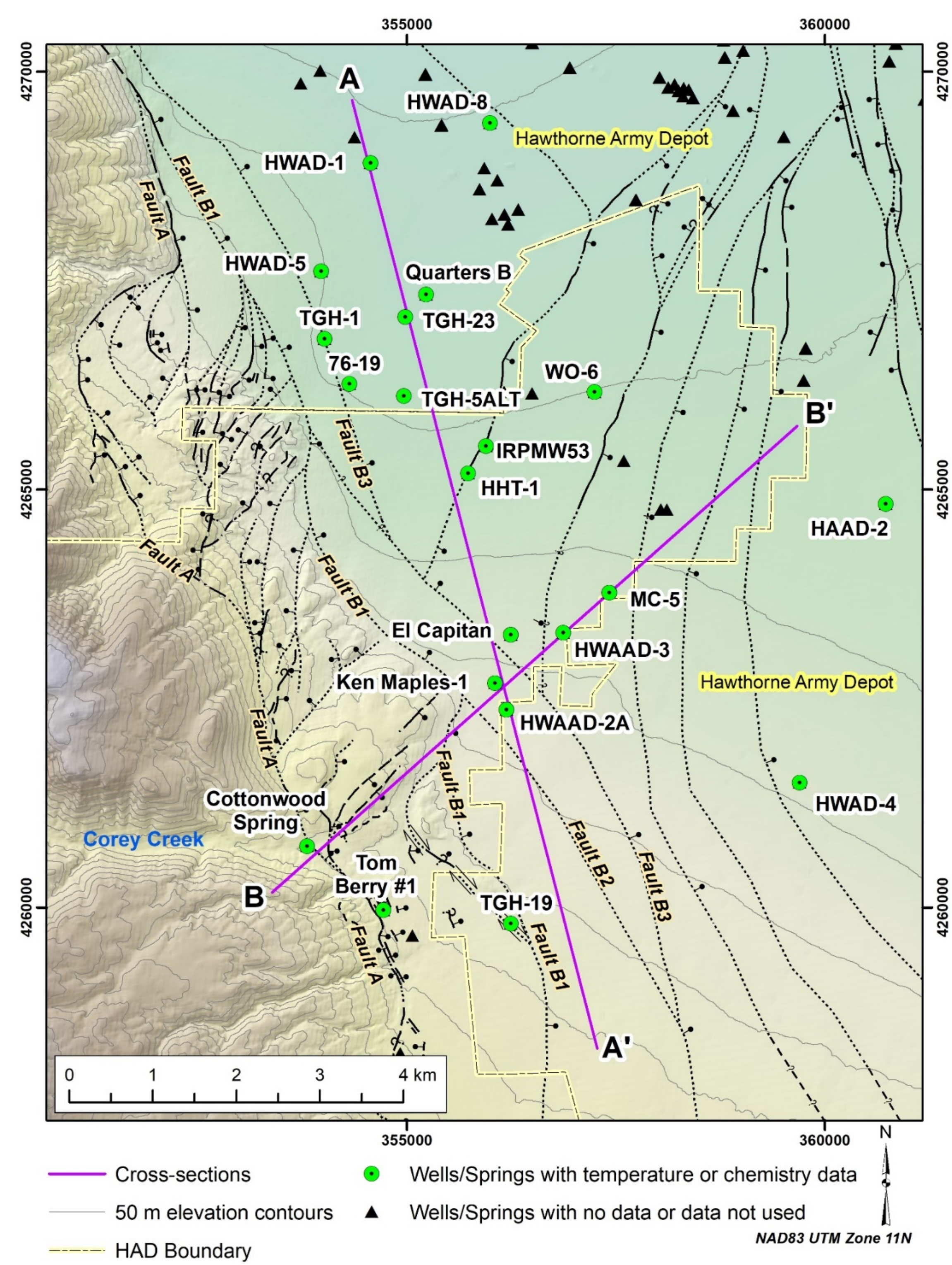

Figure 5 - Location of geothermal and water wells in Hawthorne geothermal Prospect A. Also shows faults, elevation contours, and cross sections that are presented in Section 2.4.

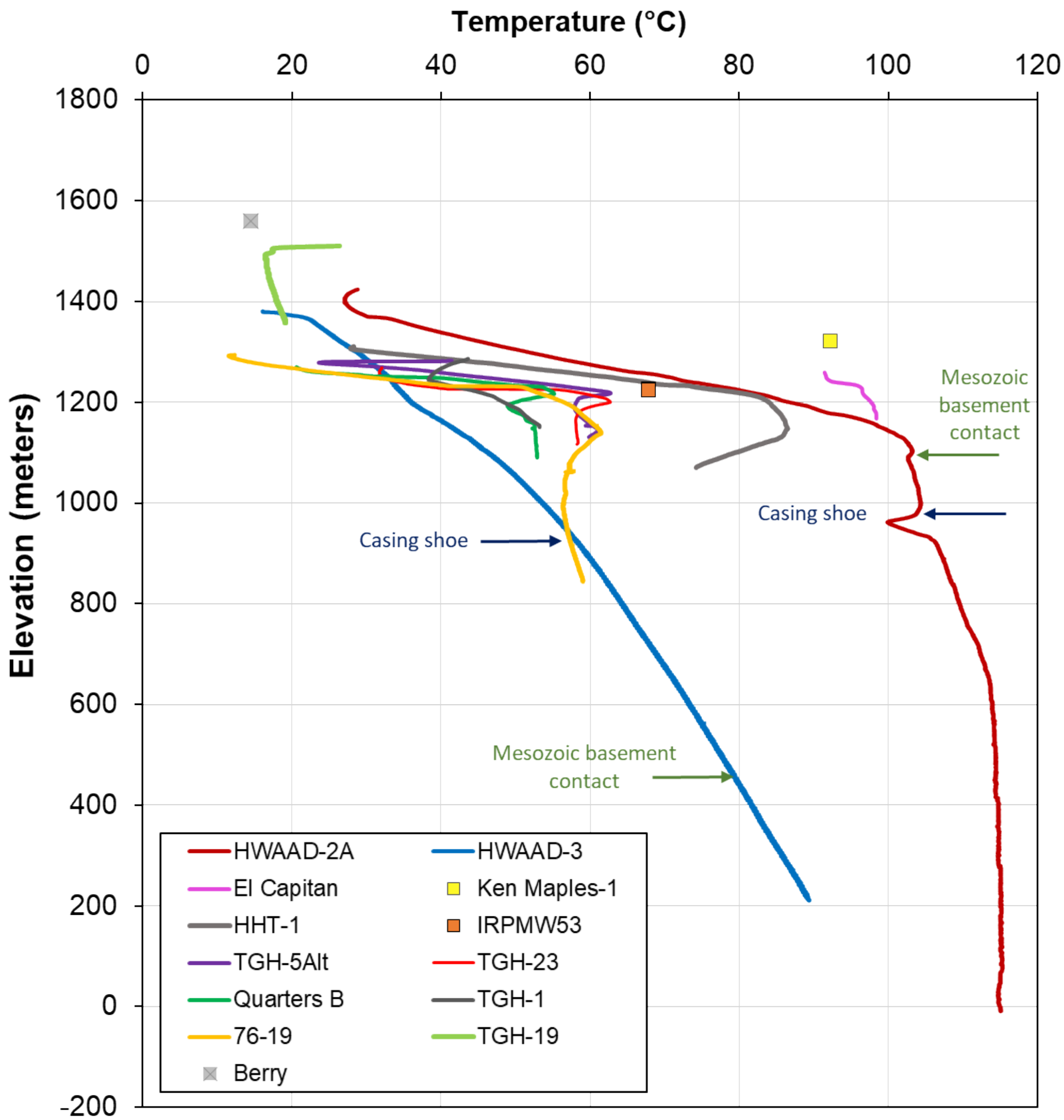

Figure 6 - Downhole temperature data from wells in and adjacent to Hawthorne geothermal Prospect A. The wellhead elevations decrease in a northerly direction (basin-ward) hence the offset in log elevations. The wells HWAAD-2A and HWAAD-3 are the only ones to penetrate the Mesozoic basement.

2.3.3. Water chemistry data

Water chemistry data were reviewed and compiled for Prospect A; any data with charge imbalances greater than ±10 % were not used for subsequent interpretation. Observations identified three discrete fluid types with distinct chemical signatures (Figure 7 and 8). As indicated by previous studies (Koenig et al., 1981; Katzenstein et al., 2002), samples obtained from the shallow water wells in the basin and deeper geothermal wells (El Capitan and Ken Maples-1) exhibit a sodium-sulfate fluid chemistry, and generally have total dissolved solids (TDS) values between 700-1,000 ppm. Samples collected from the river drainages on the eastern side of the Wassuk Range (e.g. Corey Creek and Cottonwood Creek) have low TDS (< 235 ppm) and are bicarbonate fluids. Two samples collected from the deep well HWAAD-2A (production interval in the Mesozoic granite) are unique, with an alkali-chloride composition and much higher TDS (~4,200 ppm) (Figure 8).

The two fluid types observed in the basin (alkali-chloride and sodium-sulfate) do not exhibit any mixing trends, and appear to be chemically distinct (Figure 7 and 8). This contrasts with the observed mixing trend between the surface water fluids and the sulfate fluids that do fall on a mixing line, and is inferred to reflect the flow of relatively-fresh meteoric waters from the Wassuk Range through the basin infill, where it collects more dissolved solids such as sulfate. The sulfate fluids were all sampled from wells that are less than 200 m deep and are completed in the Miocene and Pliocene basin infilling sediments, whereas the chloride fluid from well HWAAD-2A was sampled from fractured zones in the Mesozoic granite near the bottom of the well (> 1,300 m depth) during flow testing of the well (GeothermEx, 2009). Thus, it appears the reservoir hosting the alkali-chloride fluid is compartmentalized, and these chloride fluids are not intermixing with the sodium-sulfate fluid encountered in the shallow wells.

Most of the fluids sampled in the basin are not mature, alkali-chloride and are thus unsuitable for conventional cation geothermometry. For this study, only samples from the hottest wells (HWAAD-2A and El Capitan) were selected for geothermometry, as it is likely these samples have been least affected by cooling or mixing after leaving the reservoir and may provide the most reliable estimates of equilibration temperatures in the reservoir(s). The quartz geothermometer estimates equilibration temperatures between 117 and 125 °C, which is a maximum of 10 °C warmer than the hottest measured temperature at Hawthorne (at the bottom of the HWAAD-2A well) (Table 1). The conventional cation Na/K geothermometers for HWAAD-2A indicate a range of equilibration temperatures ~120-140 °C. Multi-component equilibrium modelling was conducted to provide further constraint on possible equilibration temperatures using the GeoT code (Spycher et al., 2014) and mineralogy constraints in the reservoir from XRD analyses (Jones and Moore, 2012). These results for both the El Capitan and HWAAD-2A well are similar, and suggest temperatures no greater than 120 °C. Thus, the various approaches suggest that the fluids are equilibrating somewhere between ~120 – 140 °C, and there are no obvious indications of a substantially hotter (>150 °C) system nearby.

Table 1 - Geothermometry estimates for representative fluid samples at Hawthorne Prospect A.

Sample Name	Max measured T (°C)	Quartz conductive	Quartz adiabatic	Na-K-Ca	Na/K Fournier 1979	Na/K Giggenbach 1988	K/Mg Giggenbach 1988	GeoT simulations
HWAAD-2A	115.0	118.7	116.9	137.4	119.6	139.8	122.5	117-119 ± 15
El Capitan - HAW6	98.4	122.6	120.2	-	-	-	-	120 ± 6
El Capitan - ECT11	98.4	125.3	122.5	-	-	-	-	120 ± 6

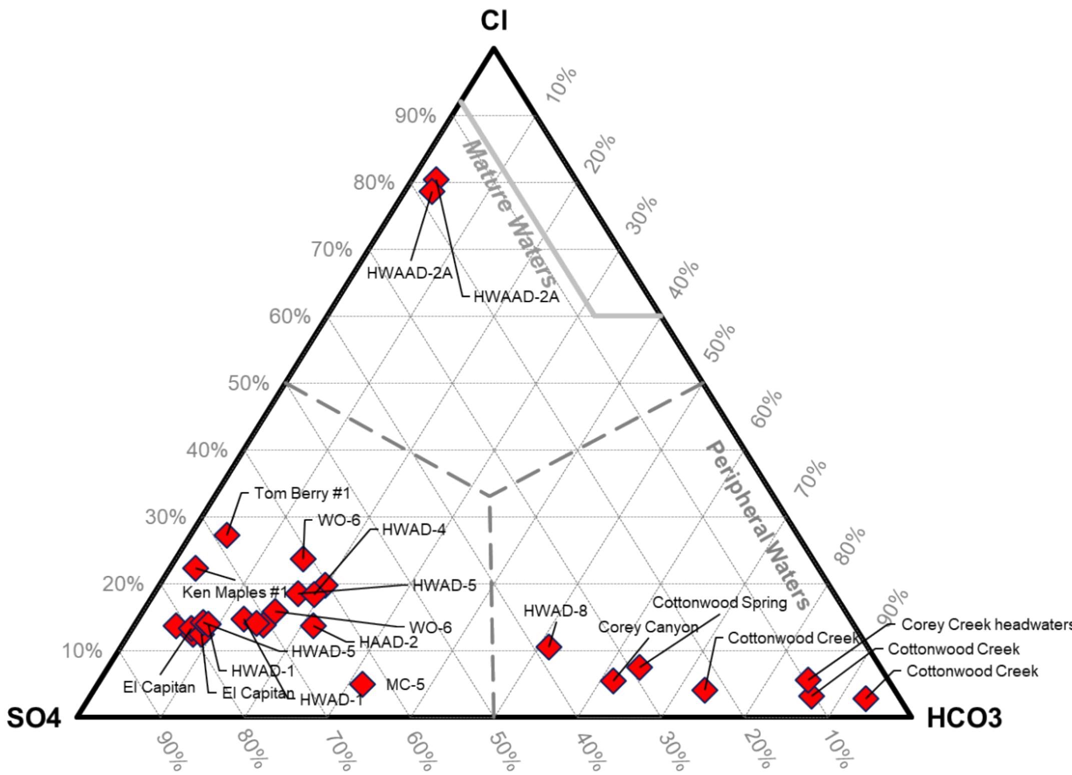

Figure 7 - Trilinear plot illustrating the three fluid types at Hawthorne.

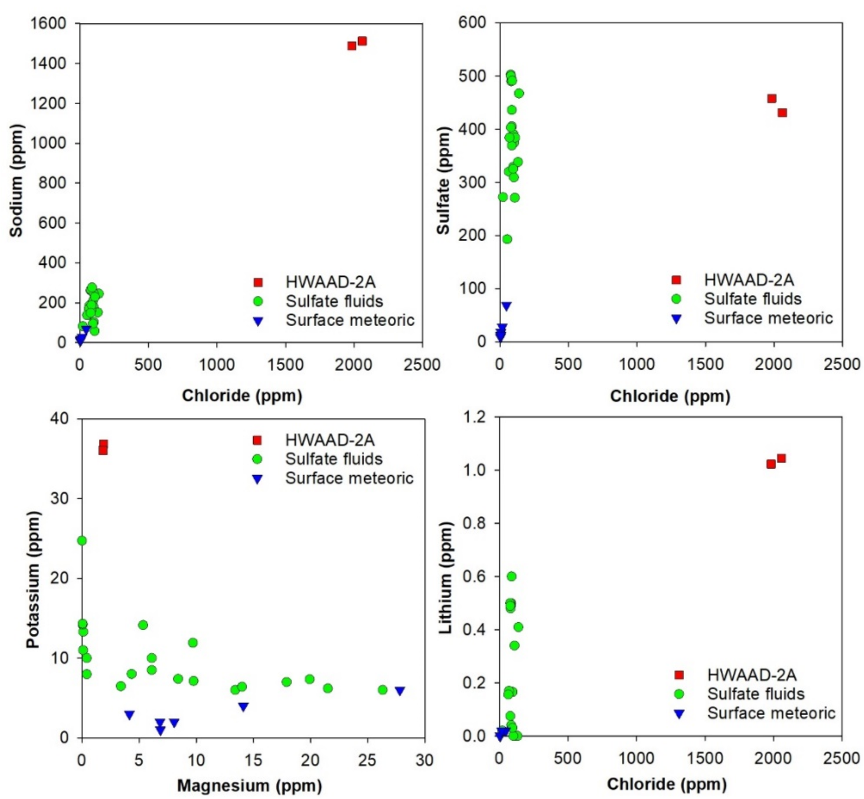

Figure 8 - Geochemistry cross plots illustrating the three fluid types encountered in geothermal Prospect A at Hawthorne.

2.3.4. *Well test results*

Well tests have been performed on some of the wells in Prospect A and indicate promising productivity for direct-use applications (Table 2). A short pump test was performed on HWAAD-2A in 2009, and the well was found to be very productive with a productivity index (PI) of 9 gpm/psi (values above ~ 1 gpm/psi are usually considered to be commercially viable). Additionally, the production was solely sourced from the Mesozoic basement; the well is cased into the basement, and temperature-pressure-spinner data indicate that the main production zone is at ~ 1,359 m depth in the well. During this pump test, two fluids were sampled for geochemical analyses (presented in section 4.3), thus it is assumed these samples originated from this depth. The El Capitan well was pump tested in 1981 for a longer period and higher flow rate. As mentioned previously, this well is completed in the basin infill, and produces sodium sulfate fluids. The well is cased for its full depth (305 m), however the casing is perforated from 180 m to the bottom of the well, thus it is presumed that fluids are being produced from this interval. This test indicated that the drawdown levels with a pumping rate of 532 gpm were not excessive, and the well could sustain this level of production (Koenig et al., 1981). Calculations using the Koenig et al. (1981) data show a PI of a 10 gpm/psi, consistent with the data from the HWAAD-2A test data.

Table 2 - Well testing data for wells in geothermal Prospect A.

Well	Production fluid T (°C)	Well depth (m)	Test date	Test type	Test duration	Pump rate (gpm)	Productivity (gpm/psi)	Aquifer transmissivity	Comments
HWAAD-2A	97	1433	Mar-09	Constant rate	315 minutes	189	9	-	GeothermEx report
El Capitan	99	305	Sep-81	Constant rate	10 days	532	10[a]	52,000 gals/day/ft width of aquifer	Koenig et al., 1981,
HWAD-1 (NAD-1)	51	105	Apr-77	Constant rate	86 hours	1500	-	40,000 ft^2/day	Bohm and Jacobson, 1977b

[a]Calculated as part of this project using the Koenig et al. (1981) data

2.4. Updated Conceptual Model

The various subsurface datasets were integrated and used to populate geological cross-sections across Prospect A. These informed and assisted with the development of the conceptual model and eventually the numerical model. The key components included in the cross-sections were fault locations, lithologic contacts, well locations and depths (projected to the section when needed), temperature-depth points (used to build isotherms), and water table depth. Two cross section orientations were selected to maximize the intersection with well locations (and thus measured data points), as well as to capture the variability in the thermal regime and structural fabric: cross section A-A' (north to south), and B-B' (southwest to northeast) (Figures 5, 9, and 10). For each cross section, there are three probabilistic models with a log-normal size distribution: P90, P50 and P10. The P90 model is the most conservative (i.e. a 90% chance that the proposed model exists in reality), the P50 model is the most 'reasonable' model that is consistent with the available data, and the P10 model is the most optimistic (i.e. a 10% chance that the proposed model exists). The key differences between the models are the positions of the isotherms, and inferred extent of geothermal fluid upflow and outflow. Below is a summary based on the P50 conceptual model.

A deep (>1.5 – 2 km) convective, moderate-temperature (~115-120 °C) resource composed of mature, alkali-chloride fluids is the primary heat source for a shallow (<400 m depth), cooler (90-100 °C), sulfate-fluid resource. The two reservoirs are compartmentalized, and not intermixing as indicated by their distinct chemical compositions; heat is transferred from resource 1 to resource 2 via conduction. The deep resource is hosted in altered, fractured Mesozoic granite, while the shallow resource is hosted in Tertiary and Quaternary basin infilling sediments and volcanic rocks (andesites and basaltic andesites) that date back to ~14 Ma. The sulfate fluid composition of the shallow resource is interpreted to reflect dissolution of gypsum deposits in the basin infill, or oxidation of pyrite in the Tertiary volcaniclastics that form part of the basin infill. The deep resource is associated with a bend and/or local step-over in fault B1 (see Figure 4) that may contribute to increased dilation tendency given the current stress regime. In addition, fault B1 intersects NE-striking faults in the same area, thus the structural setting is complex, and likely a hybrid structural setting. Permeability for the shallow resource is likely associated with primary permeability in the basin infilling materials, such as coarse fan-glomerates and sediments.

The deep fluid upwells on one or more fault strands associated with fault B1 in the area near HWAAD-2A. This fluid does not reach the surface or directly interact with the shallow (sulfate) fluid. Instead, it appears to conductively transfer heat to the shallow fluid across an impermeable barrier that may be associated with a fault contact and/or lithological boundary (granite vs basin infill) and/or alteration zone in the granite. The deep fluid is speculated to then flow in a NW direction at depth, bounded by the B2 and A faults. No thermal signature of the deep fluid is observed in well HWAAD-3 to the east. It is possible that the deep fluid could also be flowing to the SW, but still bounded by faults B2, B1 and A. This area is associated with complex fault bends and step-overs, and the deep thermal signature could be masked by shallow water flow out of Corey Canyon. There are limited data in this area to constrain the thermal regime at depth. The deep fluid is apparently not intersected in any other well in the area given the geochemistry constraints.

The shallow fluid is meteoric water that originates in the Wassuk Range and percolates through the alluvium and fan-glomerates in the basin to form a shallow aquifer. This aquifer is locally heated by the upwelling of the deep fluid in the vicinity of the HWAAD-2A, Ken Maples-1, and El Capitan wells. Permeable sedimentary zones in the lower part of QTsv between Fault B2 and B3 allow up-dip buoyant flow, which results in the 110 °C and 100 °C isotherms bulging diagonally upward and outward to the east (Figure 10). This provides a broader 'heating plate' for the shallow reservoir that is intersected by the Ken Maples-1 and El Capitan water wells. The heated fluid then flows in a northerly direction in a vertically constrained plume at shallow depths (<250 m) and is observed to cool off with distance from the El Capitan well. The plume appears to be intersected/interacting with possible shallow cold groundwater that may be flowing into the basin infill from the Wassuk Range (in the vicinity of wells TGH-5, Quarters B, 76-19, TGH-23). Also, 'lensing' of the basin sedimentary infill appears to separate the plume in places (i.e. double over-turns are observed in the temperature logs for wells TGH-5, and Quarters-B; refer to Figure 3). The shallow warm plume does not appear to be flowing to the south or the east, as constrained by temperature gradient data in wells HWAAD-3 and MC-5.

2.4.1. Assumptions for the P50, P90 and P10 conceptual models

All models (P10, P50, P90) agree with existing available data, however the P10 model is the most optimistic (predicts the largest resource) and the P90 model is the most conservative (predicts the smallest resource). This section outlines the subtleties of the models for each cross section.

2.4.1.1. Deep resource details

In cross section B-B' (southwest to northeast), for the P90 scenario the upflow is restricted to fault B1 and is very narrow (Figures 9 and 10). Also, the isotherms are depressed on the west by cold water down-flow along fault A. For the P50 scenario, upflow is largely restricted to fault B1, but no cool water is flowing down fault A. In the P10 scenario, upflow is along fault B1, in addition to synthetic cross faults west of B1, and no cool water down-flow is occurring along fault A. In cross section A-A' (north to south) for the P90 scenario, upflow is restricted to the B1 fault strand, and occurs right at the apex of the bend of this fault (also coincident with the intersection of fault B1 and B2) (Figure 10). In the P50 scenario, upflow is also restricted to the apex of the fault bend in B1 but has a broader zone of upflow along the bend of fault B1. In the P10 scenario, upflow occurs on cross faults and synthetic faults between fault B1 and A. The range in the P10-P90 estimates ultimately reflect how much along the strike of fault B1 upflow is happening, as well as the width of the upflow zone (constrained to fault B1 or also occurring along fracture zones between fault A and B1).

2.4.1.2. Shallow resource details

In cross section B-B' (south-west to north-east), for the P90 scenario, the resource is found by the El Capitan and Ken Maples-1 wells (90-100 °C fluid) in a thick section of basin infill. The location is immediately above the proposed P90 upflow of the deep resource (Figures 9, 10, and 11). In the P50 scenario, the resource/reservoir extends all the way to fault B1 (west of Ken Maples-1 and El Capitan): this is the stratigraphic limit of any appreciable thickness of basin fill (<10 m) that is thought to be the primary reservoir for the shallow resource. Also, any sediments west of B1 are above the water table. For the P10 scenario, the resource/reservoir extends halfway to fault A, and is consistent with the P10 for the deep resource in which upflow is distributed along several cross faults, synthetic faults, and fractures in between B1 and A that could conductively heat a shallow resource. The shallow resource would need to be hosted in a fracture zone at the top of the granite given the lack of sediment basin infill in this area. This would in turn also require a clay-cap barrier in the granite to hydraulically isolate the deep chloride fluid from the shallow fluid.

In cross section A-A' (north to south), the P90-10 estimates reflect differences in the area of potential conductive heat-transfer from the deep resource. The temperatures are constrained at the surface in the south by the top of HWAAD-2, and in the north by HHT-1. For the P90 scenario, the resource is restricted to a narrow zone around Ken Maples-1 and El Capitan. In the P50 scenario, the resource extends halfway between the El Capitan and HHT-1 wells. In the P10 scenario, the resource is more laterally extensive, reflecting a greater heat-conduction area from the deep resource. The isotherms are constrained at the northern end by measured temperatures in HHT-1.

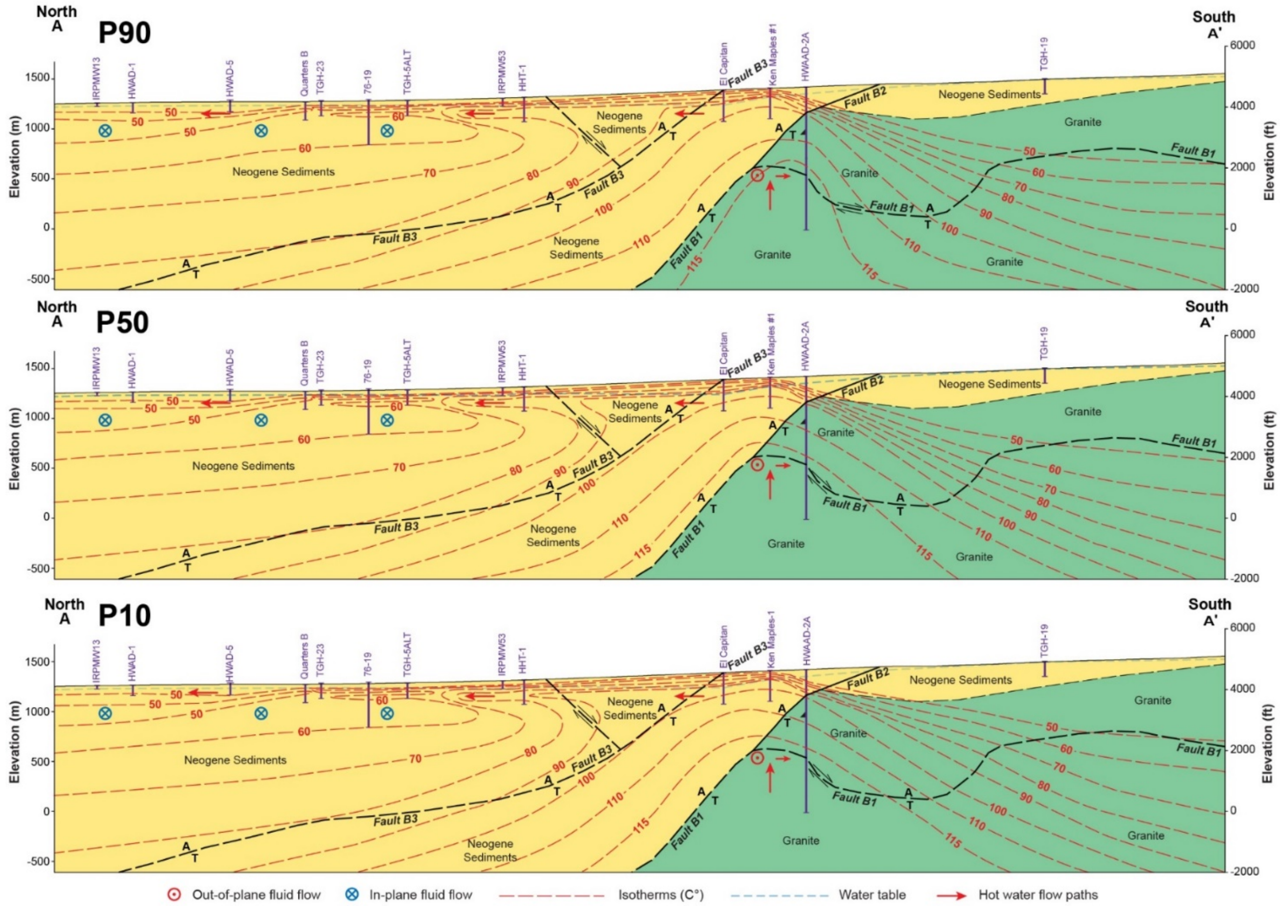

Figure 9 - Cross section A-A' (north to south, Figure 5) across Prospect A. Interpreted isotherms are in dashed red lines in °C, red arrows indicated interpreted fluid flow directions, and black lines (solid and dashed) lines represent inferred fault intersections with the cross-section plane.

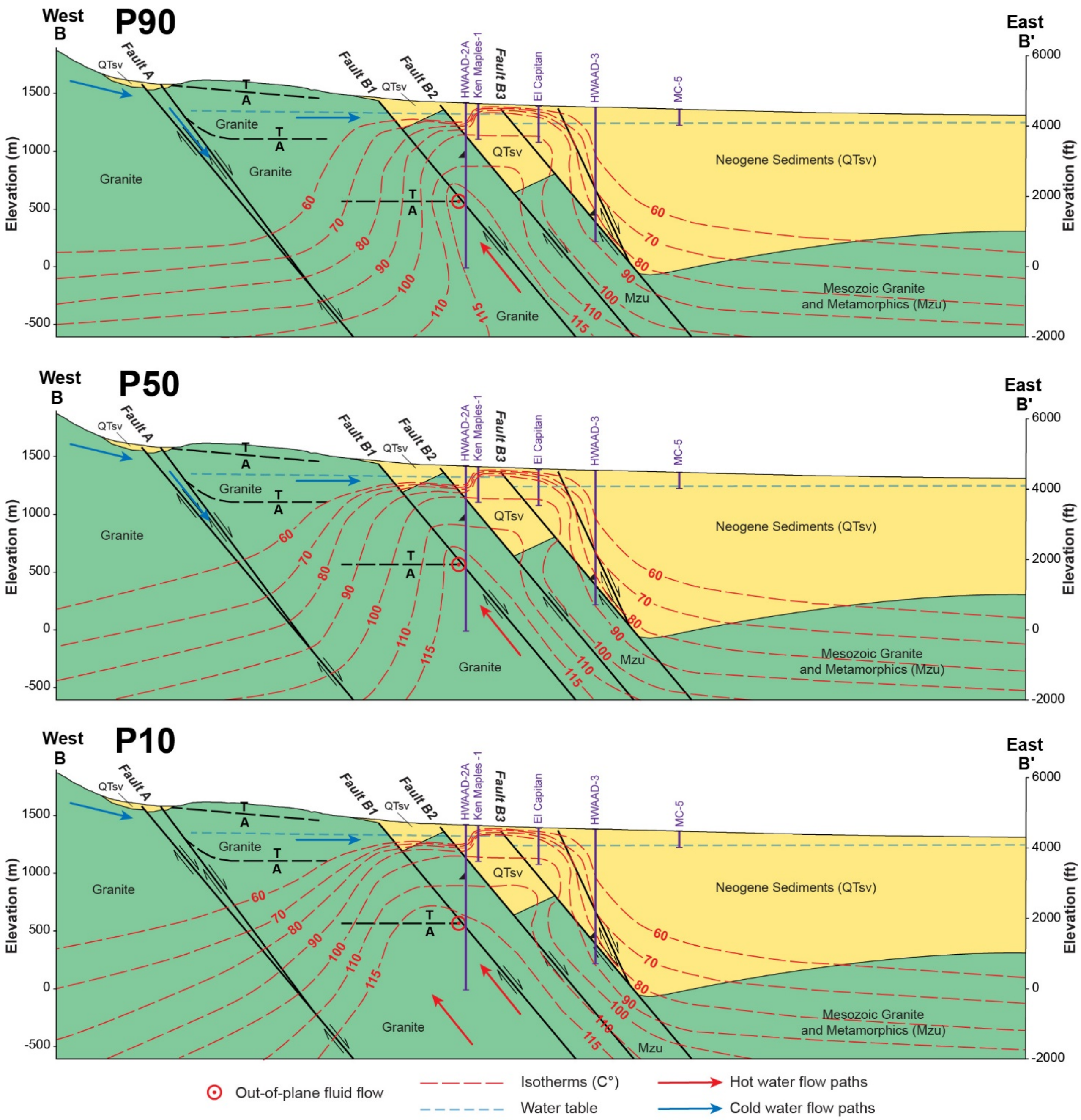

Figure 10 - Cross section B-B' (south-west to north-east, Figure 5) across Prospect A. Interpreted isotherms are in dashed red lines in °C, red arrows indicated interpreted fluid flow directions, and black (solid and dashed) lines represent inferred fault intersections with the cross-section plane.

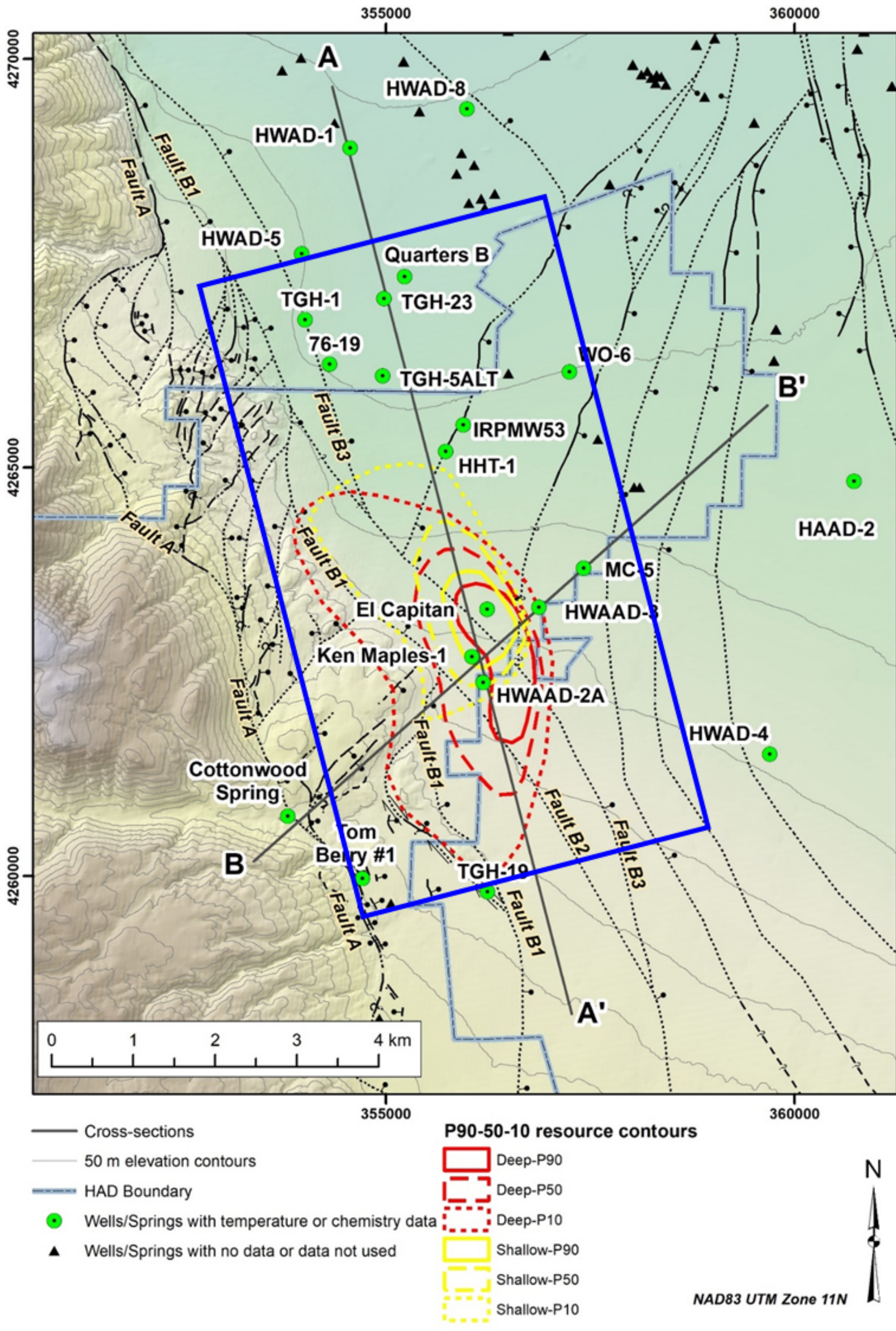

Figure 11 - P90-50-10 outlines for the deep and shallow resources at Hawthorne Prospect A; the deep resource outline was derived from the intersection of the 115 °C isotherm and a 2,000 m depth slice, and the shallow resource outline was derived from the intersection of a 90 °C isotherm and a 250 m depth slice. The blue outline is the extent of the numerical model domain.

2.5. Power Density Analysis

There are a variety of ways to estimate resource capacity in geothermal systems. Heat-in-place estimates for geothermal systems are common but often overestimate resource capacity by large factors, even orders of magnitude, due to unreasonably optimistic recovery factors (Grant, 2015). Power density estimates (Cumming, 2016) of geothermal resource power capacity can be more representative of actual outcomes than heat-in-place estimates at the exploration stage because they rely on fewer parameters and are calibrated against a much larger number of known operating fields (Wilmarth and Stimac, 2015; Wilmarth et al., 2019). These operating fields range from small to large fields, from low to high temperature, and from a broad range of geologic settings and associated reservoir characteristics.

The intent of the power density approach is to account for the uncertainty of the resource by estimating the most optimistic values (P10, or a 10% probability that the resource is that large) and the most pessimistic values (P90, or a 90% probability that the resource is at least that large) and creating a statistical median estimate for power capacity (P50). The P10 values are considered optimistic because it provides a larger resource as compared to the P90 estimate, albeit at a smaller probability. The estimates have been made using the worksheet provided by Cumming (2016) that assumes lognormal distributions. These estimates use lognormal distributions for area (km^2) of the reservoir and power density (MW/km^2), with supporting data provided for fields in analogous geological settings and with a comparable range of expected minimum and maximum reservoir production temperatures (°C). That is, the analogies to other fields considered in choosing a power density range are used to constrain parameters not explicitly included in the estimation, like reservoir thickness, porosity, water table depth and recovery factor.

The estimated power density for a given field is derived from the power densities associated with greater than 100 operating geothermal systems worldwide (Figure 12), which provide a range of power densities based on the minimum and maximum reservoir temperatures and a suite of geological analogs spanning a range of proven power capacities and reservoir areas. In the Basin and Range, there are a range of established power densities for systems ranging from 100 to 180 °C (Figure 12), although there are relatively few producing analogs with reservoirs <125 °C.

As a whole, Hawthorne seems similar to other Basin and Range systems with upflow associated with a key structural setting associated with a fault system at the edge of a basin and a with a long thin outflow in basin sediments. The difference here is that the sub-boiling, sulfate fluid outflow is not actually direct outflow from the chloride fluid upflow but is instead conductively heated. It is not yet known where the chloride outflow goes and this outflow does not figure directly into the aerial extent of the deeper upflow, or shallower outflow. Other systems in the Basin and Range produced only from outflow such as Salt Wells, Wabuska, and Don Campbell. The production at Don Campbell is not only in outflow, but is also associated with a conductively heated reservoir, overlying a deeper hotter reservoir without hydrologic connection.

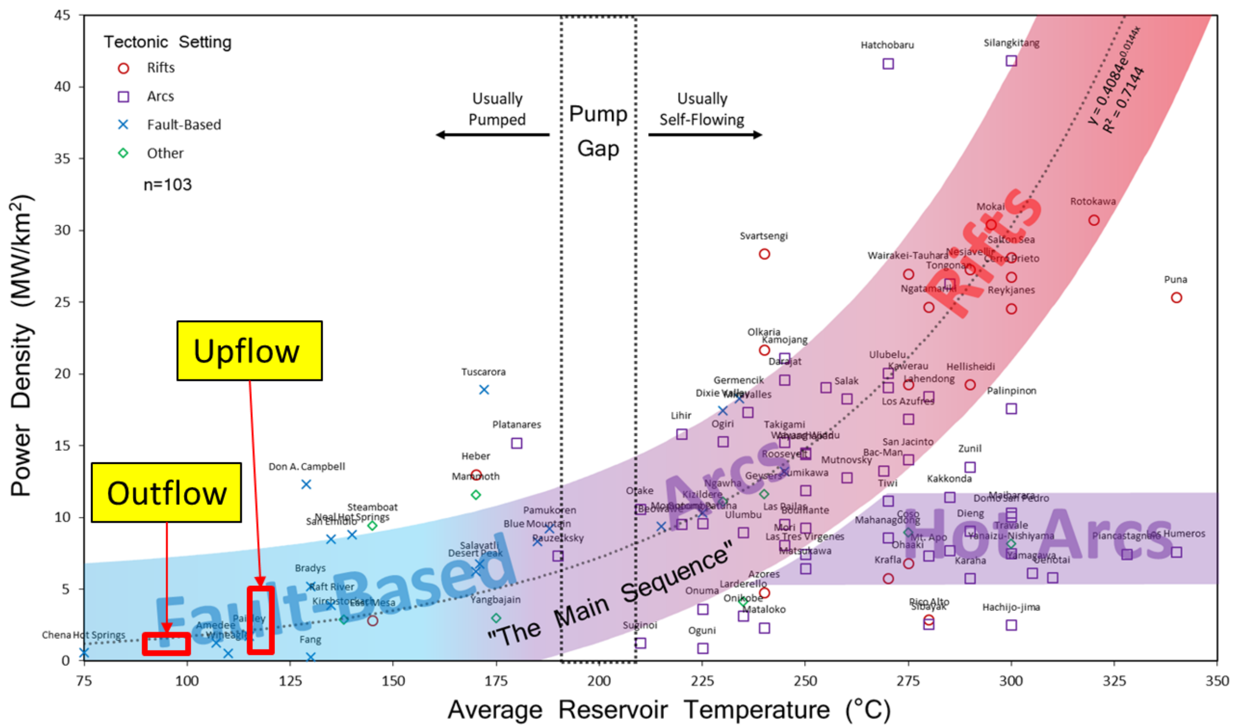

Figure 12 - Power densities selected for high and low temperature ranges that are likely for both the deep and shallow resources at Hawthorne (base figure from Wilmarth et al., 2019).

Based on the conceptual model, upflow is likely to be 115 to 120 °C and confined to part of the Wassuk range-front fault system in granitic rock. Outflow is <100 °C and is within basin-fill sediments. Given the available of data for characterizing Hawthorne, a range of 1 to 5 MW/km^2 was selected for modeling the upflow and, a range of 0.5 to 1.5 MW/km^2 was selected for modeling the 90 to 100 °C part of the outflow. The range for the upflow fits within the window between Paisley at 115 °C and a cluster of systems at ~120 to 135 °C, such as Don Campbell and Brady's, but probably not as high as Don Campbell because that resource is associated with a relatively shallow, silicified and re-fractured reservoir that has very high reservoir permeability and well flow rates. Deep drilling at Hawthorne has not encountered similar conditions to the Don Campbell Reservoir. The range for the outflow fits below systems such as Amedee and is bookended by the low temperature China Hot Springs resource.

Using the probabilistic reservoir models and the power density estimates described above, the expected power capacity of Hawthorne is presented in Table 3. Based on these reservoir models there is a 90% chance that the upflow part of the resource has a capacity of at least 1.9 MWe and a 50% chance it is as big as 7 MWe. For the outflow part of the resource, there is a 90% chance that the upflow part of the resource has a capacity of at least 0.5 MWe and a 50% chance it is as big as 1.6 MWe.

Table 3 - Hawthorne area and power density estimates for the optimistic 10%, median 50% and pessimistic 90% confidence models and MWe capacity from multiplying these lognormal distributions.

Case	Upflow Portion			Outflow Portion		
	Area (km^2)	Power Density 115-120 °C (MW$_e$/km^2)	MW$_e$ Capacity	Area (km^2)	Power Density 90-100 °C (MW$_e$/km^2)	MW$_e$ Capacity
P10	8.8	5.0	25.9	4.8	1.5	4.8
P50	3.1	2.2	7.0	1.8	0.9	1.6
P90	1.1	1.0	1.9	0.7	0.5	0.5

2.6. Modeling

The original intent of the project was to develop a simple lumped-parameter groundwater model that would simulate heat extracted over time as a percentage of the total heat in place and power density estimates. However, after the water chemistry analysis and the reformulation of the conceptual model to include separate shallow and deep resources, it was decided that the lumped parameter model would be too simple to capture the complexities of the system and thus a fully 3D numerical model was constructed. The intent was to provide a boundary on the thermal performance of the system over time and to provide thermal drawdown curves to the WSA as a function of pumping rate, well location, and the number of wells. This also allowed for the inclusion of the P10, P50, and P90 power density estimations by adjusting the boundary conditions of the model to fit the conceptualization of each capacity estimate.

The simulations were conducted on Sandia's 1,848 node (16 cores/node) 'Skybridge' high-performance computing cluster using the open-source groundwater modeling code PFLOTRAN (www.pflotran.org). PFLOTRAN is a massively parallel subsurface flow and transport code that simulates thermal, hydrological, and chemical (THC) processes making it ideal for probabilistic modeling of geothermal systems.

2.6.1. Numerical Model

The model uses a simplified construct of the shallow reservoir by assuming a constant temperature bottom boundary condition that is constructed from the thermal cross-sections above (Figure 9 and 10). This is consistent with the conceptual model of there being little to no mixing between the shallow and deep waters and that the shallow system is heated through a conductive process as opposed to upwelling and mixing. The model is built on a structured grid that is centered on the A-A' line (Figure 11) through Prospect A that measures 5,000 m (west to east: X-axis) by 8,000 m (south to north: Y-axis) by 325 m thick (Z-axis), and uses a grid spacing of 50 m in the X and Y directions and 25 m in the Z direction, resulting in 208,000 grid cells. Three different constant temperature bottom boundary conditions are used (Figure 13); one each for the P10, P50, and P90 capacity estimates. Despite the relatively small grid, the ability to run the model on a parallel system was important for the calibration and the uncertainty analysis. The model is run in 'TH' (thermal-hydrological) mode, which assumes that the system is fully saturated and single phase.

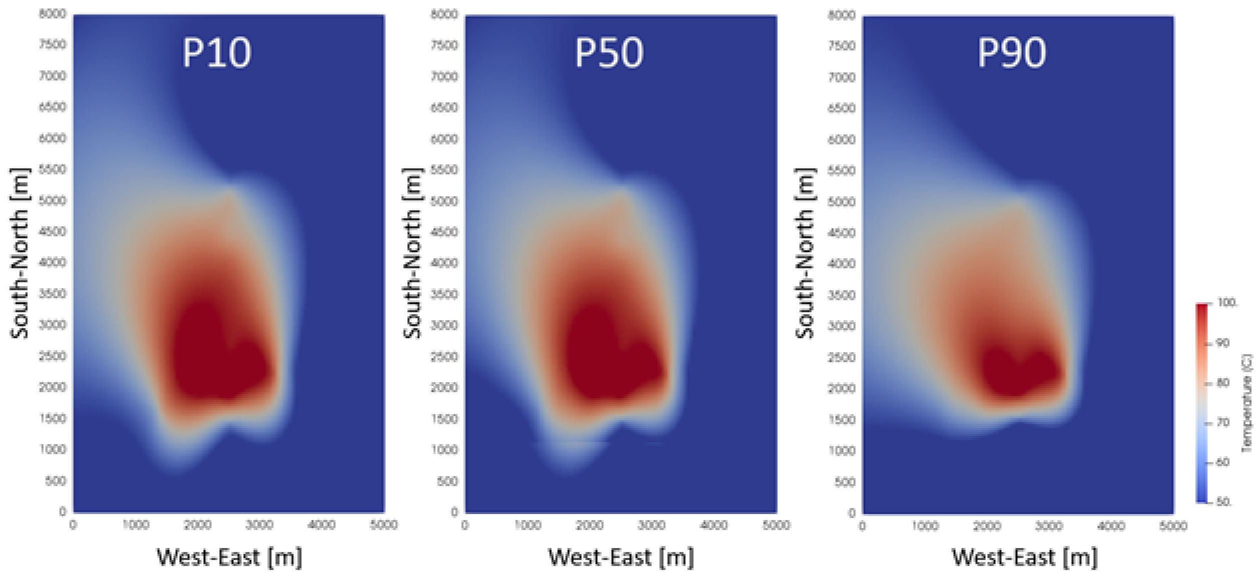

Figure 13 - Constant bottom boundary condition for the P10, P50, and P90 cases. The area of >90 °C is largest for the P10 case and smallest for the P90 case.

Boundary conditions assume a no-flow, constant temperature along the bottom boundary, constant flux to represent recharge on the top boundary, constant pressure along the south and north boundaries to create a regional flow from south to north, and no-flow along the east and west boundaries. The model is calibrated using the root mean squared error (RMSE) between the model simulation and the temperature profile data of 13 wells within the model domain, using Sandia's 'Design Analysis Kit for Optimization and Terrascale Analysis' (DAKOTA – dakota.sandia.gov) by changing permeability, anisotropy, recharge rate, and recharge temperature. There is a distinct change in the slope of the water table moving from south to north (see Figure 9) that coincides with a change in rock type from predominately basement granite (material 1) to the south to predominantly neogenic sediments (material 2) to the north. To capture this, the model uses two permeability zones, one from Y = 0 m to Y = 3,200 m for material 1, and another from Y > 3,200 m to Y = 8,000 m for material 2 (Figure 14). It was assumed that only the permeability differed between the material types with the other inputs set to represent a fractured, porous media. Model layers are horizontal, and no attempt was made to model the numerous faults and shifted geology.

The calibration simulations assume no pumping and are run for 10,000 years to reach a steady-state condition from which to match the field data. Only the P50 case was calibrated under the assumption that it represents the most likely configuration. Figure 15 shows the results of the calibration against the 13 temperature profiles. The P10 and P90 cases are also included showing that there is little variation between the cases. A cross-section of the calibrated model for the P50 case is shown in Figure 16. The final calibrated values are listed in Table 4.

Table 4 - Calibrated PFLOTRAN model parameters.

Material #	1	2
Porosity [%]	0.25	0.25
Rock Density [kg/m³]	2800	2800
Rock Specific Heat [J/(kg°K)]	900	900
Rock Thermal Cond. [W/(m°K)]	2.75	2.75
PermX and PermY [m²]	1.102×10^{-13}	1.653×10^{-12}
PermZ [m²]	8.404×10^{-15}	1.261×10^{-13}
Recharge Rate [mm/yr]	0.446	0.446
Recharge Temp. [°C]	25.1	25.1

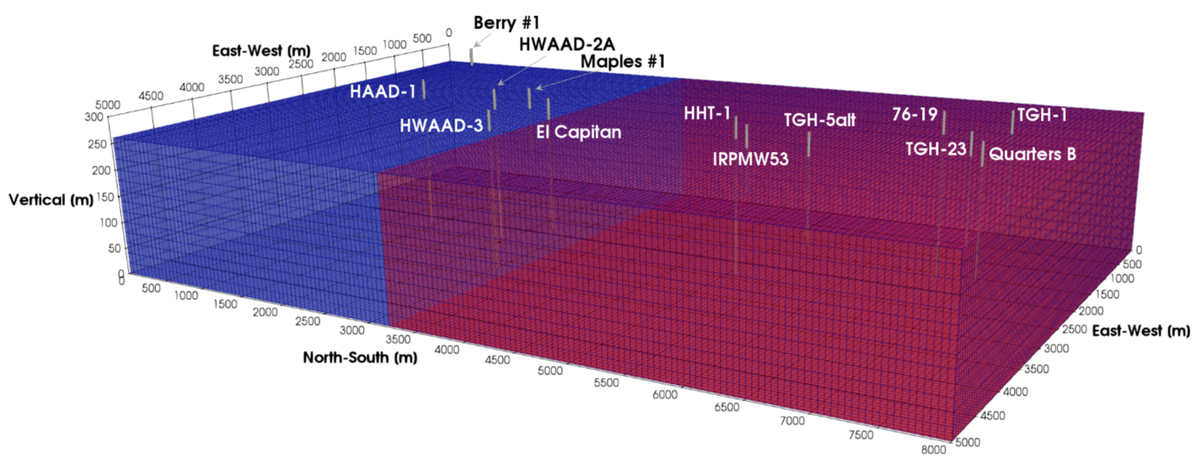

Figure 14 - Model domain showing the two material types, location of the 13 calibration wells, and the grid. Material 1 is blue, material 2 is red.

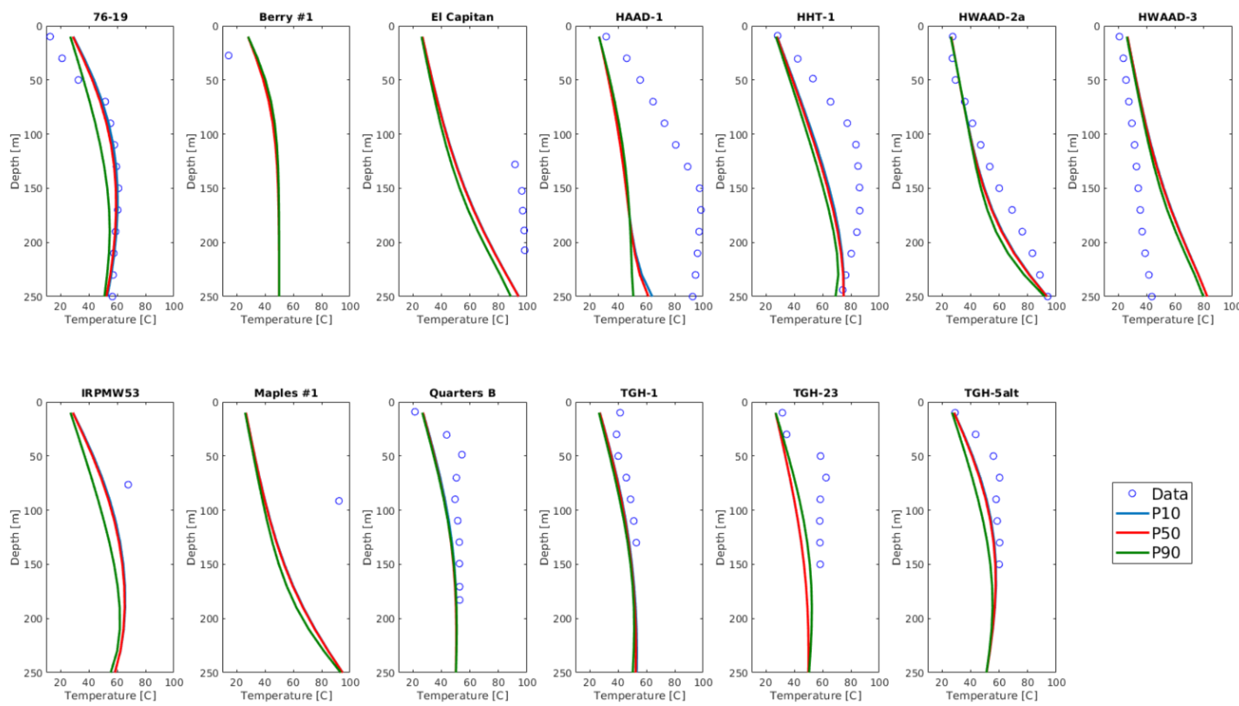

Figure 15 - Calibration results of the model simulations against the temperature profile data. Calibration was conducted using the P50 case boundary condition.

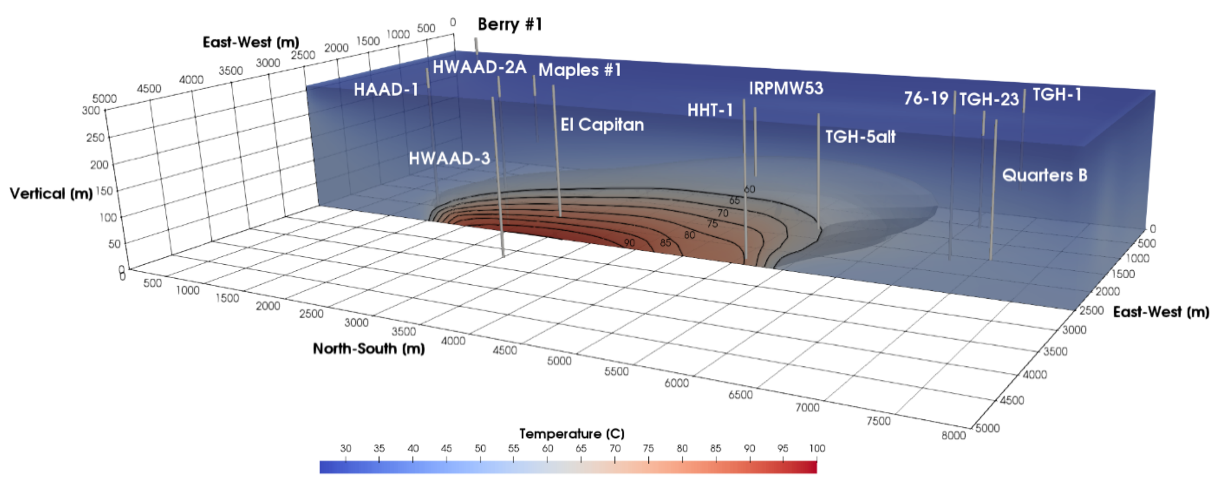

Figure 16 - Cross section through the steady-state plume for the calibrated P50 case. Vertical lines represent the location of the wells used for the calibration.

2.6.2. Scenarios

Once calibrated, the model is run for 10,000 years for the P10, P50, and P90 cases to achieve steady-state conditions (Figure 16). The output from the 10,000-year simulations serve as the initial condition for running the model in 'production mode', which simulates the system over a 30-year period with one or more production wells. Injection wells are not included in the model under the assumption that injection occurs far enough down gradient to not interfere with production. Injection wells are included in the GEOPHIRES analyses presented below.

Scenarios are developed for single (1 well) and double (2 wells) production wells, each with three different pumping rates. For the single production well scenarios, pumping rates are set at 100, 300, and 600 gpm while the double production well scenarios assume *total wellfield* pumping rates (i.e., the sum of both wells) of 200, 600, and 1,200 gpm. Using the assumption that the best placement of the wells cannot be known for certain, five different well locations were simulated for each of the production well/pumping rate scenarios. All wells are assumed to be completed at a depth of 312.5 m, which is the center of the bottom layer of the model and thus implies a production interval of 25 m (the thickness of the bottom layer). For the single well scenarios, wells were randomly placed within the 92.5 °C contour of the P90 capacity estimate (Figure 17), making sure that the well was more than two cell widths (100 m) away from the contour. The same was done with the two production well scenarios but with the added limitation that the wells had to be at least three cell widths (150 m) apart. The two well scenarios use the same location as the single well scenarios for the first well, and then add a second well. The combinations of the three capacity estimates, the number of production wells, pumping rates, and well locations resulted in 90 sensitivity simulations. Two additional 'wildcat' scenarios were also included in the WSA that assume 1200 gpm for a single production well, and 1800 gpm for the double production well scenario, but with zero thermal drawdown over time.

The scenario names are designated first by the capacity estimate, then the flow rate, the number of production wells, and the location number. For instance, the scenario name P10_100_1Prod_1 refers to the P10 capacity estimate with a single production well pumping at 100 gpm from location #1.

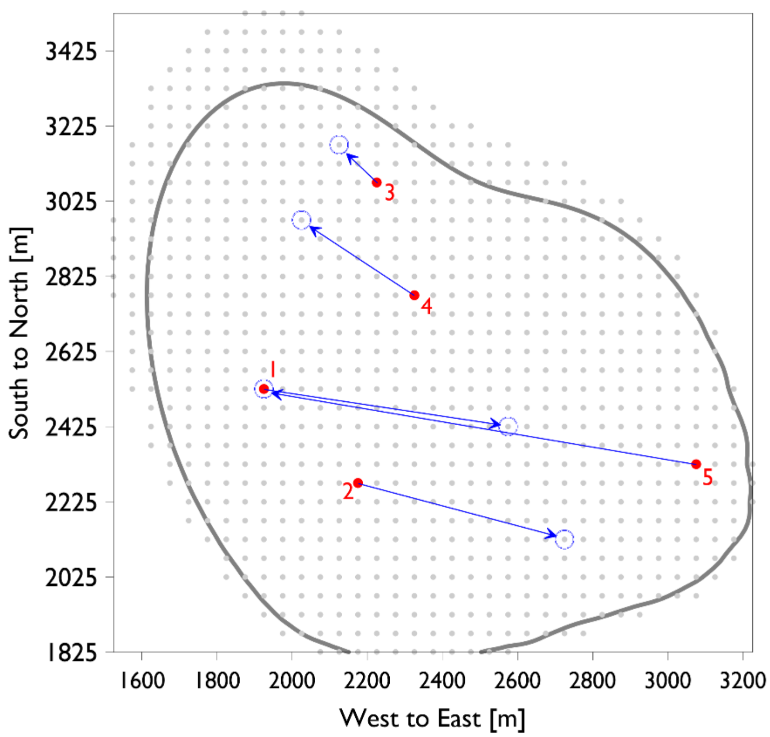

Figure 17 - The P90 92.5 °C contour (gray line) with the locations of the randomly placed wells. The red dots are the locations of the single production well scenarios while the blue circles represent the corresponding second well for the double well scenarios. The numbers refer to the location number in the scenario name.

To make the simulations more realistic, it was assumed that pumping only occurs for 8 months out of the year (October through May) varying in a truncated sinusoidal manner with the peak in January. To determine the relative pumping rate for each month, data of diesel fuel consumption from October 2017 through September 2018 for the HAD was combined with propane heating bills for the county courthouse. The propane data was only available for October 2017 through January 2018. Each dataset was scaled based on its maximum month and then averaged for the months that both datasets exist (Table 5). The averaged result was rescaled to produce a maximum equal to 1. The final step involved fitting a second order polynomial to the re-scaled averages to smooth out the data (Figure 18). The polynomial values were then re-scaled, producing the pumping schedule multiplier for the numerical simulations. The actual pumping rates are the product of the schedule multiplier and the scenario pumping rate meaning that only January is pumped at capacity.

Table 5 - Data and scaling process to determine the 8-month pumping schedule.

Month	Raw Data		Scaled		Averaged	Re-Scaled	Polynomial Re-Scaled
	Diesel Use [gal]	Propane Cost	Diesel Use	Propane			
Oct. 2017	59,669	$1,576.69	0.40	0.34	0.37	0.39	0.39
Nov. 2017	97,462	$3,080.48	0.66	0.66	0.66	0.69	0.71
Dec. 2017	148,226	$1,634.19	1.00	0.35	0.67	0.70	0.91
Jan. 2018	136,276	$4,669.26	0.92	1.00	0.96	1.00	1.00
Feb. 2018	117,807		0.79		0.79	0.83	0.98
Mar. 2018	125,125		0.84		0.84	0.88	0.84
Apr. 2018	76,577		0.52		0.52	0.54	0.59
May 2018	24,016		0.16		0.16	0.17	0.22

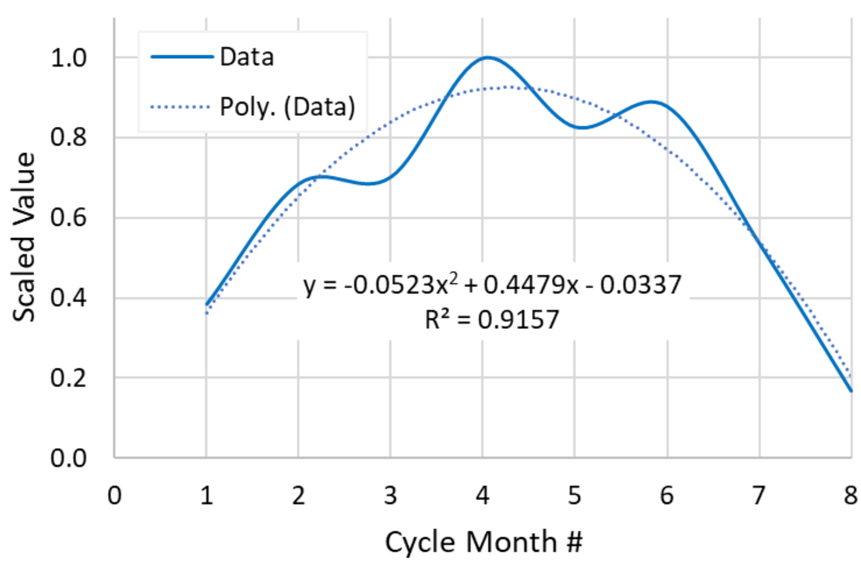

Figure 18 - Plot of the combined, scaled data and the second order polynomial fit.

2.6.3. *Modeling Results*

Of interest to the feasibility study is the production temperature and flow rate of the system over time. Due to the way that PFLOTRAN handles boundary conditions, production temperatures at time zero were 7-9 °C below the known initial temperatures in HWAAD-2a and the El Capitan well. To compensate for this, the production temperature over time was shifted upwards by the difference between 100 °C and the initial temperature to produce an initial pumping temperature of 100 °C. For the scenarios with two production wells, both wells were shifted by the difference between 100 °C and the warmest initial temperature, meaning that one well begins with an initial temperature of 100 °C while the second well is less than that.

Figure 19 shows the average production temperature across the five well locations as a function of flow rate and the number of producers. The sawtooth pattern is due to the periodic pumping schedule. Not surprisingly, the thermal drawdown over time is sensitive to flow rate with a temperature drop of > 10 °C over 30 years at the higher pumping rates. However, by comparing the 600 gpm, 1 production well scenario to the 600 gpm, 2 production well scenario it can be seen that the addition of a second production well helps reduce thermal drawdown by distributing the 600 gpm pumping rate across 2 locations.

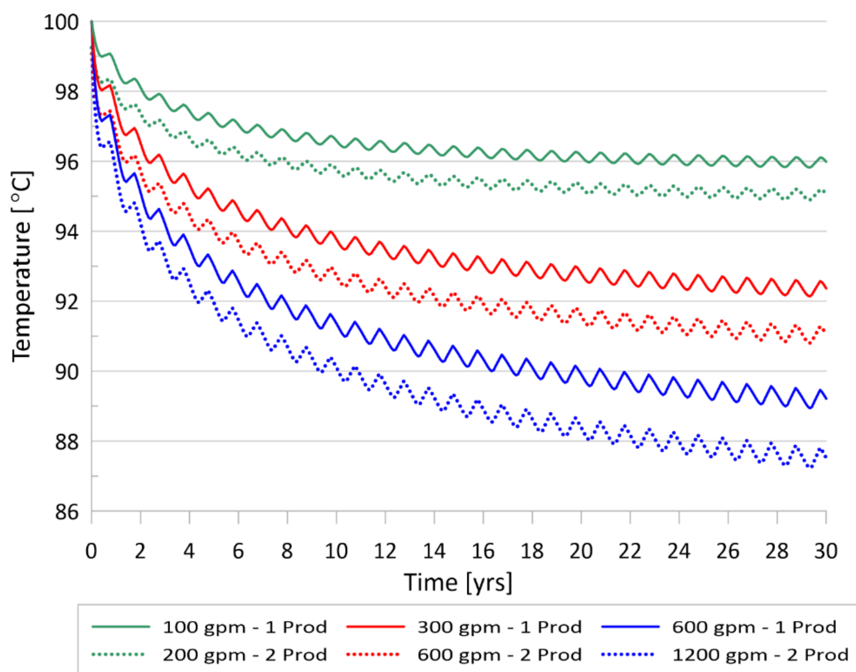

Figure 19 - The average production temperature across all well locations as a function of flow rate and number of production wells.

The model simulations are also sensitive to well location. Figure 20 shows the spread between the 5th and 95th percentiles of the production temperature over time as a function of well location and capacity estimate for the 600 gpm, 1 production well scenario. Depending on the well location and capacity estimate, the production temperature after 30 years can vary up to 9-10 °C. However, variability is low between capacity estimates, with the P90 case showing the widest range of 10 °C, and the P10 and P50 estimates each at 9 °C.

Looking closer at the variability due to location, the locations that are located towards the north end of the drilling zone (locations 3 and 4) tend to have the smallest drawdown over time while location 5, which is furthest south, has the highest thermal drawdown (Figure 21). Given that the regional flow is from the south to the north, this result makes sense. It also tells us that variability due to location can be minimized by placing the wells towards the north end of the drilling zone.

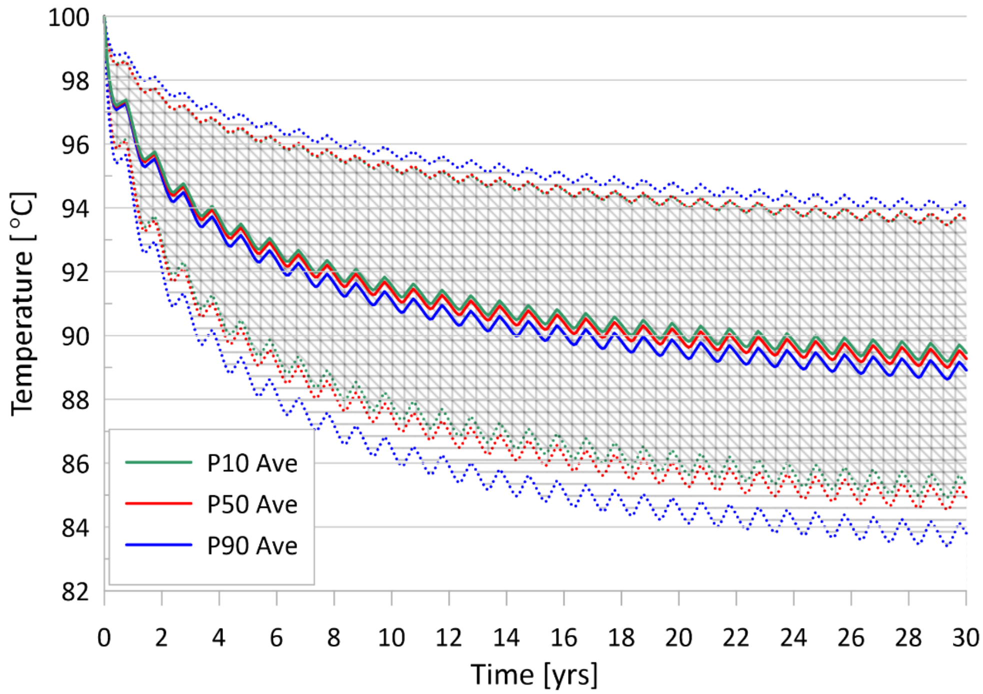

Figure 20 - The spread in production temperature as a function of well location and capacity estimate for the 600 gpm, single production well scenario. The dotted lines at the high and low ends of the range are the 95th and 5th percentile, respectively while the solid lines represent the average.

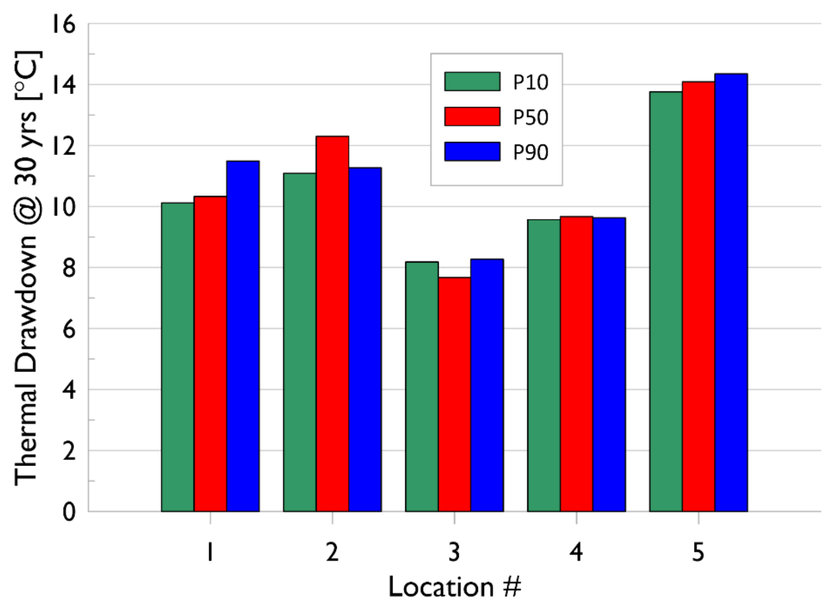

Figure 21 - Thermal drawdown after 30 years as a function of location and capacity estimate for the 600 gpm, 1 production well case.

The DSA requires single effective values of temperature and flow rate in its calculation of square footage heating capacity so the time varying curves are post processed to give an effective temperature at each given flow rate. Because location #1 is in the middle of the thermal drawdown variability due to location (see Figure 21), only that location was used in the DSA calculations.

To process the results to provide an effective temperature, the total heat production over 30 years was calculated for each of the location #1 scenarios and then used to calculate the necessary effective constant temperature that would deliver the same amount of heat as the variable pumping schedule (Figure 22). The flow rates and temperatures, including the two 'wildcat' scenarios that are passed to the DSA are listed in Table 6.

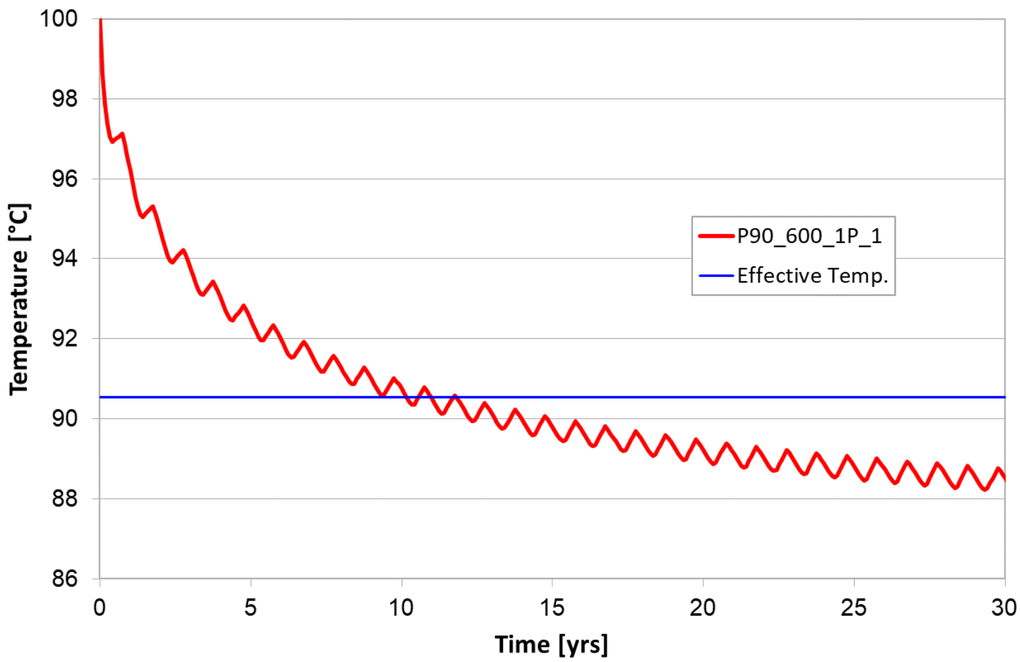

Figure 22 - Production temperature over time and the effective constant temperature at a constant pumping rate for the P90_600_1P_1 scenario.

Table 6 - List of effective temperatures and constant flow rates for the scenarios passed to the DSA.

Scenario Name	Flow [gpm]	Effective Temp. [°C]
P10_100_1Prod_1	100	96.886
P50_100_1Prod_1	100	96.823
P90_100_1Prod_1	100	96.321
P10_200_2Prod_1	200	96.135
P50_200_2Prod_1	200	96.021
P90_200_2Prod_1	200	96.247
P10_300_1Prod_1	300	94.168
P50_300_1Prod_1	300	94.048
P90_300_1Prod_1	300	93.190
P10_600_2Prod_1	600	90.629
P50_600_2Prod_1	600	93.039
P90_600_2Prod_1	600	92.997
P10_600_1Prod_1	600	91.802
P50_600_1Prod_1	600	91.612
P90_600_1Prod_1	600	90.533
P10_1200_2Prod_1	1200	91.158
P50_1200_2Prod_1	1200	90.399
P90_1200_2Prod_1	1200	90.168
WC_1Prod	1200	100.000
WC_2Prod	1800	100.000

3. DEMAND SIDE ANALYSIS

3.1. Introduction

There have been previous studies completed to evaluate the financial viability of using geothermal energy for direct use heating in and around Hawthorne, Nevada. The "Preliminary Plan for the Development of Geothermal Energy in the Town of Hawthorne, Nevada" was completed in November 1981 (GDA, 1981). This report focused on a district heating system for the City of Hawthorne. The study used a geothermal fluid flow rate of 780-991 gpm at a temperature of 210 °F (98.8 °C) to determine that the schools, the courthouse, and the library could be heated with a direct use geothermal system. The costs for the system to heat the public buildings in the City of Hawthorne were $1.86 million (1981 dollars).

The Navy GPO funded the Hawthorne Army Depot, Direct Use Feasibility Study, completed in September 2012, to evaluate the possible energy savings of using a direct use geothermal system to supplement the boiler heating system (Power Engineers, 2012). The study used a geothermal fluid flow rate of 600 gpm at a temperature of 180 °F (82 °C) and determined that a full retrofit of the existing housing heating systems could be completed with a simple payback of eight years. The payback was based upon a capital cost of $8 million (2012 dollars) and a fuel savings of $1 million per year (2012 dollars).

The Demand Side Analysis (DSA), establishes the number of BTU's required to heat a set of priority buildings in Hawthorne and/or the Hawthorne Army Depot (HAD) (e.g., office buildings, hospital, retail businesses, base housing). Utilizing energy modeling software, the building heating requirements are modeled for the heating season with the impacts of the shoulder seasons (March, April, early May and October, November) being met by utilizing geothermal heating early in the mornings and mechanical cooling (i.e., electric) when needed.

The goal of the demand side modeling is to balance the heating of buildings with the available geothermal capacity of the southern Walker Lake Region. The size and design of a geothermal heating system is directly related to the amount of heat energy available from the geothermal resource. The production side analysis is based upon the scenarios shown in Tables 6 and 7. The demand side model uses the flow rate and temperature of the geothermal fluid as the heat input for the Trane TRACETM 700 modeling software to model the building square footage that can be heated with geothermal fluid. This software package is inexpensive, readily available, easy to use, and proven to be accurate and reliable.

For the purpose of this study, 20 different geothermal production scenarios were considered, ranging from 100 GPM at 96.3 °C (206°F) to 1,800 GPM at 100 °C (212°F). Table 7 shows the geothermal fluid flow rate and temperature as well as the square footage of building that can be heated based upon the flow rate and temperature. The calculations for Table 7 are shown in Appendix 1.

The well supplying the hot water is assumed to be one mile from the heat exchanger, which is rated for between 620,000 BTU/hr and 11,000,000 BTU/hr depending on flow rate of geothermal fluid from the extraction well. The spent geothermal fluid is re-injected into the ground at a separate well assumed to be two miles from the heat exchanger and down gradient of the production well so as to not create interference with production. Assuming the pipe will be well insulated, temperature drop along the one-mile pipe between well and heat exchanger is assumed to be negligible.

Heating will be provided by a water loop on the "cold side" of the heat exchanger. This water will be pumped from the heat exchanger directly to the air handler units at each building selected for geothermal heating. Figure 23 shows the block flow diagram of the geothermal heating system.

The available geothermal energy does not support a case for cost effective cooling using absorption chillers. Compared to mechanical chillers, absorption chillers have a low coefficient of performance (COP = chiller load/heat input). Single-effect machines provide a thermal COP of approximately of 0.7. Electric Water-Cooled Centrifugal Chiller COP is on the order of 6.5. Single state chillers need heat with a minimum temperature of 80 °C to properly function. A simple cost-benefit analysis showed that cooling less than half of the square footage that can be heated, does not justify the capital expense of utilizing absorption chillers to cool buildings (See Appendix 2 for a fact sheet on absorption chillers).

For the demand side model, the building heating requirements are established during the heating season. The demand model yielded the total heating demand and its variability to ensure that the geothermal resource is not depleted. Key parameters include: (1) building size and function, (2) occupancy rate, (3) utilization factor, and (4) meteorological data.

Tables 8 and 9 show the environmental design parameters to be used in developing the heating loads for the direct use system. The shoulder seasons (March, April, early May and October, November) require both heating and cooling in the same day.

Table 7 - Geothermal fluid flow/temperature input for building heating capacity.

Geothermal Flow (GPM)	T(°(C)	BTU/hr Available for Heating	Square Feet of Building Heating
100	96.886	621,150	24,618
100	96.823	621,150	24,618
100	96.321	621,150	24,618
200	96.135	1,244,350	73,854
200	96.021	1,244,350	73,854
200	96.247	1,244,350	73,854
300	94.168	1,867,550	98,472
300	94.048	1,867,550	98,472
300	93.190	1,867,550	98,472
600	91.802	3,741,250	221,562
600	90.629	3,741,250	221,562
600	91.612	3,741,250	221,562
600	93.039	3,741,250	221,562
600	90.533	3,741,250	221,562
600	92.997	3,741,250	221,562
1200	91.158	7,451,750	443,124
1200	100.000	7,451,750	443,124
1200	90.399	7,451,750	443,124
1200	90.168	10,450,900	640,068
1800	100.000	11,178,650	664,686

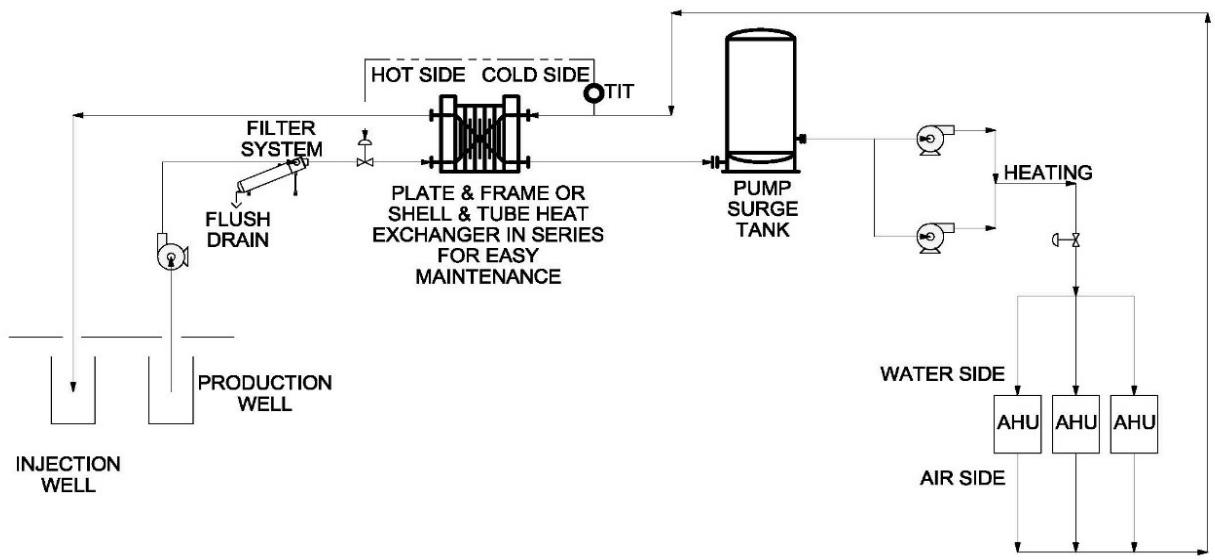

Figure 23 - Block flow of demand side heating system.

Table 8 – Design parameters for the Trane TRACE™ 700 model.

Design Parameters	
Plant Location (approximate)	Lat 38.545 N Long 118.658 W
Elevation above sea level	4167 FT
Atmospheric Pressure	12.6 psia
Ambient Temperatures: Summer dry bulb (mean, August) Winter dry bulb (mean, January) Winter dry bulb (building HVAC design) Winter dry bulb (freeze protection w/15 mph wind)	 70.2 ^{o}F 25.1 ^{o}F 11 ^{o}F -3 ^{o}F

Table 9 - Historical monthly temperatures from 2018 U.S. Climate Data.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ave. High Temp (^{o}F)	48^{o}	55^{o}	61^{o}	69^{o}	78^{o}	87^{o}	95^{o}	93^{o}	84^{o}	71^{o}	58^{o}	48^{o}
Ave. Low Temp (^{o}F)	25^{o}	29^{o}	34^{o}	39^{o}	47^{o}	54^{o}	61^{o}	59^{o}	51^{o}	41^{o}	32^{o}	25^{o}
Humidity %	55	50	40	35	35	26	25	28	29	25	47	50

The relative location of the City of Hawthorne to Hawthorne Army Depot is shown in Figure 24. The location of the geothermal extraction and injection wells will have an impact on effectiveness of the geothermal district heating system. The closer the extraction well is to the locations to be heated, the more cost effective the district heating system will be. The City of Hawthorne has identified the critical buildings to be the 35-bed Mount Grant General Hospital and the Sherriff's Office/Courthouse complex. The Sherriff's Office complex is within three city blocks of the hospital. The layout and relative location of these buildings is shown in Figure 25. Other buildings in close proximity that could be heated with a district heating system include the library and the firehouse. Photos of these buildings are shown in Figures 26 to 33.

Discussions with HAD personnel indicate that their top priority is heating the 42 housing units and office buildings that are currently using steam heat. Figures 34 to 37 show the typical office building and a typical housing unit that would be connected to a district heating system at HAD.

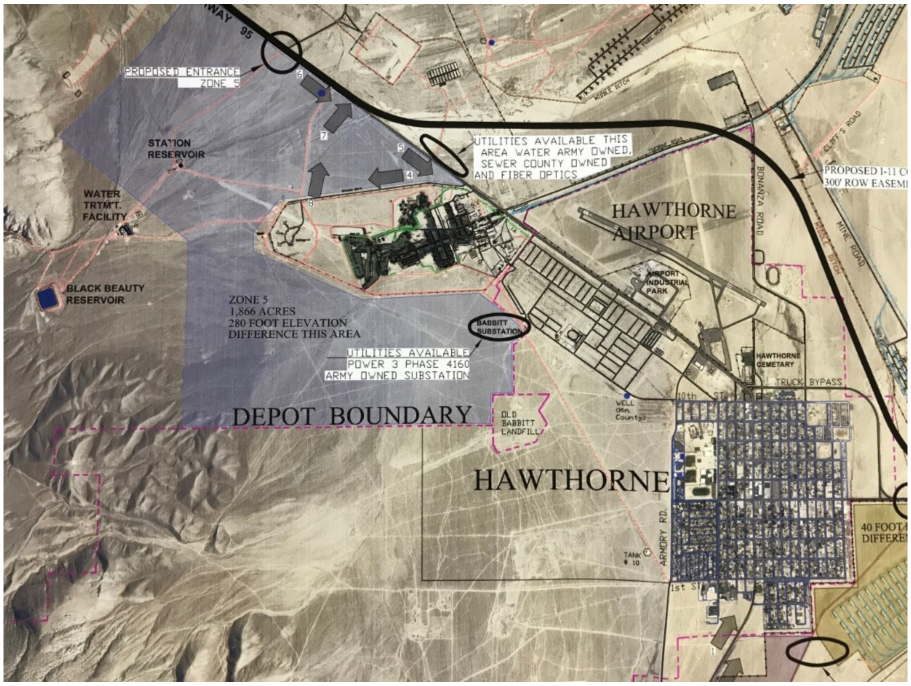

Figure 24 - The relative location of the City of Hawthorne to Hawthorne Army Depot

Figure 25 - Relative Location of the Hospital, Sherriff's Office/Courthouse Complex, Public Library and the Fire House.

Figure 26 - Mount Grant General Hospital.

Figure 27 - Mount Grant General Hospital.

Figure 28 - Mineral County Courthouse/Sherriff's Office Complex.

Figure 29 - Mineral County Courthouse/Sherriff's Office Complex.

Figure 30 - Hawthorne Fire Department Station.

Figure 31 - Hawthorne Fire Department Station.

Figure 32 - Mineral County Library.

Figure 33 - Mineral County Library.

Figure 34 - Admin General Purpose Building at Hawthorne Army Depot.

Figure 35 - SOC Admin General Purpose Building at Hawthorne Army Depot.

Figure 36 - Information Services Building.

Figure 37 - Typical Single-Family Residential Structure on Hawthorne Army Depot.

3.2. Conceptual Model

As mentioned above, the team developed the demand side model assuming various flow rates and temperatures for the geothermal fluid. Appendix 3 shows the block flow diagram for geothermal heating loop with the various scenarios for temperature and flow of the geothermal fluid. The geothermal fluid gathering system piping will be buried at sufficient depth for heat conservation as well as live load requirements for passing under roadways and structures. The heat loss for the buried insulated pipe is negligible (less than 1 °C per mile of buried pipe).

The district heating system will utilize a closed loop on the geothermal fluid side to return the fluid into an injection well at a location that ensures the sustainability of the resource. The closed loop on the heating side will direct the hot water to fan cooling units for heating the selected buildings.

As with any modeling exercise, the inputs to the system are important. Critical elements include local climate conditions, building construction, building size and layout, occupancy, lighting systems, equipment, and ventilation. The team collected drawings and usage requirements of the priority buildings from the City of Hawthorne and HAD and then determined the square footage of the buildings and their ventilation requirements to provide inputs to the model. Model inputs for typical heating loads for the building usage (i.e. hospital, office, house, retail store) are available from the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). These are the typical loads that were used for the model. The demand side model balances the heating capacity of the geothermal resource with the “best fit” for heating the priority buildings. A rough order of magnitude of cost has been developed for the geothermal heating system and is shown in Appendix 4.

Building information was available for HAD but was not readily available for the City of Hawthorne with the exception of blueprints of the Sherriff’s office/courthouse complex. For the HAD, two ‘typical office use’ buildings were analyzed as well as a typical single-family residential structure. The HAD buildings selected for the demand side modeling are Admin General Purpose Buildings (Figure 34 and 35) with a conditioned area of 24,618 ft^2, Information Services Building (Figure 36) with a conditioned area of 8,601 ft^2, and Quarters L (Figure 37), a four-bedroom residential house with a conditioned area of 2,247 ft^2.

3.3. Results

The results from the Trace model show that the 24,618 ft^2 Admin General Purpose building (large office building) requires 400,000 Btu/hr to be heated properly. The results of the scenarios displayed in Table 7 show that from 1-27 buildings of this size and usage may be heated depending upon the geothermal fluid flow rate. The assumptions made for this calculation are:

- The current HVAC system uses a rooftop multizone unit
- Standard office equipment and lighting is in the office building, no heavy use motors or other heat generating equipment is used
- 143 ft^2 per person
- Brick exterior wall with 2.42" insulation
- Steel sheet roof with 4" insulation
- Thermostat set at 68 °F

For the 8,601 ft^2 Information Services (small office building) the results show it requires 168,000 Btu/hr to be properly heated meaning that from 3-66 buildings of this size and usage may be heated depending upon the geothermal fluid flow rate. The assumptions for this calculation are:

- The current HVAC system uses a rooftop multizone unit
- Standard office equipment and lighting is in the office building, no heavy use motors or other heat generating equipment is used
- 143 ft^2 per person
- Brick exterior wall with 2.42" insulation
- Steel sheet roof with 4" insulation
- Thermostat set at 68 °F

The modeling results show that the 2,247 ft^2 Quarters L housing unit requires 51,380 Btu/hr to be properly heated meaning that from 12-217 buildings of this size and usage may be heated depending upon the geothermal fluid flow rate. The assumptions for this calculation are:

- Rooftop HVAC unit
- Standard office equipment and school equipment
- 2,000 watts of lighting with incandescent bulbs
- 3-5 people per building
- Brick exterior wall with 2.42" insulation
- Wood roof with 3-inch insulation at 45° pitch
- Thermostat set 68 °F

For the City of Hawthorne, the large building is represented by the Courthouse and Sheriff's office (one building). The sheriff's office/courthouse complex was the only facility with detailed construction blueprints available. This complex is approximately 18,600 ft^2 and is comparable in size and function to the Admin General Purpose Building located on HAD. The modeling results show that this facility requires 293,100 Btu/hr to be properly heated and that 2-38 buildings of this size and usage may be heated depending upon the geothermal fluid flow rate. The assumptions for this calculation are:

- The current HVAC system uses a rooftop multizone unit
- Standard office equipment and lighting is in the office building, no heavy use motors or other heat generating equipment is used
- 143 ft^2 per person
- Brick exterior wall with 2.42” insulation
- Steel sheet roof with 4” insulation
- Thermostat set 68 °F.

When heating multiple building types and sizes, it is recommended that the total heating load not exceed 25,000 to 500,000 ft^2 depending upon the flow rate and temperature of the geothermal fluid. Detailed information on the individual buildings under consideration for geothermal heating will need to be collected and the model run again if a district heating system moves into the engineering study phase.

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4. WHOLE SYSTEM ANALYSIS

4.1. Introduction

The WSA was originally designed to capture the feedback between the demand (i.e., how heavily is the system stressed) and the available heat. For systems where the injection well is close enough to the production well to interfere with production well temperatures, capturing this feedback is important. However, the nature of the Hawthorne area allows for the placement of the injection wells far away from the production wells so there is no real dynamic feedback between the demand and available heat, other than the thermal drawdown due to pumping. For this reason, it was determined that a dynamic systems model was not necessary for the WSA and thus a deterministic systems approach was taken.

The objective of the WSA is to determine how the entire system performs over time and at what cost and performance. The GEOPHIRES model (Beckers and McCabe, 2018) was used to determine the system performance along with the scenarios generated from the PSA above. Fourteen extra scenarios are added based on an assumed performance of tapping the deep resource. These are then compared to the needs of the demand side to calculate the LCOH, ROI, and carbon offset from developing deep direct-use geothermal for the Hawthorne area.

4.2. Scenarios

The 92 PSA modeling scenarios (including the 2 'wildcat' scenarios) of the shallow resource are based on variations in the capacity estimate, the number of production wells, the location of the production wells, and the pumping rate. GEOPHIRES includes the number of injection wells in its calculation so for the double production well scenarios from the PSA, single and double injection well scenarios are included, bringing the total number of scenarios for the WSA to 137. This allows for examining the tradeoff between the capital cost of the additional injection well and the savings in pumping. The savings in pumping comes from lower friction losses and formation resistance losses from injecting the same amount of water into two wells instead of one. The scenarios are listed in Table 10.

Table 10 - List of scenarios for the shallow resource WSA.

Capacity Estimate	Pumping Rate[a] [gpm]	# Producers	# Injectors	Locations #'s
P10, P50, P90	100	1	1	1, 2, 3, 4, 5
	300			
	600			
	200	2	1 and 2	
	600			
	1200			
'Wildcat'	1200	1	1	NA
	1800	2	1 and 2	

[a]Pumping rate is the total for the well field.

GEOPHIRES requires a wide range of inputs from parameters that define reservoir characteristics to those that define the economics. The inputs common to all scenarios are listed in Table 11. For the shallow resource scenarios, thermal drawdown curves are fed directly to the model whereas the deep resource scenarios rely on a linear thermal drawdown rate of 0.5%, which is the default value in GEOPHIRES and a reasonable guestimate for the deep reservoir. However, it does produce an unrealistic drawdown curve that may be overly optimistic (Figure 38). Because GEOPHIRES does not handle variable pumping rates, the utilization factor was adjusted downward to a value of 0.481. This value is based on the required constant flow rate necessary to deliver the total heat over 30 years at the effective temperature, which was described above. The ratio of the required constant flow rate to the capacity flow rate in January is 0.481.

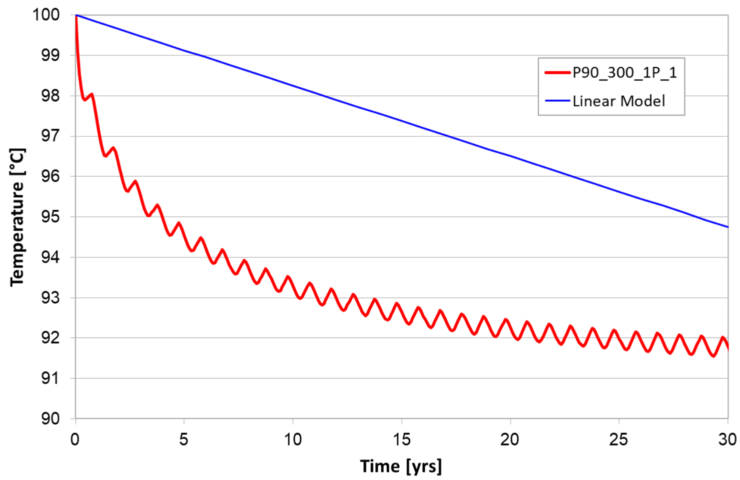

Figure 38 - Linear thermal drawdown model using a drawdown parameter of 0.005/yr in GEOPHIRES versus the P90 300 gpm, 1 production well case. The linear model is likely to be overly optimistic.

Table 11 - List of common inputs into GEOPHIRES.

Parameter Name	Value	Parameter Name	Value
Reservoir Model	5[a]	Injectivity Index [kg/s/bar]	4.25
Reservoir Depth [m]	312.5	Injection Temp. [°C]	70
# of Segments	1	Res. Heat Cap. [J/kg/°K]	900
Gradient [°C/km]	272.0[b]	Res. Density [kg/m³]	2800
Max. Temp. [°C]	100	Res. Thermal Cond. [W/m/°K]	2.75
# of Prod. Wells	1 or 2	End-Use Option	2[f]
# of Inj. Wells	1 or 2	Circ. Pump Eff.	80%
Prod. Well Diam. [in]	9.625	Utilization Factor	0.481
Inj. Well Diam. [in]	9.625	Surface Temp. [°C]	15.0
Ramey Model	1[c]	Ambient Temp. [°C]	15.0
Production Rate [kg/s]	6.024, 12.0479, 18.0719, 36.1437, 72.2874, 108.4311[d]	End-Use Eff. Factor	90%
Reservoir Vol. Option	4[e]	Plant Lifetime [yrs]	30
Reservoir Volume [m³]	199,750,000	Economic Model	2[g]
Water Loss Fraction	2%	Discount Rate	7%
Prod. Index [kg/s/bar]	4.25		

[a]User defined drawdown curve
[b]Not relevant when Reservoir Model = 5
[c]Use Ramey borehole temperature model
[d]Based on water density of 954.75 kg/m³
[e]Reservoir volume provided as input
[f]Direct-use
[g]Standard LCOH calculation

4.3. Results

Because the thermal resource at Hawthorne is relatively shallow (~500 m) the economic feasibility of the system is driven more by the total heat delivered than the drilling costs. The results are broken into two sections, one for the uncertainty analysis associated with the shallow resource and the other for the more deterministic assessment of the deep resource.

4.3.1. Shallow resource

Figure 39 plots the LCOH as a function of pumping rate across all scenarios and well configurations, including the wildcat scenarios. A power-law relationship between the flow rate and the LCOH is evident. Despite there being lower drilling costs, the scenarios with 1 production well have the highest LCOH due to their higher thermal drawdown and lower average annual heat production (shown in Figure 40). The outlier in Figure 40 is the 'wildcat' single production well scenario at 1,800 gpm. Figures 39 and 40 also show that there is very little difference between the 2 production well scenarios with 1 and 2 injection wells due to the shallow depth of the resource and the low drilling costs.

Figure 41 shows the LCOH as a function of the average annual heat production over the 30-year lifespan of the system, breaking the results out by capacity estimate. The relationship between average annual heat production and LCOH is strong with the only outliers (i.e., the points lying above the fitted line) being the 2 production well, 200 gpm scenarios. Also evident is the lack of variability between the capacity estimates. The exception to this for the 1,200 gpm 2 production well scenarios where the variability in the capacity estimate can be seen (zoomed box in Figure 41). For the P10 case, the average annual heat production ranges from 42.22 GWh/yr to 49.16 GWh/yr with a mean of 45.80 GWh/yr. The P50 case ranges from 41.48 GWh/yr to 48.91 GWh/yr with a mean of 45.22 GWh/yr. The P90 case ranges from 39.79 GWh/yr to 48.73 GWh/yr with a mean of 44.83 GWh/hr. These differences illustrate how uncertainty in the geologic conceptual model translates to uncertainty in the economic estimates with the average P10 case producing almost a GWh/yr more heat on average than the P90 case.

The same dynamic as the variability in thermal drawdown is evident when looking at the variability due to well location (Figure 42), with the locations with the smallest thermal drawdown (locations 3 and 4) also having the smallest LCOH. Of interest here is that there are some differences between the three capacity estimate at each location from that associated with thermal drawdown. This is apparent with location 3 where the P50 case has the highest LCOH in Figure 42 but the smallest thermal drawdown in Figure 21. This illustrates the fact that the smallest thermal drawdown over 30 years does not necessarily mean the highest total heat production since the thermal drawdown only represents the difference between the starting temperature and the ending temperature while the total heat produced is the integration of the thermal drawdown curve over time.

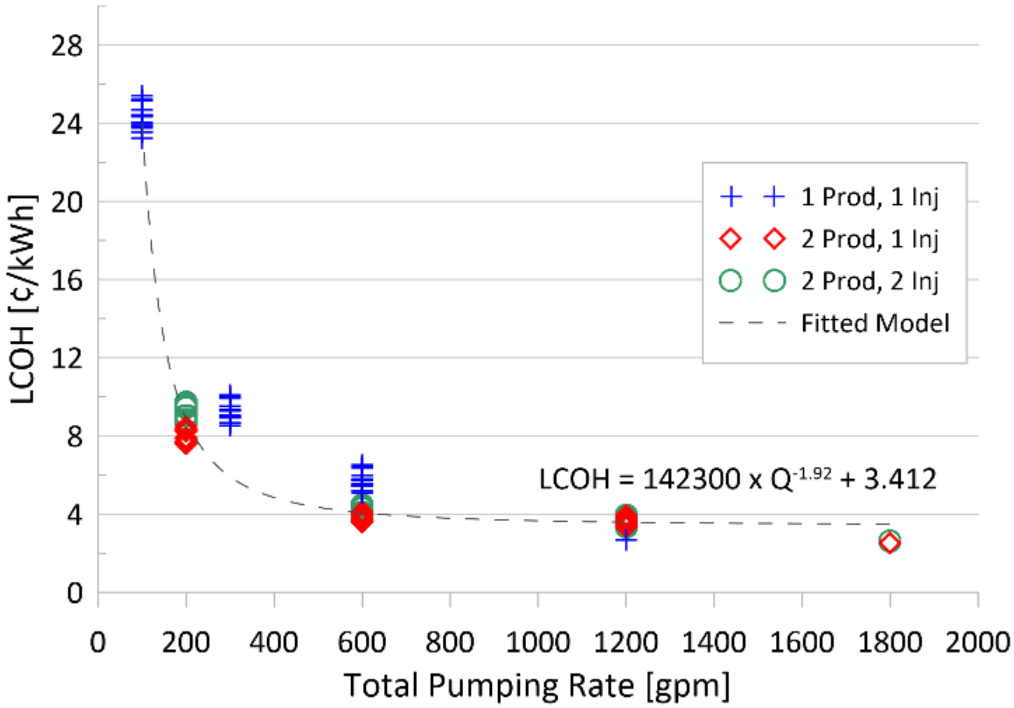

Figure 39 - Relationship between pumping rate and LCOH for the shallow resource. The dotted line is the fitted model given by the equation in the plot.

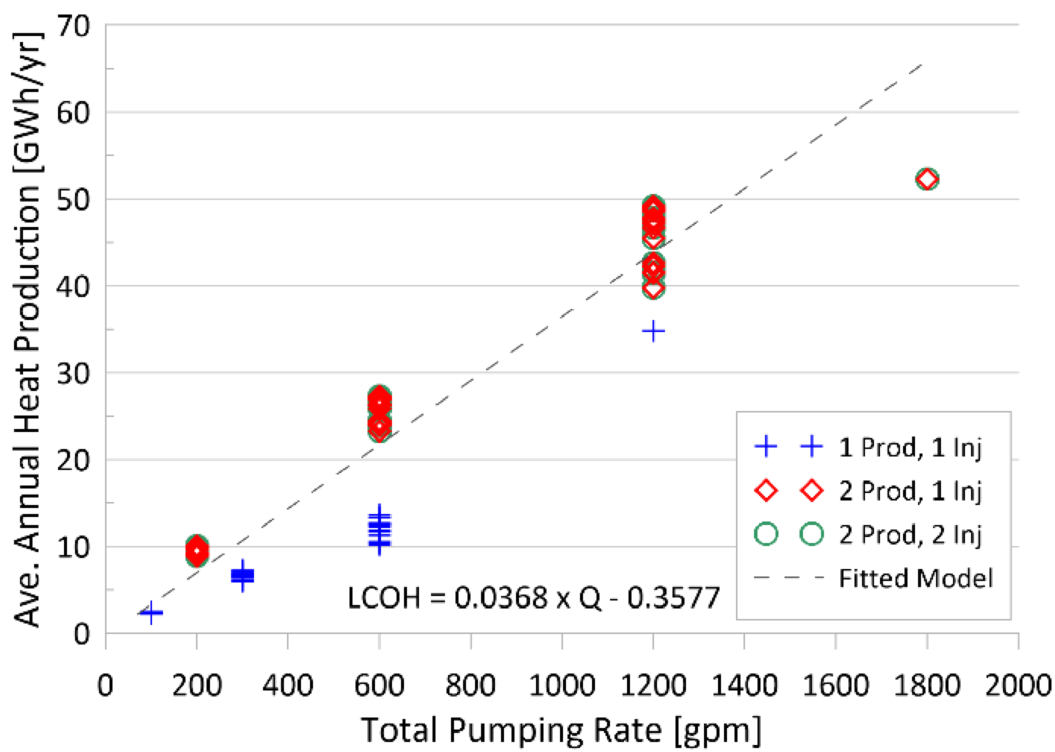

Figure 40 - Relationship between pumping rate and the average annual heat production for the shallow resource. The dotted line is the fitted model given by the equation in the plot.

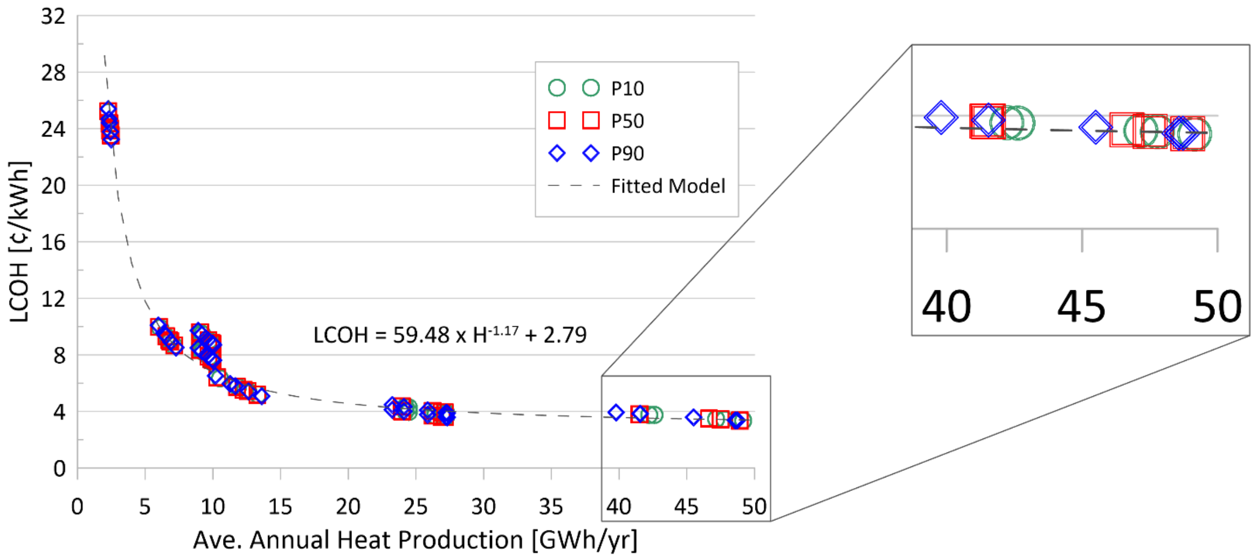

Figure 41 - Relationship between the LCOH and the average annual heat production for the shallow resource. The dotted line is the fitted model given by the equation in the plot. The zoomed portion focuses on the variability between the capacity estimates at high pumping rates.

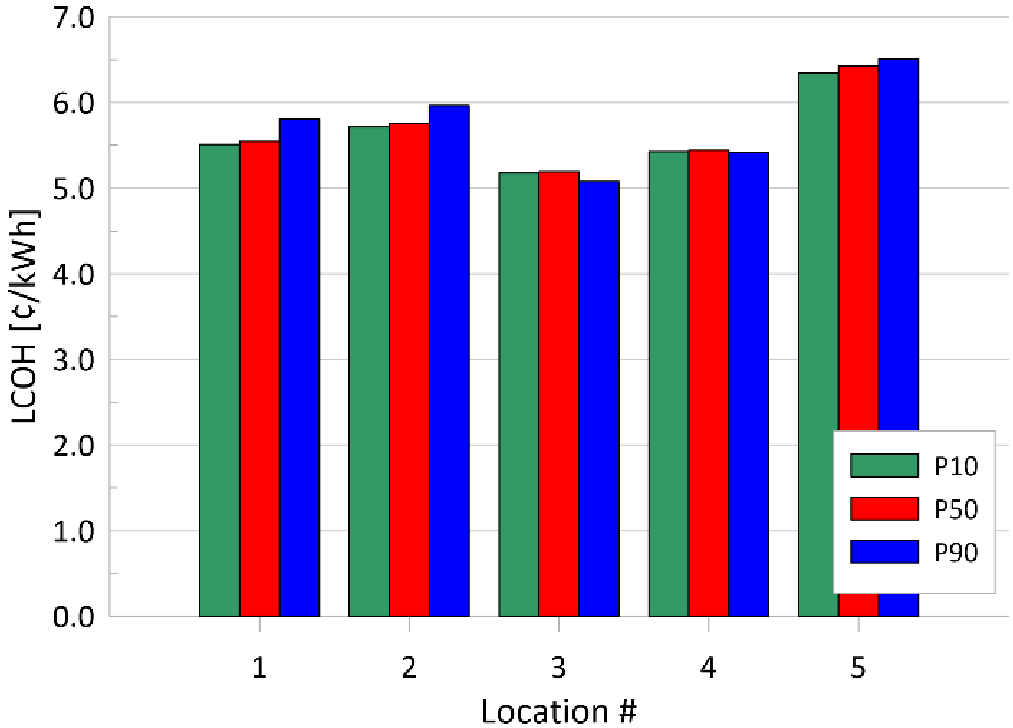

Figure 42 - The LCOH as a function of well location and capacity estimate. Like the thermal drawdown, locations 3 and 4, which are in the north portion of the hot spot, perform the best.

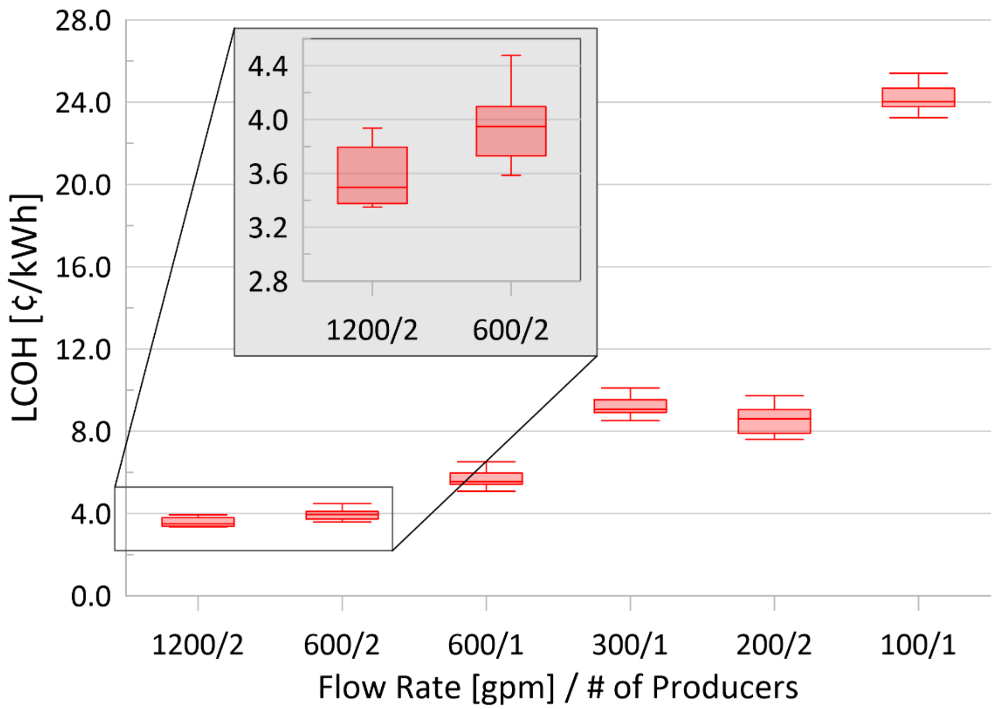

Figure 43 - Variability of the LCOH based on pumping rate and number of production wells.

4.3.2. Deep resource

While there was no 3-D model completed for the deep resource, an economic assessment was still completed using assumptions of the deep resource from the geologic conceptual model. For the deep resource assessment, the wells are extended to 500 m deep, which puts the extraction zone in the upper part of the deep resource. One could argue that the upper part of the deep resource should coincide with the bottom boundary of the shallow resource but given the lack of sensitivity of the LCOH to the capacity estimates for the shallow resource it was decided to not distinguish between them in the deep resource analysis.

The scenarios for the deep resource assessment are similar to the shallow resource assessment except pumping at 100 and 200 gpm were eliminated and there is no variability due to capacity estimate and well location. The scenarios for the deep resource are listed in Table 12.

Table 12 - List of scenarios for the deep resource analysis.

Pumping Rate[a] [gpm]	# Producers	# Injectors
300, 600, 1200, 1800	1	1
300, 600, 1200, 1800	2	1 and 2
1800, 2700	3	2

[a]Pumping rate is total for the well field.

The results from the deep resource analysis are similar to the shallow resource in that there is a strong relationship between the flow rate, the amount of heat produced, and the LCOH (Figure 44). However, because there is no feedback between the pumping rate and drawdown, the scenarios with the minimal number of wells have the lowest LCOH (i.e., the 1 production 1 injection well scenarios). This is opposite to the shallow resource model where the 1 production well scenarios had the highest LCOH due to higher thermal drawdowns.

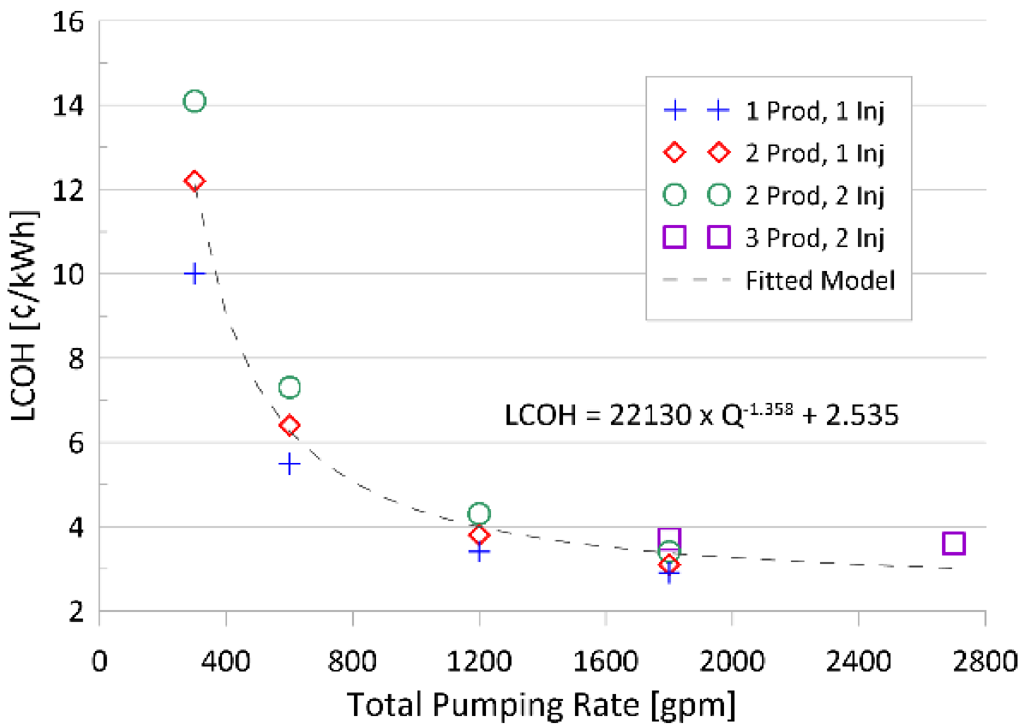

Figure 44 - Relationship between pumping rate and LCOH for the deep resource. The dotted line is the fitted model given by the equation in the plot.

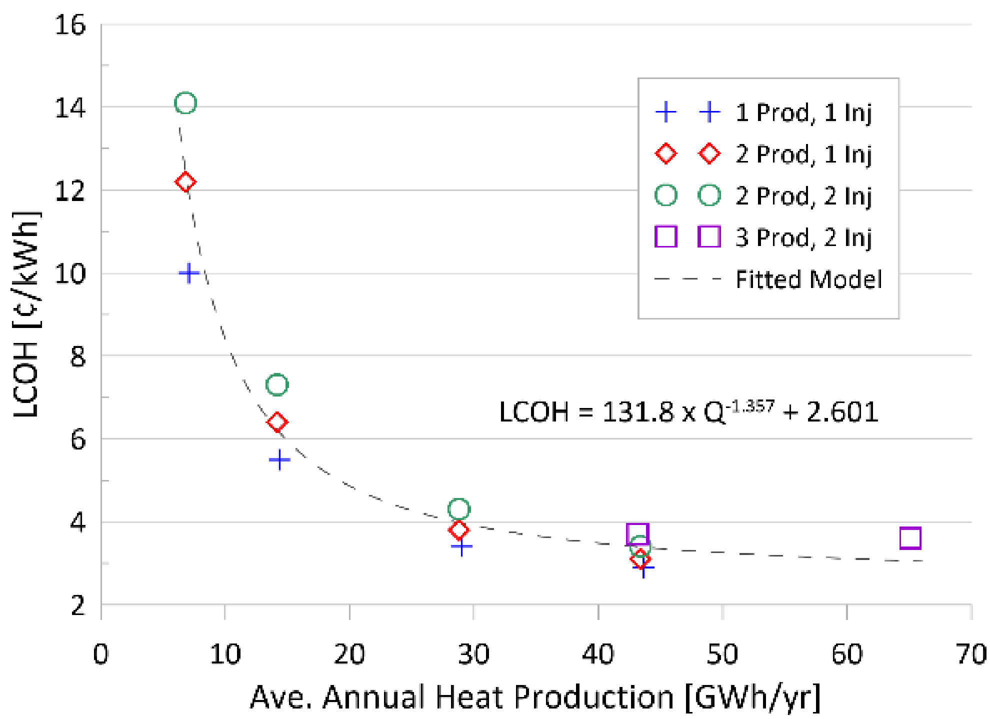

Figure 45 - Relationship between the LCOH and the average annual heat production for the deep resource. The dotted line is the fitted model given by the equation in the plot.

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5. ANALYSIS AND DISCUSSION

The analysis confirms that developing deep direct-use geothermal in the Hawthorne area is feasible as well as economical; however, there are caveats and subtleties that are important to understand. This section explores those issues by examining the LCOH, ROI, and the carbon offset.

5.1. LCOH

Adding up the total square footage for the priority buildings identified in the DSA (the admin and general purpose building, the information services building, and the 42 residence quarters on the HAD, as well as the courthouse/sheriffs building, the hospital, and the library) and making estimates for the buildings with no data, the total square footage to be heated is approximately 180,000 ft^2 (the Hawthorne schools were originally identified as priority buildings but were removed from the analysis after the city invested in geothermal heat pumps for the schools). Projecting out the heating demand based on the results of the DSA, this amounts to a total demand of approximately 3.6 MBTU/hr. Given the inflow temperature of the geothermal fluid, this demand can be met with a pumping rate of 582 gpm. Using the fitted model from Figure 39, the resource can support the regions demand over 30 years at a LCOH of 4.11 ¢/kWh. This is very competitive compared to other forms of energy.

However, part of the economics is the scale of the problem. If one looks exclusively at the HAD, the total square footage of the priority buildings is approximately 128,000 ft^2, which translates into a demand of 2.7 MBTU/hr. To supply this demand 438 gpm would need to be pumped, which increases the LCOH to 4.62 ¢/kWh. For the city buildings, the demand is approximately 0.9 MBTU/hr, which requires pumping at 146 gpm at a LCOH of 13.36 ¢/kWh. At this point it is not cost effective for the city, on its own, to transition to direct-use geothermal.

5.2. Return on Investment and Payback Period

LCOH is a good measure of the cost of an energy source but is not directly comparable to systems that already exist. Thus, the ROI and the payback period for the three build-out scenarios discussed above (HAD and City/County, HAD only, City/County only) are also calculated. The calculation assumes capital costs and only wellfield maintenance and pumping costs for the geothermal system over 30 years, under the assumption that operation and maintenance (O&M) costs for plant and surface infrastructure will be similar between the current systems and a new geothermal system. Diesel and propane are assumed to cost $3.00/gal and $2.75/gal, respectively, with energy contents of 139,00 btu/gal for diesel and 91,647 btu/gal for propane. The estimates of the current system are based on the demand rates for each buildout scenario and the new geothermal system is assumed to have 2 producers and 1 injector to minimize costs and thermal drawdown.

Table 13 shows the yearly, capital, and total 30-year costs for the existing systems and their geothermal direct-use replacement. As was mentioned in the LCOH discussion above, the scale of the system is important. Changing just the city and county buildings is not cost effective over the 30-year example because the initial costs and the wellfield maintenance costs are too high with respect to the demand it would serve. The best option is to retrofit both the HAD and the city and county buildings. This provides a total ROI of 85% (annualized at 2.1%/yr) and a payback period of 10 years. Changing over just the HAD is also cost effective, with a 30 yr ROI of 49% (1.3%/yr) and a payback period of 13 years.

Table 13 - Costs and economic performance of three build-out scenarios.

Cost / Metric	HAD & City/County	HAD Only	City/County Only
Current System			
Fuel Costs [$/yr]	$839,769	$601,280	$238,489
30 yr Cost [$M]	$25.2	$18.0	$7.2
New Geothermal System			
Capital Costs [$M]	$7.6	$7.0	$5.7
Wellfield Maint. and Pump. Costs [$/yr]	$201,419	$171,932	$112,137
30 yr Cost [$M]	$13.6	$12.1	$9.0
Performance			
Profit [$M]	$11.6	$5.9	$(1.9)
ROI [total / annualized]	85% / 2.1%	49% / 1.3%	-21% / -0.8%
Simple Payback [yrs]	10	13	45

5.3. Carbon Emissions

With concern of the impacts of climate change growing daily, consideration of the carbon emissions is an important factor. Matching the three scenarios above and using the relationship between pumping rate and average annual heat production from Figure 40, the average annual heat production for each pumping rate is calculated. Knowing the annual heat production and using U.S. Energy Information Administration (EIA) CO_2 emission coefficients (https://www.eia.gov) the amount of CO_2 offset from using geothermal as compared to various different fuels is also calculated. The HAD relies on two diesel boilers to meet their heating needs while the City/County indicated they rely on propane. Both of those fuels can be evaluated accordingly. The results are listed in Table 14.

Table 14 - Average annual carbon emission offset using geothermal versus diesel for the HAD and propane for the city/county. Units are in metric tons (MT = 1,000 kg) per year.

Scenario	Pumping Rate [gpm]	Ave. Annual Heat Production [GWh/yr]	Avail. Heat Cold Side [MBTU/hr]	Diesel Carbon Offset [MT CO_2]	Propane Carbon Offset [MT CO_2]	Total Carbon Offset [MT CO_2]
HAD & City/County	582	20.8	3.63	1747	501	2248
HAD Only	438	15.8	2.73	1747	0	1747
City/County Only	146	5.0	0.91	0	501	501

To place these values in perspective, according to the U.S. EPA, a car driving 15,000 miles per year at 20 miles per gallon produces 6.7 MT CO_2/yr (MT = metric ton = 1,000 kg), meaning that a geothermal system for both the HAD and the City/County offsets the equivalent CO_2 as 335 cars, or 5,000,000 miles of driving per year.

6. REGULATIONS AND PERMITTING

6.1. Lease Requirements

Initial geothermal exploration activities on federal land that do not have a surface disturbance or penetrate a geothermal reservoir, are not required to have a geothermal lease in place. This includes activities such as surface geophysical surveys or drilling thermal gradient holes. Such initial exploration is covered under the Bureau of Land Management's (BLM) Notice of Intent (NOI) to Conduct Geothermal Resource Exploration Operations (Form 3200-9). Any further development beyond this initial exploration requires a geothermal lease to be in place (obtained either through competitive or non-competitive means with the BLM). BLM issues competitive and non-competitive leases for geothermal exploration and development on lands owned or controlled by the federal government. Both are issued for a 10-year period that can be extended for two subsequent five-year periods by completing appropriate work programs and diligence on the lease hold (e.g. suitable expenditure towards exploration activities). For exploration or development on private land, a lease agreement would need to be developed with the private land owner.

6.2. Well Permits

Any wells drilled on federal land are required to apply for a drilling permit with the BLM (form 3260-2), and with the Nevada Division of Minerals (NDOM). Any wells to be drilled on private land only require a drilling permit from NDOM (including thermal gradient holes). A Geothermal Project Area Permit is required from NDOM if the project involves drilling more than one well at the project location. In addition, developers must file a Sundry Notice with NDOM if they intend to make a minor change in the manner in which the well is operated, conduct a temperature or pressure survey, conduct a flow test, or perform routine maintenance of a well.

The cost to file a geothermal drilling permit with the BLM for any geothermal well on federal land is free. But all drilling permits or projects on federal land, or federally funded wells or projects (even on private land), are required to do a National Environmental Policy Act (NEPA) evaluation. If the well is a thermal gradient well, a categorical exclusion from a full NEPA evaluation may apply. The cost of a NEPA evaluation will vary depending on what is required. For example, surveys for cultural artifacts or endangered species will require appropriate experts to conduct the surveys.

Permit application fees with NDOM for well drilling are as follows:

- Industrial well (commercial production or injection) - $500/well
- Observation well - $300/well
- Thermal gradient hole - $100/well
- Direct use well - $200/well (production or injection)

6.3. Well Bonding Requirements

Any wells drilled on federal land require permits from both the BLM and NDOM, however BLM manages the well bonding that is required to ensure that the well will be properly plugged and abandoned (P&A) at the end of the project, and that any necessary environmental remediation is completed. For thermal gradient wells drilled on federal lands under a NOI, the bond is $5,000 minimum for one project area[1]. For multiple projects involving thermal gradient well drilling or geophysical surveys, a state-wide bond of

[1] https://www.ecfr.gov/cgi-bin/text-idx?SID=362f5947371444d3922eead0ce712be3&mc=true&node=pt43.2.3200&rgn=div5#sp43.2.3200.3214

$25,000 minimum is required. The actual bond amount can be more depending on the number of wells to be drilled, operator history of performance, and other factors. For wells drilled under a BLM geothermal lease, the drilling bond is a minimum of $10,000, and the state-wide bond is $50,000 minimum.

NDOM manages the bond requirements for wells drilled on private land: a minimum of $10,000 per well is required (this is likely to increase to $25,000 in 2020 if the proposed revised regulations are approved).

6.4. Water Permits – Pollution Control

Depending on the type of well (production or injection), additional permits may be required from the Nevada Division of Environmental Protection (NDEP) for the injection and/or removal of fluids. These are called Water Pollution Control permits. If geothermal water is to be injected (in any well type such as commercial, domestic, space heating or industrial use), a permit is required for underground injection control (UIC) to prevent degradation of all current and potential underground sources of drinking water due to injection practices[2,3,4]. All injection wells require testing during the well construction phase to acquire the data needed to satisfy the UIC permit application. Minimum tests that are required are: 1) Water chemistry of injection zone, 2) Static temperature survey of entire hole, 3) Pressure test on surface casing, 4) Pressure test on intermediate or production/injection casing, and 5) Cement evaluation log. Geothermal injection wells associated with electricity production have varying UIC permit application fees depending on how much power is being produced at the site (for example, if power production is greater than 25 MWe a $6,250 application fee and $625 per well is required. For power production < 10 MWe, a $3,750 application fee and $625 per well is required). If the geothermal injection well is associated with space heating, the application fee ranges between $875 and $1,875 depending on how much water is being injected[5]. Additional fees are required for any major modifications to the permit, annual services, and permit renewal. UIC permits are issued for a five-year period. UIC permits for small residential and commercial heat pump systems require a different application form (U211)[6] and a $200 permit application fee (one-off charge and no annual fees required); injection wells associated with these systems have well depth and flow rate constraints (< 600 ft deep and < 35,000 gallons/day respectively)[7].

In addition to UIC permits, discharge permits may also be required to protect the waters of the State of Nevada from potential pollutants. NDEP requires a National Pollutant Discharge Elimination System (NPDES) permit to be issued when produced geothermal fluids are discharged into surface waters of the State of Nevada (including river, lakes, streams, drainage systems, ponds and marshes)[8]. Temporary discharge or injection permits can also be issued by NDEP for activities that are expected to last between 48 hours and six months (e.g., well pump testing, aquifer drawdown testing, or underground injection of fluids).

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[2] https://ndep.nv.gov/uploads/water-wpc-permitting-stormwater-uic-docs/uic-form-u200-app-5-2017.pdf

[3] https://ndep.nv.gov/uploads/water-wpc-permitting-stormwater-uic-geothermal-docs/geothermal-uic-faq-08-May2017.pdf

[4] https://ndep.nv.gov/uploads/water-wpc-permitting-stormwater-uic-geothermal-docs/uic-request-geothermal-proj-5-2017.pdf

[5] https://ndep.nv.gov/uploads/water-wpc-permitting-stormwater-uic-docs/uicfees-may2017.pdf

[6] https://ndep.nv.gov/uploads/water-wpc-permitting-stormwater-uic-geothermal-docs/uic-domgeo-heat-pump-app-5-2017.pdf

[7] https://ndep.nv.gov/uploads/water-wpc-permitting-stormwater-uic-geothermal-docs/uic-domgeo-heat-pump-fs-5-2017.pdf

[8] https://ndep.nv.gov/uploads/water-wpc-permitting-individual-npdes-docs/discharge-permit-overview-2017.pdf

6.5. Water Permits – Water Rights

If produced geothermal fluids are discharged to the surface, or 100% of the produced fluids are not reinjected (e.g. due to evaporative losses), water rights need to be obtained from the State of Nevada's Division of Water Resources in order to appropriate the waters of the State[9]. The filing fee for a water rights permit application is $360. If the water right is granted, an additional issuance fee of $300 plus $3/acre-ft of water being applied for is required, and the user must demonstrate proof of beneficial use within the applied timeframe (for example, 1 year). If this timeline cannot be met, an extension can be applied for. It is possible that the water rights for a basin are fully appropriated. In this case, negotiating the transfer and sale of water rights from existing water rights holders would be required. For water requirements during geothermal drilling, a waiver can be requested to temporarily use water from an existing well to explore for geothermal resources[10].

6.6. Past Experience

Past drilling by the Navy GPO was conducted on HAD land, which is considered 'withdrawn' from BLM lands and thus has a different set of permitting requirements. The approvals required for geothermal drilling at the HAD included completing a Record of Environmental Consideration (REC; Appendix 5). This document describes the proposed action, the dates and duration of drilling, and indicates whether the proposed work qualifies for a Categorical Exclusion (Title 32 Part 651 Appendix B Section II) pending an Environmental Baseline Study (EBS). An EBS was prepared by the Navy GPO and provided to the HAD's Environmental Coordinator for approval. The EBS lists the proposed action, answers questions regarding the environmental setting, and anticipates impacts from this action such as potential impacts to air, soil, water and cultural resources (Appendix 6).

One of the last wells drilled at the HAD included a potential flow test. The approval required for this well includes receiving a temporary Authorization to Discharge permit from the state (Appendix 7), as described above. This document also describes the proposed work and imposes limits on the discharge process.

[9] http://water.nv.gov/waterforms.aspx?water=Water%20Right
[10] http://water.nv.gov/home/pdfs/WD%20regs.pdf

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7. SUMMARY

7.1. Background

The Hawthorne Nevada, deep direct-use geothermal study was a two-year effort funded by the U.S. Department of Energy to determine the techno-economic feasibility of implementing a large-scale, direct-use geothermal for the Hawthorne Army Depot (HAD) and facilities in the city of Hawthorne. Hawthorne, Nevada is in the western part of the Basin and Range province and has been the focus of geothermal investigations for over 40 years. Over the last 15 years, several studies have identified the existence of several low temperature geothermal prospects, the most promising of which is called Prospect A. The promise of Prospect A (Figure 4) is based on drilling and flow testing that produced ±100 °C water at flow rates of up to 31 l/s. Measured productivity indexes range from 30-300 l/s/MPa, suggesting a warm and productive heat source.

The analysis links a production side analysis (PSA) and demand side analysis (DSA) into a whole-system analysis (WSA) to provide an integrated assessment of the resource and the probability of delivering economically viable direct-use energy to Hawthorne.

7.2. Production Side Analysis

The PSA required a detailed review of all existing geoscience data acquired at the site to date and developed a quantitative estimate of geothermal resource potential for the Prospect A geothermal resource. This includes a review of substantial well data from water wells and geothermal exploration wells (downhole temperature logs, lithology, water chemistry, borehole televiewer, and alteration mineralogy), detailed geological and structural mapping information, geophysical data (gravity, magnetic, and seismic reflection), 2-m temperature data, and an existing 3D geological model of the basin.

We find that the thermal anomalies associated with Prospect A reflect the influence of two, related geothermal fluids in close proximity that are chemically distinct, with different temperatures and spatial extent (lateral and vertical). One fluid represents a deeper resource, hosted in altered, fractured Mesozoic granitic basement along a segment of the Wassuk Range-front fault system, and characterized by mature, alkali-chloride fluids, with ~4,000 ppm total dissolved solids (TDS) and a maximum measured temperature of ~115 °C at ~1,500 m depth. A second fluid is hosted in Neogene basin sediments at <400 m depth, with maximum measured temperatures of ~100 °C, TDS of ~1,000 ppm, and a sodium-sulfate fluid chemistry (Figures 7 and 8). The outflow of this shallow resource can be tracked down gradient (towards the NNE) into the basin using well temperature data, which map a vertically constrained plume that cools with distance from the inferred upflow location. The data suggest that the deeper resource is conductively transferring heat to the shallow resource, and structural and/or stratigraphic compartmentalization is preventing direct interaction and fluid mixing (Figures 9 and 10).

From the new conceptual model of Prospect A, P10, P50, and P90 estimates of the resource capacity are constructed, where the P10 scenario exists as the 10th percentile between most optimistic and most pessimistic (Figure 11).

Using the P10, P50, and P90 power density maps, a 3-D numerical thermal-hydrologic (TH) model was constructed to provide a bounds on the thermal performance of the system over time and to provide thermal drawdown curves to the WSA as a function of pumping rate, well location, and the number of wells. The model uses a simplified construct of the shallow reservoir by assuming a constant temperature bottom boundary condition that is constructed from the conceptual model thermal cross-sections (Figures 13 and 14). This is consistent with the conceptual model of there being little to no mixing between the shallow and deep waters and that the shallow system is heated through a conductive process as opposed to upwelling and mixing. The model was calibrated to temperature profile data from 13 wells within Prospect A.

Scenarios are developed for single (1 well) and double (2 wells) production wells, each with three different pumping rates. For the single production well scenarios, pumping rates are set at 100, 300, and 600 gpm while the double production well scenarios assume *total wellfield* pumping rates (i.e., the sum of both wells) of 200, 600, and 1,200 gpm. In addition, five different pseudo-random well locations were simulated for each of the production well/pumping rate scenarios (Figure 17). The combinations of the three capacity estimates, the number of production wells, pumping rates, and well locations resulted in 90 sensitivity simulations. Two additional 'wildcat' scenarios were also included in the WSA that assume 1200 gpm for a single production well, and 1,800 gpm for the double production well scenario, but with zero thermal drawdown over time.

7.3. Demand Side Analysis

The DSA establishes the number of BTU's required to heat a set of priority buildings in Hawthorne and/or the HAD (e.g., office buildings, hospital, retail businesses, base housing, etc.). Utilizing energy modeling software, the building heating requirements are modeled for the heating season with the impacts of the shoulder seasons (March, April, early May and October, November) being met by utilizing geothermal heating early in the mornings and mechanical cooling (i.e., electric) when needed.

The goal of the demand side modeling was to balance the heating of buildings with the available geothermal capacity of the southern Walker Lake Region. The demand side model uses the flow rate and temperature of the geothermal fluid as the heat input for the Trane TRACETM 700 modeling software to model the building square footage that can be heated with geothermal fluid. Critical elements include local climate conditions, building construction, building size and layout, occupancy, lighting systems, equipment, and ventilation. The team collected drawings and usage requirements of the priority buildings from the City of Hawthorne and the HAD and then determined the square footage of the buildings and their ventilation requirements to provide inputs to the model. Model inputs for typical heating loads for the building usage (i.e. hospital, office, house, retail store) were acquired from the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). The demand side model balances the heating capacity of the geothermal resource with the "best fit" for heating the priority buildings.

For the purpose of this study, 20 different geothermal water (well water) production scenarios were considered, ranging from 100 GPM at 96.3 °C (206°F) to 1,800 GPM at 100 °C (212°F) (Table 7). The geothermal flow rates match those simulated with the 3-D TH model.

7.4. Whole System Analysis

The objective of the WSA was to determine how the entire system performs over time and at what cost and performance. To determine the system performance, the GEOPHIRES model (Beckers and McCabe, 2018) was used along with the 92 scenarios generated from the PSA above. Fourteen extra scenarios based on an assumed performance of tapping the deep resource were also added. These are then compared to the needs of the demand side to calculate the LCOH, ROI, and carbon offset from developing deep direct-use geothermal for the Hawthorne area.

GEOPHIRES includes the number of injection wells in its calculation so for the double production well scenarios from the PSA, single and double injection well scenarios are also simulated, bringing the total number of scenarios for the WSA to 137. This allows for examining the tradeoff between the capital cost of the additional injection well and the savings in pumping. The savings in pumping comes from lower friction losses and formation resistance losses from injecting the same amount of water into two wells instead of one.

7.5. Results

As a whole, Hawthorne is similar to other Basin and Range systems with upflow associated with a key structural setting associated with a fault system at the edge of a basin and a with a long thin outflow in basin sediments. The difference here is that the sub-boiling, sulfate fluid outflow is not actually direct outflow from the chloride fluid upflow but is instead conductively heated. It is not yet known where the chloride outflow goes and this outflow does not figure directly into the areal extent of the deeper upflow, or shallower outflow. Upflow is likely to be 115 to 120°C and confined to part of the Wassuk range-front fault system in granitic rock. Outflow is <100°C and is within basin-fill sediments.

Based on the probabilistic reservoir models and the power density estimates there is a 90% chance that the upflow part of the resource has a capacity of at least 1.9 MWe and a 50% chance it is as big as 7 MWe (Table 3). For the outflow part of the resource, there is a 90% chance that the capacity is at minimum 0.5 MWe and a 50% chance it is as big as 1.6 MWe. These values indicate that electricity production is not feasible but do show that the system can support direct-use applications.

The 3-D modeling shows that thermal drawdown over time is sensitive to flow rate with a temperature drop of > 10 °C over 30 years at higher pumping rates ≥ 600 gpm/well. Simulations also show that the addition of a second production well reduces thermal drawdown by distributing the total pumping rate across 2 locations. The model simulations are sensitive to well location (Figure 20). Depending on the well location, the production temperature after 30 years can vary up to 9-10 °C. Well locations that are located towards the north end of the drilling zone tend to have the smallest drawdown over time while locations to the south have the highest thermal drawdown. Conversely, there is not much variability between capacity estimates, with the P90 case showing the widest thermal drawdown range of 10 °C, and the P10 and P50 cases each at 9 °C (Figure 21). On average, the effective temperature over time (effective temperature is the constant temperature required to deliver the same heat to the system over 30 years as a system experiencing thermal drawdown) varies between 4 °C and 10 °C of thermal drawdown.

The results of the DSA indicate that anywhere from 620,000 to 11,500,000 BTU's of heating demand can be met depending on the flow rates. The lower end figure is enough to heat the large general administration building on the HAD (~24,000 ft^2) while the upper figure is approximately 3 times the demand for all the priority buildings (the admin and general purpose building, the information services building, and the 42 residence quarters on the HAD, as well as the courthouse/sheriffs building, the hospital, and the library).

Because the thermal resource at Hawthorne is relatively shallow (~500 m) the economic feasibility of the system is driven more by the total heat delivered than the drilling costs. For the shallow resource, the WSA shows a power-law relationship between the flow rate and the LCOH with LCOH values ranging from < 4 to > 20 ¢/kWh (Figure 39). For scenarios that meet all the demands of the priority buildings at the HAD and for the city and county, the LCOH is ≤ 4 ¢/kWh. The 2 production well, 1 injection well configurations perform the best. Variability due to capacity estimate is minimal (Figure 41) while variability due to well placement can be as much as ± 20% (Figure 42).

The ROI and the payback period are calculated for three build-out scenarios; HAD and City/County, HAD only, City/County only. The calculation does not assume O&M costs for plant and surface infrastructure under the assumption that those costs will be similar between the current systems and a new geothermal system (well O&M costs are included). The estimates of the current system are based on the demand rates for each buildout scenario and the new geothermal system is assumed to have 2 producers and 1 injector to minimize the thermal drawdown.

The simple pay back periods are 10 years for the HAD and City/County scenario, 13 years for the HAD only scenario, and 45 years for the City/County only scenario, while the ROI is 85%, 49%, and -21% (Table 13). The City/County only scenario is not cost effective due to the large up-front costs of installing a geothermal system versus the relatively small demand (~4.0 GWh/yr versus ~13 GWh/yr).

The amount of CO_2 offset from using geothermal as compared to various different fuels is calculated using heat production equivalents for diesel for the HAD, and propane for the City/County (currently, the HAD relies on two diesel boilers to meet their heating needs while the City/County rely on propane). For the HAD and City/County scenario, installing geothermal will offset 2,248 MT CO_2/yr, with the HAD only scenario contributing 1,747 MT CO_2/yr and the City/County only scenario contributing 501 MT CO_2/yr to the total. According to the US EPA, 2,248 MT CO_2/yr is equivalent to taking 335 cars off the road.

8. CONCLUSIONS AND RECOMMENDATIONS

The work prior to this study showed that the area around Hawthorne, Nevada has potential for low-temperature applications. This study looked deeper to create a more thorough understanding of the resource and its sustainability over time. This study shows that there is ample heat in the system to serve the HAD and the community of Hawthorne for 30-50 years.

One of the lessons from this study is that there is a threshold demand that must be met before deep direct-use becomes economically viable. The demand to heat just the City and County buildings is not enough to justify the cost of installing a geothermal system. The HAD on its own is economically viable but the economics improve when the demand for both the HAD and the City and County buildings are met. This implies that the resource can be 'marketed' to businesses and industries that require low-grade heat by touting its reliability, sustainability, and favorable economics, which would produce a secondary economic benefit to the community.

For deep direct-use geothermal to come to fruition at Hawthorne, the following steps are recommended:

1. Conduct a detailed MT survey.
2. Drill two exploration wells, one in the shallow system and one in the deep system, and then perform long-term pumping tests on both of them.
3. Refine the TH model to better represent the geology and hydrology of the system and to include both the shallow and deep systems.
4. Extend the economic analyses to include CHP, solar hybrid, and the potential of additional industry coming to the area.

The first step will provide a clearer picture of the lithology in the area and allow for the identification of pathways and barriers to fluid and heat flow through the system. It will also allow us to refine the shallow/deep geologic conceptual model and provide better estimates of the P10, P50, and P90 capacity estimates. The well drilling and pump tests in Step 2 will allow us to further refine the conceptual model as well as to validate the existing (and future) TH model. The pump tests should include monitoring for drawdown, temperature, and water chemistry over time. In addition, the pump tests should be conducted using multiple other wells in the area as monitoring wells for drawdown.

Step 3 will extend the capabilities of the TH model to gain a better understanding the flow paths, including the mechanism and source of recharge to the system and the fate of waters for the deep and shallow systems. In turn, this will reduce the uncertainty in the thermal drawdown predictions and provide a more accurate estimate of system response over time. The model should also include simulating the deep resource.

Finally, the economic analysis should be extended to examine 'what-if' scenarios that include future use of industrial users and advanced build-outs such as hybrid geothermal/solar CHP systems that utilize reservoir thermal energy storage. This extension should include an exploration of the upper limits of the system to place a maximum demand that the system can support to aid in attracting potential industry and businesses to the area.

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APPENDIX 1. GEOTHERMAL FLOW RATE IN BTU/HR AND BUILDING HEATING INFORMATION

Heat Exchanger													
Geothermal Water							Hot Water for facility Heating						
Flow [gpm]	T [F]	Scenario	T[F] HX oulet	btu/hr	MBH	ΔT (F)	Flow [gpm]	T [F]	Scenario	T[F] HX oulet	btu/hr	MBH	ΔT (F)
100	206.4	P10_100_1Prod_1	193.8	630000	630	12.6	30.3	129	P10_100_1Prod_1	170	621150	621.15	41
100	206.28	P50_100_1Prod_1	193.68	630000	630	12.6	30.3	129	P50_100_1Prod_1	170	621150	621.15	41
100	205.38	P90_100_1Prod_1	192.78	630000	630	12.6	30.3	129	P90_100_1Prod_1	170	621150	621.15	41
200	205.04	P10_200_2Prod_1	192.44	1260000	1260	12.6	60.7	129	P10_200_2Prod_1	170	1244350	1244.35	41
200	204.84	P50_200_2Prod_1	192.24	1260000	1260	12.6	60.7	129	P50_200_2Prod_1	170	1244350	1244.35	41
200	205.24	P90_200_2Prod_1	192.64	1260000	1260	12.6	60.7	129	P90_200_2Prod_1	170	1244350	1244.35	41
300	201.5	P10_300_1Prod_1	188.9	1890000	1890	12.6	91.1	129	P10_300_1Prod_1	170	1867550	1867.55	41
300	201.29	P50_300_1Prod_1	188.69	1890000	1890	12.6	91.1	129	P50_300_1Prod_1	170	1867550	1867.55	41
300	199.74	P90_300_1Prod_1	187.14	1890000	1890	12.6	91.2	129	P90_300_1Prod_1	170	1867550	1867.55	41
600	197.24	P10_600_1Prod_1	184.64	3780000	3780	12.6	182.5	129	P10_600_1Prod_1	170	3741250	3741.25	41
600	195.31	P10_600_2Prod_1	182.53	3834000	3834	12.78	182.6	129	P10_600_2Prod_1	170	3741250	3741.25	41
600	196.9	P50_600_1Prod_1	184.3	3780000	3780	12.6	182.5	129	P50_600_1Prod_1	170	3741250	3741.25	41
600	199.47	P50_600_2Prod_1	186.87	3780000	3780	12.6	182.4	129	P50_600_2Prod_1	170	3741250	3741.25	41
600	194.96	P90_600_1Prod_1	182.34	3786000	3786	12.62	182.9	129	P90_600_1Prod_1	170	3741250	3741.25	41
600	199.4	P90_600_2Prod_1	186.8	3780000	3780	12.6	182.4	129	P90_600_2Prod_1	170	3741250	3741.25	41
1200	196.08	P10_1200_2Prod_1	183.48	7560000	7560	12.6	365	129	P10_1200_2Prod_1	170	7451750	7451.75	41
1200	212	WC_1Prod	199.4	7560000	7560	12.6	363.5	129	WC_1Prod	170	7451750	7451.75	41
1200	194.72	P50_1200_2Prod_1	182.12	7560000	7560	12.6	365.2	129	P50_1200_2Prod_1	170	7451750	7451.75	41
1200	199.3	P90_1200_2Prod_1	181.7	10560000	10560	17.6	509.8	129	P90_1200_2Prod_1	170	10450900	10450.9	41
1800	212	WC_2Prod	199.4	11340000	11340	12.6	545.3	129	WC_2Prod	170	11178650	11178.65	41

Nomenclature
The scenarios names are defined as follows:
Ppp_QQQ_#Prod_placement
where
Ppp = the probability scenario (P10, P50, or P90)
QQQ = peak flow rate in gpm

		Number of structures that may be heated							
		Admin General		Information Services		4 Bedroom Quarters		Courthouse	
Scenario	btu/hr	24,618 Square Feet Each	Total Square Feet	8,601 Square Feet Each	Total Square Feet	2,247 Square Feet Each	Total Square Feet	18,600 Square Feet Each	Total Square Feet
P10_100_1Prod_1	621150	1	24618	3	25803	12	26964	2	37200
P50_100_1Prod_1	621150	1	24618	3	25803	12	26964	2	37200
P90_100_1Prod_1	621150	1	24618	3	25803	12	26964	2	37200
P10_200_2Prod_1	1244350	3	73854	7	60207	24	53928	4	74400
P50_200_2Prod_1	1244350	3	73854	7	60207	24	53928	4	74400
P90_200_2Prod_1	1244350	3	73854	7	60207	24	53928	4	74400
P10_300_1Prod_1	1867550	4	98472	11	94611	36	80892	6	111600
P50_300_1Prod_1	1867550	4	98472	11	94611	36	80892	6	111600
P90_300_1Prod_1	1867550	4	98472	11	94611	36	80892	6	111600
P10_600_1Prod_1	3741250	9	221562	22	189222	72	161784	12	223200
P10_600_2Prod_1	3741250	9	221562	22	189222	72	161784	12	223200
P50_600_1Prod_1	3741250	9	221562	22	189222	72	161784	12	223200
P50_600_2Prod_1	3741250	9	221562	22	189222	72	161784	12	223200
P90_600_1Prod_1	3741250	9	221562	22	189222	72	161784	12	223200
P90_600_2Prod_1	3741250	9	221562	22	189222	72	161784	12	223200
P10_1200_2Prod_1	7451750	18	443124	44	378444	145	325815	25	465000
WC_1Prod	7451750	18	443124	44	378444	145	325815	25	465000
P50_1200_2Prod_1	7451750	18	443124	44	378444	145	325815	25	465000
P90_1200_2Prod_1	10450900	26	640068	62	533262	203	456141	35	651000
WC_2Prod	11178650	27	664686	66	567666	217	487599	38	706800

Nomenclature

The scenarios names are defined as follows:

Ppp_QQQ_#Prod_placement

where

Ppp = the probability scenario (P10, P50, or P90)

QQQ = peak flow rate in gpm

#Prod = # of producers (1 or 2)

placement = randomized location

APPENDIX 2. ABSORPTION CHILLERS FOR CHP SYSTEMS

Absorption Chillers for CHP Systems

Chillers are used in commercial buildings and industrial plants to provide air conditioning, refrigeration, and process fluid cooling. There are two basic types of chiller cycles: vapor compression and sorption. Vapor compression chillers use reciprocating, screw, or centrifugal compressors to power the cycle. The compressors are most often driven by electric motors, although they can also be powered by natural gas engines or steam turbines. Sorption chillers, which are available as either absorption or adsorption designs[1], are driven with thermal energy produced from a direct fired burner integrated with the chiller, or with thermal energy supplied indirectly to the chiller. Indirect thermal sources include hot water, steam, or combustion exhaust. Absorption chillers are often exhaust fired using thermal energy recovered from combined heat and power (CHP) prime movers (e.g., reciprocating engines, microturbines, and combustion turbines). **Table 1** provides an overview of absorption chiller use in CHP applications.

A 400-ton single-stage absorption chiller integrated with three 600 kW reciprocating engines provides hot water for process and space heating. The system is located at a metal fabrication facility in Fitchburg, Massachusetts. *Photo courtesy of Northeast CHP Technical Assistance Partnership (CHP TAP).*

Applications

Absorption chillers use a binary solution of a refrigerant and an absorbent, and different solutions allow absorption chillers to meet a range of site cooling needs. For space conditioning and other requirements that require chilling fluid temperatures of 40°F or higher, water/lithium bromide (refrigerant/absorbent) is the most common solution. For lower temperatures, ammonia/water (refrigerant/absorbent) is typically used. Absorption chillers are most cost effective at sites that have significant space conditioning requirements or year-round cooling loads. Applications with significant year-round space conditioning loads include hospitals, hotels, large commercial office buildings, and college campuses. Sites that may require steady year-round cooling include manufacturing plants with process cooling needs, cold storage warehouses, data centers, and district energy plants.

Table 1. Summary of Absorption Chiller Attributes for CHP Systems

Size range	5 to 3,000 refrigeration tons
Input Heat	Hot water, steam, or prime mover exhaust
Configuration	Available in single and two stage designs. Single stage machines can be driven with hot water (200-240°F) or low pressure steam (15 psig) and are often used with reciprocating engine CHP installations. Compared to single stage chillers, two stage machines require higher temperature hot water (e.g., 350°F) or higher pressure steam (e.g., 115 psig) and are often used with combustion turbine CHP installations. In addition to hot water and steam, absorption chillers can also be exhaust fired (required exhaust temperatures typically above 750°F).
Refrigerant / Absorbent	For 40°F and higher chilling fluid temperatures (e.g., building air conditioning), a common mixture is water (refrigerant) and lithium bromide (absorbent). For chilling fluid temperatures below 40°F (e.g., cold storage), a common mixture is ammonia (refrigerant) and water (absorbent).

1 Absorption chillers use fluid refrigerants and absorbents. Adsorption chillers use a solid sorbent (typically silica gel) and a fluid refrigerant (typically water).

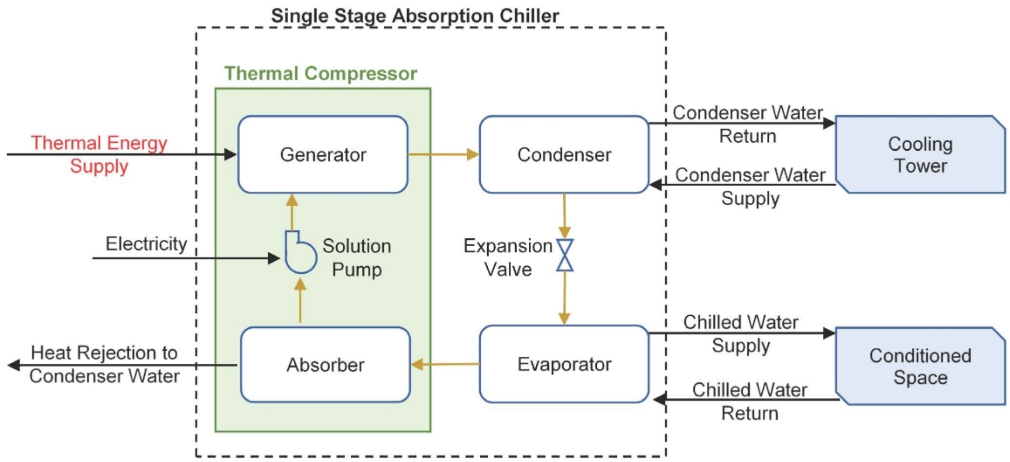

Figure 1. Single stage absorption cycle.
Graphic credit Exergy Partners

Technology Description

The absorption cycle is similar to the vapor compression cycle except the prime mover (typically an electric motor) and compressor are replaced by a thermal compressor system consisting of an absorber, solution pump, and generator (see **Figure 1**). Like a mechanical compressor in a vapor compression chiller, the thermal compressor takes low pressure/low temperature refrigerant vapor from the evaporator and delivers high pressure/high temperature refrigerant vapor to the refrigerant condenser. Instead of directly compressing the refrigerant vapor using a large amount of mechanical energy (typically electricity), a thermal compressor uses an absorbent fluid to chemically bond with the refrigerant vapor (essentially compressing it by changing phase from a gas to a liquid). This dilute solution of absorbent/refrigerant is easily pumped to the generator using a relatively small electric pump. In the generator, the refrigerant is boiled using thermal energy, and the refrigerant vapor then migrates to the condenser where it is changed back into a liquid refrigerant to begin the process over again. The absorbent is returned from the generator to the absorber to bond again with refrigerant vapor. The absorption process is exothermic (i.e., it generates heat), and heat must be rejected from the absorber to the condenser water and cooling tower loop. Because of this additional heat rejection load, absorption chillers require a larger cooling tower compared to a mechanical chiller with the same capacity.

Ammonia/water absorption chiller integrated with a CHP system consisting of two reciprocating engines.
Photo courtesy of Energy Concepts.

The basic absorption cycle shown in **Figure 1** is the same for both water/lithium bromide and ammonia/water absorption chillers. The difference is that ammonia/water chillers can serve lower temperature cooling requirements (e.g., refrigerated warehouses for cold storage) compared to water/lithium bromide systems. The picture on the left shows a CHP system with an integrated ammonia/water absorption chiller. This installation consists of two 415 kW reciprocating engine generators and an absorption chiller that produces 160 tons of 25°F refrigeration from the engine waste heat. The 160 tons of refrigeration is supplied directly to a cold room at a food processing plant where 1,900 gallons per minute of refrigerant (ammonia) cascades over the evaporator coils.

Performance Characteristics

The efficiency of an absorption chiller is measured by the coefficient of performance (COP), which is defined as useful thermal energy output (i.e., chiller load) divided by heat input. COP is a unit-less number and does not include energy consumed by pumps, fans, or other ancillary components. COP values for single stage chillers are less than one, and COP values for two stage systems are greater than one (i.e., chilled energy delivered exceeds heat required to drive the system).

Because absorption chiller capacity is a function of thermal energy input quantity and quality, as well as chiller design (single or two stage), it is important to match CHP prime movers with the right absorption chiller. While a two stage absorption chiller has a higher COP compared to a single stage chiller, a two stage chiller also requires a generator temperature about 150°F higher than a single stage chiller. Where high temperature heat sources are available, either design can be used. While a two stage heat recovery absorption chiller can produce more capacity from a high temperature heat source compared to a single stage chiller, a single stage chiller is less complex and typically less expensive.

Table 2 shows representative performance characteristics for single and two stage water/lithium bromide absorption chillers ranging in capacity from 50 to 1,320 tons. Three capacities are included for single stage chillers (Systems 1-3), and four capacities are included for two stage units (Systems 4-7). The three single stage examples are based on using either hot water or low pressure steam to drive the absorption chiller. The four two stage examples are based on using either high pressure steam or CHP prime mover exhaust as the heat source. All seven systems deliver 44°F chilled water based on an inlet water temperature of 54°F. The three single stage absorption chillers have COP values of 0.70 to 0.79, and the four two stage units, which are more efficient compared to single stage designs, have COP values of 1.35 to 1.42. Characteristics for the thermal

Table 2. Absorption Chiller Performance Characteristics

(typical values for water/lithium bromide chillers)

Description	System						
	1	2	3	4	5	6	7
Design	Single stage			Two stage			
Heat Source	Hot Water		Steam (low pressure)	Steam (high pressure)		Exhaust Fired	
Nominal Cooling Capacity (tons)	50	440	1,320	330	1,320	330	1,000
Thermal Energy Input							
Hot Water Inlet Temp (°F)	190	208	n/a	n/a	n/a	n/a	n/a
Hot Water Outlet Temp (°F)	181	190	n/a	n/a	n/a	n/a	n/a
Steam Pressure (psig)	n/a	n/a	14.5	116	116	n/a	n/a
Exhaust Gas Temperature (°F)	n/a	n/a	n/a	n/a	n/a	530	850
Heat Required (MMBtu/hr)[2]	0.85	7.1	20.1	2.8	11.2	2.9	8.7
Energy Output (chilled water)							
Inlet Temperature (°F)	54						
Outlet Temperature (°F)	44						
Cooling COP (full load)	0.70	0.74	0.79	1.42	1.42	1.35	1.38

Note: *Performance characteristics are based on multiple sources, including vendor data and discussions with industry experts. The characteristics are intended to illustrate typical absorption chillers, and are not intended to represent performance of specific products.*

2 For the hot water and steam examples, the boiler efficiency is not considered in the calculations.

Table 3. Absorption Chiller Capital and O&M Costs

(typical values for water/lithium bromide chillers)

Description	System						
	1	2	3	4	5	6	7
Design	Single stage			Two stage			
Heat Source	Hot Water		Steam (low pressure)	Steam (high pressure)		Exhaust Fired	
Nominal Cooling Capacity (tons)	50	440	1,320	330	1,320	330	1,000
Equipment Cost ($/ton)	$2,010	$930	$820	$1,190	$1,000	$1,330	$930
Construction and Installation ($/ton)	$3,990	$1,370	$980	$1,810	$1,200	$1,970	$1,070
Installed Cost ($/ton)	$6,000	$2,300	$1,800	$3,000	$2,200	$3,300	$2,000
O&M Costs (¢ / ton-hr)	0.6	0.2	0.1	0.3	0.1	0.3	0.1

***Note:** Costs are based on multiple sources, including vendor data and discussions with industry experts. The values shown are composite results, and are not intended to represent a specific product.*

energy that drives the seven absorption chillers shown in the table are: hot water temperature of 190 to 208°F (Systems 1 and 2, respectively), steam pressure of 14.5 psig (System 3, low pressure), steam pressure of 116 psig (Systems 4 and 5, high pressure), and exhaust gas temperature of 530 to 850°F (Systems 6 and 7, respectively).

Capital and O&M Costs

Table 3 shows estimated capital and maintenance costs for the same seven systems described in **Table 2**. Installed costs range from $1,800 to $6,000 per ton for the three single stage systems, and from $1,600 to $3,300 per ton for the four two stage chillers. Capital cost per ton of cooling capacity declines as chiller size increases, with costs being comparable for both single and two stage units. For example, the installed cost of a 1,320-ton single stage unit is $1,800/ton, and the cost for the same capacity two stage unit is $1,600/ton. Operation and maintenance (O&M) costs range from 0.1 to 0.6 cents per ton-hour (¢/ton-hr) for the three single stage chillers, and 0.1 to 0.3 ¢/ton-hr for the four two stage chillers. O&M costs do not include energy costs required for operation, but do include all maintenance requirements associated with an absorption chiller, including periodic purging of non-condensable gases, and monitoring cooling tower and chilled water quality.

Emissions

Absorption chiller emissions depend on the application. If the chiller is integrated with a CHP system and driven by thermal energy from the CHP system, there are no incremental emissions from the absorption chiller. If the absorption chiller is a stand-alone unit that is direct fired, emissions will depend on the fuel used to produce thermal energy to drive the system and the specific combustion technology used for direct firing. Natural gas, which is relatively low cost and clean burning, is a common fuel used for direct firing. For direct firing, absorption chillers can use low NOx burner technologies and other emission control measures to comply with local air quality requirements as needed. ■

U.S. DEPARTMENT OF ENERGY
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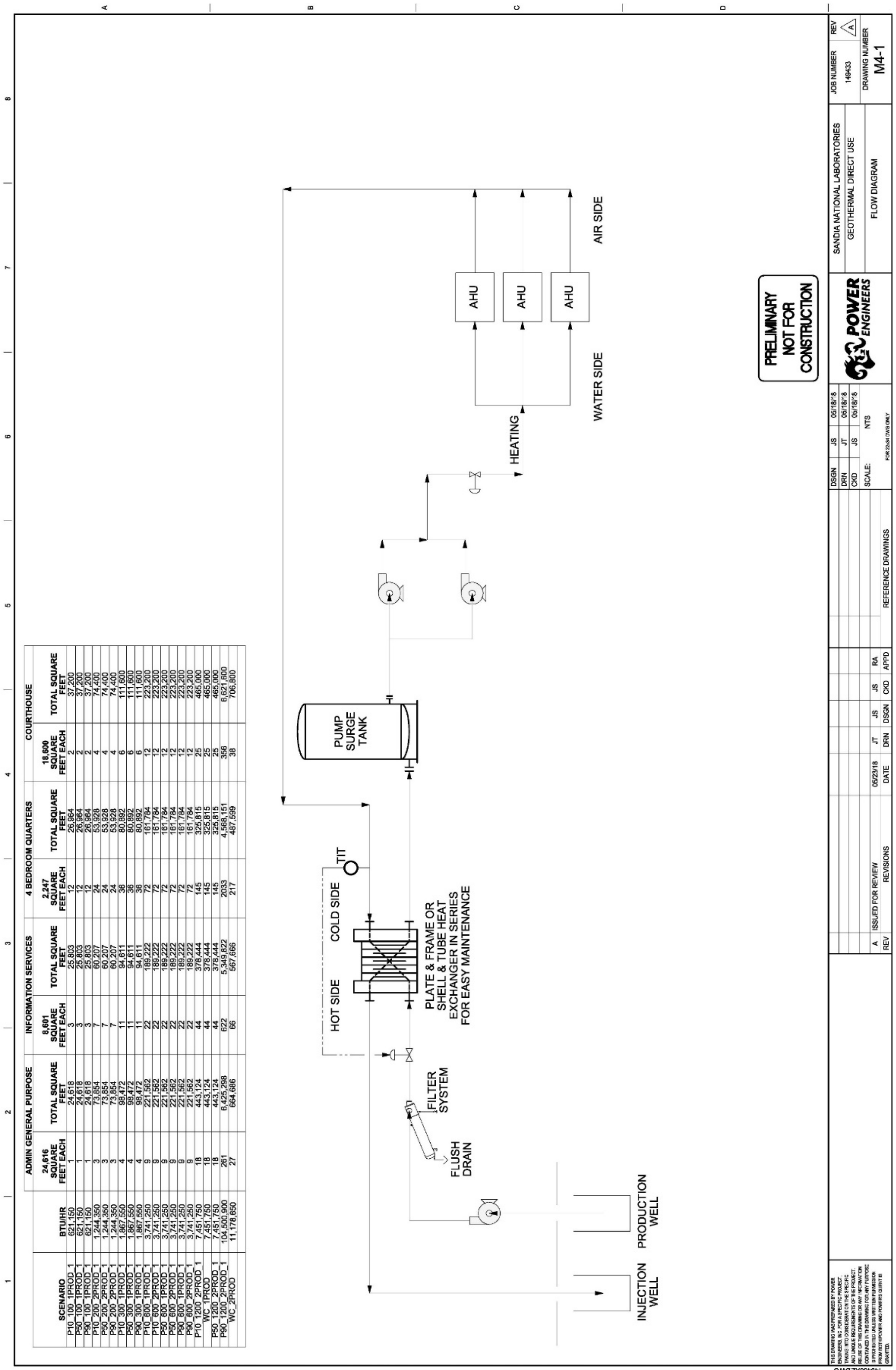
APPENDIX 3. BLOCK FLOW DIAGRAM OF DEMAND SIDE WITH SCENARIOS



		ADMIN GENERAL PURPOSE		INFORMATION SERVICES		4 BEDROOM QUARTERS		COURTHOUSE	
SCENARIO	BTU/HR	24,616 SQUARE FEET EACH	TOTAL SQUARE FEET	8,601 SQUARE FEET EACH	TOTAL SQUARE FEET	2,247 SQUARE FEET EACH	TOTAL SQUARE FEET	18,600 SQUARE FEET EACH	TOTAL SQUARE FEET
P10_100_1PROD_1	621,150	1	24,618	3	25,803	12	26,964	2	37,200
P50_100_1PROD_1	621,150	1	24,618	3	25,803	12	26,964	2	37,200
P90_100_1PROD_1	621,150	1	24,618	3	25,803	12	26,964	2	37,200
P10_200_2PROD_1	1,244,350	3	73,854	7	60,207	24	53,928	4	74,400
P50_200_2PROD_1	1,244,350	3	73,854	7	60,207	24	53,928	4	74,400
P90_200_2PROD_1	1,244,350	3	73,854	7	60,207	24	53,928	4	74,400
P10_300_1PROD_1	1,867,550	4	98,472	11	94,611	36	80,892	6	111,600
P50_300_1PROD_1	1,867,550	4	98,472	11	94,611	36	80,892	6	111,600
P90_300_1PROD_1	1,867,550	4	98,472	11	94,611	36	80,892	6	111,600
P10_600_1PROD_1	3,741,250	9	221,562	22	189,222	72	161,784	12	223,200
P10_600_2PROD_1	3,741,250	9	221,562	22	189,222	72	161,784	12	223,200
P50_600_1PROD_1	3,741,250	9	221,562	22	189,222	72	161,784	12	223,200
P50_600_2PROD_1	3,741,250	9	221,562	22	189,222	72	161,784	12	223,200
P90_600_1PROD_1	3,741,250	9	221,562	22	189,222	72	161,784	12	223,200
P90_600_2PROD_1	3,741,250	9	221,562	22	189,222	72	161,784	12	223,200
P10_1200_2PROD_1	7,451,750	18	443,124	44	378,444	145	325,815	25	465,000
WC_1PROD	7,451,750	18	443,124	44	378,444	145	325,815	25	465,000
P50_1200_2PROD_1	7,451,750	18	443,124	44	378,444	145	325,815	25	465,000
P90_1200_2PROD_1	104,500,900	261	6,425,298	622	5,349,822	2033	4,568,151	356	6,621,600
WC_2PROD	11,178,650	27	664,686	66	567,666	217	487,599	38	706,800

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APPENDIX 4. ROUGH ORDER OF MAGNITUDE BUDGET FOR THE DEMAND SIDE DISTRICT HEATING SYSTEM

Cost escalation 2012 to 2018

1- Labor escalation based on RS Means Labor Rates for the Construction Industry, Skilled Trade Average for Nevada.
2- Equipment pricing escalated using the POWER Engineers Equipment Pricing Database.
3- Material pricing escalation based on the Bureau of Labor Statistics Producer Price Indices, RS Means Construction Cost Data and Richardson Cost Data Online.

Geothermal Direct Use Installation project cost summary

Account	MH	Labor Costs		Material Costs		Total Costs	
Equipment	117	$	8,481	$	2,265,831	$	2,274,312
Piping	27280	$	930,736	$	1,165,454	$	2,096,190
Civil	11683	$	192,000	$	825,633	$	1,017,633
Steel	6	$	347	$	604	$	951
Instruments	4699	$	259,197	$	199,780	$	458,977
Electrical	3853	$	119,786	$	82,765	$	202,551
Insulation	6728	$	347,034	$	204,040	$	551,074
Paint	42	$	1,295	$	1,197	$	2,492
Direct Totals	**54,408**	**$**	**1,858,876**	**$**	**4,745,303**	**$**	**6,604,179**
		Construction Equipment and Indirect Costs				**$**	**290,584**
Freight						$	528,334
Taxes and Permits						$	528,334
Engineering						$	330,209
Contract Fees (contractor)						$	412,761
Indirect / Non-Field Totals					Indirect / Non-Field Totals	**$**	**1,799,639**
Total Power Plant Cost (USD)						**$**	**8,694,402**

Geothermal Direct Use Installation project cost summary

Account	Category	Key Qty	Key Units	MH	Labor		Matl		Total	
(2) Equipment	(160) Pumps	4	ITEM(S)	117	$	8,481	$	2,251,200	$	2,259,681
(2) Equipment	(260) Heat Exchangers	2	ITEM(S)		$	-	$	14,631	$	14,631
(3) AG Pipe	(300) Piping - General			1,643	$	38,227	$	-	$	38,227
(3) AG Pipe	(310) Carbon Stl Pipe/Fittings			8,301	$	357,629	$	120,936	$	478,566
(3) AG Pipe	(310) Carbon Stl Pipe/Fittings	23,623	FEET		$	-	$	254,318	$	254,318
(3) AG Pipe	(360) Piping Specialties			5,233	$	218,653	$	161,807	$	380,460
(3) UG Pipe	(340) Lined Pipe/Fittings				$	-	$	1,049	$	1,049
(3) UG Pipe	(350) Non-Metal Pipe/Fittings			7,729	$	169,732	$	201,322	$	371,054
(3) UG Pipe	(350) Non-Metal Pipe/Fittings	16,500	FEET		$	-	$	357,117	$	357,117
(3) UG Pipe	(360) Piping Specialties			1,348	$	56,319	$	49,847	$	106,166
(3) UG Pipe	(370) Firewater, Buried Pipe			3,027	$	90,176	$	19,059	$	109,234
(4) Bldg - Arch	(470) Buildings			7,568	$	33,228	$	768,175	$	801,403
(4) Concrete	(440) Concrete			850	$	30,169	$	18,909	$	49,078
(4) Concrete	(440) Concrete	165	CY	356	$	17,453	$	-	$	17,453
(4) Concrete	(450) Rebar, Formwork, Etc.			2,909	$	111,150	$	38,549	$	149,699
(5) Steel	(530) Other Steel Items	0	TONS	5	$	326	$	604	$	930
(5) Steel	(590) Other Steelwork			0	$	21	$	-	$	21
(6) Instrumentation	(610) Field Instrumentation	164	EACH	2,216	$	162,590	$	136,892	$	299,482
(6) Instrumentation	(620) Panels, Panel Devices			381	$	8,574	$	16,500	$	25,074
(6) Instrumentation	(630) Instrument Runs			860	$	49,633	$	33,326	$	82,958
(6) Instrumentation	(640) Instr. Support & Encl.			1,069	$	29,129	$	13,063	$	42,191
(6) Instrumentation	(690) Other Instrument Work			173	$	9,271	$	-	$	9,271
(7) AG Electrical	(790) Other Electrical			3	$	82	$	-	$	82
(7) UG Electrical	(710) Wire, Cable, Etc.			487	$	13,974	$	18	$	13,992
(7) UG Electrical	(710) Wire, Cable, Etc.	54,060	FEET		$	-	$	11,232	$	11,232
(7) UG Electrical	(720) Conduit, Trays, Etc.			1,618	$	44,081	$	19,925	$	64,006
(7) UG Electrical	(760) Buried Cable			1,745	$	61,649	$	51,590	$	113,239
(8) Pipe Insulation	(810) Insulation			6,728	$	347,034	$	27,569	$	374,604
(8) Pipe Insulation	(810) Insulation	26,874	FEET		$	-	$	176,471	$	176,471
(9) Paint	(910) Painting	4,800	SF	34	$	1,072	$	1,197	$	2,269
(9) Paint	(920) Surface Preparation			8	$	223	$	-	$	223
Totals:				**54,408**	**$**	**1,858,876**	**$**	**4,745,303**	**$**	**6,604,179**

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APPENDIX 5. RECORD OF ENVIRONMENTAL CONSIDERATION FOR HAD WELL

RECORD OF ENVIRONMENTAL CONSIDERATION (REC)

PROJECT TITLE:

Perform shallow borings at various locations on the Hawthorne Army Depot (HWAD)

DESCRIPTION OF PROPOSED ACTION:

Project involves the boring of potentially 1 shallow boring to develop information necessary to define and delineate geothermal resources on the Hawthorne Army Depot. These boring will occur on previously disturbed areas which are primarily located next to developed roads. The borings will be less than 1600 feet deep.

ANTICIPATED DATE/OR DURATION OF PROPOSED ACTION:

Project will occur over approximately a one month period, beginning in (mid or end) September and concluding in October 2012.

Reason for using Record of Environmental Consideration:

The proposed action qualifies for Categorical Exclusion Title 32 Part 651 Appendix B Section II (d) (4): Studies, data collection, monitoring and information gathering that do not involve major surface disturbance. (REC required).

AN ENVIRONMENTAL BASELINE STUDY (EBS) IS:

__X__ Required for this action and is attached.

______ Not required for this action.

Name ________ Signature ________

8/29/12 (Date) ________ (Date)

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APPENDIX 6. ENVIRONMENTAL BASELINE CHECKLIST FOR HAD WELL

ENVIRONMENTAL CHECKLIST

(Sections 1-5 to be completed by the Proponent)
(Section 6 to be completed by the Installation Environmental Coordinator)

The PROPONENT is the organization/person that plans and implements the project, i.e., the agency/person that has the need to accomplish their specific assigned Army mission.

1. BACKGROUND

a. Name of Proponent: Navy Geothermal Program Office
b. Office Symbol:
c. Phone Number: xxx-xxx-xxxx
d. Name of Proposal: Perform shallow borings at various locations on the Hawthorne Army Depot (HWAD)
e. Site Ownership History and Use:
Current Owner: Army
Current Land Use: Military
Previous Owner(s): Navy
Previous Owner(s) Land Use: Military

2. DESCRIPTION:

a. Description (activity/construction/training/R&D/policy/etc):

Collection of geothermal data

b. Location of proposal:

Various locations on HWAD (see attached map).

c. Present land use of proposed area (if unknown, check master plan):
Industrial – previously distrubed

d. Check all that apply:

Residential _______	Industrial __X____	Mixed _______
Agricultural _______	Commercial ________	Other ________

e. Adjacent Property Use:
North:

South:

East:

West:

f. Topographic Relationship:

North: Higher: ______	Lower: ________	Same: ________
South: Higher: ______	Lower: ________	Same: ________
East: Higher: ______	Lower: ________	Same: ________
West: Higher: ______	Lower: ________	Same: ________

g. Attach a copy of the installation map showing footprint of the area under consideration.

3. ENVIRONMENTAL SETTING - (What are the baseline or current environmental conditions of the proposed area):

a. Air (Clean Air Act):

	Yes	Maybe	No	N/A
Is there any impact to the Installation Air Quality operating permit?			X	
Is the subject area currently in compliance?	X			
Is the subject area currently in compliance with the Asbestos Management Plan?	X			

b. Water (Clean Water Act):

	Yes	Maybe	No	N/A
Is the subject area currently in compliance with the NPDES Permits	X			
Is the subject area currently in compliance with the SPCCP (Spill Prevention Control& Countermeasure Plan)?	X			
Are there any existing permits?			X	
Are there surface waters in the vicinity?			X	
If so what are they?				
Is there any groundwater contamination?			X	

c. Water (Safe Drinking Water Act):

	Yes	Maybe	No	N/A
What is the water supply source (surface water, groundwater, aquifer, etc)?				X
Is water supply adequate in quantities necessary?				X
Does quality meet the needs?				X

d. Hazardous Substances/Wastes Generated:

	Yes	Maybe	No	N/A
Are hazardous substances currently being used at the proposed location?			X	
Is hazardous waste currently generated at the proposed area?			X	
Is there any known asbestos?			X	
Is there any known lead paint?			X	
Are there any known PCBs?			X	

e. Soil:

	Yes	Maybe	No	N/A
Is the subject area a SWMU (Solid Waste Management Unit) site?			X	
Is there any evidence of contaminated soil?			X	

	Yes	Maybe	No	N/A
Is there any UXO (unexploded ordnance) present			X	
Is the subject area on an active or inactive firing range?			X	
Has a review of the depot's SWMU's Master Plan Map been performed for land use restrictions?	X			
Has a review of existing environmental documents been performed (decision documents, initial investigations, ground water monitoring reports			X	
What were the findings?				
Has the proposed site been overlaid with existing SWMU survey data?	X			
Are there above or below ground storage tanks on the site?			X	
Are there unusual conditions at this site (i.e., odors, stained soil, pits, debris piles or signs of historical operations)?			X	

f. **Describe the utilities usage:**

N/A

g. **Describe the economic conditions:**

N/A

h. **Describe the environmental justice issues (what is the quality of life and conditions immediately bordering the installation):**

N/A

i. **Describe transportation flow:**

N/A

4. **ENVIRONMENTAL IMPACT ANALYSIS: (Select most correct answer to the question. Explanations and/or mitigation of all "yes" and "maybe" answers are required in paragraph 5).**

a. **Air - Will the proposal result in:**

	Yes	Maybe	No	N/A
Creation of objectionable odors?			X	
Introduction of smoke, dust, suspended particles, or noxious gas into the air?			X	
Particulate or dust migration beyond installation boundaries?			X	
Disturbance of more than five acres of soil?			X	

b. **Traffic - Will the proposal result in:**

	Yes	Maybe	No	N/A
Generation of new activity or increase in aircraft traffic associated with training?				X

Generation of new activity or an increase in vehicular movement?			X	
Unimproved road usage?			X	
Development of new roads?			X	

c. Noise - Will the proposal result in:

	Yes	Maybe	No	N/A
The Installation Compatible Use Zones (ICUZ) Plan to be out of compliance?			X	
Increased noise levels?			X	
Noise that might affect the population outside the facility boundaries?			X	

If so, provide distance to nearest noise sensitive land use (i.e., residence, hospital, church, etc.):

Aircraft operations?				

If so, specify the minimum altitudes and flight times for aircraft operations to ensure noise impacts are minimized:

Additional night (2200-0700 hours) operations (i.e., firing, aircraft flights, vehicular traffic)?				X

d. Earth - Will the proposal result in:

	Yes	Maybe	No	N/A
Long-term disruptions, displacements, compaction or over &/or covering of the soil?			X	
Permanent change in topography or ground surface relief features?			X	
Long-term increase in wind or water erosion, either on or off the site?			X	

e. Natural Resources - Will the proposal result in:

	Yes	Maybe	No	N/A
Change in the diversity of species or numbers of any species of plants including trees, shrubs, grass, crops, micro-flora or aquatic plants?			X	
Reduction of the numbers of any threatened, unique, rare, or endangered species of plants?			X	
Reduction or disturbance of the numbers of any unique, rare, or endangered species of animals?			X	
Changes in the diversity of species or numbers of any species of mammals, birds, reptiles, amphibians, or fish?			X	
Introduction of new species of animals into an area, or result in a barrier to the migration or movement of animals?			X	
Deterioration, alteration, or destruction to existing fish or wildlife habitat?			X	

	Yes	Maybe	No	N/A
Increase in the rate of use of any natural resource?			X	
Depletion of any non-renewable natural resource?			X	
Alteration, destruction, or significant impact on environmentally sensitive areas (i.e. wetland, floodplain, critical habitat, prime farm land, coastal zones, etc)?			X	

f. **Land Use - Will the proposal result in:**

	Yes	Maybe	No	N/A
Alteration of the present land use or area?			X	
The proposed activity taking place on withdrawn land?	X			
The proposed activity taking place on Federal or DoD owned land?	X			
The proposed activity taking place on privately owned land?			X	
If another type of owned land please specify:				
The proposed activity needing real estate action?			X	
Requiring an increase of acreage/amendment to an existing lease, license land use permit?			X	
Requiring new purchase of acres with federal or other funds			X	
Requiring new lease, license, land easement?			X	
Demolition, disposal, or replacement of existing facilities?			X	
Pesticides usage?			X	

g. **Hazardous Risk/Waste Disposal - Will the proposal result in:**

	Yes	Maybe	No	N/A
Generation of hazardous waste?			X	
Treatment, storage, and/or disposal of hazardous waste?			X	
Will a RCRA permitted facility be used?			X	
A risk of an explosion or the release of hazardous substances including, but not limited to oil, pesticides, chemicals or radiation?			X	
A need for procedures to be specified for the proper handling, storage, use, and disposal of hazardous and toxic materials?			X	
A need for trained personnel to be available for handling and disposal of hazardous and/or toxic materials?			X	
Generation of solid wastes which must be disposed of onsite or offsite by a contractor?			X	

Will work be performed at a RCRA closure site or at a permitted storage or

	Yes	Maybe	No	N/A
treatment site?			X	

h. Solid Wastes:

	Yes	Maybe	No	N/A
Will the project require use of a landfill (DZHC/Mineral County)?			X	
Will solid waste be contracted out?			X	
Will any material be recycled?			X	
Will a new landfill be required?			X	

i. Water - Will the proposal result in:

	Yes	Maybe	No	N/A
Any water withdrawal permits?			X	
Changes in currents, or the course or direction of water movements, in either marine or fresh waters? (i.e., paving of land areas, site clearing near water)?			X	
Discharge (i.e., liquid or solid waste) into surface waters, or in any alteration of surface water quality?			X	
Change in the quantity &/or quality of ground waters, either through direct additions or withdrawals, or through interception of an aquifer by cuts or excavations?			X	
Reduction in the amount of water otherwise available for public water supplies?			X	
Potential for accidental spills of hazardous or toxic material near or in a body of water?			X	
Need for spill prevention and contingency measures to be modified (SPCC &/or ISCP)?			X	
Construction of facilities or implementation of actions within flood-plains &/or wetlands?			X	
Require a Wetland Permit?			X	

j. Archeological/Historical – Will the proposal result in:

	Yes	Maybe	No	N/A
An alteration or destruction of an archeological or historical site, structure, object or building on or eligible for inclusion in the National Register of Historic Places?			X	

k. Population - Will the proposal result in:

	Yes	Maybe	No	N/A
Alteration of the location, distribution, density, or growth of an area?			X	

l. Utilities – Will the proposal result in:

	Yes	Maybe	No	N/A
A need for new systems, or alteration to the power, fossil fuel, or other kind of fuel?			X	
If other, please specify:				
A need for new systems, or alteration to drinking water?			X	

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A need for a utility clearance?	X			
A need for new systems or alteration to wastewater treatment?			X	
A need for new systems, or alteration to sewer collection system?			X	

m. Human Health - Will the proposal result in:

	Yes	Maybe	No	N/A
Creation of any health hazard or potential health hazard, excluding mental health?			X	

n. Natural Resources/Endangered Species:

	Yes	Maybe	No	N/A
Has a federally listed endangered/threatened species survey been performed?	X			
Has a Rare Plant Survey performed?	X			
Has the land management program been reviewed?	X			
Has the Fish and Wildlife Division been consulted?			X	
Was the INRMP (Integrated Natural Resources Plan) reviewed?	X			

o. Historical/Cultural Resources:

	Yes	Maybe	No	N/A
Is reviewing the SHPPO (State Historic Preservation Office) required			X	
Was the Cultural Resource Management Plan reviewed?	X			

p. Will Mineral County be involved in the project?

	Yes	Maybe	No	N/A
			X	

If so, describe:

q. Mandatory Findings of Significance (if the answer is Yes then an EA or EIS will be required):

	Yes	Maybe	No	N/A
Does the project have the potential to degrade the quality of the environment, or curtail the diversity in the environment			X	
Does the project have the potential for cumulative impacts on environmental quality when effects are combined with those of other actions or when the action is of lengthy duration (i.e. multiple construction, training exercises, mission expansion)?			X	
Does the project have environmental affects which will cause substantial adverse effects on humans either directly or indirectly (i.e. environmental justice)?			X	

5. DISCUSSION OF ENVIRONMENTAL ANALYSIS OF POTENTIAL IMPACTS TO INCLUDE MITIGATION: (all "Yes" and "Maybe" answers in Paragraph 4 above need to be explained here):

6. DETERMINATION: (To be completed by the installation Environmental Coordinator or their representative)

Subpart D—Categorical Exclusions

§ 651.28 Introduction.

Categorical Exclusions (CXs) are categories of actions with no individual or cumulative effect on the human or natural environment, and for which neither an EA nor an EIS is required. The use of a CX is intended to reduce paperwork and eliminate delays in the initiation and completion of proposed actions that have no significant impact.

§ 651.29 Determining when to use a CX (screening criteria).

(a) To use a CX, the proponent must satisfy the following three screening conditions:

	Yes	Maybe	No	N/A
(1) Will the action has not been segmented? Determine that the action has not been segmented to meet the definition of a CX. Segmentation can occur when an action is broken down into small parts in order to avoid the appearance of significance of the total action. An action can be too narrowly defined, minimizing potential impacts in an effort to avoid a higher level of NEPA documentation. The scope of an action must include the consideration of connected, cumulative, and similar actions (see §651.51(a))			X	
(2) Will there be exceptional circumstances exist? Determine if the action involves extraordinary circumstances that would preclude the use of a CX (see paragraphs (b) (1) through (14) of this section).			X	
(3) One (or more) CX encompasses the proposed action. Identify a CX (or multiple CXs) that potentially encompasses the proposed action (Appendix B of this part). If no CX is appropriate, and the project is not exempted by statute or emergency provisions, an EA or an EIS must be prepared, before a proposed action may proceed. Will an EA or EIS need to be prepared?			X	

(b) Extraordinary circumstances that preclude the use of a CX are:

	Yes	Maybe	No	N/A
(1) Will there be reasonable likelihood of significant effects on public health, safety, or the environment?			X	
(2) Will there be reasonable likelihood of significant environmental effects (direct, indirect, and cumulative)?			X	
(3) Will there be imposition of uncertain or unique environmental risks?			X	
(4) Will there be a greater scope or size than is normal for this category of action?			X	
(5) Will there be reportable releases of hazardous or toxic substances as specified in 40 CFR part 302, Designation, Reportable Quantities, and Notification?			X	
(6) Will there be releases of petroleum, oils, and lubricants (POL) except from a properly functioning engine or vehicle, application of pesticides and herbicides, or where the proposed action results in the requirement to develop or amend a Spill Prevention, Control, or Countermeasures Plan?			X	
(7) When a review of an action that might otherwise qualify for a Record of Non-applicability (RONA) reveals that air emissions exceed de minimis levels or otherwise that a formal Clean Air Act conformity determination is required be				

		Yes	Maybe	No	N/A
	needed?			X	
(8)	Will there be a reasonable likelihood of violating any federal, state, or local law or will requirements be imposed for the protection of the environment?			X	
(9)	Will there be any unresolved effect on environmentally sensitive resources, as defined in paragraph (c) of this section?			X	
(10)	Will the proposed involve effects on the quality of the environment that are likely to be highly controversial?			X	
(11)	Will the proposed involve effects on the environment that are highly uncertain, involve unique or unknown risks, or are scientifically controversial?			X	
(12)	Will the proposed establish a precedent (or makes decisions in principle) for future or subsequent actions that are reasonably likely to have a future significant effect?			X	
(13)	Will there be a potential for degradation of already existing poor environmental conditions. Also, will there be an initiation of a degrading influence, activity, or effect in areas not already significantly modified from their natural condition?			X	
(14)	Will the proposed introduce /employ unproven technology?			X	

(c) If a proposed action would adversely affect "environmentally sensitive" resources, unless the impact has been resolved through another environmental process (e.g., CZMA, NHPA, CWA, etc.) a CX cannot be used (see paragraph (e) of this section). Environmentally sensitive resources include:

		Yes	Maybe	No	N/A
(1)	Will the proposed affect federally listed, threatened, or endangered species or their designated critical habitats?			X	
(2)	Will there be properties listed or eligible for listing on the National Register of Historic Places (AR 200–4)?			X	
(3)	Are there areas having special designation or recognition such as prime or unique agricultural lands; coastal zones; designated wilderness or wilderness study areas; wild & scenic rivers; National Historic Landmarks (designated by the Secretary of the Interior); 100-year floodplains; wetlands; sole source aquifers (potential sources of drinking water); National Wildlife Refuges; National Parks; areas of critical environmental concern; or other areas of high environmental sensitivity?			X	
(4)	Will Cultural Resources as defined in AR 200–4 be affected?			X	

(d) The use of a CX does not relieve the proponent from compliance with other statutes, such as RCRA, or consultations under the Endangered Species Act or the NHPA. Such consultations may be required to determine the applicability of the CX screening criteria.

(e) For those CXs that require a REC, a brief (one to two sentence) presentation of conclusions reached during screening is required in the REC. This determination can be made using current information and expertise, if available and adequate, or can be derived through conversation, as long as the basis for the determination is included in the REC. Copies of appropriate interagency correspondence can be attached to the REC. Example conclusions regarding screening criteria are as follows:

(1) "USFWS concurred in informal coordination that E/T species will not be affected".

(2) "Corps of Engineers determined action is covered by nationwide general permit".

(3) "SHPO concurred with action".

(4) "State Department of Natural Resources concurred that no effect to state sensitive species is expected".

§ 651.30 CX actions.

Types of actions that normally qualify for CX are listed in Appendix B.

§ 651.31 Modification of the CX list.

The Army list of CXs is subject to continual review and modification, in consultation with CEQ. Additional modifications can be implemented through submission, through channels, to ASA (I&E) for consideration and consultation. Subordinate Army headquarters may not modify the CX list through supplements to this part. Upon approval, proposed modifications to the list of CXs will be published in the Federal Register, providing an opportunity for public review and comment

Appendix B to Part 651 – Categorical Exclusions
Screening must be met before choosing the following CX

b. Administration / Operation Activities:

	Yes	Maybe	No	N/A
1. Routine law and order activities performed by military / military police and physical plant protection and security personnel, and civilian natural resources and environmental law officers?				X
2. Emergency or disaster assistance provided to federal, state, or local entities? (REC required)				X
3. Preparation of regulations, procedures, manuals, and other guidance documents that implement, without substantive change, the applicable HQDA or other federal agency regulation, procedures, manuals, and other guidance documents that have been environmentally evaluated? (Subject to previous NEPA review)				X
4. Proposed activities & operations to be conducted in an existing non-historic structure which are within the scope and compatibility of the present functional use of the building, will not result in substantial increase in waste discharged to the environment, will not result in substantially different waste discharges from current or previous activities, and emission will remain within established permit limits, if any? (REC required)				X
5. Normal personnel, fiscal, and administrative activities involving military and civilian personnel (recruiting, processing, paying, and records keeping)?				X
6. Routinely conducted recreation and welfare activities not involving off-road recreational vehicles?				X

7. Deployment of military units on a temporary duty (TDY) or training basis where existing facilities are used for their intended purposes consistent with the scope

and size of existing mission? ___ _____ ___ _X_

8. Preparation of administrative or personnel-related studies, reports, or investigations? ___ _____ ___ _X_

9. Approval of asbestos or lead-based paint management plans drafted in Accordance with applicable laws and regulations? (REC required) ___ _____ ___ _X_

10. Non-construction activities in support of other agencies / organization involving community participation projects and law enforcement activities? ___ _____ ___ _X_

11. Ceremonies, funerals, and concerts. This includes events such as state funerals, to include flyovers? ___ _____ ___ _X_

12. Reduction and realignments of civilian and / or military personnel that: fall Below the thresholds for reportable action as prescribed by statute (10 U.S.C. 2687) and do not involve related activities such as construction, renovation, or demolition activities that would otherwise require an EA or an EIS to implement (REC required). This includes reorganizations and reorganizations and reassignments with no changes in force structure, unit re-designations, and routine administrative reorganizations and consolidations (REC required)? ___ _____ ___ _X_

13. Actions affecting Army property that fall under another federal agency's list of categorical exclusions when the other federal agency is the lead agency (decision maker), or joint actions on another federal agency's property that fall under that agency's list of categorical exclusions (REC required)? ___ _____ ___ _X_

14. Relocation of personnel into the existing federally-owned (or state-owned in the case of ARNG) or commercially-leased space, which does not involve a substantial change in the supporting infrastructure (for example, an increase in vehicular traffic beyond the capacity for the supporting road network to accommodate such an increase is an example of substantial change) (REC required)? ___ _____ ___ _X_

c Construction and demolition:

Yes Maybe No N/A

1. Construction of an addition to an existing structure or new construction on a previously undisturbed site if the area to be disturbed has no more than 5.0 cumulative acres of new surface disturbance. This does not include construction of facilities for the transportation, distribution, use storage, treatment, and disposal or solid waste, medical waste, and hazardous waste (REC required)? ___ _____ ___ _X_

2. Demolition of non-historic buildings, structures, or other improvements and disposal of debris therefrom, or removal of a part thereof for disposal, in accordance with applicable regulations, including those regulations applying to removal of asbestos, polychlorinated biphyenyls (PCBs), lead-based paint, and other special hazard items (REC required)? ___ _____ ___ _X_

3. Road or trail construction and repair on existing rights-of-ways or on previously disturbed areas? ___ _____ ___ _X_

d. Cultural and Natural Resources Management Activities:

Yes Maybe No N/A

1. Land regeneration activities using only native trees and vegetation, including site preparation. This does not include forestry operations (REC required)? ___ _____ ___ _X_

	Yes	Maybe	No	N/A
2. Routine maintenance of streams and ditches or other rainwater conveyance structures (in accordance with USACE permit authority under Section 404 of the Clean Water Act and applicable state and local permits), and erosion control and stormwater control structures (REC required)?				X
3. Implementation of hunting and fishing policies or regulations that are consistent with state and local regulations?				X
4. Studies, data collection, monitoring and information gathering that do not involve major surface disturbance. Examples include topographic surveys, bird counts, wetland mapping, and other resources inventories (REC required)?	X			
5. Maintenance of archaeological, historical, and endangered / threatened species avoidance markers, fencing, and signs?				X

e. Procurement and Contract Activities:

	Yes	Maybe	No	N/A
1. Routine procurement of good and services (complying with applicable procedures for sustainable or "green" procurement) to support operations and infrastructure, including routine utility services and contracts?				X
2. Acquisition, installation, & operation of utility & communication systems, mobile antennas, data processing cable & similar electronic equipment that use existing right-of-way, easement, distribution systems, and / or facilities (REC required)?				X
3. Conversion of commercial activities under the provisions of AR 5-20. This includes only those action that do not change the actions or the missions of the organization or alter the existing land-use patterns?				X
4. Modification, product improvement, or configuration engineering design change to materiel, structure, or item that does not change the original impact of the materiel, structure, or item on the environment (REC required)?				X
5. Procurement, testing, use, and / or conversion of a commercially available product (for example, forklift, generator, chain saw, etc.) which does not meet the definition of a weapon system (Title 10, U.S.C., Section 2403. "Major weapon systems: Contractor guarantees"), and does not result in any unusual disposal requirements?				X
6. Acquisition or contracting for spares and spare parts, consistent with the approved Technical Data Package (TDP)?				X
7. Modification and adaptation of commercially available items and products for military application (for example, sportsman's products and wear such as holsters, shotguns, sidearems, protective shields, etc.), as long as modifications do not alter the normal impact to the environment (REC required)?				X
8. Adaptation of non-lethal munitions & restraints from law enforcement suppliers & industry (such as rubber bullets, stun grenades, smoke bombs, etc.) for military police & crowd control activities where there is no change from the original product design and there are no unusual disposal requirements. The development & use by the military of non-lethal munitions and restraints which are similar to those used by local police forces & in which there are no unusual disposal requirements (REC required)?				X

f. Real Estate Activities:

	Yes	Maybe	No	N/A
1. Grants or acquisitions of leases, licenses, easements, and permits for use of real property or facilities in which there is no significant change in land or facility use. Examples include, but are not limited to, Army controlled property & Army leases of civilian property to include leases of training, administrative, general use, special purpose, or warehouse space (REC required)?				X
2. Disposal of excess easement areas to the underlying fee owner (REC required)?				X
3. Transfer of real property administrative control within the Army, to another military department, or to other federal agency, including the return of public domain lands to the Department of Interior, and reporting of property as excess and surplus to the GSA for disposal (REC required)?				X
4. Transfer of active installation utilities to a commercial or governmental utility provider, except for those systems on property that has been declared excess & proposed for disposal (REC required)?				X
5. Acquisition of real property (including facilities) where the land use will not change substantially or where the land acquired will not exceed 40 acres and the use will be similar to current or ongoing Army activities or adjacent land (REC required)?				X
6. Disposal of real property (including facilities) by the Army where the reasonably foreseeable use will not change significantly (REC required)?				X

g. Repair and Maintenance Activities:

	Yes	Maybe	No	N/A
1. Routine repair and maintenance of buildings, airfields, grounds, equipment, & other facilities. Examples include, but are not limited to: Removal and disposal of asbestos-containing material (for example, roof material and floor tile) or lead-based paint in accordance with applicable regulations; removal of dead, diseased, or damaged trees; and repair of roofs, doors, windows, or fixtures (REC required for removal & disposal of asbestos-containing material & lead-based paint or work on historic structures)?				X
2. Routine repairs & maintenance of roads, trails, & firebreaks. Examples include, but are not limited to: grading & clearing the roadside of brush with or without the use of herbicides; resurfacing a road to its original conditions; pruning vegetation, removal of dead, diseased, or damaged trees & cleaning culverts; and minor soil stabilization activities?				X
3. Routine repair & maintenance of equipment & vehicles (for example, autos, tractors, lawn equipment, military vehicles, etc.) which is substantially the same as that routinely performed by private sector owners & operators of similar equipment & vehicles. This does not include depot maintenance of unique military equipment?				X

h. Hazardous Materials / Hazardous Waste

	Yes	Maybe	No	N/A
1. Use of gauging devices, analytical instruments, & other devices containing sealed radiological sources; use of industrial radiograph; use of radioactive material in medical & veterinary practices; possession of radioactive material incident to performing services such as installation, maintenance, leak tests, &				

calibration; use of uranium as shie3lding material in containers or devices; & radioactive tracers (REC required)? ___ _____ ___ _X_

2. Immediate responses in accordance with emergency response plans (for example, Spill Prevention Control & Countermeasure Plan (SPCCP) / Installation Spill Contingency Plan (ISCP), and Chemical Accident & Incident Response Plan) for release or discharge of oil or hazardous materials / substances; or emergency actions taken by Explosive Ordnance Demolition (EOD) detachment or technical Escort Unit? ___ _____ ___ _X_

3. Sampling, surveying, well drilling & installation, analytical testing, site preparation, & intrusive testing to determine if hazardous wastes, contaminants, pollutants, or special hazards (for example, asbestos, PCBs, lead-based paint, or unexploded ordnance) are present (REC required)? ___ _____ ___ _X_

4. Routine management, to include transportation, distribution, use, storage, treatment, & disposal of solid waste, medical waste, radiological & special hazards (for example, asbestos, PCBs, lead-based paint, or unexploded ordnance), & / or hazardous waste that complies with EPA, Army, or other regulatory agency requirements. This CX is not applicable to new construction of facilities for such management purposes? ___ _____ ___ _X_

5. Research, testing, & operations conducted at existing enclosed facilities consistent with previously established safety levels & in compliance with applicable federal, state, & local standards. For facilities without existing NEPA analysis, including contractor-operated facilities, if the operation will substantially increase the extent of potential environmental impacts or is controversial, and EA (& possibly an EIS) is required? ___ _____ ___ _X_

6. Reutilization, marketing, distribution, donation, & resale of items, equipment, or materiel; normal transfer of items to the Defense Logistics Agency. Items, equipment, or materiel that have been contaminated with hazardous materials or wastes will be adequately cleaned & will conform to the applicable regulatory agency's requirements? ___ _____ ___ _X_

i. Training & Testing

	Yes	Maybe	No	N/A
1. Simulated war games (classroom setting) & on-post tactical & logistical exercises involving units of battalion size or smaller, & where tracked vehicles will not be used (REC required to demonstrate coordination with installation range control & environmental office)?	___	_____	___	_X_
2. Training entirely of an administrative or classroom nature?	___	_____	___	_X_
2. Intermittent on-post training activities (or off-post training covered by an ARNG land use agreement) that involve no live fire or vehicles off established roads or trails. Uses include, but are not limited to, land navigation, physical training. Federal Aviation Administration (FAA) approved aerial over flights, & small unit level training?	___	_____	___	_X_

j. Aircraft & Airfield Activities

	Yes	Maybe	No	N/A
1. Infrequent, temporary (less than 30 days) increases in air operations up to 50% of the typical installation aircraft operation rate (REC required)?	___	_____	___	_X_

2. Flying activities in compliance with Federal Aviation Administration Regulations & in accordance with normal flight patterns & elevations for that facility, where the flight patterns / elevations have been addressed in an installation mater plan or other planning document that has been subject to NEPA public review? ___ _____ ___ _X_

3. Installation, repair, or upgrade of airfield equipment (for example, runway visual range equipment, visual approach slope indicators)? ___ _____ ___ _X_

4. Army participation in established air shows sponsored or conducted by non-Army entities on other than Army property? ___ _____ ___ _X_

Signature: ____ 8/29/12
Person Who Prepared This Document Date

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APPENDIX 7. EXAMPLE DISCHARGE PERMIT

STATE OF NEVADA

Department of Conservation & Natural Resources

DIVISION OF ENVIRONMENTAL PROTECTION

NEVADA DIVISION OF ENVIRONMENTAL PROTECTION
protecting the future for generations

Brian Sandoval, Governor

Leo M. Drozdoff, P.E., Director

Colleen Cripps, Ph.D., Administrator

September 25, 2012

Ms. Kelly Blake
Navy Geothermal Office
429 E. Bowen Road Stop 4011
China Lake, CA 93555

Subject: Temporary Permit TNEV2013344 –Hawthorne Army Depot –Well 76-19 flow test

Dear Ms. Blake:

Enclosed please find a copy of the temporary permit for the above-cited project. The permit will be in effect from September 26, 2012 through March 25, 2012. The temporary permit authorizes the discharge of groundwater, from the testing of a geothermal well, located in the Hawthorne Army Depot, directed to a nearby bermed basin, for evaporation and infiltration, as described in the application and supplemental information, and any significant changes would require a new permit.

The permit requires monthly discharge monitoring reports, due on the 28th day of each month for the life of the permit; the first DMR is due **October 28, 2012**. The permit also requires a final narrative report with documentary photos and final DMR, due **April 28, 2013**, or by the 28th day of the month following project completion, whichever comes first.

Please give me a call at 775-687-9502 if you have any questions.

Sincerely,

Jason Ferrin

Jason M. Ferrin, E.I.
Bureau of Water Pollution Control

Enclosures: Temporary Permit TNEV2013344
Discharge Monitoring Report (DMR) Form

cc: Compliance Coordinator, BWPC (hand-delivered)

ecc: Andy Tiedeman, US Navy Geothermal Program Office, Fallon, NV.

901 S. Stewart Street, Suite 4001 • Carson City, Nevada 89701-5249 • p: 775.687.4670 • f: 775.687.5856 • ndep.nv.gov

TNEV2013344

NEVADA DIVISION OF ENVIRONMENTAL PROTECTION

TEMPORARY
<u>AUTHORIZATION TO DISCHARGE</u>

In compliance with the provisions Chapter 445A of the Nevada Revised Statutes (NRS), the Permittee,

Navy Geothermal Program Office
429 E. Bowen Road, Stop 4011
China Lake, CA 93555

is authorized to discharge groundwater extracted for flow testing of a geothermal well for potential geothermal production evaluation at:

Well 76-19
Hawthorne Army Depot
128 N. Maine Ave.
Mineral County, NV 89415
Section 19, T8N R30E MDB&M
Latitude: 38.534083° N Longitude: 118.670400° W

to:

groundwaters of the State via percolation from discharge to nearby settling basin

in accordance with the discharge limitations, monitoring requirements, and other conditions set forth in Parts I, II, and III hereof.

This permit shall become effective on **<u>September 26, 2012</u>**.

This permit shall expire at midnight **<u>March 25, 2012.</u>**

Signed this <u>25th day of September, 2012</u>.

Jason Ferrin

Jason M. Ferrin, E.I.
Bureau of Water Pollution Control

PART I

I.A. DISCHARGE LIMITATIONS, MONITORING, AND CONDITIONS

Introduction: The Permittee, Navy Geothermal Program Office (GPO), is proposing to flow test an approximately 1500' deep geothermal well, Well 76-19, on the Hawthorne Army Depot, approximately 2.5 miles northwest of Hawthorne, Mineral County, Nevada. The purpose of the well is to evaluate the potential for development of geothermal power resources. The well will be flow tested for up to 8 hours. The purpose of the test is to clean out the well bore of any drilling mud and conduct tests to measure temperature, flow rate and water chemistry.

The flat ground conditions at the well site preclude the construction of a retention basin, so the discharge will be directed to an existing drainage, and hence to a nearby bermed basin for cooling and energy dissipation. From there the basin will allow the water to evaporate and infiltrate into the ground. Appropriate Best Management Practices shall be employed.

I.A.1. **Discharge Limitations:** During the period beginning on the effective date of this permit and lasting until the permit expires, the Permittee is authorized to discharge to groundwaters of the State geothermal water from the well flow test located at the Hawthorne Army Depot, in Mineral County. There shall be no discharge to surface waters. Water from the well flow test shall be routed and handled to prevent sediment transport and soil erosion in accordance with the plans and information submitted to the NDEP.

The discharge shall be limited and monitored by the Permittee as specified below:

Table I.A.1. Discharge Limitations and Sampling and Monitoring Requirements

Discharge Parameters & Units		Discharge Limits	Sampling Locations	Monitoring Frequency	Monitoring Type
Flow Rate [1]	gpm	190	001	Continuous	Flow meter
Total Volume [1]	MG	0.0912	001	Continuous	Calculation
Profile I [2]	mg/l	M&R	001	Daily	Discrete
Temperature [3]	°F	M&R	001, 002	Daily	Discrete

001 = Outfall 001: discharge outlet from Well 76-19, prior to discharge to drainage feature and basin.
002 = Outfall 002: bermed settling basin.
gpm = gallons per minute MG = million gallons
mg/l = milligrams per liter M&R = Monitor and Report

1. Monitor daily the discharge rate from the well flow test; report the maximum daily rate, and report the total cumulative discharge volume at the end of the well flow test on the monthly DMR form.
2. Sample and analyze for all Profile I parameters daily (1 time during 8-hour flow test), and report on applicable monthly DMR form.
3. Measure and record temperature values from the well at Outfall 001, and at Outfall 002, after cooling in the settling basin.

I.A.2. **Monitoring Requirements:** The project monitoring shall be conducted by means of Monthly Discharge Monitoring Reports (DMR), to be received by NDEP by the 28th of each month; the first DMR is due **October 28, 2012**. The final DMR, and a narrative report describing the pump test and discharges, are due by the 28th day of the month following expiration of the permit or conclusion of the project whichever is less. Analytical results shall be reported on DMRs, and copies of the lab reports, QA/QC procedures and chain of custody forms shall accompany the DMR forms.

I.A.3. **Documentation:** Documentation must be submitted as specified in Part I.A.2.

I.A.4. **Monthly DMRs and Final Report:** The monthly discharge monitoring reports (DMRs) shall be submitted by the 28^{th} day of the month following project inception, and continue to be submitted each month through project conclusion. The final DMR and narrative report describing the results of the discharge activities shall be submitted to the address below, by the 28^{th} day of the month following project completion, or permit expiration, whichever comes first, at latest by **April 28, 2013**:

Nevada Division of Environmental Protection
Bureau of Water Pollution Control
901 S. Stewart St., Ste. 4001
Carson City, Nevada 89701-5249

I.A.5. **Water Quality Standards:** There shall be no discharge of substances that would cause a violation of water quality standards of the State of Nevada.

I.A.6. **Sediment Discharge:** There shall be no discharge of sediment in other than trace amounts.

I.A.7. **Safety & Security:** If the discharge is allowed to pond for evaporation and infiltration, access to that area shall be controlled to prevent human contact, erosive activities, and sediment transport.

I.A.8. **Odors:** There shall be no objectionable odors generated in the conduct of this project.

I.A.9. **Authorized Project Activities:** There shall be no water management or rolling stock activities undertaken except those as authorized by this permit.

I.A.10. **Plan Approval:** The project elements/components/activities shall be constructed and or conducted in accordance with the plans submitted to and approved by the Division. The plans must be approved by the Division prior to the start of construction. **All changes to the approved plans must be approved by the Division.**

I.A.11. **Presumption of Possession and Compliance:** Copies of this permit, any subsequent modifications shall be maintained at the permitted project site at all times.

I.A.12. **Schedule of Compliance:** The Permittee shall achieve compliance with the permit limitations upon issuance of the permit.

I.B. MONITORING AND REPORTING

I.B.1. Monitoring

a. **Representative Samples:** Samples and measurements taken as required herein shall be representative of the volume and nature of the monitored discharge.

b. **Test Procedures:** Analyses shall be conducted by a "certified laboratory" using an "approved method of testing", as defined in NAC 445A.0564 and NAC 445A.0562, respectively.

c. **Recording the Results:** For each measurement or sample taken pursuant to the requirements of this permit, the Permittee shall record the following information:

  i. The exact place, date, and time of sampling;
  ii. The dates the analyses were performed;
  iii. The person(s) who performed the analyses;
  iv. The analytical techniques or methods used; and
  v. The results of all required analyses, including reporting limits.

d. **Additional Monitoring by Permittee:** If the Permittee monitors any pollutant at the location(s) designated herein more frequently than required by this permit, using approved analytical methods as specified above, the results of such monitoring shall be included in any calculation and/or reported value required by this permit. Such increased frequency shall also be indicated in required reports.

e. **Records Retention:** All records and information resulting from monitoring activities; the permit application; reporting required by this permit, including all records of analyses performed, calibration and maintenance of instrumentation, and recordings from continuous monitoring instrumentation shall be retained for a minimum of five (5) years or longer if required by the Administrator.

f. **Reporting Limits:** Unless otherwise allowed by the Division, the approved method of testing selected for analyses shall have a reporting limit which is:

  i. Half or less of the discharge limit; or, if there is no discharge limit,
  ii. Half of less of the applicable water quality criteria; or, if there is no limit or criteria,
  iii. The lowest reasonably obtainable limit using an approved test method.

g. **Modification of Monitoring Frequency and Sample Type:** After considering monitoring data, discharge flow, discharge frequency, and receiving water conditions, the Division and/or Administrator may, for just cause, modify the monitoring frequency and/or sample type by issuing an order to the Permittee.

h. **Definitions**

i. **<u>30-day average discharge</u>:** means the total discharge during a month divided by the number of samples in the period that the facility was discharging. Where less than daily sampling is required by this permit, the 30-day average discharge shall be determined by the summation of all the measured discharges divided by the number of samples during the period when the measurements were made.

ii. **<u>Daily maximum</u>:** is the highest measurement obtained during the monitoring period.

iii. **<u>30-day average concentration</u>:** means the arithmetic mean of measurements made during a month.

iv. **<u>"Discrete" sample</u>:** means any individual sample collected in less than 15 minutes.

v. **<u>Composite sample:</u>** flow rate composite means the arithmetic mean of no fewer than six individual measurements taken at equal time intervals for 24 hours, or for the duration of discharge, whichever is shorter. For other than flow rate a composite sample means a combination of no fewer than six individual flow-weighted samples obtained at equal time intervals for 24 hours, or for the duration of the discharge, whichever is shorter. Flow-weighted sample means that the volume of each individual sample shall be proportional to the discharge flow rate at the time of sampling.

I.B.2. **Reporting:** Analytical data and monitoring results shall be summarized and/or tabulated for presentation in standardized Discharge Monitoring Reports (DMRs). Laboratory reports for quantitative analyses conducted by State of Nevada certified laboratories must accompany DMR submittals.

DMRs shall be received by the 28^{th} day of the month following the effective date of the permit and the 28^{th} day of each month for the duration of the permit. If no discharge occurs during the reporting period, summarize the project status and report "no discharge" on the submitted DMR.

DMRs must be signed by the authorized representative that is responsible for the facility. The first DMR submitted under this permit must include the written designation of the authorized representative elected to sign DMRs. The designated representative responsible for facility operations must sign each subsequent DMR submitted to the Division. If the authorized representative changes, a new designation letter must be submitted.

a. **Monthly Reporting:** Monitoring results for the effluent discharge monitoring requirements described in Part I.A.1. shall be summarized and tabulated for each month. The Permittee is considered in compliance if the reported results are less than the established permit limit. Photographs of the well pump tests and discharges shall be submitted for the appropriate months.

b. **Other Information:** Where the Permittee becomes aware of failure to submit any relevant facts in a permit application or has submitted incorrect information in a permit application or in any report to the Division, the Permittee shall promptly submit such facts or information.

c. **Planned Changes:** The Permittee shall give notice to the Division as soon as possible of any planned physical alterations or additions to the permitted facility. Notice is required only when the alteration or addition to a permitted facility:

i. Could significantly change the nature or increase the quantity of pollutants discharged; or
ii. Results in a significant change to the Permittee's sludge management practice or disposal sites.

d. **Anticipated Noncompliance:** The Permittee shall give advance notice to the Administrator of any planned changes in the permitted facility or activity which may result in noncompliance with permit requirements.

e. **Submittal:** An original signed copy of these and all other reports required herein, shall be submitted to the Division at the following address:

Nevada Division of Environmental Protection
Bureau of Water Pollution Control
901 South Stewart Street, Suite 4001
Carson City, Nevada 89701-5249

I.B.3. **Signatory Certification Required on Application and Reporting Forms:**

a. All applications, reports, or information submitted to the Administrator shall be signed and certified by making the following certification:

"I certify under penalty of law, that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gathered and evaluated the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations."

b. All applications, reports, or other information submitted to the Division shall be signed by one of the following:

i. A principal executive officer of the corporation (of at least the level of vice president) or his authorized representative who is responsible for the overall operation of the facility from which the discharge described in the application or reporting form originates;
ii. A general partner of the partnership;
iii. The proprietor of the sole proprietorship; or

iv. A principal executive officer, ranking elected official, or other authorized employee of the municipal, state, or other public facility.

c. **Changes to Authorization:** If an authorization under Part I.B.3. is no longer accurate because a different individual or position has responsibility for the overall operation of the facility, a new authorization satisfying the requirements of Part I.B.3. must be submitted to the Administrator prior to or together with any reports, information, or applications to be signed by an authorized representative.

PART II

II.A. MANAGEMENT REQUIREMENTS

II.A.1. **Change in Discharge:** All discharges authorized herein shall be consistent with the terms and conditions of this permit. The discharge of any pollutant identified in this permit more frequently than, or at a level in excess of, that authorized shall constitute a violation of the permit.

Any anticipated facility expansions that will result in new, different, or increased discharges of pollutants must be reported by submission of a new application or, if such changes will not violate the effluent limitations specified in this permit, by notice to the permit issuing authority of such changes. Any changes to the permitted facility must comply with NAC 445A.283 to 445A.285. Pursuant to NAC 445A.263, the permit may be modified to specify and limit any pollutants not previously limited.

II.A.2. **Facilities Operation-Proper Operation and Maintenance:** The Permittee shall, at all times, maintain in good working order and operate as efficiently as possible all control facilities, collection systems, or pump stations installed or used by the Permittee to achieve compliance with the terms and conditions of this permit.

II.A.3. **Adverse Impact-Duty to Mitigate:** The Permittee shall take all reasonable steps to minimize releases to the environment resulting from noncompliance with any effluent limitations specified in this permit, including such accelerated or additional monitoring as necessary to determine the nature and impact of the noncomplying discharge. The Permittee shall carry out such measures, as reasonable, to prevent significant adverse impacts on human health or the environment.

II.A.4. **Noncompliance, Unauthorized Discharge, Bypassing, and Upset:**

a. Any diversion, bypass, spill, overflow, or discharge of wastewater from evaporation or conveyance facilities under the control of the Permittee is prohibited except as authorized by this permit. In the event the Permittee has knowledge that a diversion, bypass, spill, overflow, or discharge not authorized by this permit is probable, the Permittee shall immediately notify the NDEP Spill Hotline at 1-888-331-6337.

b. The Permittee shall notify the Administrator by calling the NDEP Spill

Hotline at 1-888-331-6337 within twenty-four (24) hours of any diversion, bypass, spill, upset, overflow, or release of discharge other than that which is authorized by the permit. The following shall be included as information which must be reported within 24 hours:

i. Any unanticipated bypass which exceeds any effluent limitation in the permit;
ii. Any upset which exceeds any effluent limitation in the permit; and
iii. Any violation of a limitation for any toxic pollutant or any pollutant identified as the method to control a toxic pollutant.

c. A written report shall be submitted to the Division within five (5) days of diversion, bypass, spill, overflow, upset, or discharge detailing the entire incident including:

i. Time and date of discharge;
ii. Exact location and estimated amount of discharge;
iii. Flow path and any bodies of water which the discharge contacts;
iv. The specific cause of the discharge; and
v. The preventive and/or corrective actions taken.

d. The Permittee shall report all instances of noncompliance not reported under Part II.A.4.c. at the time monitoring reports are submitted. The reports shall contain the information listed in Part II.A.4.c.

e. A "bypass" means the intentional diversion of waste streams from any portion of a facility.

i. <u>Bypass not exceeding limitations:</u> The Permittee may allow any bypass to occur which does not cause effluent limitations to be exceeded, but only if it also is for essential maintenance to assure efficient operation. These bypasses are not subject to the provisions of Parts II.A.4.a. and II.A.4.b.
ii. <u>Anticipated bypass:</u> If the Permittee knows in advance of the need for a bypass, it shall submit prior notice, if possible, at least ten (10) days before the date of bypass.

f. Bypass is prohibited, and the Division may take enforcement action against a Permittee for bypass, unless:

i. The bypass was unavoidable to prevent loss of life, personal injury, or severe property damage;
ii. There were no feasible alternatives to the bypass, such as the use of auxiliary evaporation facilities or maintenance during normal periods of equipment down time. This condition is not satisfied if adequate back-up equipment should have been installed in the exercise of reasonable engineering judgment to prevent a bypass which occurs during normal periods of equipment downtime or preventative

maintenance; and

iii. The Permittee submitted notices as required under Part II.A.4.e.

g. The Division may approve an anticipated bypass, after considering its adverse effects, if the Division determines that it will meet the three conditions listed in Part II.A.4.f.

h. An "upset" means an exceptional incident in which there is unintentional and temporary noncompliance with technology-based permit effluent limitations because of factors beyond the reasonable control of the Permittee. An upset does not include noncompliance to the extent caused by operational error, improperly designed facilities, lack of preventive maintenance, or careless or improper operation.

i. A Permittee who wishes to establish the affirmative defense of upset shall demonstrate, through properly signed, contemporaneous operating logs, or other relevant evidence that:

i. An upset occurred and the Permittee can identify the cause(s) of the upset;
ii. The permitted facility was at the time being properly operated;
iii. The Permittee submitted notice of the upset as required under Part II.A.4.e.; and
iv. The Permittee complied with any remedial measures required under II.A.3.

j. An upset constitutes an affirmative defense to an action brought for noncompliance with such technology-based permit effluent limitations if the requirements of Part II.A.4.i. are met.

k. In selecting the appropriate enforcement option, the Administrator shall consider whether or not the noncompliance was the result of an upset. The burden of proof is on the Permittee to establish that an upset occurred.

II.A.5. **Removed Substances:** Solids, sludges, filter backwash, or other pollutants removed in the course of control of process wastewaters shall be disposed of in a manner such as to prevent any pollution from such materials from entering any navigable waters.

II.A.6. **Safeguards to Electric Power Failure:** In order to maintain compliance with the effluent limitations and prohibitions of this permit the Permittee shall either:

a. Provide, at the time of discharge, an alternative power source sufficient to operate the wastewater control facilities; or

b. Halt or reduce all discharges upon the reduction, loss, or failure of the primary source of power to the wastewater control facilities.

II.B. RESPONSIBILITIES

II.B.1. **Right of Entry and Inspection:** The Permittee shall allow the Administrator and/or his authorized representatives, upon the presentation of credentials, to:

a. Enter, at reasonable times, upon the Permittee's premises where an effluent source is located or in which any records are required to be kept under the terms and conditions of this permit;

b. Have access to and copy any records required to be kept under the terms and conditions of this permit;

c. Inspect, at reasonable times, any facilities, equipment (including monitoring and control equipment), practices, or operations required in this permit; and

d. Perform any necessary sampling or monitoring to determine compliance with this permit at any location for any parameter.

II.B.2. **Transfer of Ownership or Control:** In the event of any change in control or ownership of facilities from which the authorized discharge emanates, the Permittee shall notify the succeeding owner or controller of the existence of this permit, by letter, a copy of which shall be forwarded to the Administrator. The Administrator may require modification or revocation and re-issuance of the permit to change the name of the Permittee and incorporate such other requirements as may be necessary. The Division shall approve all transfer of permits.

II.B.3. **Availability of Reports:** Except for data determined to be confidential under NRS 445A.665, all reports prepared in accordance with the terms of this permit shall be available for public inspection at the office of the Administrator. As required by the Act, effluent data shall not be considered confidential. Knowingly making any false statement on any such report may result in the imposition of criminal penalties as provided for in NRS 445A.710.

II.B.4. **Furnishing False Information and Tampering with Monitoring Devices:** Any person who knowingly makes any false statement, representation, or certification in any application, record, report, plan, or other document filed or required to be maintained by the provisions of NRS 445A.300 to 445A.730, inclusive, or by any permit, rule, regulation, or order issued pursuant thereto or who falsifies, tampers with, or knowingly renders inaccurate any monitoring device or method required to be maintained under the provisions of NRS 445A.300 to 445A.730, inclusive or by any permit, rule, regulation, or order issued pursuant thereto is guilty of a gross misdemeanor and shall be punished by a fine of not more than $10,000 or by imprisonment. This penalty is in addition to any other penalties, civil or criminal, provided pursuant to NRS 445A.300 to 445A.730, inclusive.

II.B.5. **Penalty for Violation of Permit Conditions:** NRS 445A.675 provides that any person who violates a permit condition is subject to administrative and judicial sanctions as outlined in NRS 445A.690 through 445A.705.

II.B.6. **Permit Modification, Suspension, or Revocation:** After notice and opportunity for a hearing, this permit may be modified, suspended, or revoked in whole or in part during its term for cause including, but not limited to, the following:

a. Violation of any terms or conditions of this permit;

b. Obtaining this permit by misrepresentation or failure to disclose fully all relevant facts;

c. A change in any condition that requires either a temporary or permanent reduction or elimination of the authorized discharge;

II.B.7. **Toxic Pollutants:** Notwithstanding Part II.B.6., if a toxic effluent standard or prohibition (including any schedule of compliance specified in such effluent standard or prohibition) is established under Section 307(a) of the Act for a toxic pollutant which is present in the discharge and such standard or prohibition is more stringent than any limitation for such pollutant in this permit, this permit shall be revised or modified in accordance with the toxic effluent standard or prohibition and the Permittee so notified.

II.B.8. **Liability:** Nothing in this permit shall be construed to preclude the institution of any legal action or relieve the Permittee from any responsibilities, liabilities, or penalties established pursuant to any applicable Federal, State, or local laws, regulations, or ordinances.

II.B.9. **Property Rights:** The issuance of this permit does not convey any property rights, in either real or personal property, or any exclusive privileges, rights, or rights of access or easement; nor does it authorize any injury to private property, any invasion of personal rights, or any infringement of Federal, State, or local laws or regulations.

II.B.10. **Severability:** The provisions of this permit are severable, and if any provision of this permit or the application of any provisions of this permit to any circumstance is held invalid, the application of such provision to other circumstances and the remainder of this permit shall not be affected thereby.

II.B.11. **Need to Halt or Reduce Activity Not a Defense:** The need to halt or reduce permitted activities in order to maintain compliance with the conditions of this permit shall not be a defense for a Permittee in an enforcement action.

II.B.12. **Duty to Provide Information:** The Permittee shall furnish to the Administrator, within a reasonable time, any relevant information which the Administrator may request to determine whether cause exists for modifying, revoking and reissuing, or terminating this permit, or to determine compliance with this permit. The Permittee shall also furnish to the Administrator, upon request, copies of records required to be kept by this permit.

PART III

III.A. OTHER REQUIREMENTS

III.A.1. **Reapplication:** If the Permittee desires to continue to discharge, he shall reapply not later than 180 days before this permit expires on the application forms then in use. The application shall be accompanied by the renewal application fee required by NAC 445A.232.

III.A.2. **Signatures Required on Application and Reporting Forms**

a. Application and reporting forms submitted to the department must be signed by one of the following:

i. A principal executive officer of the corporation (of at least the level of vice president) or his authorized representative who is responsible for the overall operation of the facility from which the discharge described in the application or reporting form originates; or

ii. A general partner of the partnership; or

iii. The proprietor of the sole proprietorship; of

iv. A principal executive officer, ranking elected official of or other authorized employee of the municipal, state, or other public facility.

b. Each application must contain a certification by the person signing the application that he is familiar with the information provided that, to the best of his knowledge and belief, the information is complete and accurate, and that he has the authority to sign and execute the application.

c. **Changes to Authorization:** If an authorization under paragraph b of this section is no longer accurate because a different individual or position has responsibility for the overall operation of the facility, a new authorization satisfying the requirements of paragraph b of this suction must be submitted to the Division prior to or together with any reports, information, or applications to be signed by an authorized representative.

III.A.3. **Holding Pond Conditions:** If any wastewater from the Permittee's facility is placed in ponds, such ponds shall be located and constructed so as to:

a. Contain with no discharge the once –in-25 year 24-hour storm at said location;

b. Withstand with no discharge the once-in-one-hundred year flood of said location; and

c. Prevent escape of wastewater by leakage other than as authorized by this permit.

III.A.4. **Flow Rate Notification:** The Permittee shall notify the Administrator, by letter, not later than 90 days after the 30-day average daily influent flow rate first equals or exceeds 85% of the design treatment capacity of the Permittee's facility given in Part I.A above. The letter shall include:

a. The 30-day average daily influent flow rate;

b. The maximum 24-hour flow rate during the 30-day period reported above, and the date the maximum flow occurred;

c. The Permittee's estimate of when the 30-day average influent flow rate will equal or exceed the design treatment capacity of the Permittee's facility;

d. A status report on the treatment works which will outline but not be limited to past performance, remaining capacity of the limiting treatment and disposal units or sites, past operational problems and improvements instituted, modifications to the treatment works which are needed to attain the permitted flow rate due to changing site specific conditions or design criteria; and

e. The Permittee's schedule of compliance to provide additional treatment capacity before the 30-day average daily influent flow rate equals the present design treatment capacity of the Permittee's facility.

PERMITTEE ADDRESS
(Include Facility Name/Location if different)

STATE OF NEVADA TEMPORARY GROUNDWATER DISCHARGE
DISCHARGE MONITORING REPORT (DMR)

Form Approved
OMB No. 2000-0015

NAME: Navy Geothermal Program Office
ADDRESS: 429 E. Bowen Road Stop 4011
China Lake, CA 93555

FACILITY: Hawthorne Army Depot
LOCATION: NW of Hawthorne, Mineral County, NV

TNEV2013344	NA
PERMIT NUMBER	REUSE SUPPLIER PERMIT NUMBER

Pg. 1 of __

NOTE: Read instructions before completing this form.

OUTFALL:

	MONITORING PERIOD							REPORTING QUARTER
	YEAR	MONTH	DAY		YEAR	MONTH	DAY	
FROM				TO				____, ____ QUARTER YEAR

PARAMETER		QUANTITY OR LOADING			QUALITY OR CONCENTRATION				No. of Exceptions	Frequency of Analysis	Sample Type
		30-DAY AVERAGE	MAXIMUM	Units	MINIMUM	AVERAGE	MAXIMUM	Units			
	Sample Measurement										
	Permit Requirement										
	Sample Measurement										
	Permit Requirement										
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	Permit Requirement										
	Sample Measurement										
	Permit Requirement										

Name/Title Principal Executive Officer
(Typed or Printed)

TELEPHONE NO.:

I certify under penalty of law that I have personally examined and am familiar with the information submitted herein; and based on my inquiry of those individuals immediately responsible for obtaining the information. I believe the submitted information is true, accurate and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment. See 18 U.S.C. §1001 and 33 U.S.C. §1319. (Penalties under these statutes may include fines up to $10,000 and/or maximum imprisonment of between 6 months and 5 years.)

Signature of Principal Executive Officer or Authorized Agent

DATE: ________ ________, ________
Month Day Year

COMMENT AND EXPLANATION OF ANY VIOLATIONS ***(Reference all attachments here)***

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