Advanced Seismic Data Analysis Program (The Hot Pot Project)

DOE Award: DE-EE0002839
Phase 1 Report

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OSKI ENERGY

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Executive Summary

The Hot Pot geothermal prospect in north central Nevada was selected for funding under United States Department of Energy DE-FOA-0000109 to validate innovative exploration technologies in order to reduce geothermal exploration risk. The project objective was to improve geothermal well target selection and reduce drilling risk through the application of an innovative and advanced analytical method for interpreting reflection seismic data. Oski Energy, LLC ("Oski") proposed to accomplish this goal in three phases:

- **Phase 1** – Compilation of all previous exploration data, establishment of a project Geographic Information System (GIS) database, completion of a reflection seismic survey, analysis of the seismic data utilizing the proposed advanced techniques, and selection of drilling locations for two intermediate depth slim holes based on all available exploration data.

- **Phase 2** – Completion of two intermediate depth slim holes and one full-size resource confirmation well.

- **Phase 3** – Well testing and final report submittal.

The phases of the Oski innovative exploration program are intended to integrate detailed knowledge of the regional and local geology, tectonic history, existing exploration data, and advanced reflection seismic interpretation to select locations for the slim hole drilling in Phase 2. Data obtained from the slim holes will be used to confirm that shallow temperatures persist to greater depths, infer the location of upwelling geothermal fluids and select the site for a full-scale production test well.

Prior to the funding award, Oski also completed independent work to expand and improve on the existing published information on the Hot Pot prospect. This work included:

- Detailed local gravity survey (655 ft, 200m station spacing)
- Soil Hg geochemistry study
- A series of six (6) shallow (500 ft; 150 m) temperature gradients holes over 24 mi^2 (64 km^2)

Phase 1 tasks identified in the Statement of Project Objectives have been completed by Oski and are discussed in this report. These include:

- Compilation of available data into a Geographic Information System database

  Compiled data includes:

  - Background geology
  - Structural interpretations
  - Regional gravity data
  - Regional MT data
  - Regional TG data
  - Shallow well logs from:

    - Publically available water wells and monitoring wells
    - Published mineral exploration well data
    - Proprietary mineral exploration data
- Acquiring 22.7 line miles (36.5 km)of reflection seismic data
- Performing the 2.5D seismic data analysis utilizing the advanced techniques applied by Optim, Inc.
- Integration of all project information to select drilling locations for the slim holes to be completed in Phase2.

Preliminary results from Phase 1 suggest:

- Advanced seismic data processing yielded drillable subsurface targets in a region where conventional processing appears to be of questionable value.
- Geologic input to the seismic velocity model significantly improved data quality.
- Structures were identified deep within a potential geothermal reservoir.

With the completion of Phase 1 studies, slim hole locations have been selected for the next phase of this project based on the best interpreted information to target zones of potential upflow. Several candidate well locations - more than the two required to meet the Phase 2 drilling requirements - are discussed and evaluated in the report to accommodate unanticipated limitations of land management sensitivity and allow alternative locations to be considered. Based on Oski's experience, defending rigid location selections does not allow for minor program alterations to mitigate site access costs, environmental restrictions and cultural clearance limitations.

Each proposed location is considered a reasonable test of areas within the prospect that may be upwelling centers for geothermal fluids and could, based on slim hole results, become the site selected for a deep full-scale production test. Drilling of the two slim holes proposed in Phase 2 will help detail the nature of the faults and fractures interpreted in this Phase I report. Confirmation of elevated gradients to greater depth and the location of potential faults will support the future application of advanced seismic data analytical techniques to other Basin and Range geothermal exploration projects. Based on the temperature and structural information from intermediate depth slim holes, a full-scale production test may be targeted and could intersect specific fault zones at greater depth to achieve reasonable production temperatures for potential resource development. The results of this project provide a template for reducing production well drilling risk, thereby accomplishing a major DOE program objective.

1.0 INTRODUCTION

United States Department of Energy (DOE), through the Geothermal Technologies Program, issued Funding Opportunity Announcement (FOA) DE-FOA-0000109 on May 27th 2009. The Announcement requested Proposals covering three topic areas with funding made available through the American Recovery and Reinvestment Act of 2009. Oski Energy, LLC (Oski) submitted a proposal titled *Advanced Seismic Data Analysis – The Hot Pot Project* under the Innovative Exploration Technologies topic and was awarded a match-share grant of $4,214,086 (DOE Award DE-EE0002839). The goal of this project is to validate specific seismic technologies in order to reduce geothermal exploration risk.

The proposed project is located in the vicinity of a geothermal feature known as Hot Pot hot springs, in Humboldt County, Nevada, approximately 32 miles (51 km) east of Winnemucca (Figure 1). The project area includes approximately 25 square miles (65 square kilometers) centered on the former Hot Pot spring location. The project objective is to improve geothermal well target selection and reduce drilling risk through the application of an innovative and advanced analytical method of processing seismic reflection data. Reduced risk can lead to lower project costs and more rapid resource development.

Three project phases were presented under the Statement of Project Objectives (SOPO) within the Oski proposal:

- **Phase 1** – Compilation of all previous exploration data, establishment of a project Geographic Information System (GIS) database, completion of a reflection seismic survey, analysis of the seismic data utilizing the proposed advanced techniques, and selection of drilling locations for two intermediate depth slim holes based on all available exploration data.

- **Phase 2** – Permitting and completion of two intermediate depth slim holes and one full-size resource confirmation well.

- **Phase 3** – Well testing and final report submittal.

This report presents the results of all activities completed under the SOPO Phase1, and is intended to provide the basic rationale and justification for continuing to Phase 2. Specifically, the report contains:

- Summarized exploration data for the Oski lease area and the immediate vicinity presented in GIS format assembled for the project

- Results of the seismic reflection survey completed for Oski by Optim, Inc., including data interpretation and lessons learned. The Optim Seismic Report is included as Appendix A.

- Integrated analysis of results, utilizing both the seismic program and relevant pre-existing data

- Proposed locations for two 2,500 ft (760 m) slim holes.

- Conceptual resource model and discussion of the role of the innovative technology in target selection, selection rationale and probability of success
- Detailed drilling plan and budget for Phase 2 (slim holes)
- Foreseeable drilling phase obstacles and risk mitigation plans

Upon completion of the stage-gate review by DOE and concurrence with proposed Phase 2 slim hole locations, Oski will initiate a permitting program including federal (NEPA), Bureau of Land Management and State of Nevada approvals. This process will be documented in a report addendum, to be submitted a minimum of three weeks prior to drill site construction.

2.0 GEOLOGY AND REGIONAL TECTONICS

An understanding of regional geology is essential in order to plan and interpret site-specific exploration surveys, develop resource conceptual models, and reduce exploration risk. Aspects of regional geology most relevant to the Hot Pot project are discussed in this section along with results of additional site-specific reconnaissance investigations.

2.1 Regional Setting

The Hot Pot geothermal prospect lies in the Humboldt River valley in the eastern part of Humboldt County, between Battle Mountain and Winemucca (Figure 1). Hot Pot is approximately equidistant from Edna Mountain, approximately 12 mi (20 km) to the west, the Osgood Mountains to the northwest, Antler Peak to the south, the Snowstorm Mountains to the northeast, and the Sheep Creek Range to the east (Figure 2). Treaty Hill, a small, low lying hill to the southwest, is the nearest rock outcrop and lies approximately 3 mi (5 km) to the south west, near Valmy. The Valmy power plant is immediately southwest of the project area.

2.1 Geologic History

The project area is located within the Antler and Sonoma orogenic belts, two regions marked by evidence of generally east-vergent thrusting of oceanic sedimentary and volcanic rocks onto the shallow marine continental shelf of North America. The Antler belt was formed by Late Devonian-Early Mississippian thrusting of the Roberts Mountains allochthon, and the Sonoma belt experienced Permian to Early Triassic thrusting of the Golconda allochthon (Stewart, 1980).

Little record of Mesozoic activity exists in the Hot Pot region, and the area is interpreted to have been a broad highland, with Mesozoic thrust faulting occurring both west and east of the Humboldt River valley (Stewart and Carlson, 1978). During the Paleogene, calc-alkaline volcanic and volcaniclastic rocks ranging broadly between 43 and 34 million years (Ma) were erupted and deposited widely in north-central Nevada. Large silicic calderas formed during and after this interval erupting silicic ash flow tuffs over much of the central part of the state (John et al., 2008).

During the Neogene, a complex series of tectonic events produced features that had a strong influence on geothermal resource exploration and development in northern Nevada:

- A prominent, north-northwest striking rift system developed in north-central Nevada approximately 17-15 Ma (Ponce and Glen, 2008), and is associated with thick sequences of andesitic and basaltic lavas and volcaniclastic rocks that are exposed northeast of Hot Pot.

- Extensional basins began to develop during or after rift formation in areas northeast of Hot Pot (Wallace et al., 2008). North to north-northeast striking normal faults began to define modern mountain ranges.

- Pliocene basalts were erupted from areas west and south of Hot Pot unconformably overlying Paleogene and Miocene rocks.
- During Pliocene to Holocene times, the Humboldt River established its course through the area, and fluvial or alluvial deposits buried older bedrock highs in the Hot Pot area.
- Both Mio-Pliocene and Pleistocene-Holocene normal faults deform the Hot Pot region.

2.3 Inferred Subsurface Geology

Subsurface geology at Hot Pot is inferred, from the geology of the surrounding ranges, to consist of a thick section of i) lower Paleozoic deep marine sedimentary and volcanic rocks of the Roberts Mountains allochthon (probably the Valmy Formation), and ii) possible local occurrences of stratified units of the Mississippian to Permian Antler overlap sequence (Figure 1). The section of Paleozoic rocks is unconformably overlain by a succession of Cenozoic rocks that may include: a) Paleogene tuffs and lavas, b) Miocene basin deposits, c) Pliocene basaltic rocks, and d) Pleistocene to Holocene alluvial deposits of the Humboldt River.

Roberts Mountains allochthon

In the region, the most widespread unit of the Roberts Mountains allochthon is the Ordovician Valmy Formation, a structurally complex assemblage of both coherent and chaotic units imbricated along numerous low-angle thrusts. Rock types principally include chert, shale (or argillite), quartzite, and lesser basaltic volcanic rocks and marine limestone. In exposures at the Marigold Mine, 12 mi (20 km) south of Hot Pot, chert, argillite, and quartzite of the Valmy are highly silicified and intensly fractured. Thickness of the Valmy is highly variable, but probably exceeds 3000 ft (915 m) in many places. In the Osgood Mountains (Hotz and Willden, 1964) and in many areas of north-central Nevada, the Valmy has been thrust over phyllitic and quartzitic units of the North American passive margin.

Antler overlap sequence

The Antler overlap sequence unconformably overlies the Valmy in many areas south and west of Hot Pot Typical units at Antler Peak, 12 mi (20 km) south of Hot Pot, include the Missippian Battle Formation (pebble and boulder conglomerate and sandstone), the Pennsylvanian Antler Peak Limestone (thickly bedded, fossiliferous, shallow marine limestone), and the Permian Edna Mountain Formation (fossiliferous coarse-grained sandstone and conglomerate). The Edna Mountain Formation rests disconformably upon the Antler Peak Formation (Roberts, 1964; Erickson and Marsh, 1974a, b). Additional named units have been mapped at Edna Mountain and in the Osgood Mountains. There is a low probability this sequence occurs in the Hot Pot area.

Golconda allochthon

The Golconda allochthon is a structurally complex assemblage of upper Paleozoic deep marine chert, shale, basalt, sandstone, and limestone. At Antler Peak, in the Marigold Mine, and at Edna Mountain, rocks of the Golconda allochthon are emplaced over rocks of the Antler overlap sequence along the Golconda thrust. Although some regional maps include Paleozoic rocks on Treaty Hill as part of the

Golconda allochthon, available map data make the presence of the Golconda allochthon at Hot Pot unlikely.

Cenozoic succession

In north-central Nevada, moderately to weakly consolidated Cenozoic strata and volcanic rocks overlie Paleozoic basement along a major unconformity. The thickness and distribution of these Cenozoic cover rocks is unknown beneath the Hot Pot area; however, if Paleogene strata occur in the subsurface at Hot Pot, they would most likely include sedimentary and volcanic rocks of Eocene to Oligocene age. Ranges to the northeast and south include fluvial sandstone, siltstone, and conglomerate, with interbedded tuffaceous sedimentary rocks and scattered ash flow tuffs (John et al., 2008; Henry, 2008).

Neogene strata at Hot Pot probably accumulated within normal fault-bounded basins and are assumed to include fluvial sandstone and conglomerate, lacustrine deposits, and ash-rich sediments. These strata may be similar to 17-14 Ma units described in the Chimney and Ivanhoe basins in the Snowstorm Mountains and Sheep Creek Range by Wallace et al. (2008). Andesitic to basaltic lava flows related to the Northern Nevada Rift may well occur within this package. Pliocene vesicular and olivine basalts crop out on the east flank of Edna Mountain and on Treaty Hill, resting unconformably on Paleozoic rocks in both places.

2.4 Quaternary Geology

The project area lies northeast of the Humboldt River in a very wide, alluviated valley (Figure 1). Broad alluvial fans spread southwest from the Snowstorm Mountains to the northeast and Sheep Creek Range to the east and ephemeral streams that originate in canyons in the ranges flow southwest across the alluvial fans and down a broad, gentle piedmont slope toward the northwest flowing Humboldt River. Hot Pot Creek turns abruptly northwest and flows parallel to the regional piedmont slope. Hot Pot hot springs form a prominent, circular topographic mound within the channel of the northwest-trending segment of Hot Pot Creek. Hot Pot hot springs do not currently flow at the surface.

The USGS fault database shows several Quaternary faults in and near the project area (Figure 2). A north-northwest striking fault (referred to as the eastern fault in later sections of this report), with east-facing Quaternary scarps, lies along the eastern edge of the area, and several short, north-northeast-trending scarps are plotted within, and north of, the project area (Figure 2). One of the north-northeast-trending scarps is plotted at the location of Hot Pot hot springs, reflecting the alignment of the springs (Figures 3 and 4)

Hot Pot hot springs and the northeast portion of the project area are shown in Figure 3. The eastern fault shows prominently as a north-trending line separating white sandy (and salt?) deposits from a broad piedmont area with reddish to brownish tones in an image of Hot Pot hot springs and the northeastern parts of the project area. Hot Pot Creek passes from the east-central part of the image, where it consists of numerous branching channels across this fault where it narrows to a single incised channel to the southern edge of the figure where it flows west to the hot springs and then northwest. Hot Pot hot springs is in the southwest part of the image.

Several scarps and other linear features are visible in this image (Figure 3). A subtle northwest-striking scarp branches from the eastern fault near the point where seismic line 401 crosses the fault (Section 4.0). This unmapped scarp, which is approximately 3-10 ft (1-3 m) in height, extends approximately 3000 ft (915m), faces northeast and is convex northeast. In the southwest part of the image, the southwestern edge of the channel of Hot Pot Creek appears to be a 20 ft (~7 m) high scarp facing northeast. This scarp, is strongly degraded by gullies carved into the soft, unconsolidated alluvial sand and contrasts with the northeastern edge of the channel that slopes very gradually from the piedmont slope down to the floor of Hot Pot Creek. The northwest alignment of Hot Pot Creek together with this scarp, are believed to mark the position of a northwest-striking Hot Pot normal fault.

Northeast-trending linear features visible in Figure 3 include spring alignments at Hot Pot (discussed below), a line marking an abrupt limit of sand dunes, and a very subtle alignment of vegetation and topographic features. The spring alignments and the sand dune limit are colinear, suggesting the existence of fractures perpendicular to Hot Pot Creek, passing through Hot Pot hot springs vents.

An enlargement of the USGS topographic map (contour interval is 5 ft (1.5 m)) at Hot Pot hot springs (Figure 4), shows field observations at the hot spring complex. The site is dominated by three circular mounds approximately 25-30 ft (7-8 m) high and approximately 500 ft (150 m) in diameter in a northeast (~N40°E) alignment, with a fourth, smaller mound approximately 20 ft (6m) high on the west side of the central large mound. Most of the surface at the mounds is covered with sand. The main spring vent, with a travertine rim, is approximately 82-ft-wide and 26-ft-deep (25 X 8 m) and lies at the summit of the fourth, smaller mound. The vents are currently dry (see Section 3.1) but the hot springs were referenced up to the late 1970's (Waring, 1965; Muffler, 1979). Numerous abandoned spring vents within the three large mounds produce two subparallel, N45°E alignments, as noted above. These aligned spring vents probably record open fractures within underlying bedrock and possibly within alluvium. The scale of the mounds, together with the dry stream channel surrounding the spring complex (visible in Figures 3 and 4) indicate considerable flow volumes from this complex of springs during the Holocene.

3.0 PREVIOUS EXPLORATION - (SOPO Subtask 1.1)

The earliest Hot Pot geothermal exploration known to authors of this report occurred in 1973-74, when Chevron Resources Company conducted geological reconnaissance and geochemical sampling in the region. Other resource companies, possibly including Phillips Petroleum, Unocal Geothermal, Anschutz, and other similar organizations, in all probability conducted comparable studies. Chevron determined that Hot Pot hot springs was not a high priority prospect because of the relatively low estimated geothermometer base temperatures, the lack of obvious drilling targets, and a BLM acreage limit of ~20,000 acres/state. The limited acreage in each state was generally reserved for prospects with potential geochemical base temperatures of at least 350˚F (175 °C), and preferably 400˚F (205°C).

Interest in the geothermal potential of the Hot Pot area continued into the early 1980's. Trexler et al. (1982) investigated the Pumpernickel valley and included areas to the northeast into the Hot Pot hot springs area. The survey work included 2-m (6.5 ft) probes (Figure 5) with additional temperature data obtained from two temperature gradient holes and seven shallow (15 to 298 ft; 5 to 90 m) mineral exploration wells in the vicinity of the springs. A maximum temperature of 112°F (44.6°C) at 15 ft (4.5 m) was measured in a well close to the hot springs. A 140 ft (35 m) depth temperature gradient hole (PVHT-5), was drilled 2 miles (3.2 km) southwest of the Hot Pot hot springs (Figure 5). The hole encountered a thick sequence of alluvium, and bottomed in the basaltic bedrock of probable Quaternary age. The estimated temperature gradient for this well was approximately 12°F/100 ft (220°C/km). A second 120 ft (35 m) depth gradient well, PVHT-4, drilled approximately 7 miles (11 km) south of the springs, between the Marigold and the Lonetree mines penetrated mostly alluvium and yielded a calculated temperature gradient of 5.5°F/100 ft (100°C/km).

Numerous mineral exploration projects also added to the information obtained from geothermal exploration activities including gravity, soil geochemistry, MT, and shallow coreholes. Results are in most cases proprietary.

Geothermal exploration activity at Hot Pot hot springs resumed in 2009, when Oski acquired geothermal leases, began data compilation, and initiated several field surveys including gravity, soil geochemistry, and shallow temperature gradient holes. Much of this work yielded information useful for planning and interpretation of the DOE-funded Advanced Seismic Data Analysis Program under DE-FOA 0000109 and is discussed in some detail in following sections.

3.1 Geochemistry

Hot Pot springs (aka Blossom Hot Springs) was a hot spring assemblage that flowed 70 gallons per minute (gpm) (265 L/min) of 136°F (58°C) water (Waring, 1965; Muffler, 1979) until the springs dried up in the 1980s when groundwater withdrawal for the nearby Valmy power plant and dewatering at the adjacent Lone Tree mine lowered the local water table. Details on the evolution and composition of the hot spring deposits are unknown. The area of past outflow is currently defined by four travertine mounds (Figures 3 and 4) several hundred feet in diameter, suggesting extensive long term geothermal fluid flow to the surface. The deposits are predominantly carbonates and there is no surface evidence of higher temperature outflow such as changes in composition to more siliceous sinters. Regional geochemical surveys by the Nevada Bureau of Mines and Geology (NBMG) (Trexler, 1982) collected what may have been the last sample taken from Hot Pot, reporting measured spring temperatures of 136°F (58°C) and analytical results which indicated a high concentration of HCO_3, Na and K (Figure 5). The analyses indicated the sodium bicarbonate water at Hot Pot contained up to 5 milligrams per liter (mg/L) of Mg indicating a strong influence from shallow groundwater mixing.

Several compilations (Trexler,1982; Mariner et. al., 1974, 1975; Muffler, 1979; Garside, 1994) reported geothermometry estimates of 237°F (114°C) based on NaKCa (Mg corr) calculations and silica geothermometer estimates ranging from 206°F (97°C; chalcedony) to 257°F (125°C; quartz-conductive). Relatively high magnesium levels and high Na-K levels in Hot Pot spring samples preclude the use of uncorrected estimates from cation (Na-K and Na-K-Ca) geothermometers. High Na, K, Ca, Li concentrations detected in the available spring samples are likely affected by the elevated cation levels found in the alkaline groundwater common to the area. The Humboldt River flows approximately three miles south of the prospect area, and its water can be seasonally concentrated in salts because of slow evaporative processes in the arid environment.

3.2 Gravity and MT

A detailed gravity survey consisting of 1106 stations was conducted during March and April, 2010 by Thomas Carpenter under contract to Oski. Although this work was not part of the current DOE funded project, the gravity survey was important in projecting structural trends and optimizing the subsequent seismic survey. The detailed gravity results were merged with 231 stations from an earlier regional gravity survey. Products include complete Bouguer gravity at several assumed densities, residual gravity and total horizontal gravity gradient. The complete Bouguer gravity results are shown in Figure 6 and the contractor's report is included as Appendix B.

Much of the project area is located on a gravity high as shown in Figure 6. A north-northwest trending gradient occurs near the eastern project boundary. Additionally, numerous northeast and northwest trends are evident within the contoured data and these features could be evidence of bedrock faulting. The gravity data were modeled by Edcon-PRJ in order to estimate depth to basement . Model results suggest that much of the project area is underlain by broad areas of relatively shallow basement (500 – 1000 ft; 150 – 300 m, below ground surface) depending on the assumed density contrast. Gravity-derived basement depth is superposed on two representative seismic sections (Appendix B1).

A regional 38-station MT survey (Rodriguez and Williams 2002) was completed across northern-central Nevada. The nearest MT sites were located 5-10 miles (8 – 16km) from the project site. Access to detailed data from this survey was not available to Oski.

3.3 Soil Geochemistry

Initial reconnaissance studies by Trexler (1982) reported areas of elevated mercury concentration in soils around the Hot Pot spring vents. Oski Energy collected 244 additional soil samples and analyzed them for mercury concentrations during June, 2009. In the study area (Figure 7), mercury background concentrations are approximately 15 – 20 parts per billion (ppb) and 19 samples had values greater than 25 ppb. One area of 48 – 128 ppb mercury was noted coincident with the former Hot Pot spring area with five smaller peripheral areas of elevated soil mercury at or above 25 ppb (Figure 7). Three of these areas are single point anomalies and none of the mercury results in peripheral areas around Hot Pot Springs were considered sufficient to influence subsequent exploratory programs.

3.4 Shallow Temperature Gradient Drilling

3.4.1 Two-meter Probes

A 2-meter-depth (6.5-ft-depth) temperature survey was completed in the fall of 1981 (Trexler et al, 1982). The drilled holes were backfilled with drilling spoils around PVC encased probes and allowed to equilibrate for a minimum of 24 hours. Drilled material ranged from dry pebbly silt in the alluvial fans to water saturated clays on the playas. Temperature measurements on control probes in conjunction with measurements on station probes allowed corrections for annual temperature variations. Thermal variations can be depicted only after a reasonable estimate of background temperatures has been established. Even a small amount of interstitial water can significantly affect the results of the survey. Locations and data from the 2-meter (6.5 ft) probe survey are presented in Figure 5. Other than a single elevated temperature, no thermal anomaly was recorded at the Hot Pot hot springs, probably due to the large volumes of water in and on the playa sediments. Heat loss through evaporation at the surface can conceal subtle temperature differences that arise from subsurface heat source (Trexler et al, 1982).

3.4.2 Temperature Gradient Drilling

Six temperature gradient wells were drilled across the Hot Pot prospect by Oski in September, 2009, (Figure 8). The maximum depths of the holes were 500 ft although TG 9-1 stopped at 187 ft (57 m) due to drilling problems. The highest measured temperature is 103°F (39°C) at 500 ft (150 m) in well TG13-1. Temperature gradients range from approximately 3°F/100 ft (55°C/km) in well TG27-1 to 12°F/100 ft (200°C/km) in well TG9-1. For perspective, background temperature gradient in the Humboldt River Valley is approximately 1.5°F/100 ft (25°C/km).

Limited temperature gradient information was available from the Southern Methodist University (SMU) database. (Figure 8) The high gradients from BM 41 and PVHT 5 were subsequently validated by Oski TG 9-1, while the much lower gradients from locations BM 40, north of the project area, and BM 18, approximately 3 miles (5 km) east of the project area, are consistent with Oski TG 27-1.

Temperature-depth profiles for the Oski holes (Appendix C) indicate conductive heat flow with little or no evidence of hydrothermal disturbance. Linear projections of temperature gradients from wells TG9-1, TG13-1 and TG15-1 suggest that temperatures could approach 280 to 320°F (140 to 160°C) at depths as shallow as 2300 ft (700 m). This extrapolated temperature is broadly consistent with system base temperatures estimated from hot spring geochemistry, as described earlier in this section. However, simple gradient extrapolations can only be confirmed by deeper slim holes and ultimately a full-sized production test as proposed in this investigation. The Oski temperature gradient holes also provided lithologic information and details are contained in Appendix C. TG 3-1, TG15-1 and PVHT-5 penetrated a shallow basalt flow and one hole, TG 27-1, encountered Paleozoic basement.

3.4.3 Other Shallow Borings

Stratigraphic information from fifty-four shallow borings (Figure 9) show that the subsurface stratigraphy generally consists of Neogene sediments overlying bedrock, interpreted to be the Ordovician Valmy Formation. Thirty boreholes encountered Valmy (reported in boring logs as Paleozoic), at depths ranging from 107 to 1225 ft (32 to 373 m) below ground surface. Basalt, equivalent to the Pliocene basalts that crop out at Treaty Hill, was encountered in thirty-three boreholes substantiating that younger basalt flows continue northward in the subsurface. Depths to the top of basalt ranged from 15 to 430 ft (4.5 to 130 m) below ground surface, and thickness ranged from 14 to 300 ft (4.2 to 90 m).

3.5 GIS Database

Existing and newly generated data were compiled using Geographic Information System (GIS) software. ArcGIS by ESRI was used to achieve this work. As of March 2011, the database includes:

- A digitized version of the geological map of Nevada, 1:250,000 scale by the Nevada Bureau of Mines and Geology (NBMG) containing the geology, the faults and the contacts, created by E. Crafford in 2007.
- Various base maps: 1:25,000 topographic map, satellite imagery, Digital Elevation Model (DEM), Shuttle Radar Topography Mission (SRTM) model, Infrared Imagery, Orthophoto Imagery (uniform scale aerial picture)
- Statewide data collection: roads, railroads, rivers, main cities, transmission lines, county limits, Township, Ranges and Sections, springs, landowners and temperature gradient wells from the Southern Methodist University (SMU) database.
- Digitized results of Trexler et al. (1982) exploration program: 2-meter-depth (6.5-ft-depth) temperature probe survey, 115 ft (35 m) temperature gradient hole locations with temperature data, and geochemical sampling sites with analysis results.
- New Oski data (all spatially referenced using coordinate system NAD 1983 UTM Zone 11N):
  - Oski private and BLM lease blocks and access roads,
  - Sixty mineral exploration borehole locations, with total depth and lithologic information.
  - Bouguer gravity contours, the survey was carried out for Pediment Gold, LLC., on the Oski project in 2010,
  - Six 500 ft (150 m)depth Temperature gradient holes and the temperature gradient contours simulated using Oski and SMU temperature gradient holes,
  - Two hundred and forty four soil sampling locations for Mercury concentration measurements and contours,
  - 2.5D seismic survey, achieved by Optim, Inc. Seismic lines, station numbers and structural interpretation were added in the GIS database.
  - Location of potential drilling targets for 2500 ft (760 m) deep slim holes

This information, and any subsequent additions, will be delivered at the close of the project.

4.0 ADVANCED SEISMIC DATA ANALYSIS - (SOPO Subtask 1.2)

The Hot Pot seismic survey was carried out during October, 2010. Preliminary results were delivered in November, and refined during December 2010 and January 2011. Layout for the seismic lines is presented in Figure 10.

This project's premise is that the advanced and innovative processing techniques, as detailed in Appendix A, will yield results superior to those obtained by conventional processing. This potential improvement in interpretation is significant because traditionally, surface seismic surveys have not been effective as a geothermal exploration tool generally because of the complex structure and alteration common in geothermal areas, as well as absence of coherent reflectors.

The advanced processing technical approach is detailed in Appendix A, pages 7 - 9. The major processing steps include:

- Derive velocities from first arrivals
- Extend velocity control using coherency optimization
- Refine velocity model using full waveform inversion
- Perform Kirchhoff prestack depth migration to derive steeply dipping reflectors interpreted as faults
- Interpolate velocity model to define structural geometry in 3D

In addition to the advanced method, standard time domain processing with some advanced velocity analysis was applied to lines 201 and 401, so as to demonstrate the extra information that can be derived by the methods used in this project. Both lines showed marked improvement, Figure 11 illustrates the results for line 201.

Two items, not in the SOPO, were added to the work program. First, the velocity model was refined using subsurface lithologic data . The velocity contrast interfaces were manually adjusted and propagated throughout the velocity volume. This step resulted in a significant data quality improvement as shown in Figure 12. Second, the final interpretations were displayed using advanced subsurface visualization software (Figure 13). This step facilitates data interpretation and helps ensure that when good quality data is obtained, it is fully utilized. Appendix A, pages 46 – 52, contains additional displays from the subsurface visualization program .

4.1 Integrated Analysis

Five seismic lines were laid out in a grid pattern. Lines 101 and 201 are oriented N45°W approximately 6000 ft (1850 m) apart. Lines 301, 401 and 501 were oriented N45°E and approximately 6000 ft (1850

m) apart. Lines 101 and 201 were designed to image northeast-striking faults, while lines 301, 401, and 501 were designed to image northwest-striking faults. All lines show Cenozoic basin deposits that locally include Pliocene basalt flows. These deposits unconformably overlie Paleozoic basement. In the Hot Pot area, this basement mainly consists of the Ordovician Valmy Formation, an important unit of the Roberts Mountains allochthon (Section 3.0). Upper Paleozoic units may also occur within the basement. In all lines, the Valmy Formation includes both reflective and non-reflective zones, which here are interpreted to represent well-layered and non-layered subunits. The non-layered subunits may include melange, while the units with discontinuous layering may be large slices of chert, quartzite, and/or greenstone.

4.1.1 North West - South East lines (101 and 201)

Line 101

Line 101 (Figure 14) images two large normal faults with a southeast dip component. Fault A projects to the surface at the Hot Pot hot springs and has an apparent dip of approximately 45 degrees to the south east. If Fault A strikes north northeast, fracture distributions would match the hot spring vent alignments at Hot Pot. In the Valmy Formation, Fault A includes a prominent reflective zone approximately 400-500 ft (120-150 m) thick that intersects the subhorizontal reflection fabric of the Valmy. This could be interpreted as a tectonic slice along the fault. Within the top 2000 ft (600 m), Fault A shows a normal displacement of a set of two long wavelength reflections to the south east, separated by fine-scale reflections. This reflective unit is approximately 1200 ft (365 m) thick and may be part of the Valmy or part of a Paleogene volcanic unit. In line 401, a unit with similar reflection characteristics is within the upper part of the Valmy, so this unit is regarded as part of the Valmy. As interpreted, Fault A bounds a half-graben filled with approximately 900 - 1200 ft (275-365 m) of Neogene sediment.

A second fault (Fault B) has a surface projection near Station 290, where it coincides with a north-striking Quaternary fault scarp. Fault B shows large apparent normal displacement (~2800 ft; ~850 m) of a reflective unit tentatively interpreted as Paleogene volcanic and sedimentary rocks with apparent dips up to 45 degrees toward the interpreted fault plane. The hanging wall of Fault B also includes a large half-graben with up to 2000 ft (600 m)of sedimentary fill showing dip-fanning which suggests the fault is a growth fault that was active during sedimentation in hanging wall block.

A shallow, highly reflective unit lies at approximately 250 ft (75 m) in the northwest portion of Line 101 and appears discontinuously near the base of the Neogene section. Near Station 170, this reflection matches Pliocene basalt in a nearby borehole. Boreholes show no evidence of basalt in the vicinity of line sections southeast of Station 170, making the identity of this unit uncertain in other places. This highly reflective horizon may represent an older volcanic unit near the base of the Neogene section.

A third possible fault near Station 167 has a northwest dip component with a few hundred feet of apparent reverse separation and is overlapped by a possible basaltic unit near Station 170.

Line 201.

Line 201 (Figure 15) images two faults with northwest dip components, one near Station 165 and the other near Station 215. Fault C, near Station 165, produces <1000 ft (300 m) of apparent normal displacement of the top of the Valmy, and shows part of a small half-graben in its hangingwall. Fault C does not appear to cut the upper 1000 ft (300 m) of Neogene strata. Fault D, at Station 215 and may have a possible tectonic slice in the Valmy Formation aligned along the interpreted fault plane at depths of approximately 3500-4500 ft (1060-1670 m).

Fault D appears to truncate a long wavelength reflective unit in its hanging wall that, from relations in line 401, may represent a unit in the Valmy Formation. In the footwall of Fault D, Valmy is intercepted at Station 225 in a nearby borehole at a depth of 335 ft (100 m). In the hangingwall of Fault D, the top of Valmy is apparently at approximately 1000 ft (300 m), suggesting apparent vertical throw of approximately 700 ft (215 m). Line 201 may show Fault B, although at an oblique angle, near stations 350 – 360. Alternatively, this low angle (apparent dip) feature is the southerly extension of Fault F.

The top of the Valmy is at shallow depths from Station 220 to approximately 295, and then descends gradually to approximately 2000 ft (600 m) near Station 380. At Station 287, a nearby borehole intercepted greenstone at the top of the Valmy at a depth of 565 ft (170 m). The upper 200-300 ft (60-90 m) of the Valmy in this area shows some reflectivity.

The Cenozoic (Neogene?) section appears to reach maximum thicknesses at Station 155 (~2000 ft; 600 m) and at Station 380 (~2000 ft; 600 m). Pliocene basalt that is present at shallow depths (150-190 ft; 45-60 m) in boreholes between Stations 101 and approximately 250, is not imaged in line 201. Other data indicates Pliocene basalt is absent from Station 250 to 380.

4.1.2 South West – North East Lines (301, 401, and 501)

Line 301.

Line 301 (Figure 16) prominently images Fault E near Station 255, with a southwest component of dip. Fault E apparently defines a half-graben and hanging wall units show dip fanning and a hangingwall rollover anticline. The footwall of Fault E shows a gently dipping, highly reflective unit at depths of approximately 600 to 1000 ft (180-300 m) near the base of the Cenozoic section between Stations 270 and 310 that cannot be a Pliocene basalt because boreholes show Pliocene units between 100 and 200 ft (30-60 m) throughout this section. If the basalt is not imaged in this line, this prominent reflector may be an older volcanic unit near the base of the Neogene section.

The southwest end of this line, between Stations 101 and approximately 180, shows a wedge-shaped, strongly reflective and continuous unit between the Valmy and the Cenozoic section. This unit varies in apparent thickness from approximately 1500 ft (450 m) at Station 110 to a pinchout near Station 180 and may be an upper Paleozoic unit resting unconformably on the Valmy Formation. Interestingly, Permian Edna Mountain Formation that is younger than the Valmy occurs locally on Treaty Hill approximately 2.5 miles (4 km) south southwest of the end of line 301. In surface exposures, the Edna Mountain Formation rests unconformably upon Valmy Formation.

A northeast-facing scarp at Hot Pot Creek is near Station 222. Although line 401 images a northeast - dipping fault coincident with this scarp, there is no clear seismic reflection indication of a northeast - dipping fault near Station 222 on this line.

Line 401.

Line 401 (Figure 17) images two normal faults with northeast dip components. Fault B, the same fault noted in line 101, projects near a Quaternary scarp at Station 274 and is well defined in the Valmy Formation as it truncates various reflective and non-reflective zones. The hangingwall of Fault B is an asymmetric half-graben with Neogene and, speculatively, Paleogene units showing dip fanning toward the fault. Both hanging wall and footwall of Fault B are prominent reflectors and may be a volcanic unit near the base of the Neogene section (discussed previously) with approximately 1500 ft (450 m) of apparent normal displacement on the fault.

Fault F is a second prominent normal fault that projects near the surface at a NE-facing Quaternary fault scarp near Hot Pot Creek, at Station 195. Fault F, where it passes through the Valmy, has a large tectonic slice at depths of approximately 3000 to 6000 ft (1-2 km). In the footwall of Fault F, the top of the Valmy Formation is as shallow as 335 to 340 ft (102-104 m) from nearby boreholes while the top of the Valmy in the hanging wall is apparently approximately 1000-1500 ft (300-460 m) deep. The hanging wall of Fault F also includes a 1000-ft-thick (300-m-thick) Neogene section, while the footwall includes a much thinner Neogene section, approximately 300 ft (90 m) thick.

Line 401 locally displays a long wavelength reflective unit with fine-scale reflections between Stations 115 and 145 and between Stations 238 and 266. From two nearby boreholes at Stations 155 and 160 the top Valmy at 674 ft (205 m) coincides with a continuation of a long wavelength reflection suggesting that this particular distinctive reflection is part of the Valmy. Pliocene basalt occurs at depths of 160-210 ft (50-65 m) between Stations 101 and 150 but is absent elsewhere and is not imaged in this line.

Line 501.

Line 501 (Figure 18) images at least three faults. Fault B penetrates to the surface near a Quaternary fault scarp at Station 245 and is imaged in lines 101 and 401. Two other faults surface near Stations 200 (possibly Fault F) and 166 (Fault G). Fault B shows no obvious displacement of Neogene units yet has a Quaternary scarp. Fault B dips steeply as it passes into the Valmy Formation and tectonic slices in the Valmy appear to be aligned with the fault. Both the hanging wall and the footwall of Fault B have a highly reflective unit that in other sections has been tentatively interpreted as Paleogene volcanic rocks. The hangingwall of Fault B also includes a half-graben of Neogene basin fill as in lines 101 and 401. In this line, the Neogene section has a thickness up to 1500 ft (460 m) and shows dip fanning. The footwall of Fault B has a thick, well-layered section within and below the possible Paleogene reflective unit that may be part of a half-graben lying in the hangingwall of Fault F.

The footwall of Fault F has the top of the Valmy at approximately 1000 ft (300 m) depth while definite Valmy occurs below 3000 ft (900 m) beneath its hanging wall half-graben. Fault F, imaged here and in line 401, apparently strikes northwest, dips northeast and coincides with a Quaternary fault scarp mapped at the surface along Hot Pot Creek. Line 401 does not show any detectable displacement of the Neogene units at Fault F. Fault G, a third fault in this line, has a SW-dip component and produces approximately 700 ft (215 m) of apparent displacement of the top of the Valmy.

At Station 105, a nearby borehole encountered greenstone in the Valmy Formation at 555 ft (170 m) depth. The contact between Neogene sediments and Valmy greenstone is not particularly distinct at this point in line 501, probably because this is 500 ft (150 m) from the end of the line, and geophone coverage was poor. A borehole near Station 105 penetrated Pliocene basalt at 390 ft (120 m) but this unit is not imaged in line 501 and no Pliocene basalt was logged in wells lying near the central parts of the line.

4.1.3 Line intersections

As shown below, in most cases, where seismic lines cross there is usually very close correspondence in units imaged and their apparent thicknesses. This provides additional confidence in the images and in the 2.5D velocity model used to produce these images. One problem area is where lines 101 and 301 cross (near Station 165 in line 101 and Station 250 in line 301). As shown below, the units imaged where these two lines cross do not correspond very closely, and interpretations in this general area should be made with caution.

Line 101

Line 101 crosses line 301 at Station 165, line 401 at Station 230, and line 501 at Station 293.

Where lines **101 and 301** cross, there is an unexplained lack of correspondence of units. Both lines image Fault E, which must dip steeply west, but in line 101 the fault shows reverse displacement and does not appear to cut Pliocene basalt, while in line 301, the fault appears normal and has a Neogene half-graben in its hangingwall. The two lines do not match closely in the Neogene sections.

Where lines **101 and 401** cross, there is fairly close correspondence in the Neogene sections. Both lines image a prominent fault in the Valmy, Fault A at approximately 3000 ft (900 m) depth (line 101) and fault F at approximately 4500 ft (1370 m) depth (line 401). Both faults show evidence of tectonic slices in the Valmy. Nevertheless, these cannot be the same fault, because line 101 runs approximately parallel to strike of Fault F, and Fault F, if imaged in line 101, would appear horizontal.

Where lines **101 and 501** cross, both lines image Fault B, which strikes NNE, and its hangingwall half-graben. Both lines also image the highly reflective unit which is tentatively interpreted as Paleogene volcanic rocks.

Line 201

Line 201 crosses line 301 at Station 167, line 401 at Station 234, and line 501 at Station 298.

Where lines **201 and 301** cross, both show a thin Neogene section (1500 ft;460 m in 101 and ~700 ft; 215 m in 301) resting on Valmy. Fault C, which dips NW in line 201, is not imaged in line 301.

Where lines **201 and 401** cross, there is close correspondence of units and thicknesses. Both lines show very thin Neogene (<500 ft; 150 m in 201 and in 401) resting on shallow Valmy (top at approximately 335 ft; 100 m in both lines).

Where lines **201 and 501** cross, there again is close correspondence. Both lines show ~800-ft-thick (~240-m-thick) Neogene sections resting on Valmy.

4.2 Summary of Structural Interpretation

Figure 19 and Table 1 provide a summary of faults interpreted from the integrated analysis. Faults A, B, and F appear to be major faults, and have clear surface expression, while Faults C, D, E, and G appear to be minor faults. Many of these faults were originally inferred from detailed gravity data.

Fault A is a largely concealed normal fault with a northeast strike and dip to the southeast . It coincides with the spring alignments at Hot Pot hot springs and the associated lineament to the northeast. Line 101 shows a ~1000-ft-thick (~300-m-thick) Neogene section in its hangingwall.

Fault B (Eastern fault) is a normal fault which strikes to the north-northwest with a dip to the east. It is imaged in lines 101, 401, and 501. This fault has a notable east-facing scarp approximately 15-25 ft (5-8 m) high, and also has a major half-graben with over 2000 ft (600 m) of Neogene (and possibly Paleogene) strata in its hanging wall.

Fault C, which is imaged only in line 201, apparently strikes northeast and dips northwest, and does not extend to the surface. Its south west extension is inferred on the basis of gravity data. It has up to 2000 ft (600 m) of Neogene strata in its hanging wall.

Fault D is imaged in line 201, may be subparallel in strike to Fault C, and also dips northwest. It also contains a thicker Neogene section in its hanging wall, possibly over 1000 ft (300 m) in thickness.

Fault E is imaged in line 301 and appears to strike northwest and dip south west. It may be relatively short, but a half-graben in its hanging wall contains over 1300 ft (400 m) of Neogene strata.

Fault F (Hot Pot fault), which is imaged clearly in lines 401 and 501, strikes northwest, dips northeast, and coincides with a 20-ft-high (6-m-high) scarp along Hot Pot Creek. From continuity of the scarp, this fault is projected northwest toward the edge of the project area, although the fact that the fault is not imaged in line 301 is problematic. Both lines 401 and 501 show a significant half-graben with Neogene strata in the hangingwall of Fault F. Line 401 shows a large slice of Valmy aligned with the fault from approximately 3000-6000 ft (1-2 km) depth.

Fault G, which is imaged in line 501 appears to be a fairly minor normal fault with a strike to the northwest and southwest dip. It does not have any surface expression.

4.3 Discussion

Comparisons Between Optim Fault Interpretations and Faults in Integrated Analysis

The integrated seismic data analysis incorporates information from regional geology, borehole data, and local field observations, whereas Optim interpreted several faults solely on the basis of the seismic images. While in most cases there is good agreement, some differences exist between the two interpretations. Some of the proposed Optim faults are inferred within the Valmy based on assumptions of lateral continuity of reflective zones. From the chaotic nature of the Valmy, lateral continunity of reflections is unlikely, but that does not rule out the possibility of blind faults in the Valmy that may be reactivated in the current ambient stress field and might provide permeability in the subsurface. Faults shown in Figures 14-18 usually are inferred on the basis of thickening or fanning of Neogene strata together with steeply dipping reflective zones in the Valmy. Similarities and differences between Optim interpreted faults and those shown here are given below.

Line 101. Figure 14(Figure 4k of the Optim report) show that Faults A and B were also identified by Optim (faults 4 and 1, respectively).

Line 201. Figure 15 (Figure 5k of the Optim report) shows that Fault C was identified as fault 5 and fault B was identified as fault 1, but two other faults in Figure 5k are not shown in Figure 15. Faults 2 and 3 in Optim Figure 5k may represent blind faults in the Valmy, but are drawn on the assumption of lateral continuity of units within the Valmy, which we regard as unlikely. Neither of Optim's hypothetical faults can be projected into the Neogene section.

Line 301. Possible faults 2 and 6 in Optim (Figure 6k) are not shown in Figure 16. As in line 201, these features may represent blind faults in the Valmy, but we believe the evidence for these is inconclusive.

Line 401. Figure 17 (Figure 7k in the Optim report) both depict Faults B and F; these are labelled as faults 1 and 2 in Optim Figure 7k. Evidence for fault 4 in Optim Figure 7k is inconclusive, and this fault is not depicted in Figure 17.

Line 501. Faults B and F in Figure 18 were both identified in Optim Figure 8k (Optim faults 1 and 4, respectively), although Fault F is shown with a steeper dip in Optim Figure 8k. It is preferred to model a gentler dip, because the fault shown by Optim appears to project through a zone of high-amplitude reflections in the Valmy, which shows no offsets. Additionally, Optim Figure 8k depicts a third fault, fault 2, between stations 160 and 170, that is not shown in Figure 18. This possible structure may represent a blind fault in the Valmy, as it shows no expression in the Neogene section. Figure 18 also shows Fault G as dipping to the south west near station 160, on the basis of possible southwestward thickening of the Neogene section.

4.4 Lessons Learned

The main lesson learned is that the advanced seismic data analysis process is sensitive to, and receptive to, several input variables. The results obtained at Hot Pot were enhanced by informed program design, calibration for geologic information, and extensive client – contractor interaction. The contributions of each program aspect are discussed below.

4.4.1 Program design

Planning seismic lines in a grid pattern (preferentially orthogonal to structural features) enhances the interpretive power of the advanced processing methods. The grid location utilized input from other surveys, particularly gravity and temperature gradient programs and the grid was oriented to image as many known structures as possible. Faults are most easily, and accurately, imaged when the seismic line is nearly perpendicular to fault strike. At Hot Pot, the two most probable Quaternary fault orientations (from published U.S. Geological Survey information) are approximately northeast and northwest. The grid was oriented accordingly. Line length was also a factor in obtaining interpretable seismic reflection results. Lines extending (with appropriate permits) beyond the project boundary and into the adjacent basin were particularly useful because the outlying data points allowed seismic information to be obtained completely to the edge of the area of interest. Additionally, these line segments extended beyond the basement high and therefore provided information on Neogene basin fill thickness and potential Paleogene reservoirs.

4.4.2 Use of subsurface control

Lithologic data from mineral exploration borings and temperature gradient holes were vital in constraining reflection seismic interpretation. During preliminary interpretation, it was apparent that the major reflectors, such as top Paleozoic basement, appeared to be as much as 1000 ft (300 m) below their known elevation. This information was used to adjust the velocity model, and Figure 12 illustrates the resulting improvement. Not only were the reflectors moved to match the known stratigraphy, but better constraints allowed more detailed interpretation of basement structure. The detail that emerged from the deep, high velocity and sometimes acoustically isotropic basement is a major contribution of this project.

4.4.3 Interdisciplinary approach

A highly experienced interdisciplinary team helps obtain the best possible data and generate realistic interpretations. The Hot Pot project team met regularly to discuss data quality concerns, processing constraints and reprocessing options. Relevant geologic information was used to refine seismic model data input. These discussions, although time consuming, were critical to project success. The seismic products that eventually evolved were significantly improved over the initial results.

4.5 Application of Advanced Seismic Data Analysis Program

The Hot Pot project experience shows that advanced seismic data analysis applications extend beyond simply identifying faults in the subsurface. If high-quality seismic results can be obtained during the early stages of geothermal exploration, there are three major benefits:

- Good seismic interpretation constrained by other subsurface data allows better targeting of intermediate depth wells to confirm specific formations and/or structures. Wells can also be appropriately designed to carry out limited resource testing activities. While intermediate depth wells have been used in Basin and Range prospects primarily as deep temperature gradient holes (Benoit 1978, Pilkington, 1982, Fairbank, 2004, Lazaro et al, 2010), better subsurface information early in the exploration process allows intermediate depth slim holes to serve as shallow exploration wells to confirm subsurface stratigraphy and test potential fault targets before a full-scale well is sited and drilled.

- Reduced drilling risk due to improved target selection and well drilling programs designed for anticipated subsurface conditions can result in reduced exploration cost.

- Advanced seismic processing adds significant detail and additional constraints in developing a reasonable geologic conceptual model that is critical prior to committing to the expense of drilling. Utilizing a plausible and continually refined geologic conceptual model based on all relevant data is arguably the single most effective exploration risk-reduction technique. Traditionally, conceptual models are refined only during the deep well drilling phase, often as a result of unsuccessful wells. At Hot Pot, detailed conceptual models have already been developed, as discussed in the following section.

5.0 CONCEPTUAL GEOLOGIC MODELS

Conceptual models provide the framework that transforms exploration survey results into drilling targets. A well-planned exploration program contains drilling locations which test one or more conceptual models. This process leads to better system characterization and reduced risk in subsequent wells. The most basic Hot Pot conceptual model is similar to established geothermal systems in much of the Basin and Range province. Precipitation in mountainous areas slowly percolates into the exposed rock formations and migrates down-gradient toward the valleys where it infiltrates into the subsurface. The relatively high regional heat flow allows the downward percolating water to be heated to temperatures on the order of 300 - 400°F (~150 - 200˚C). The deep, heated water may then rise to drillable depths along a fault or combination of fractures to depths accessible by geothermal wells.

The major uncertainty, and hence exploration risk, is associated with where the heated fluids rise to shallow depths and how they are stored, if at all. Many conceptual models focus on structure in order to explain how and where geothermal fluids may rise to drillable depths. Other conceptual models focus on fluid storage or geothermal reservoir characteristics. Predicting plausible reservoir locations is difficult particularly in areas like Hot Pot where potential controlling faults or fractures are obscured beneath a sequence of Tertiary and Quaternary basin fill sediments between adjacent mountain ranges. The phases of the Oski innovative exploration program are intended to integrate detailed knowledge of the regional and local geology, tectonic history, existing exploration data and advanced reflection seismic interpretation to select slim-hole drilling locations to confirm that shallow temperatures persist to greater depths, infer the location of upwelling geothermal fluids and select the site for a full-scale production test well.

Through integration of the regional geology, GIS compilation of exploration data, and the advanced seismic analysis program completed in Phase 1, along with elements that have contributed to geothermal development in other areas of the Great Basin, three site-specific conceptual models have been developed:

5.1. Secondary permeability in the older deeper Paleozoic rocks.

The Ordovician Valmy Formation is a highly permeable unit in the Beowawe geothermal system, located approximately 31 miles (50 km) southeast of the Hot Pot project area, within the Roberts Mountain allochthon in central Nevada (Garg et al., 2007; NBMG, 2008; Cole and Lavinsky, 1984; Struhsacher, 1980), and is saturated by geothermal fluids within secondary fractures developed during a long structural history of tectonic emplacement during Paleozoic/Mesozoic, convergence and later Cenozoic extensional deformation. In Beowawe, as potentially at Hot Pot, the Valmy is sealed where it is overlain by Cenozoic volcanic and sedimentary units. Geothermal fluids reach the surface where the overlying Cenozoic cover is deformed by penetrative faults that locally control the circulation of deeper thermal fluids.

As discussed in Section 3.0. The Valmy Formation is a major component of the Roberts Mountains allochthon in north-central Nevada. It was emplaced along the Roberts Mountains thrust in Devonian-Mississippian time, and in late Paleozoic and Jurassic times, the Valmy has been deformed by a variety of faults and folds. Cenozoic extensional and strike-slip faults have also resulted in further brittle deformation of the Valmy (Dickinson, 2006; Wallace et al., 2008).

The Valmy is a complex mixture (melange) of structurally competent rock types including chert, quartzite, and basalt, and less competent shale and argillite. In some areas, the rocks are stratigraphically coherent but in many, if not most areas, stratigraphic continuity is lacking and chaotic zones alternate with large blocks of one or more competent units (Peters, 2000). Detailed evaluation of open pit exposures in operating gold mines such as Marigold, Getchell and others show that the Valmy can be an intensely fractured volume of rock (R. Schweickert, personal communication). The most common Valmy lithologies such as chert and quartzite are competent and highly brittle; consequently from Paleozoic, Mesozoic and Cenozoic deformation[s], these units are highly shattered and brecciated. The shale-chert matrix between larger slices of chert and quartzite, while much less competent, is also pervasively faulted and fractured. In some areas, intense silicification from hydrothermal fluids has cemented the fractures rendering the less competent rocks impermeable but also brittle. Overall, these silicified masses appear be somewhat localized but even where they are extensive, the silicified rock commonly shows signs of re-brecciation.

Gold mines at Marigold, Getchell, Turquoise Ridge, and Twin Creeks in the Osgood Mountains and piedmont ~20 miles (32 km) north of Hot Pot all exploit ore bodies in the Valmy or underlying Paleozoic units suggesting that the Valmy can be projected into the deeper Humboldt Basin and probably comprises the principal bulk of Paleozoic rock underlying the Neogene [Tertiary]/Quaternary basin fill. Dewatering of gold mines surrounding the basin as well as groundwater withdrawals to support the evaporative cooling needs of the adjacent 540 MW Valmy coal-fired power plant have most-likely contributed to the shallow water table decline and drying out of the springs at Hot Pot. The available hydrologic interpretations suggest that secondary permeability within the Valmy Formation or other parts of the Paleozoic section is regionally continuous within Paleozoic rocks underlying the Humboldt River basin around Hot Pot.

5.2. Permeability within shallower Paleogene section

Regional geophysical data summarized in previous sections suggest that 2000-3500 ft (600-1050m) of Tertiary Paleogene strata may exist between known Pliocene basalt units and the deeper Paleozoic rocks. New Oski gravity data (Section 3.2) and reflection seismic interpretations (Section 4.0) collected for this DOE-funded exploration effort at Hot Pot indicate that 1000-1500 ft (300-450 m) of Miocene and older Paleogene units probably exist beneath Quaternary sedimentary valley fill and Paleozoic basement Seismic reflection Lines 101, 401 and 501 (Section 4.0) highlight some highly reflective sections, suggesting that Miocene and pre-Miocene volcanic units are present.

If confirmed in the next project phase of slim hole drilling or the final phase of deep drilling, this Tertiary section of rocks may serve both as an impermeable cap above the Paleozoic basement or, where permeable, may channel fluid flow horizontally between faults. The Paleogene section, by analogy with surrounding regions, probably includes Eocene to Miocene gravels, sands and shales together with Oligocene-Miocene ash-flow tuffs (Wallace et al., 2008). The gravels, sands and fractured-welded tuff intercalations are likely to be highly permeable. Shale and mudstone, together with poorly welded or extensively clay-altered ash flow tuffs, may form impermeable zones within the Tertiary section. Permeable and impermeable units are likely to be interlayered in complex ways but overall the physical characteristics of these units would promote horizontal fluid flow similar to other developed Basin and Range systems like Brady's Hot Springs or Tuscarora.

5.3. Fault controlled permeability in a deeper geothermal system

Fault zones of varying dips and separation in the Basin and Range province are commonly marked by narrow to broad zones of highly fractured rock that can be primary zones of permeability and, where they penetrate deeply, eventually convey geothermal fluids to shallow levels. Common Basin and Range geothermal models also include deep penetration of surface waters along peripheral faults to increase fluid temperatures in a region of elevated heat flow by contact with hot rock (Benoit, 1997; Blackwell et al, 1999, Blackwell et al 2002; Honjas et al., 1997). In the Humboldt Basin and around Hot Pot, permeable faults could include not only steeply dipping faults with surface expression but also high and low-angle faults within the Paleozoic basement that have no surface expression. The challenge of developing innovative exploration methods is to identify and target deeply penetrating faults as zones of preferential permeability and fluid flow particularly where, as at Hot Pot, those faults are buried under thick Paleogene and Neogene deposits and/or embedded deep within fractured Paleozoic basement.

A simple conceptual model of faults controlling permeability is unsatisfactory by itself because numerous high-angle normal faults in the Basin and Range province are impermeable and several large displacement range-front faults have been drilled in geothermal prospects that have no permeable link to hot fluids (Blackwell et al., 2002). Hence, other factors, including, but not limited to, fault structure, strain history, degree and extent of cementation and the current ambient or local stress field must be considered.

5.3.1 Fault structure.

Major faults in the upper crust are commonly composed of at least a fault core and a damage zone (Caine et al., 1996). In outcrop, a fault core is typically an impermeable clay-rich zone of fine-grained, highly foliated and pulverized gouge, fault breccia and crush breccia. The damage zone is typically permeable surrounding the fault core consisting of highly fractured and/or brecciated country rock with little or no clay. A fault with well-developed core and damage zones may serve both as a permeability barrier to cross-fault fluid flow, and as a conduit for both lateral and vertical fluid flow. The degree to which fault core and damage zones are developed on a given fault are influenced by, among other things, the amount of displacement and parent rock. A fault with little displacement is unlikely have a well-developed fault core and may be characterized only by a damage zone. Along a mature fault, if the parent rock is competent, the damage zone may be extensive while damage zones tend to be weakly developed in incompetent units.

5.3.2 Rupture/strain history.

A seismogenic rupturing event commonly produces a permeable zone of fracturing and brecciation along the part of the fault rupture surface. For periods of hundreds to thousands of years following a surface-rupturing seismic event, the fault is likely to show increased permeability and pressurized fluids can escape through or along the fault. As the fluids are depressurized and lose heat, dissolved solids precipitate resulting in mineralization within fractures. If high temperature high salinity fluids make it to the surface, hot springs and sinter deposits develop as temperatures and pressures change and dissolved constituents are no longer stable in solution. Within a few thousand years of a rupturing event, a typical fault may lose most or all of its permeability because of cementation by mineralization (Sibson, 1992). A corollary of the rupture cycle hypothesis is that between rupturing events fluid pressure may build up along an impermeable fault to the point that that high fluid pressure may trigger a future rupture event (Sibson, 1992). Whether a given fault segment is permeable or not thus may be strongly influenced by its position in time within its rupture cycle. Intersections of faults and/or fractures may complicate this behavior.

5.3.3 Degree and extent of mineralization/cementation.

Fluid flow along any permeable fault or fault segment is likely to be highly variable due to variations in rock type, fracture density, fracture aperture and other factors. Hence, cementation by precipitating minerals from thermal fluids may also be highly variable along any given fault or fault segment. For example, fluid flow after a seismogenic rupturing event may be localized by any of these factors causing heterogeneous distribution of cementation sites. Quaternary faults that have ruptured within a few hundred to a thousand years in the Basin and Range are favorable targets because, all other things being equal, recent fault deformation is most likely a zone of high permeability but even in the best case, permeability may be somewhat localized. The geologic mapping and evaluations in this study have identified several potential Quaternary faults deforming Holocene sediments in the Hot Pot area including one potential scarp that appears to control the former spring outflow points and the linear distribution of sinter deposits.

5.3.4 Stress distribution.

Induced fracturing experiments in boreholes and subsequent evaluation of imaging logs (Hickman et al., 1997; Lutz et al., 2010) demonstrate that the most probable orientation of open fault-related fractures are preferentially oriented to the current ambient stress field. The relationship to current stress is imperfect because open fractures may persist at differing orientations where mineralization has preferentially propped fractures open or maintains an open network of fractures. Since fluid flow along any permeable fault or fault segment depends on open connected fracture networks, determining ambient stress and the orientation of principal horizontal stress (also termed Sh max, intermediate stress or σ-2) and least horizontal stress (Sh min or σ-3) are important in defining potential fracture orientation and preferential direction of fracture propagation (Hickman et al, 1997; Lutz et al., 2010). Studies within the Basin and Range (Blewitt et al 2002; Faulds et al.,2004) have established that stress and preferential fracture orientation in the ambient stress field of north central Nevada is conducive to the formation of many potential geothermal systems in a region of elevated heat flow. Recent studies by Faulds et al. (2006) suggest that northeast structural trends are better oriented to provide openings for geothermal fluids. Studies of northern and western Nevada, including the Hot Pot region, show correlation between northeast trending normal faults and developed geothermal fields.

5.4 Hot Pot Conceptual model

The potential geothermal system at Hot Pot is probably controlled by a hybrid of all these structural controls. The Valmy Formation is highly permeable in other systems like Beowawe and potentially allows both for regional recharge from surface waters and for deep penetration of these fluids. Numerous hot springs in the region are preferentially located along faults or fracture zones and existing high and low-angle faults within the Valmy. Ascending geothermal fluids may be trapped in part by impermeable units near the base of the Cenozoic section and may be channeled laterally within permeable units towards vertically penetrative faults. Depending on dip angle, fault structure, strain history, degree of mineralization and orientation in the ambient stress field, deeply penetrating faults may selectively channel geothermal fluids either to the surface as at Hot Pot hot springs or to near-surface levels within a few thousand feet of the surface. Fault and fracture intersections, as at Hot Pot, may produce further near-surface localization of fluids.

The key to the Hot Pot prospect area is identifying all or any of the potential faults that might control the location of the springs and ultimately the circulation of geothermal source fluids at depth in the Hot Pot area. The innovation in this study is to integrate all of the common surface exploration elements with extended processing of reflection seismic data to yield a better image of these faults or fractures that may control deeper circulation and vertical upwelling of geothermal fluids within the crust. The selection of slim hole locations has been based on the best interpreted information to target zones of potential upflow. Drilling Phase 2 slimholes will confirm that the interpreted seismic reflectors are actually faults in or near the upwelling sources of deeper geothermal fluids where a deep targeted full-scale production test can encounter sufficient fracture permeability to sustain continued production. In response to reviewer comments on the Draft Phase 1 Report a schematic conceptual model has been prepared and is included as Supplemental Figure 1.

6.0 PROPOSED DRILLING LOCATIONS - (SOPO Subtask 1.3)

Drilling locations were selected for two intermediate depth (~2500 ft; 760 m) slim holes. The purpose of intermediate depth holes has traditionally been to verify the downward continuation of high temperature gradients identified with shallow (generally 200 -500 ft; 60-150 m) boreholes (Benoit 1978; Fairbank 2004). By drilling to sufficient depths to identify the potential zones of deeper upwelling geothermal fluids, the proposed slim holes will confirm that these areas are not merely regions of outflow with potential temperature reversals. Based on interpretations of the resulting slim hole data and integration with the advanced processed seismic data, reasonable targets can be selected where a deep, full-scale production test can encounter sufficient fracture permeability to sustain continued production.

6.1 Preliminary Slim Hole Locations

Preliminary drilling locations HP 1, HP 2, and HP 3 were selected prior to the DOE-funded seismic survey and are shown in Figure 20 to provide some preliminary indication of where permitting activities might be required and to provide a backup plan in case interpretable results were not obtained from the seismic program. The preliminary site selection process considered most probable, based on existing compiled information. areas of high temperature and high permeability. Favorable site access, size of potential drill sites, lease position, and availability of appropriate permits were also part of the decision process.

At Hot Pot, existing shallow gradient hole data suggest a broad east-west trending zone of elevated temperatures and rapidly increasing shallow gradients. Consequently, the preliminary slim hole locations lie within the area of shallow elevated temperature. Locations HP 2 and HP 3 are near identified Quaternary faults or interpreted fault intersections while HP 1 was sited solely on the basis of high shallow temperature gradients. All three preliminary locations are on roads that can be improved to handle the heavy drilling equipment. All of the preliminary sites are reasonably level and large enough for a conventional full size drilling rig. Land ownership in the Hot Pot area is a checkerboard mix of private and federal (BLM) sections but all three preliminary locations are on private lands where the geothermal rights are held by Hot Pot Geothermal LLC. Oski considers that obtaining slim hole drilling permits on privately owned lands should be quicker than permitting on the BLM parcels.

6.2 Revised Drilling Locations after Integrated Analysis

After integrated analysis and advanced seismic interpretation, several other locations were selected (Figure 21); however, the initial selection criteria are unchanged. Identified temperature gradients were the most important consideration before considering the realities of terrain, access and permits. The detailed subsurface images from the innovative advanced seismic interpretations developed in this project were important in targeting specific faulted areas or potential reservoir formations with the proposed intermediate depth wells. Three target areas were identified based on interpreted structural domain. Within each area, one or more potential locations were selected for permitting. All locations are within the identified thermal anomaly and utilize results from the advanced seismic data analysis program to target specific structures. While two DOE-funded intermediate depth slim holes will be drilled, additional locations were selected to provide backup sites within the same structural domain in the event permitting or site access were to become an issue.

6.2.1 Central Hot Pot Area

Potential drill sites **HP 101** (Line 101, station 218) and **HP 104** (Line 401, station 210) target Faults A and E (Figures 22 and 23) that apparently bound a shallow (~1000 ft; 300 m depth) half graben and that are also associated with a deep highly reflective zone that is interpreted to be a fault within the Valmy Formation. A well at either location is expected to penetrate approximately 1000 ft (300 m) of Neogene basin fill, followed by ~ 1000 ft (300 m)of Paleogene or upper Valmy before passing into Paleozoic basement. Location **HP 104** is closer to the interpreted axis of the Hot Pot temperature gradient anomaly than location **HP 101**, but would require approximately a mile of road construction.

6.2.2 West Hot Pot Area

Potential drill sites **HP 102** (Line 201, station 200) and **HP 105** (Line 201, station 160), target west-dipping Faults C and D (Figure 24) that are associated with a graben filled with approximately 2000 ft (600 m) of Neogene sediments.

A well at location **HP 102** is expected to penetrate ~ 1000 ft (300 m) of Neogene basin fill before reaching strong reflectors that could represent Paleogene sediments and basalts, or alternatively, the upper Valmy Formation. **HP 102** could penetrate a fault at approximately 2000 ft (600 m). A well drilled at location **HP 105** should penetrate nearly 2000 ft (600 m) of Neogene basin fill before reaching a fault and potentially passing into Valmy in the footwall.

Location **HP 105** is less than a mile east of TG 9-1 where the temperature gradient is the highest calculated from the Oski temperature hole program; however, the boring extended to only 187 ft (57 m) TD due to drilling problems. The **HP 102** location appears to lie at the intersection of east and west dipping basement faults. The west dipping fault is also manifested by a small Neogene half graben. A well at location **HP 102** would penetrate a strongly reflective Paleogene(?) interval, and therefore provide information regarding the viability of permeability within shallower Paleogene section rocks (conceptual model #2).

6.2.3 East Hot Pot area

Potential drill site **HP 103** is located at station 282, line 401 (Figure 23) targets Fault B that forms the eastern boundary of the basement high beneath the Hot Pot area identified from seismic and gravity interpretations. Fault B is visible on the surface as an approximately 15 ft (5 m) high scarp, down to the east. The fault also appears on the USGS Quaternary fault database and corresponds to a strong horizontal gravity gradient. The HP 103 slim hole is expected to penetrate the Neogene basin fill section to approximately 1500 ft (450 m) before penetrating possible Paleogene sediments. Fault B could be penetrated at 2000 ft (600 m) followed by Paleozoic basement to TD of 2500 ft (760 m). The location is near existing roads and within, but at the north margin, of the interpreted 9˚F/100 ft (163°C/km) anomaly. The HP 103 location is at the eastern boundary of the project and a slim hole at this location might do little to define subsurface conditions over the broader project area.

6.3 Final Proposed Slim Hole Locations

The central and western Hot Pot areas are the primary locations for drilling intermediate depth (2500 ft; 760 m) slim holes in Phase 2 of the DOE funded Hot Pot project. Although all the proposed drilling locations are based on integrated analysis and would satisfy the program objective of validating the advanced seismic data analysis program, these two areas are judged to contain the highest priority sites.

Proposed slim hole HP 101 and HP 102 (Figures 22 and 23) are the proposed locations for slim hole drilling. HP 101 is proposed as the primary location with HP102 as the second site.

6.3.1 Central Hot Pot Area,

Based on access and potential road construction costs **HP 101** (Figure 22) is recommended for the first well. The central part of the Hot Pot prospect is considered a prime exploration target because faults within this area apparently extend from the former Hot Pot spring site downward into the underlying Valmy Formation. The existence of the deeper fracture zones was apparent only through the advanced seismic data analysis program. Either well **HP 101** or **HP 104** could validate the continuation of shallow temperatures to greater depths and potentially identify a central upwelling source of the Hot Pot springs and show the benefits achieved by advanced integrated interpretation and seismic processing to reduce exploration risk. **HP 101** is recommended as the first slim hole to drill given the probable additional cost to access location **HP 104.**

6.3.2 Western Hot Pot Area

The western Hot Pot exploration area includes proposed locations **HP 102** and **HP 105** (Figure 24) that are recommended as locations for the second slim hole. Both locations target west dipping faults (Faults C and D) that apparently account for several hundred feet of offset at the top of the Valmy Formation. Faults C and D were initially interpreted from gravity data but their exact location, westerly dip component, and magnitude of offset were revealed only after the seismic survey. Either location should provide an opportunity to validate the advanced seismic data analysis program. **HP 102** is recommended because of its proximity to the possible shallow subsurface extension of a deep reflective section in the Valmy in the vicinity of stations 220 – 280. Therefore, a hole at location HP 102 could validate multiple and possibly intersecting structures that might control an upwelling geothermal source.

6.3.3 Eastern Hot Pot Area

Potential drill site **HP 103** (Figure 23), located within 1000 ft (300m) of the eastern project area boundary, is considered a lower priority because the results might not be widely applicable to the entire 25 square mile (65 square kilometers) project area. Additionally, Fault B is documented in the USGS Quaternary fault database (USGS, 2006) and has an obvious surface expression. Validating all the potential contributions of the advanced seismic data analysis program is not likely from drilling results at this location.

7.0 DRILLING COSTS

Appendix D contains drilling cost estimates and detailed drilling programs for the two intermediate depth slim holes. Given the uncertainties of location and depth, a cost estimate for the resource confirmation well would not be realistic at this time.

Each slim hole is estimated to cost approximately 1.5 million dollars. The high cost is not due solely to the normal factors of ever-increasing time and material costs. As discussed earlier, results obtained with the advanced seismic data analysis program enable the intermediate depth wells to serve as much more than deep temperature gradient holes. The drilling program provides for monitoring of mechanical drilling functions and formation characteristics. The drilling program, and therefore cost estimate, also includes a limited suite of electric logs and rig time at the end of drilling for preliminary formation testing. Another factor contributing to well cost is location. Many geothermal areas are relatively remote, and Hot Pot is no exception. The remote location and probable need for some access road improvement add to mobilization/demobilization and site preparation costs.

Subsequent to preparation of the Draft Phase 1 report, alternative, and potentially less expensive, drilling techniques have been considered. Informal discussions suggest that wireline core drilling could provide rapid penetration rates with the added bonus of continuous core. The core samples would facilitate analysis of downhole structure and comparison with fault predictions from the seismic program. Although the corehole diameters are typically less than those of a mud rotary operation, electric logs, including resistivity, sonic, density and gamma ray/neutron can still be obtained. An assessment of wireline corehole drilling feasibility and preparation of revised drilling programs and cost estimates will be undertaken in Phase 2.

8.0 RISKS AND RISK MITIGATION

Exploration risks can be classified as resource, drilling, and institutional. Each type is discussed below.

8.1 Resource Risk

A successful geothermal project requires fluids of sufficient ***temperature***, ***quantity***, and ***quality*** for the intended application.

Temperature

Nature of Risk

Temperatures are insufficient for electric power generation (minimum 275°F; 135˚C).

Mitigation

Existing shallow subsurface data suggest that temperatures of 285 to 320°F (140 to 160˚C) can be reached at depths on the order of 2300 ft (700 m). These temperatures would be consistent with other northern Nevada geothermal fields. Given both the site-specific and regional data, high temperatures (275°F; 135˚C) within feasible drilling depth are a realistic expectation.

Fluid Quantity (permeability)

Nature of Risk

The fluid volumes required for geothermal applications generally require openings in the rock so that the heated water can easily migrate to an accessible depth. In northern Nevada geothermal systems, faults provide fluid migration conduits. The existence of a fault does not guarantee that it is permeable or that if permeable, it contains large quantities of hot water. Consequently, lack of permeability is the most significant risk in many geothermal prospects, and Hot Pot is no exception. Given the fault-controlled nature of the majority of producing geothermal systems, targeting fault zones would increase the probability of intersecting greater permeability.

Mitigation

As discussed in section 6, the advanced seismic techniques have been used to reduce the risk of penetrating a fault target. The seismic images suggest the position and characteristics of faults, and are used in the well design of both slim holes and deep exploration wells to target areas of potentially greater permeability.

Fluid Quality

Nature of Risk

Geothermal fluids sometimes are corrosive or toxic, requiring additional facility engineering and/or modified drilling procedures.

Mitigation

No mitigation is expected to be needed. In northern Nevada, geothermal fluids are generally benign. The geochemistry at Hot Pot has been documented and based on analytical results fluid quality is not expected to be an issue.

8.2 Drilling Risk

Geothermal resource utilization requires multiple deep exploration, production, and injection wells. The equipment and procedures are complex, and the subsurface environment is often hostile and unpredictable.

Nature of Risk

Common problems include stuck tools, holes bridging or packing off, circulation losses, drill pipe twisting off or separating, accidents or errors on the rig floor causing drill string to drop into the borehole, and separation of bit cones or teeth, necessitating a fishing job. The list is virtually endless. Drilling risks are often increased in geothermal areas because of severe drilling conditions including fractured rocks and high temperatures. Both environments can contribute to drilling problems.

Mitigation

Drilling risk can be mitigated by forecasting, as accurately as possible, anticipated subsurface conditions. This allows the drilling operator to select equipment and drilling program best suited to deal with anticipated subsurface conditions. At Hot Pot, the advanced seismic processing reveals an unusually high level of subsurface detail. The enhanced detail, in turn, facilitates better forecasting of subsurface conditions, thereby reducing drilling risk.

Drilling risk can also be reduced by utilizing an experienced contractor with good crews and equipment. Rig-related problems, while never completely avoidable, are greatly reduced by high-quality personnel and equipment. For this project, ThermaSource Inc. (TSI) is scheduled to provide drilling plans and oversight. TSI is widely regarded as an industry leader, with worldwide drilling experience.

8.3 Institutional Risk

Drilling activities require site access and often involve heavy equipment. A complex array of leases, permits and clearances must be obtained before drilling can lawfully proceed.

Permitting

Nature of Risk

Acquisition of required permits can be time-consuming, permits can expire and agency personnel and project operators may disagree on procedures and required environmental clearance. Any combination of these factors can delay field activities and result in higher project costs.

<u>Mitigation</u>

The Hot Pot Geothermal LLC project team has conducted permitted field activities for nearly two years. Private and Federal leases are in place, Rights-of-Way have been obtained for the majority of the Federal leases in the project area and private surface access has been obtained. Communication has been established with appropriate State and Federal agencies. Application of the advanced seismic techniques has focused the selection of potential well sites, reducing the risk of having to change permitted well locations, a common delay in the exploration progress resulting in increased costs, and greater environmental impacts for the project. Environmental clearance and permitting of the well sites determined in this Phase I report will be initiated after review and concurrence by the Technical Committee. Given the work done to date and the project team's extensive experience, institutional delays or problems are not expected.

Note: Subsequent to the submittal of the Draft Phase 1 Report, drilling location and access permits were obtained for five drill sites. Additionally, DOE-required SHPO and NEPA clearances were obtained.

Economic

<u>Nature of Risk</u>

Financial risk associated with the aforementioned resource, drilling and permitting risk.

<u>Mitigation</u>

Application of the advanced seismic analytical techniques on collected seismic data has the potential to reduce the economic risk associated with geothermal exploration. It has the potential to improve drill site selection, well design, and reduce permitting efforts. All of which can lead to reduced time and expense in performing geothermal exploration activities.

9.0 PROJECT MANAGEMENT - (SOPO Subtask 1.4)

As stated in the Hot Pot project SOPO, Oski has provided status reports in accordance with the Federal Assistance Reporting Checklist. Reports submitted to date include:

1. Quarterly 2839 Reports
2. Quarterly Progress Reports
3. Quarterly SF425 Financial Reports
4. Quarterly ARRA reports
5. Annual Progress Report
6. Project Survey 3-1-11
7. Spend plan 11-17-10
8. GTP ARRA Update
9. Geothermal Spending Plan
10. SF1444 – Davis Bacon Semi-Annual Report

Oski accounting staff and management have filed reports, budget updates, and expenditure justifications, and auditing procedures as required by DOE program management and accounting staff. Two external audits have been performed on Oski, relative to the Hot Pot project. First, a 2-day audit was performed by the Inspector general of DOE to evaluate the efficiency and effectiveness of the Golden Field Office relative to their award, distribution and administration of funds. A second, multi-month financial audit was performed by KPMG to evaluate the financial capability of Oski and the financial aspects of the invoicing, documentation and expenditure tracking of Hot Pot project expenses.

Oski project managers and resource staff have continued to regularly interface with DOE Geothermal Program managers involved with the Hot Pot project at every point during Phase 1. The decision process for Phase 1 is presented in Figure 25. Communications were via phone conversations, email correspondence and face-to-face meetings discussing on-going efforts, permitting requirements and activities, and presentation of project objectives, results and status at the 2010 Geothermal Resource Council Annual Meeting, 2011 Stanford Geothermal Program Annual Meeting, and scheduled DOE Geothermal Program review meetings. Additionally, project results have been presented at the 2010, 2011, and 2012 Geothermal Technologies Office Peer Review Meetings, and a presentation is scheduled for the April, 2013 meeting.

10.0 PROJECT SUMMARY AND NEXT STEPS

The completed studies discussed in this report fulfill Oski's obligations for Phase 1 of The Hot Pot project. Based on these data, The Hot Pot region is similar to several Basin and Range geothermal systems with migration of recharge water to deeper levels in a region of elevated heat flow and upward convection to drillable depths along a fault or combination of fractures. The major uncertainty, and hence exploration risk, is associated with the source and controls on heated fluids rising to shallow depths. Predicting plausible reservoir locations in the Basin and Range is difficult, particularly in areas like Hot Pot where potential controlling faults or fractures are obscured beneath a sequence of Tertiary and Quaternary basin fill sediments between adjacent mountain ranges.

The advanced seismic analysis completed as part of the innovative technology applications in this project has constrained depths to the probable reservoir rocks underlying a variable thickness of Cenozoic sedimentary cover. The seismic data processing results highlight a series of reflective zones in the subsurface that are interpreted as north-northeast and north-northwest striking faults that parallel the strike of Quaternary faults identified from various surface studies (USGS, 2006). The processed reflection data also highlights at least one and possibly two faults that parallel the alignment of the former Hot Pot springs and may represent extensional features that control the flow of geothermal fluids to the surface.

Intersections of the north-northeast and northwest striking fault systems and the potential for lateral fluid flow in the comparatively shallow Cenozoic units or the deeper Paleozoic units is a viable conceptual model for a potential geothermal system beneath the Hot Pot prospect. The Valmy Formation is highly permeable in other Nevada geothermal systems like Beowawe and potentially allows both for regional recharge from surface waters and for deep penetration of these fluids. Ascending geothermal fluids may be trapped in part by impermeable units near the base of the Cenozoic section and may be channeled laterally within permeable units towards vertically penetrative faults. Deeply penetrating faults, depending on dip angle and their fault structure, strain history, degree of mineralization and orientation in the ambient stress field selectively channel geothermal fluids either to the surface (as at Hot Pot hot springs) or to near-surface levels. Fault and fracture intersections, as at Hot Pot, may produce further near-surface localization of fluids.

Identifying any or all of the potential faults that might control the circulation of geothermal source fluids at depth is a key contribution of this study. Notably, these faults and fractures might be comparatively new structures imposed during Quaternary deformation events or, in the Paleozoic rocks these could be inherited older faults and fractures that are preferentially open and permeable in the current ambient stress field. Integrating these elements with the extended processing of reflection seismic data yields a better image of the faults or fractures that may control deeper circulation and vertically upwelling geothermal fluids within the crust that may eventually prove to be viable targets for a deep geothermal production test planned for the Hot Pot project.

The next step (Phase 2) in the Hot Pot exploration project is access road and drill site construction followed by drilling the planned slim holes. Information derived from the slim holes will be integrated with existing data before using that information to site and drill a full-sized deep confirmation well. Phase 3 activities include testing the deep well, final report preparation, and delivery of all project data.

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