Warm Springs Power & Water Enterprises

Geothermal Power Development Feasibility Study
Warm Springs Indian Reservation

US Department of Energy
Tribal Energy Program Review
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Confederated Tribes of Warm Springs
Warm Springs, Oregon
Project Participants

• Jim Manion, GM, Warm Springs Power & Water Ent.
• David McClain, DW McClain Associates
• GeothermEx Inc.
• Power Systems Engineers, Inc
• Tribal Attorneys
Study Location:

- East and North Flank of Mt. Jefferson
- Shitike Creek Area
- Whitewater River Area
Mt. Jefferson Geothermal Area
Dacite Domes
Mt. Jefferson
Indications of Geothermal Potential
On
Warm Springs Reservation:

- Mt. Jefferson and the High Cascade Mountain has been the site of volcanic activity extending over the past 35 million years.

- Volcanic rocks in the north and east areas of Mt. Jefferson are young in age, some eruptions areas are less than 5,000 years old.

- Volcanic rocks in the area are high in silica (dacite domes) and there is a high probability that one or more shallow magma chambers are present generating significant heat flow.

- Hydrothermal Alteration is present in the upper slopes of Mt. Jefferson.

- Thermal mineralized springs and seeps are present in the river valleys on the Warm Springs Reservation just east of Mt. Jefferson.

- The Mt. Jefferson volcanic area has similar characteristics as geothermal projects in Indonesia, the Philippines, Mexico, Nicaragua and Costa Rica.
Area of Highest Potential
Scope of Study

- Evaluate existing data from prior studies, government and academic sources.
- Review the project area data and compare it to other sites in the world using GeothermEx data from geothermal projects in other locations.
- Complete a site visit and collect water samples for geochemical analysis.
- Complete geochemical analysis of water samples.
- Create a conceptual hydrological model of the resource.
- Estimate the recoverable geothermal reserves based on the existing data and conceptual models.
- Estimate potential well flow rates and production potential based on conceptual models.
- Identify the appropriate power cycles.
- Estimate possible range of cost for power project.
- Prepare a Plan of Exploration and Development.
Summary

- Geochemical analysis of mineralized water in Shitike Creek on the east flank of Mt. Jefferson is similar to Breitenbush Hot Springs on the west side of Mt. Jefferson.
- The geochemical analysis suggests a common origin from a geothermal source.
- Geochemical data indicates that the source water temperature is in the range of 150°-200°C (302° to 392°F).
- GeothermEx’s Monte Carlo probability models indicate there is sufficient volumetric heat in place in the Shitike Creek area to suggest a minimum of 20 MW or resource reserves
- 90% confidence level.
- The most likely value of reserves is 37 MW
- The median value is 50 MW.
Most Likely Area for Development

The area between
• Whitewater River Canyon
• Shitike Creek Canyon
• Well site WS-2 and WS-3
View of ridge line from Lionshead point
Proposed site for WS2 & WS3 test holes
View of White Water Meadows & Milk Creek from Lionshead
Next Phase

- Drilling 3 Temperature Gradient Holes to a depth greater than 4,000 feet.

- Conduct geophysical surveys in the area of interest

- Drilling 3 to 4 confirmation test wells in areas with anomalous geophysical data and high thermal gradients.
Figure 4.5: Completion diagram for hypothetical core hole, Warm Springs Indian Reservation

4-inch drilling valve

5-inch, slip-on-weld (SOW) casing head with kill and fill line

3-ft x 3-ft x 2-ft cellar

8-inch conductor pipe cemented at 30 feet

6-inch hole (rotary drilled). PQ rods cemented to surface from 300 feet.

3.782-inch (HQ) hole. HQ rods (3.5-inches) cemented as deep as possible (1,000 - 1,500 feet).

2.98-inch (NQ) hole drilled to 3,000 - 4,000 feet

2.36-inch (contingent) hole drilled with BQ bit to 5,000 feet

1.66-inch (OD), J-55, 2.75-lb/ft tubing, slotted at permeable zones
Figure 4.6: Completion diagram for hypothetical slim hole, Warm Springs Indian Reservation

- 6-inch (nominal) FM master valve
- 7-inch x 6-inch 50CW casing head
- 11-inch conductor pipe, cemented inside 16-inch hole at 30 feet
- 8.88-inch surface casing cemented inside 12-1/4-inch hole at ~300 feet
- 7-inch casing cemented inside 8-1/2-inch hole at ~1,500 feet
- 6-inch slotted and blank liner (top 4 joints), hung from 7-inch casing
- 6-5/8-inch open hole to 3,000-4,000 feet
Schematic of Well Depth

- Ridge Level
- Valley Floor / Water Table
- Top of Reservoir
- Top of Production
- Temperature Gradient Hole
- Production Well
- Elevations (meters)
- Potentially High Thermal Gradient with Little Fracturing
- Potentially Fractured Zones at High Temperatures
- Sea Level
- Maximum Depth Range for Production Wells (2,000-2,500 m)
- Maximum Well Depth
Power Cycles and Price

• Binary Power Plant
  – Most likely scenario given the current data

• Flash Steam Plant
  – If confirmation drilling indicates temperatures above 450°F

• Economics
  – Minimum Price required $0.075 / kWh
    PTC
Figure 6.1: Present value vs electricity price for a 30-MW geothermal project at Warm Springs Indian Reservation (discount rate = 12%, interest rate = 8%)

If developer can use Production Tax Credit (incremental 1.9¢/kWh for first 10 years)

No Production Tax Credit
Figure 6.2: Present value vs discount rate for a 30-MW geothermal project at Warm Springs Indian Reservation (electricity price without PTC = 7.5¢/kWh, interest rate = 8%)

If developer can use Production Tax Credit (incremental 1.9¢/kWh for first 10 years)

No Production Tax Credit
## Probabilistic Estimate of Geothermal Energy Reserves

<table>
<thead>
<tr>
<th>Statistics</th>
<th>MW</th>
<th>MW/sq. km</th>
<th>Recovery Efficiency</th>
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<tbody>
<tr>
<td>Mean</td>
<td>60</td>
<td>5.5</td>
<td>1.20%</td>
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<tr>
<td>Std. Deviation</td>
<td>39</td>
<td>3.0</td>
<td>0.42%</td>
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<tr>
<td>Minimum (90% prob.)</td>
<td>19</td>
<td>2.1</td>
<td>0.62%</td>
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<tr>
<td>Median (50% prob.)</td>
<td>50</td>
<td>4.8</td>
<td>1.19%</td>
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<tr>
<td>Most-likely (Modal)</td>
<td>37</td>
<td>3.5</td>
<td>1.21%</td>
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## Schedule

**Figure 4.2: Development schedule for 30-50 MW geothermal project, Warm Springs Indian Reservation**

<table>
<thead>
<tr>
<th>Task Description</th>
<th>Duration</th>
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<tbody>
<tr>
<td><strong>Exploration Phase</strong></td>
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<tr>
<td>1.1 Baseline environmental monitoring</td>
<td>12 months</td>
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<tr>
<td>1.2 Permits for slim-holes &amp; geophysics</td>
<td>1 month</td>
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<tr>
<td>1.3 Slim-hole design and procurement</td>
<td>1 month</td>
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<tr>
<td>1.4 Road access and pad construction</td>
<td>2 weeks</td>
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<tr>
<td>1.5 Slim-hole drilling (3 wells)</td>
<td>4 months</td>
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<tr>
<td>1.6 Geophysical surveys</td>
<td>4 months</td>
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<tr>
<td>1.7 Begin work on Environmental Impact Statement (EIS)</td>
<td>2 months</td>
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<td>1.8 Report of exploration results</td>
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<tr>
<td><strong>Confirmation Phase</strong></td>
<td>18 months</td>
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<tr>
<td>2.1 Complete EIS (started during Exploration Phase)</td>
<td>1 month</td>
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<tr>
<td>2.2 EIS comment and approval</td>
<td>3 months</td>
</tr>
<tr>
<td>2.3 Well design and procurement</td>
<td>1 month</td>
</tr>
<tr>
<td>2.4 Permits for full-size confirmation wells</td>
<td>1 month</td>
</tr>
<tr>
<td>2.5 Road access and pad construction</td>
<td>1 month</td>
</tr>
<tr>
<td>2.6 Confirmation well drilling (up to 4 wells)</td>
<td>10 months</td>
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<tr>
<td>2.7 Well testing and analysis</td>
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<td>2.8 Resource assessment report</td>
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<td><strong>Development Phase</strong></td>
<td>30 months</td>
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<tr>
<td>3.1 Preliminary project design</td>
<td>1 month</td>
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<tr>
<td>3.2 Negotiate EPC contract</td>
<td>3 months</td>
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<tr>
<td>3.3 Negotiate power sales contract</td>
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<tr>
<td>3.4 Obtain project financing</td>
<td>3 months</td>
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<td>3.5 Procurement for development wells</td>
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<tr>
<td>3.6 Development drilling</td>
<td>21 months</td>
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<td>3.7 Plant procurement and construction</td>
<td>26 months</td>
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<td>3.8 Online date</td>
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Figure 4.1: Decision points in exploration and confirmation phases of geothermal development at Warm Springs Indian Reservation

**Decision Points**

- Base-case development
- Alternate scenarios

**Exploration Phase - First Year**
- Start
- Perform geophysical surveys over entire area of potential interest
- Evaluate 1st-year results

**Exploration Phase - Possible Second Year**
- Drill 3 northern TGHs
- Drill 3 southern TGHs
- Northern TGHs are all bad, but southern geophysics is encouraging
- Southern TGHs also bad
- Stop Project

**Confirmation Phase**
- At least one northern TGH is successful
- At least one TGH is successful
- All southern TGHs are bad
- Focus on northern area
- Drill at least 2 full-sized wells
- Both full-sized wells non-commercial
- Re-evaluate drilling strategy
- No better strategy identified
- Better strategy identified (possible focus on south)
- Complete confirmation drilling (cumulatively 3-4 full-sized wells)
- Stop Project
Cost

- Temperature Gradient Well: $700,000 per well
- 3 Wells: $2,100,000
- Slim Well: $1,000,000
- Total Initial Exploration Cost: $3,500,000
- Confirmation Drilling: $4,000,000 per well
- 4 Wells: $16,000,000
- Well Field Development: $42,000,000
  - 12 wells, production and injection
- 37.5 MW gross power plant and pipelines
  - $75,000,000
- 230-kV Transmission Line: $4,000,000
- Total Cost: $137,016,000
- $3,650 per gross kW installed
- Range of capital cost for Geothermal projects in Western USA
  - $3,000 to $4,000 per kW installed