Warm Springs Power & Water Enterprises

Geothermal Power Development Feasibility Study
Warm Springs Indian Reservation

US Department of Energy
Tribal Energy Program Review
October 23-27 2006

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

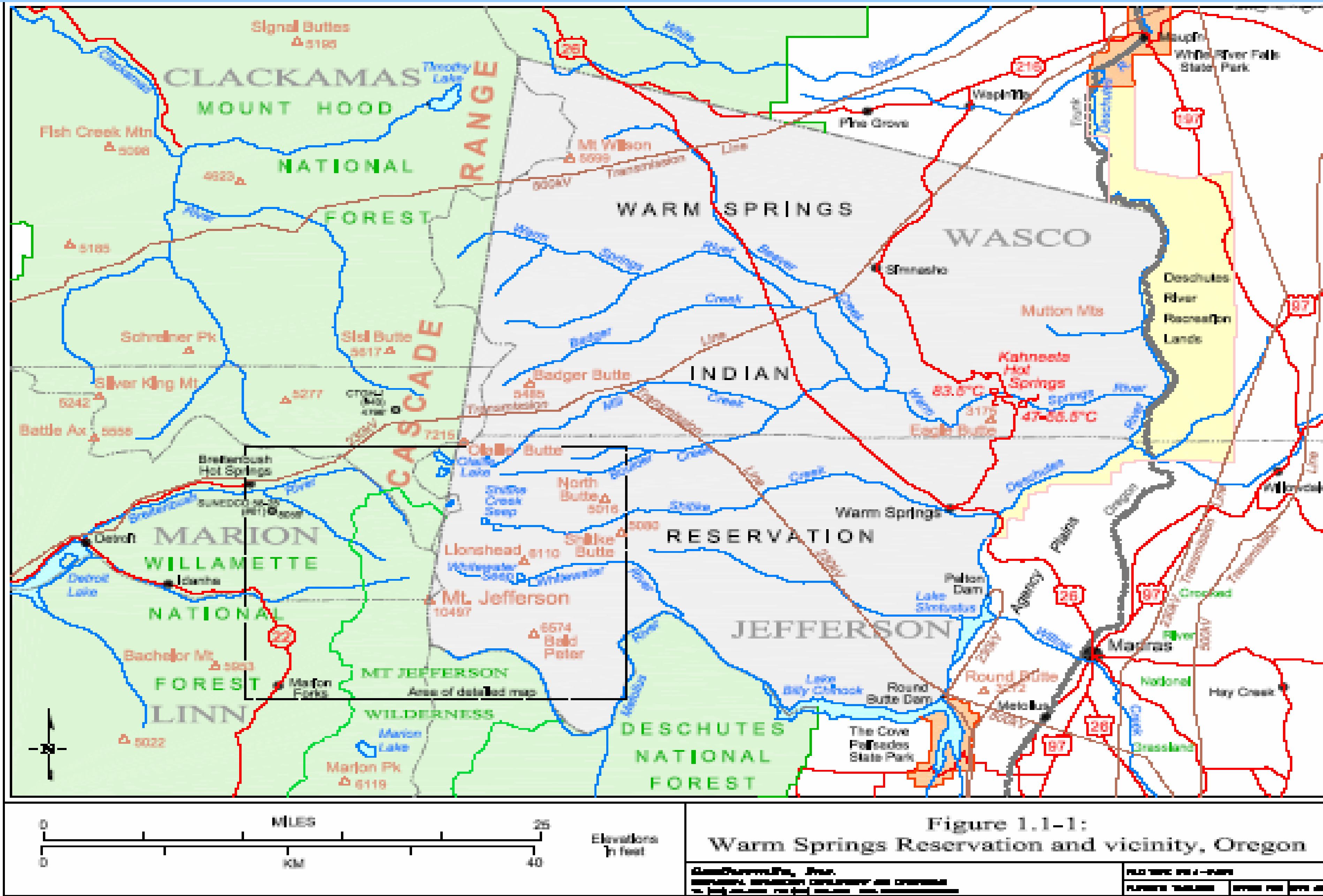
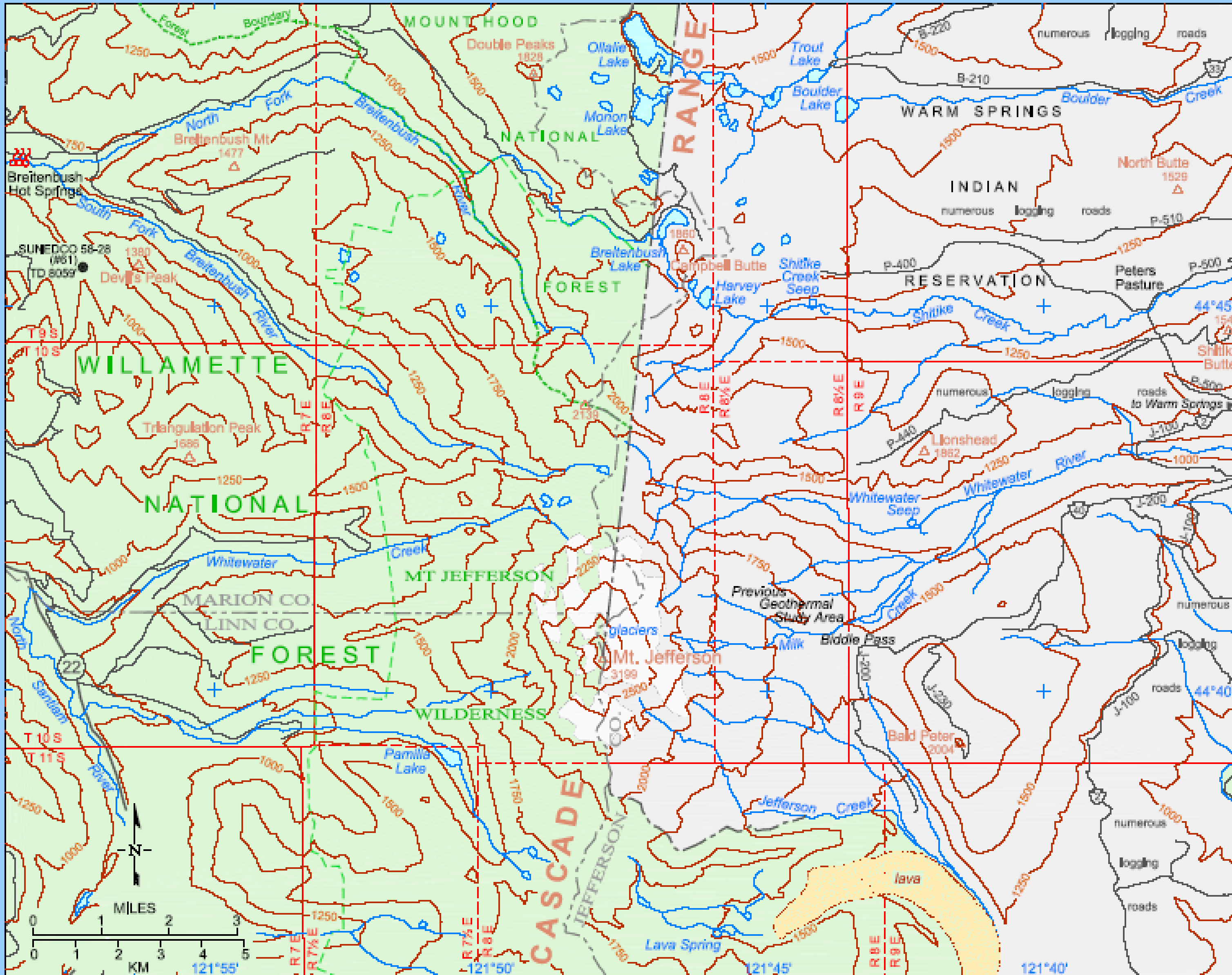


Figure 1.1-1:
Warm Springs Reservation and vicinity, Oregon


MOUNT HOOD
Double Peaks
1828
Olallie Lake
Trout Lake
Boulder Lake
Monon Lake
Forest Boundary
North Fork Breitenbush River
Breitenbush Mt
1477
Breitenbush Hot Springs
South Fork Breitenbush River
SUNEDCO 58-28 (#61) TD 8059'
Devils Peak
NATIONAL
FOREST
WILLAMETTE
NATIONAL
FOREST
Triangulation Peak
1686
Breitenbush Lake
Campbell Butte
1860
Harvey Lake
Shitike Creek Seep
Shitike Creek
WARM SPRINGS
INDIAN
RESERVATION
Boulder Creek
North Butte
1529
numerous logging roads
B-220
B-210
P-510
P-400
P-500
P-440
Peters Pasture
Shitike Butte
1546
roads to Warm Springs
Lionshead
1862
Whitewater Seep
Whitewater River
Whitewater Creek
MT JEFFERSON
WILDERNESS
MARION CO.
LINN CO.
JEFFERSON CO.
glaciers
Mt. Jefferson
3199
Previous Geothermal Study Area
Biddle Pass
Milk Creek
Bald Peter
2004
Pamelia Lake
Jefferson Creek
lava
Lava Spring
North Santiam River
CASCADE RANGE
T 9 S
T 10 S
T 11 S
R 7 E
R 7½ E
R 8 E
R 8½ E
R 9 E
44°45'
44°40'
121°55'
121°50'
121°45'
121°40'
N
MILES
0 1 2 3
KM
0 1 2 3 4 5

LEGEND

(22) Major road	1686 △ Principal summit, meters	Hot spring
Selected minor road	1000 Elevation contour, meters (interval 250meters)	Cold spring

Figure 1.1-2: Location of project area

GeothermEx, Inc.
GEOTHERMAL EXPLORATION DEVELOPMENT AND OPERATIONS

FILE: WSPE FIG1.1-2r.DWG
PLOTDATE: 12JUL2006 DRAWN: RRS APP.: CWK

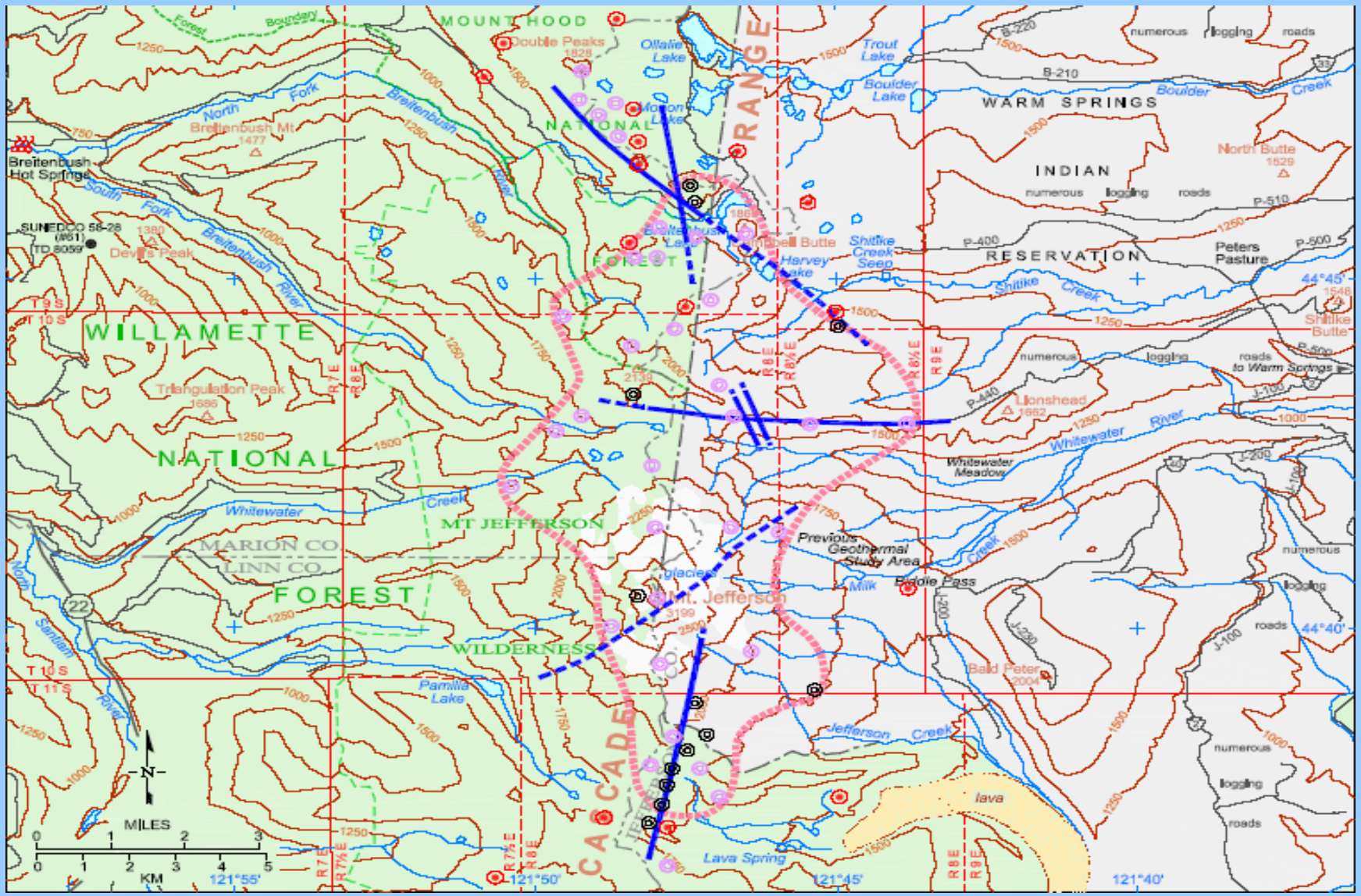
Mt. Jefferson Geothermal Area

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

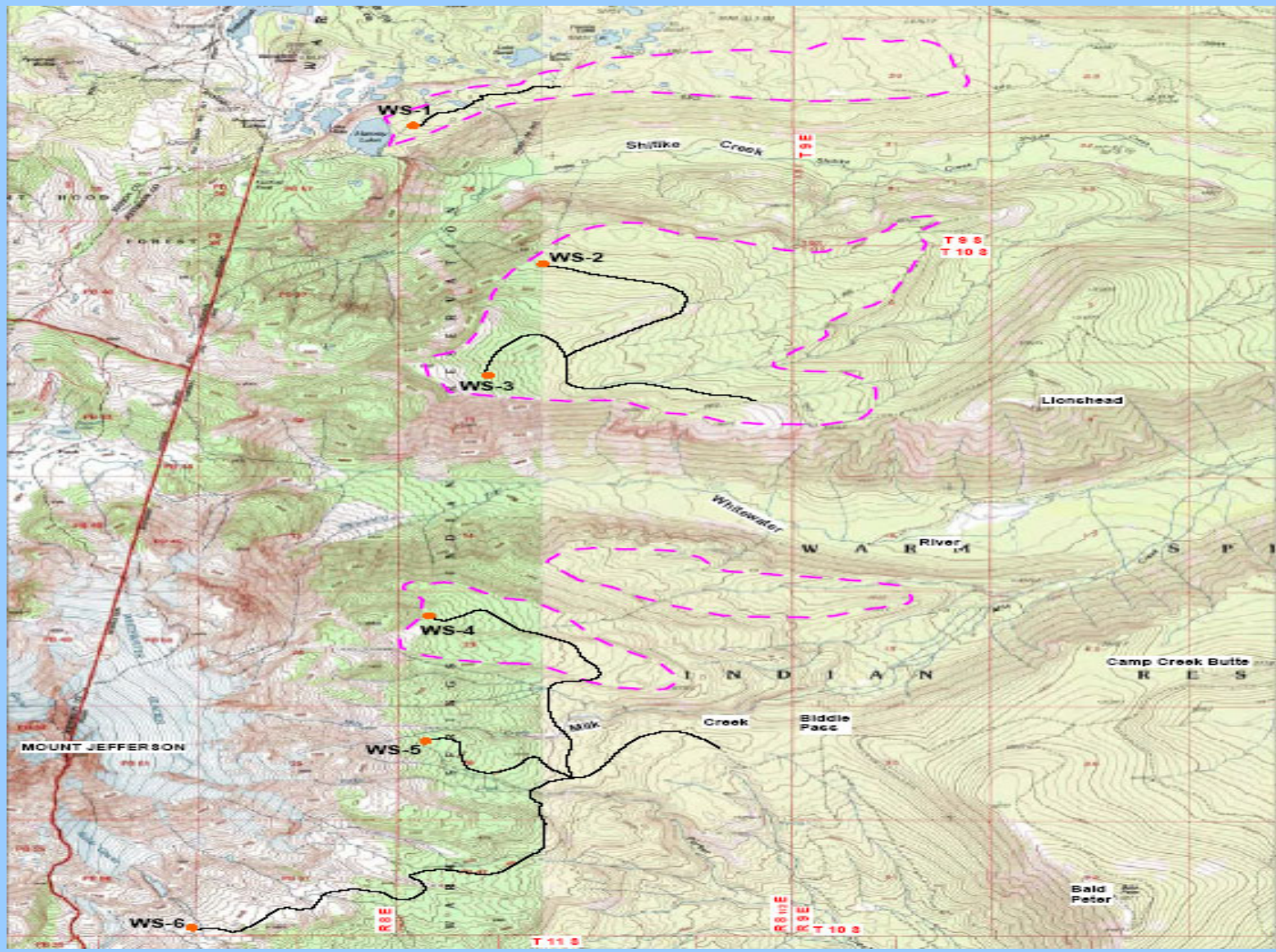
- Geochemical analysis of mineralized water in Shitike Creek on the east flank of Mt. Jefferson is similar to Breitenbush Hot Springs on the west side of Mt. Jefferson.
- The geochemical analysis suggests a common origin from a geothermal source.
- Geochemical data indicates that the source water temperature 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

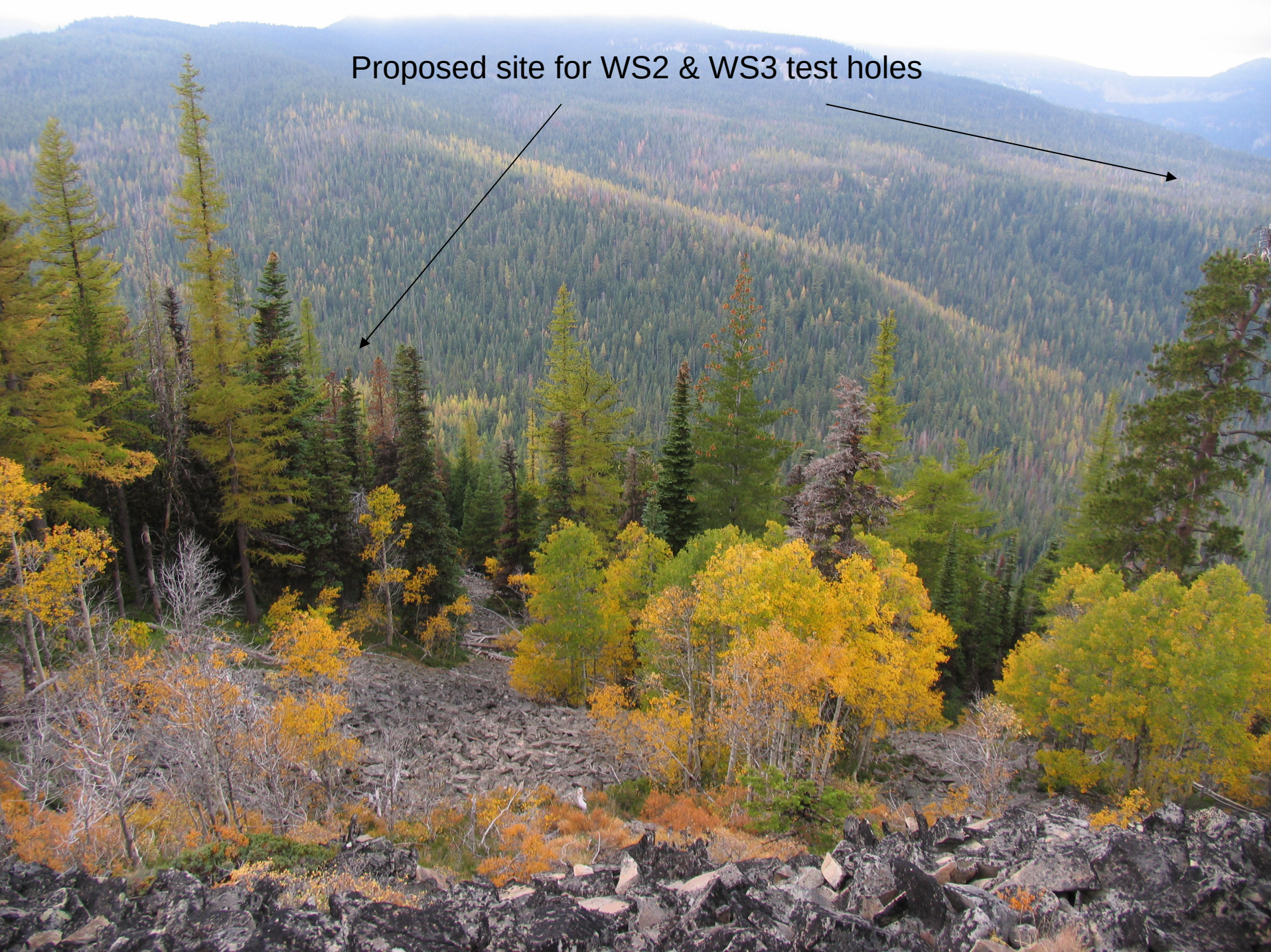
The area between

- **Whitewater River Canyon**
- **Shitike Creek Canyon**
- **Well site WS-2 and WS-3**

Exploration Well Locations



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 on 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

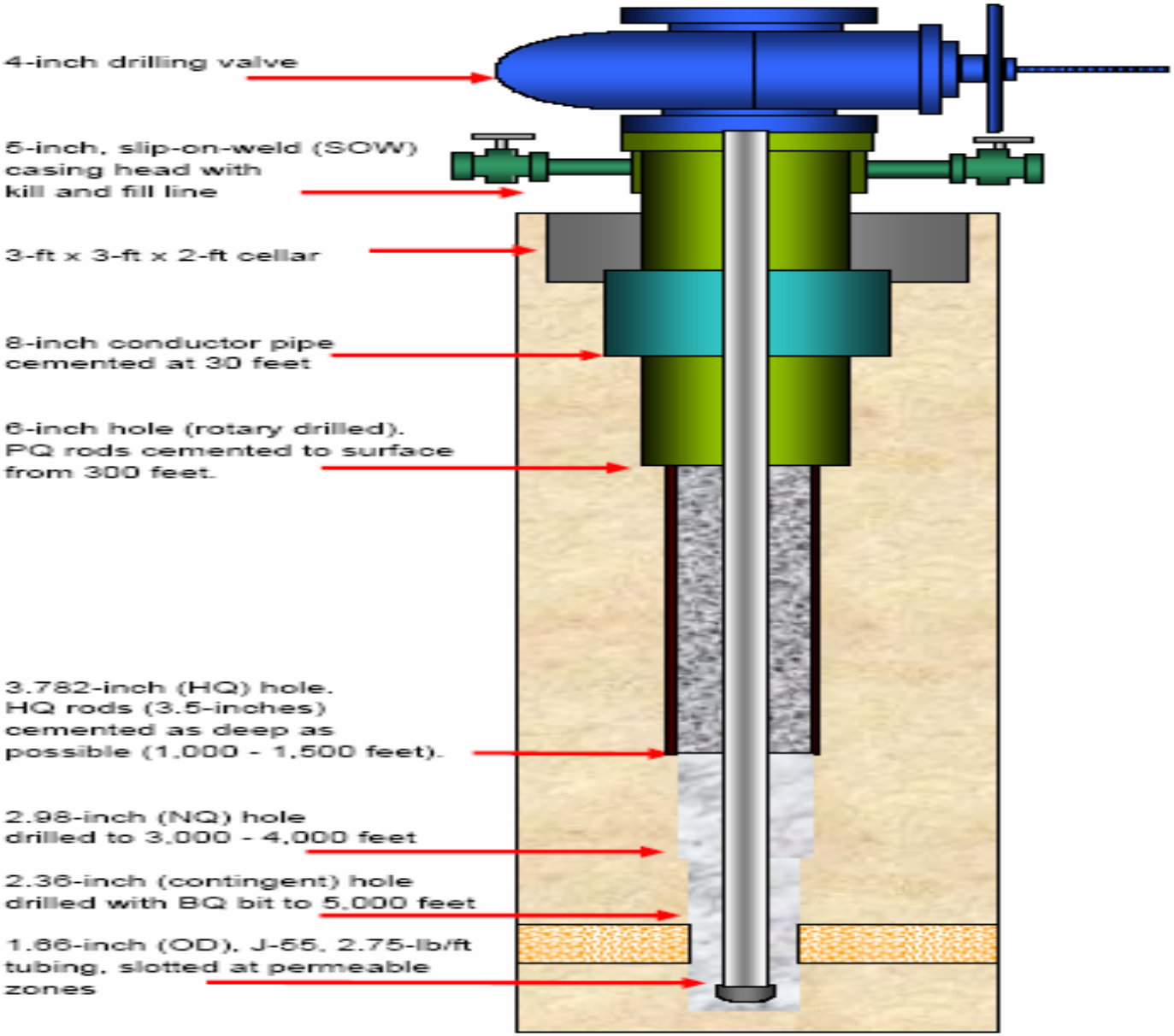
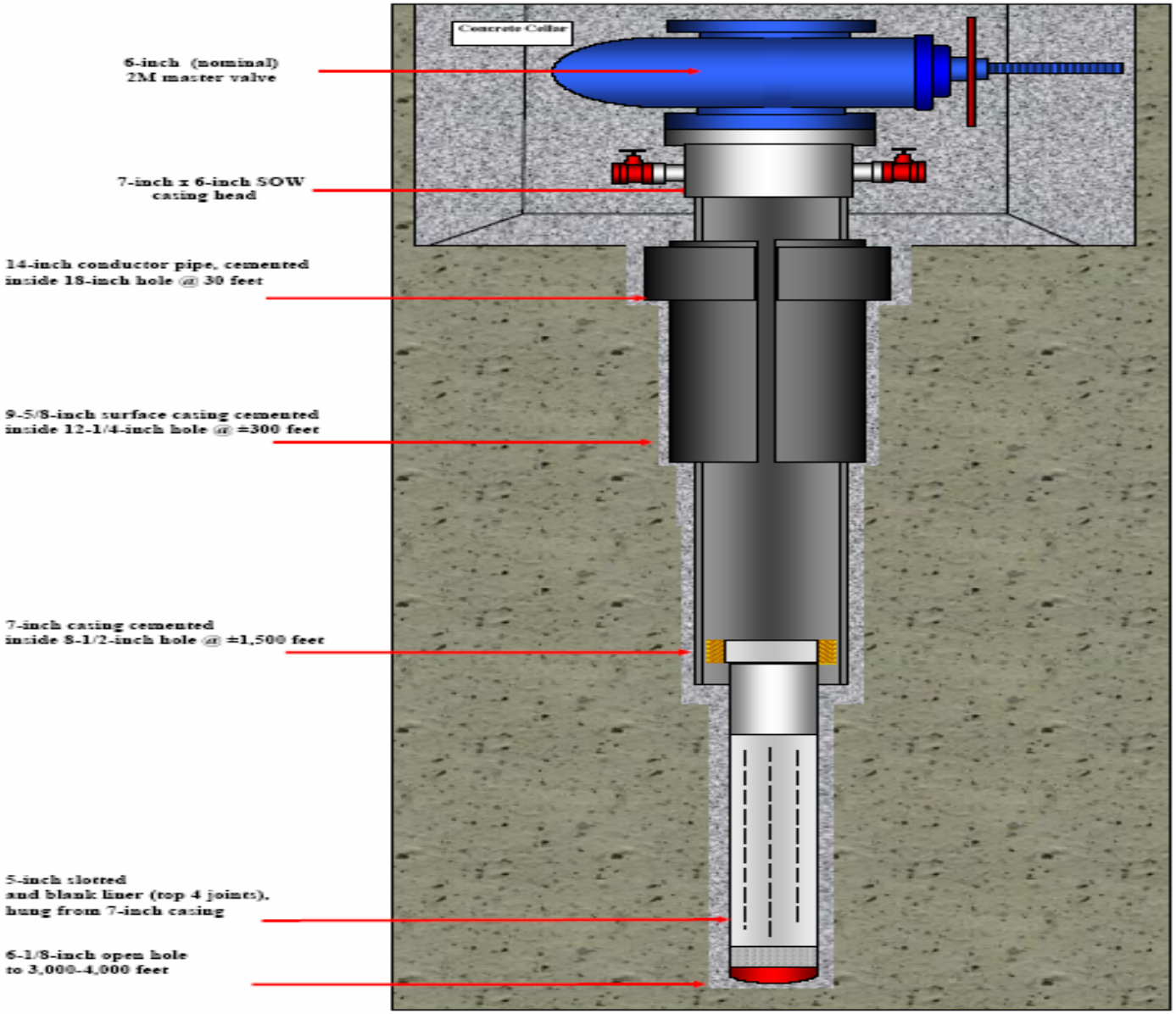
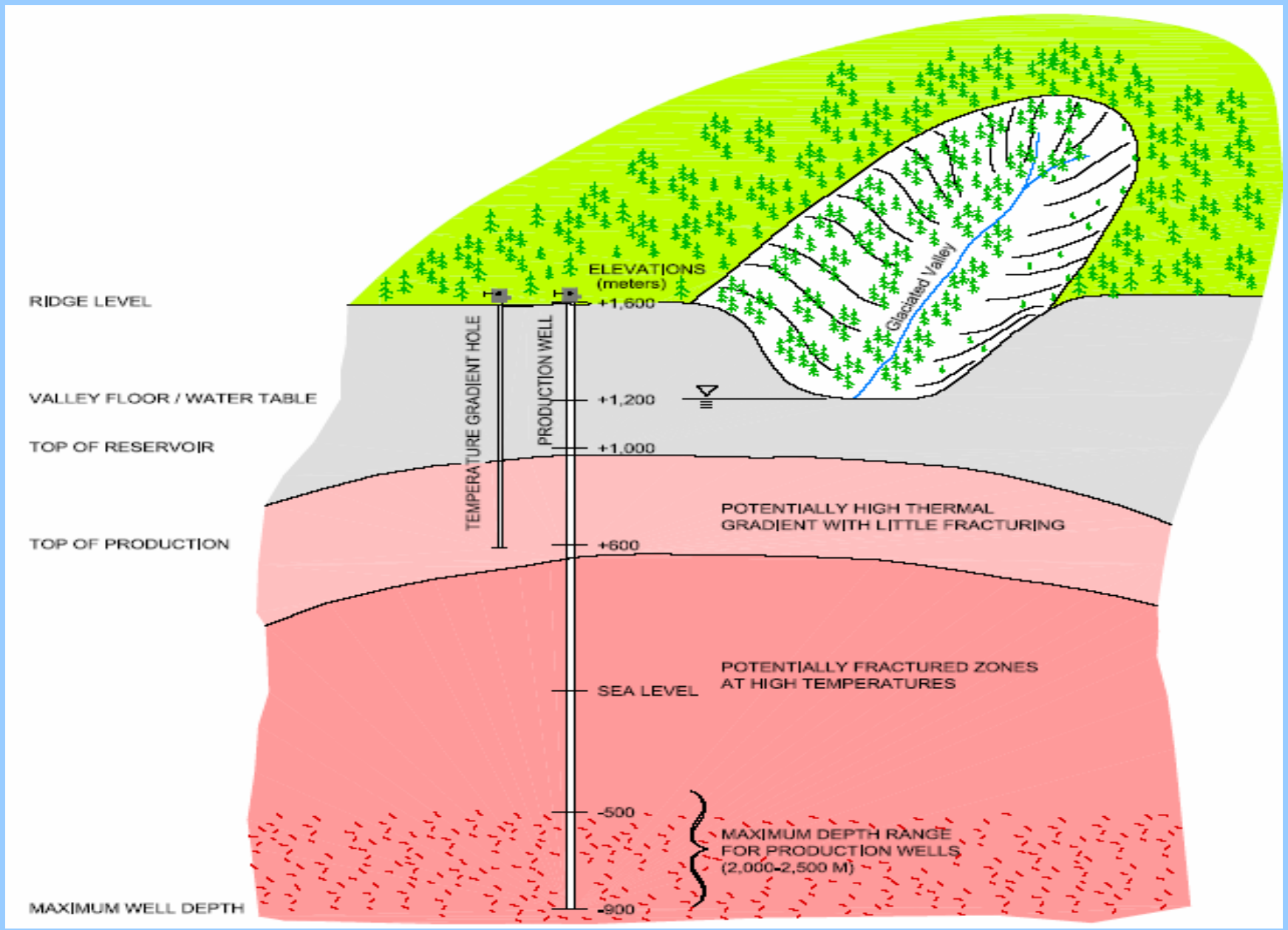


Figure 4.6: Completion diagram for hypothetical slim hole, Warm Springs Indian Reservation



Schematic of 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 $.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%)

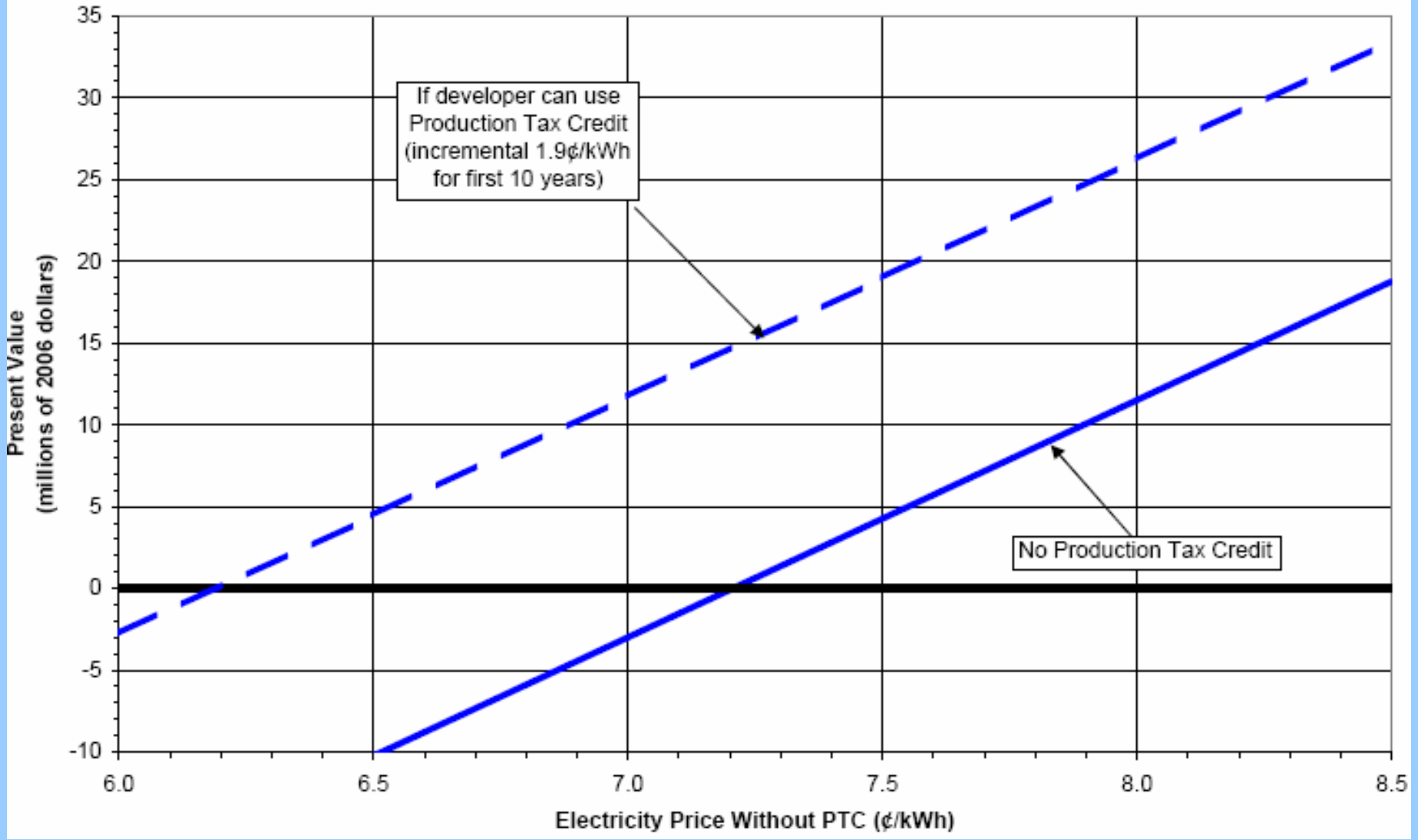
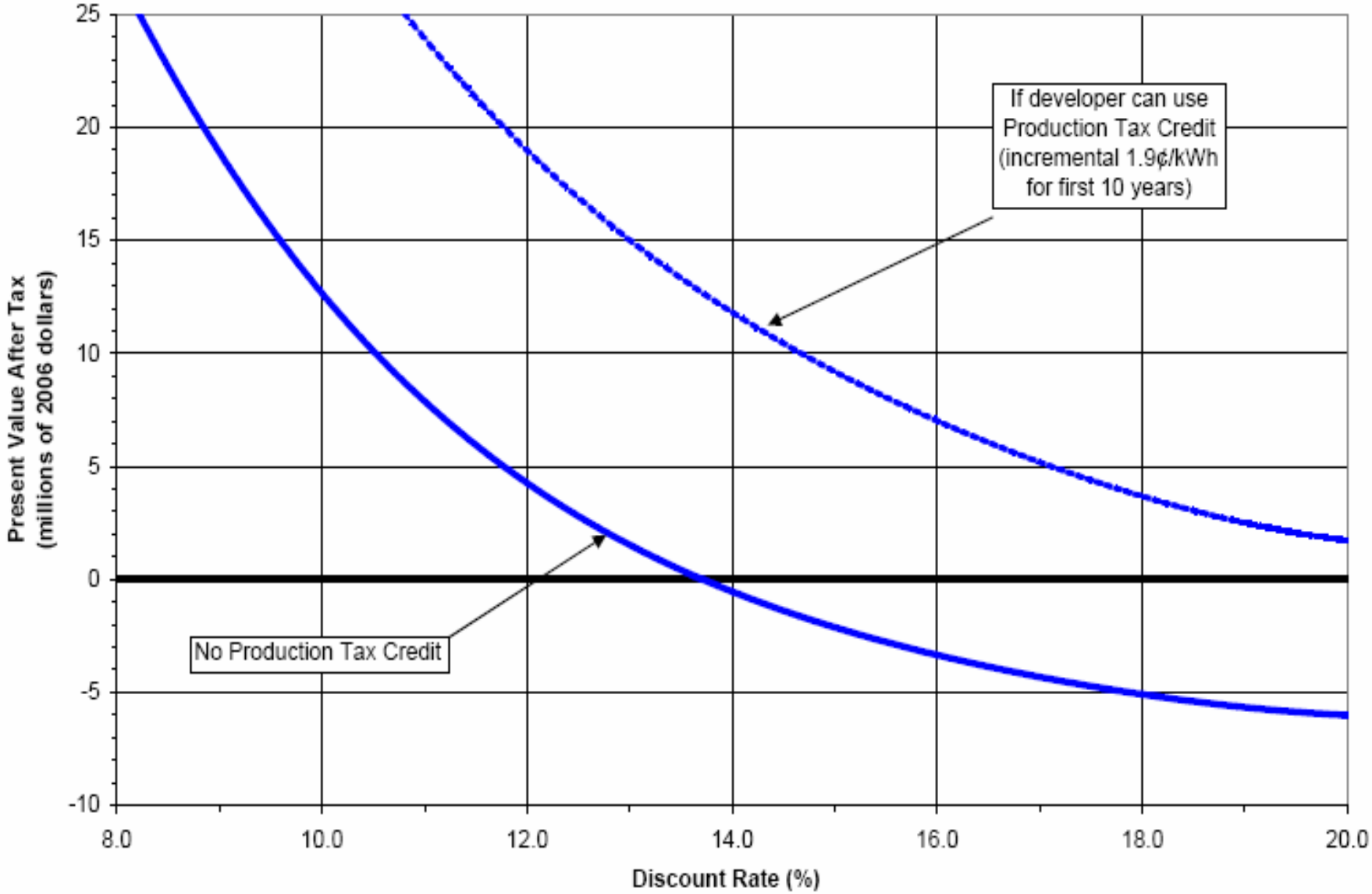
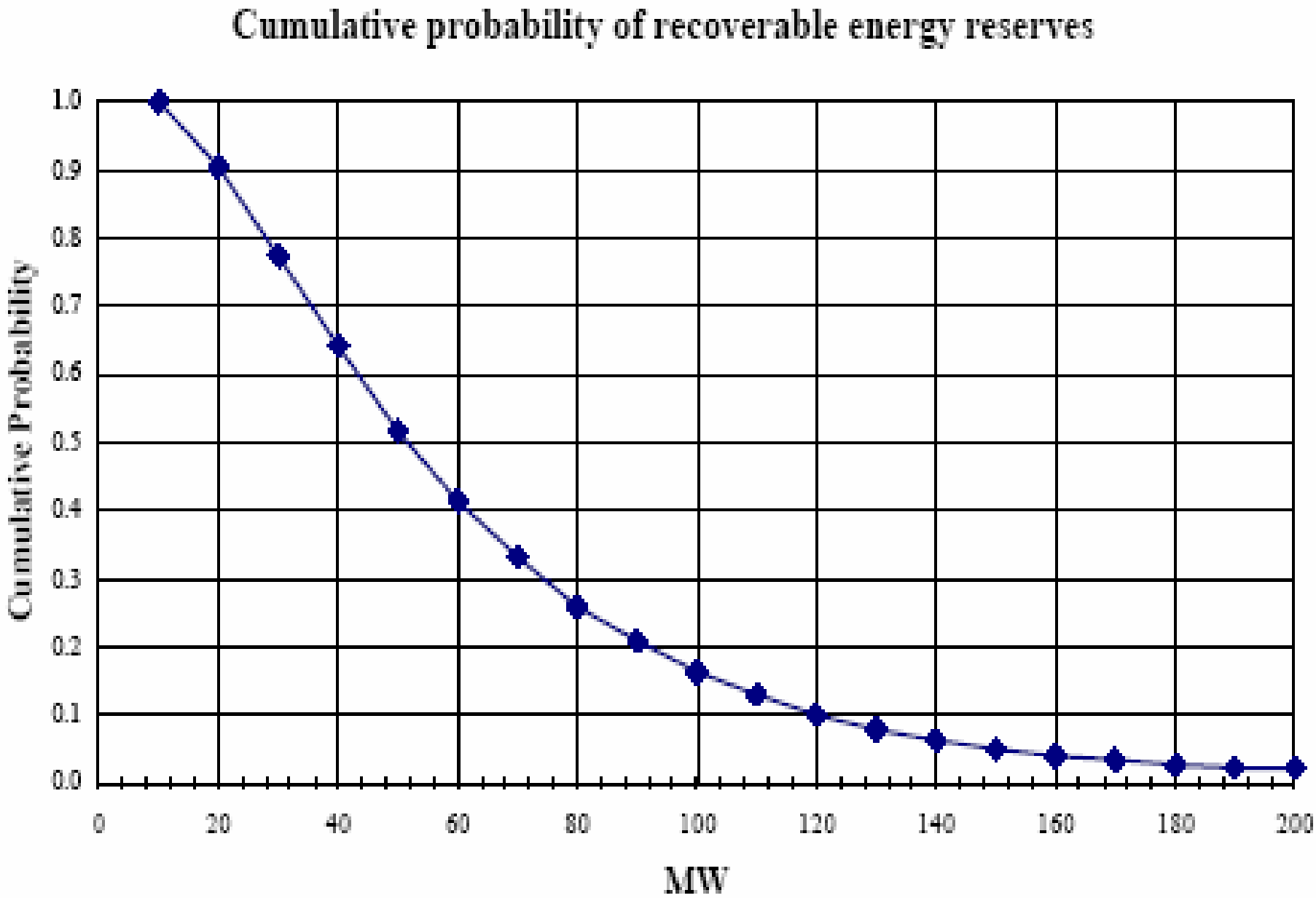


Figure 6.2: Present value vs discount rate for a 30-MW geothermal project at Warm Springs Indian Reservation (electricity price without PTC = 7.5¢/kWh, interest rate = 8%)




Cumulative probability of recoverable energy reserves
Cumulative Probability
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
20
40
60
80
100
120
140
160
180
200
MW

Probabilistic Estimate of Geothermal Energy Reserves

Statistics			
	MW	MW/sq. km	Recovery Efficiency
Mean	60	5.5	1.20%
Std. Deviation	39	3.0	0.42%
Minimum (90% prob.)	19	2.1	0.62%
Median (50% prob.)	50	4.8	1.19%
Most-likely (Modal)	37	3.5	1.21%

Schedule

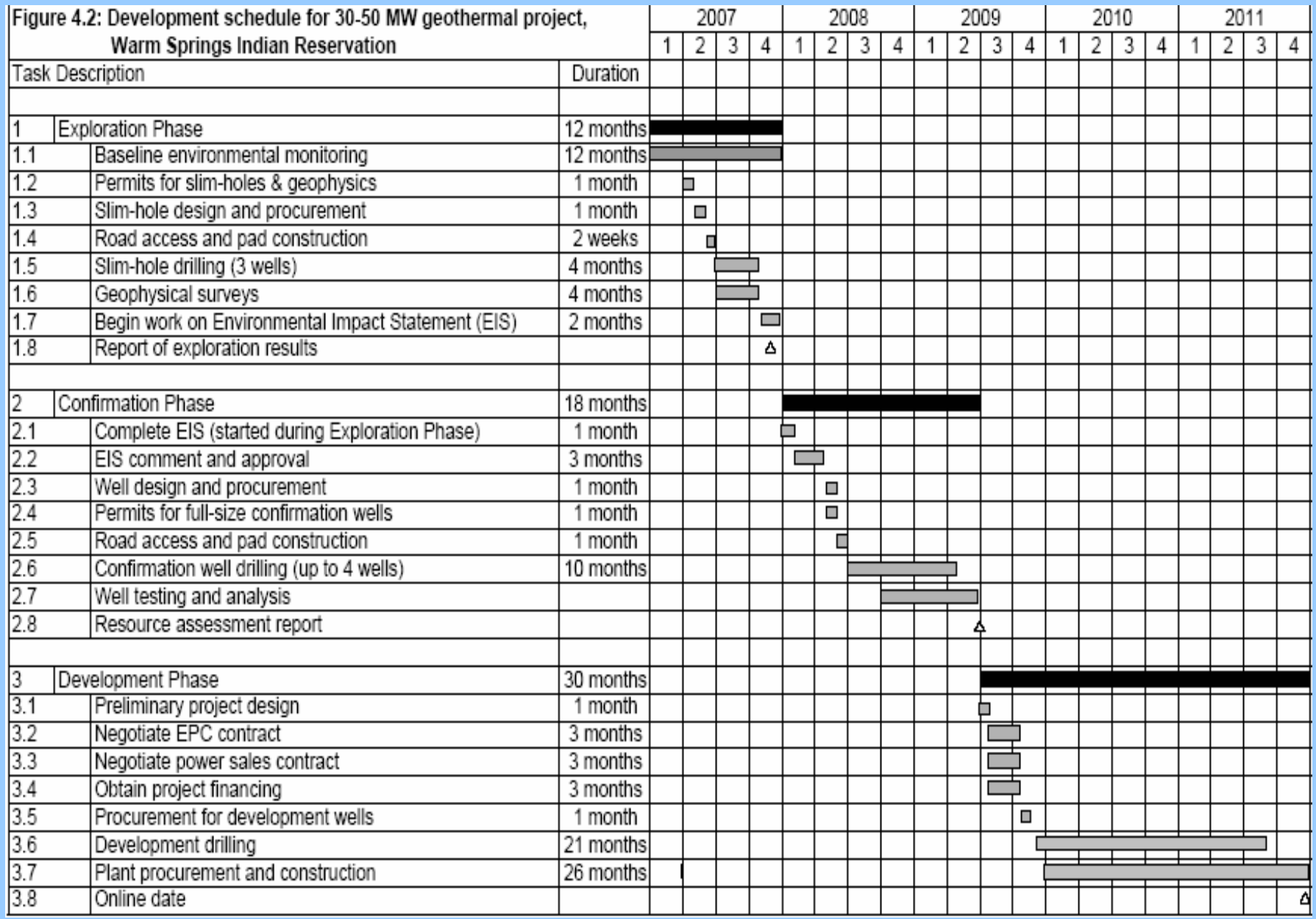
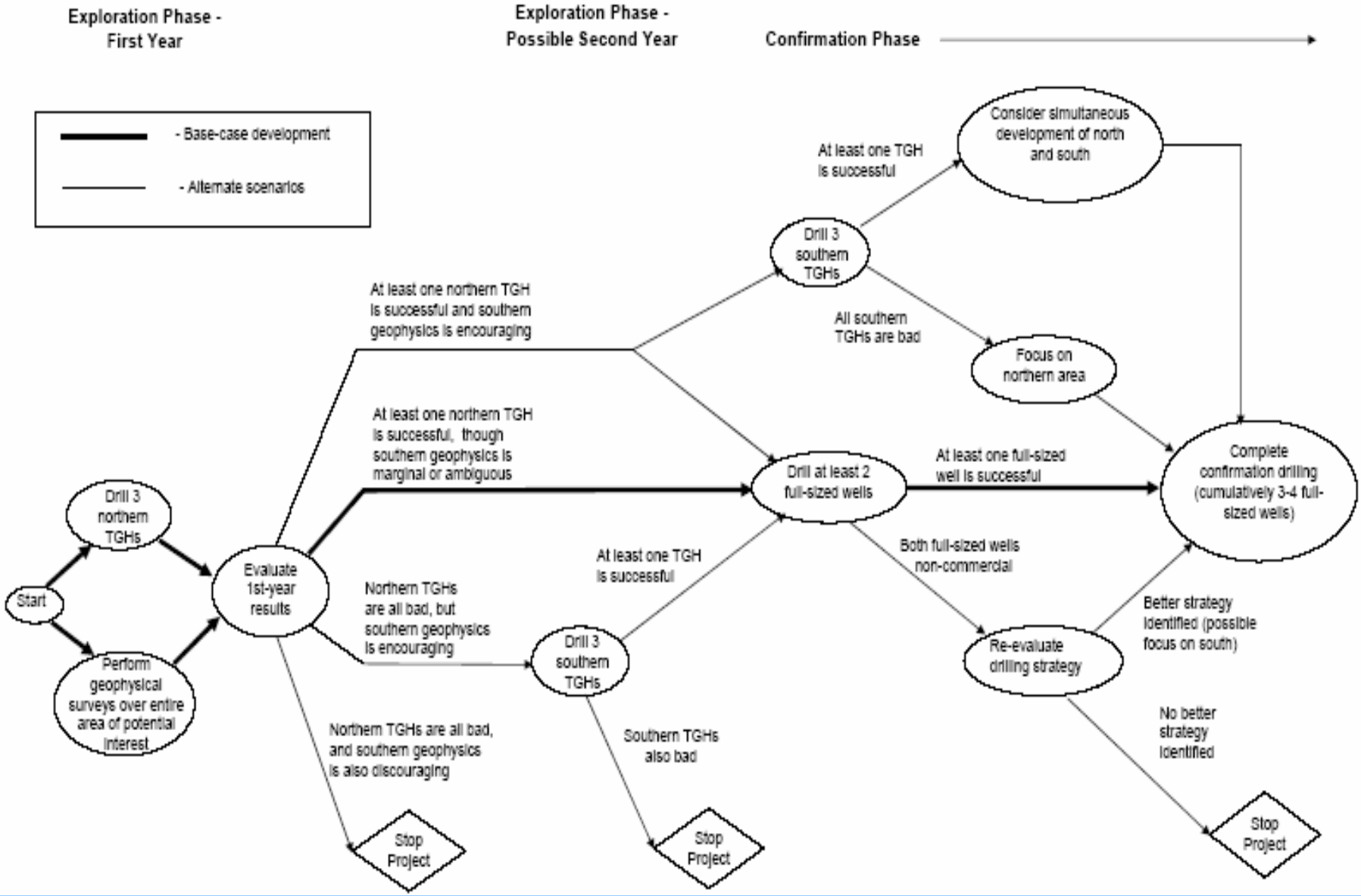


Figure 4.2: Development schedule for 30-50 MW geothermal project, Warm Springs Indian Reservation

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

Decision Points

Figure 4.1: Decision points in exploration and confirmation phases of geothermal development at Warm Springs Indian Reservation



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