GEOTHERMAL POWER FROM OIL, GAS AND GEOPRESSURED WELLS IN TEXAS AND LOUISIANA

by

Subir K. Sanyal

GeothermEx, Inc.
Richmond, California

Presented at

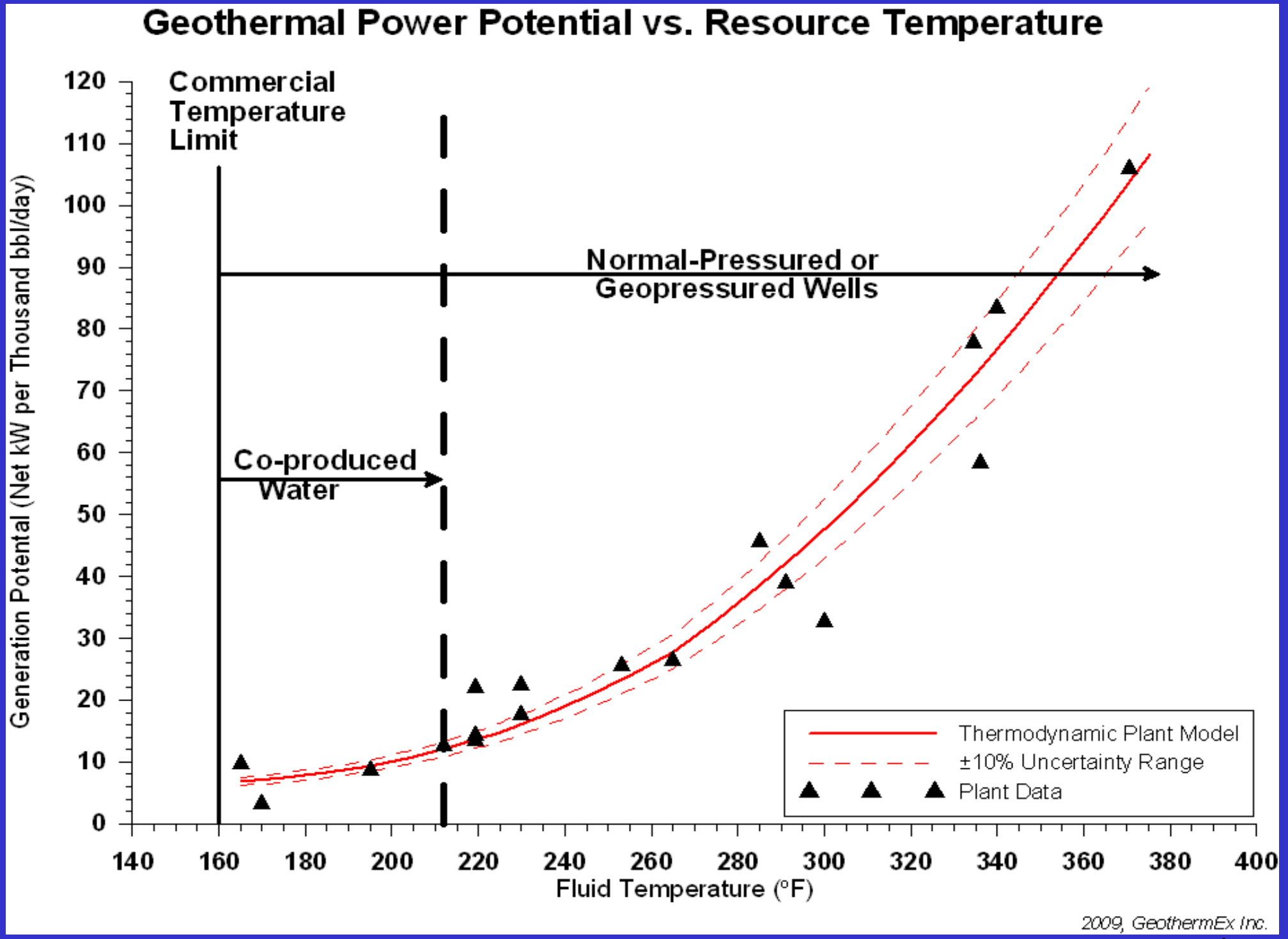
Geothermal Energy Utilization Associated with Oil and Gas Development
Southern Methodist University
Dallas, Texas
4 November 2009

TYPES OF PETROLEUM WELLS POTENTIALLY CAPABLE OF PRODUCING GEOTHERMAL POWER

- CO-PRODUCED WATER FROM OIL OR GAS FIELD
- OIL OR GAS WELL SHUT IN OR ABANDONED BECAUSE OF A HIGH WATER CUT
- GAS WELL TEMPORARILY SHUT IN BECAUSE OF LOW GAS PRICE
- GEOPRESSURED BRINE WELL
- NORMAL-PRESSURED BRINE WELL

FACTORS DETERMINING THE GEOTHERMAL POWER CAPACITY OF A WATER-CUT PETROLEUM WELL

- Water Production Rate
- Temperature of Produced Water
- Ambient Temperature
- Conversion Efficiency of Power Plant


Geothermal Power Potential vs. Resource Temperature
Commercial Temperature Limit
Normal-Pressured or Geopressured Wells
Co-produced Water
Generation Potental (Net kW per Thousand bbl/day)
Fluid Temperature (°F)
Thermodynamic Plant Model
±10% Uncertainty Range
Plant Data
2009, GeothermEx Inc.

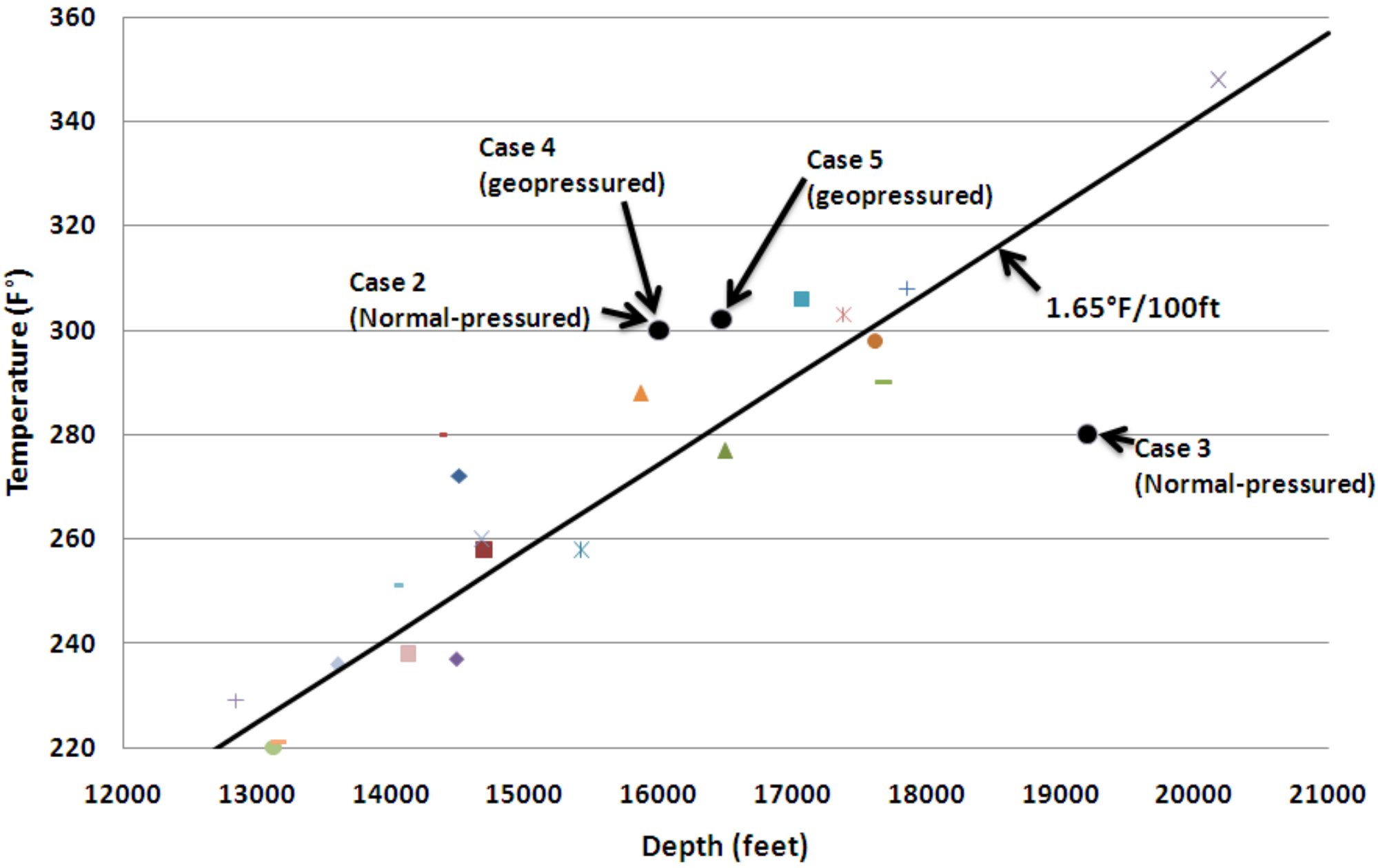
CASE 1: CO-PRODUCED WATER

- Surface Temperature of Water: 160° to 212°F
- Power Capacity: 6 to 12 kW per thousand bbl/day
- Unit Capital Cost: $2,800 per kW
- Pay-out Time: 4.2 years*

---

* Assuming a geothermal power price of 10¢/kWh (with renewable energy subsidies), an operating cost of 2¢/kWh net generation, 95% plant capacity factor, and no injection or power transmission cost

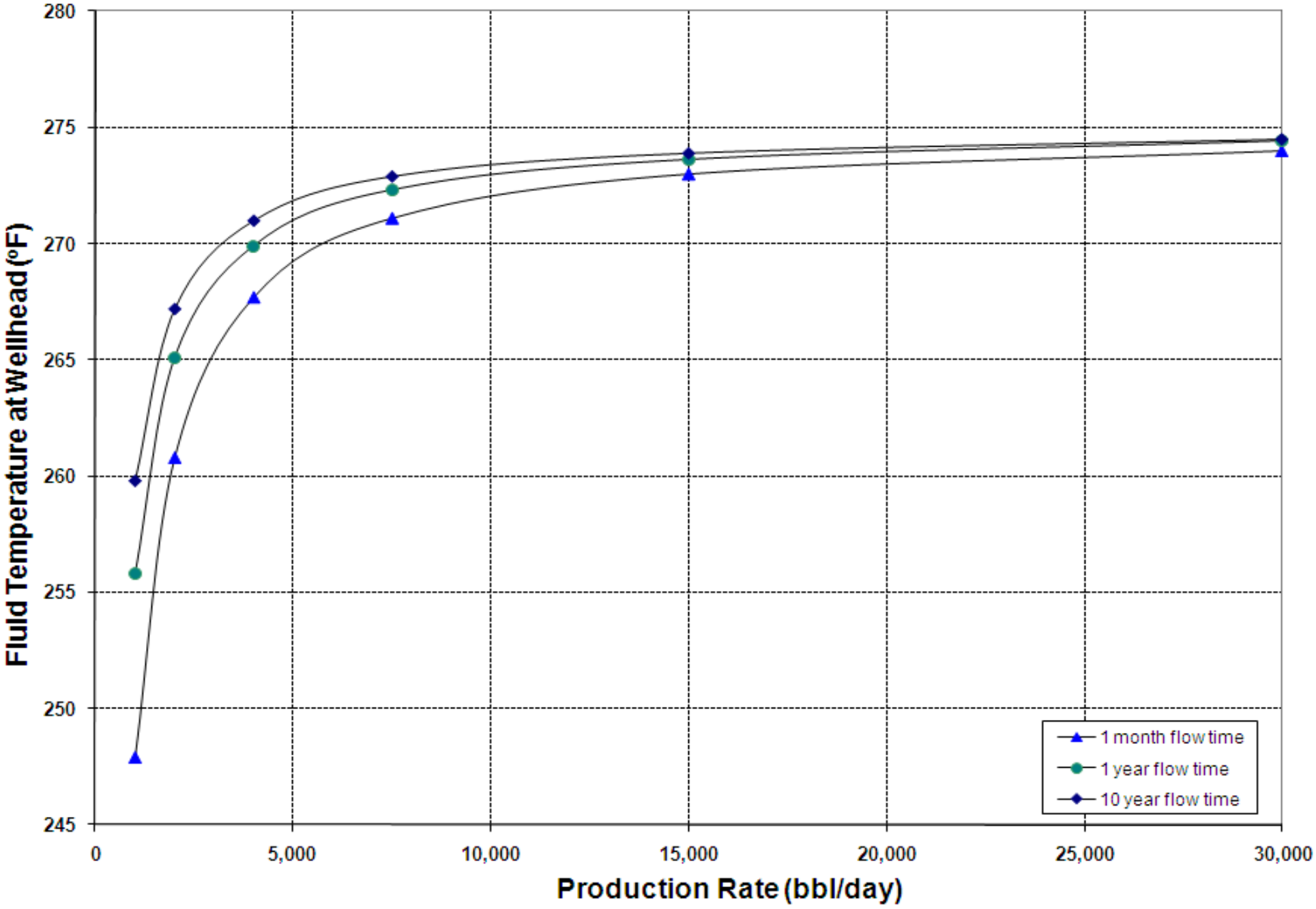
Temperature vs. Depth of abandoned wells in an area of the U.S. Gulf Coast



FACTORS THAT DETERMINE WELLHEAD TEMPERATURE OF THE PRODUCED FLUID

- WELL DEPTH
- BOTTOMHOLE TEMPERATURE
- PRODUCTION RATE
- WELL DIAMETER

Reduction in Wellhead Temperature Due to Heat Loss



CASE 2: AN ABANDONED WATER-CUT GAS WELL IN TEXAS

- 10-3/4-inch casing to 13,400 feet
- 7-5/8-inch liner to 19,200 feet
- Productivity Index: 14.8 bbl/day/psi
- Static reservoir pressure: 9,000 psig
- Bottomhole temperature: 280°F
- Flowing wellhead temperature: 270°F
- Dissolved methane: 40 SCF/bbl
- Solution Gas-Oil Ratio= 1,000 SCF/bbl
- Gas gravity: 0.583 API

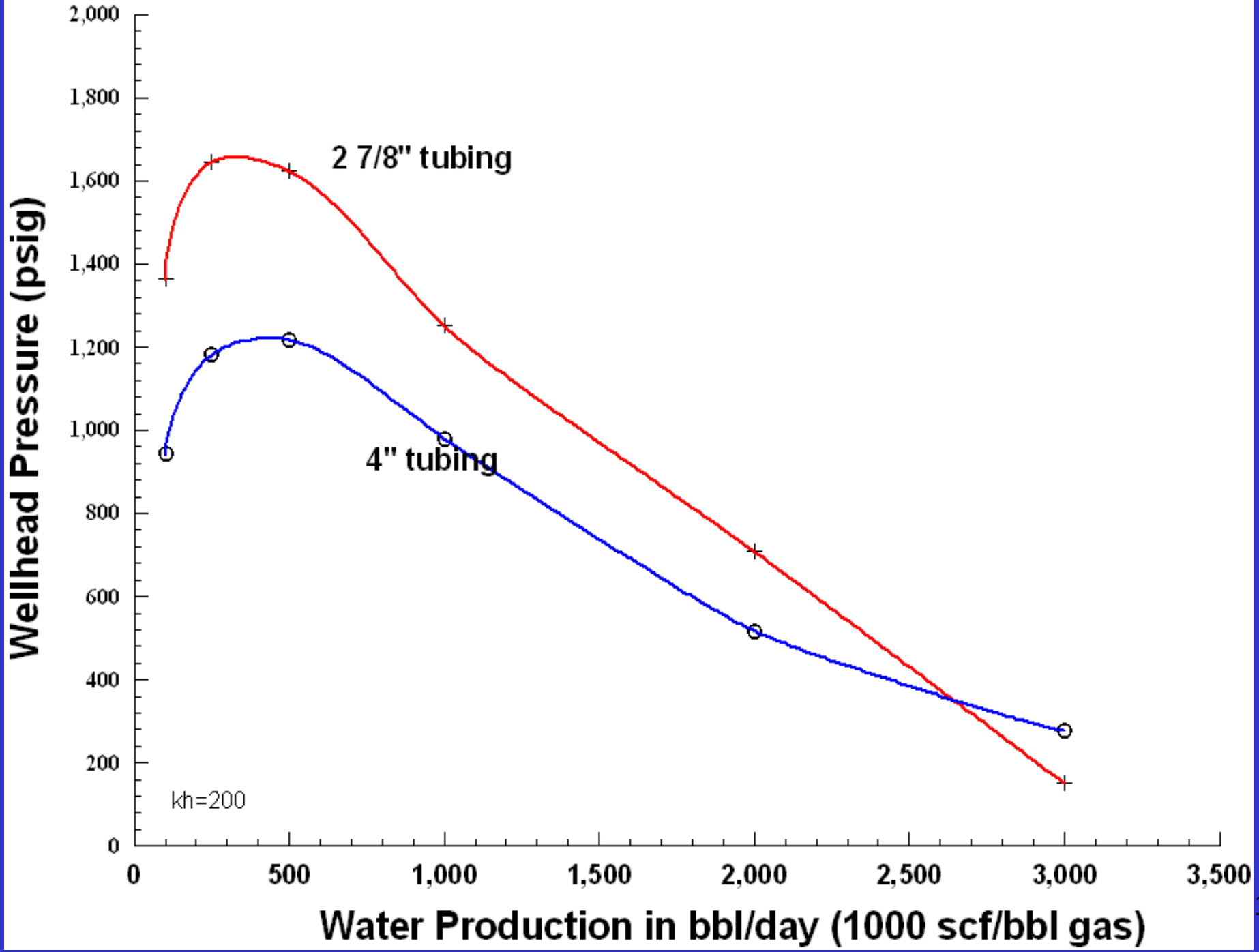
ASSUMPTIONS FOR ECONOMIC ASSESSMENT FOR CASES 2 THROUGH 5

- Unit capital Cost for Geothermal Plant: $2,800/kW
- Unit capital Cost for Gas-fired Plant: $1,500/kW
- Gas-derived or purchased power used for injection
- Geothermal Power Price: 10¢/kWh
- Gas-derived (or Purchased) Power Price: 6¢/kWh
- Gas price: $3/MCF (net of operating cost)
- Injection issue ignored for normal-pressured wells

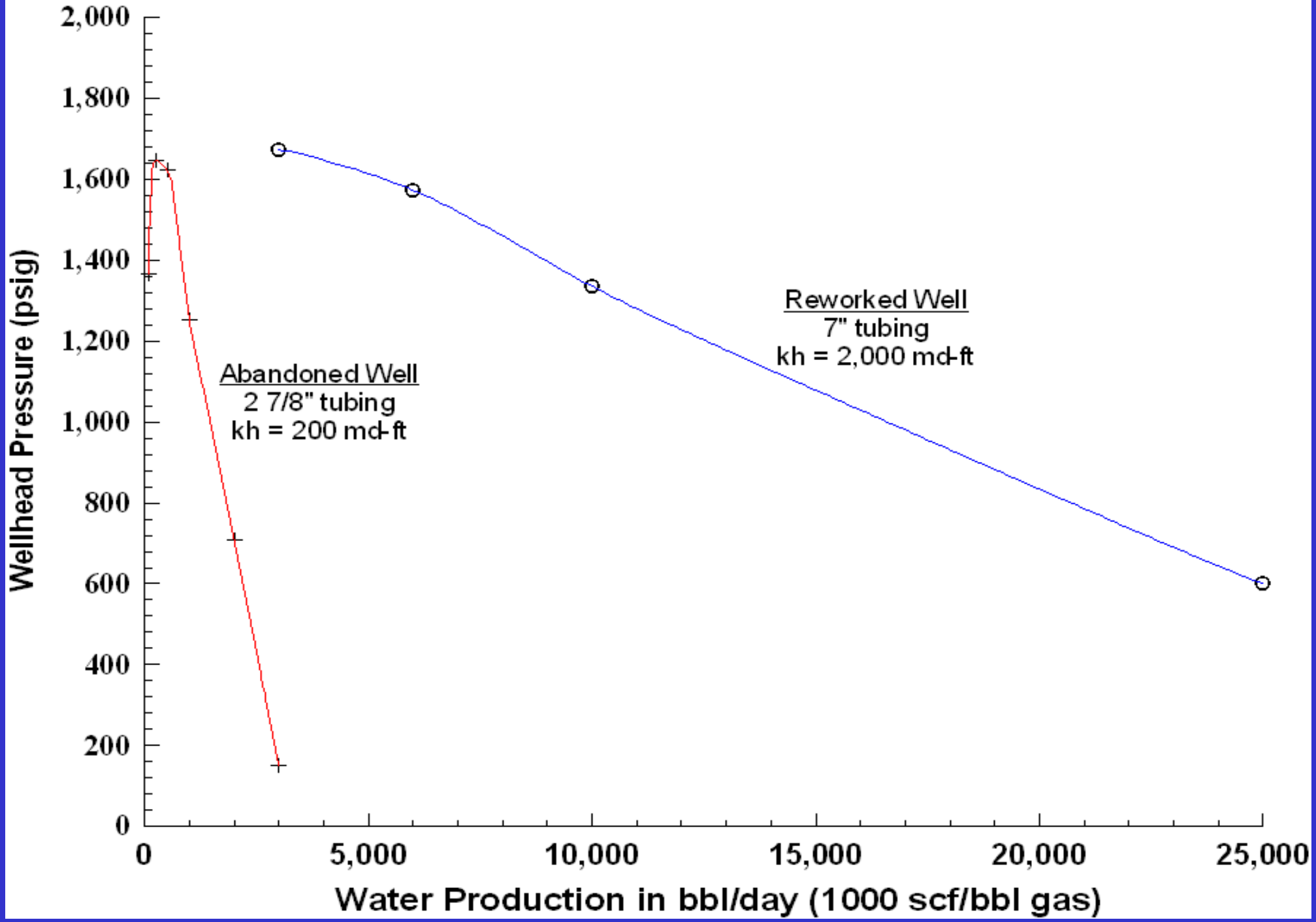
ASSUMPTIONS FOR ECONOMIC ASSESSMENT FOR CASES 2 THROUGH 5 (continued)

- For geopressured systems injection parasitic is 25% of geothermal power generation
- Operations cost: 2¢/kWh net for normal-pressured/2.5¢/kWh for geopressured wells
- Capacity factor for geothermal plant: 95%
- Capacity factor for combined geothermal and gas power plant (or gas sales system): 90%
- Costs of well acquisition and gas pipeline or transmission line connection not considered
- Resource degradation with time not considered

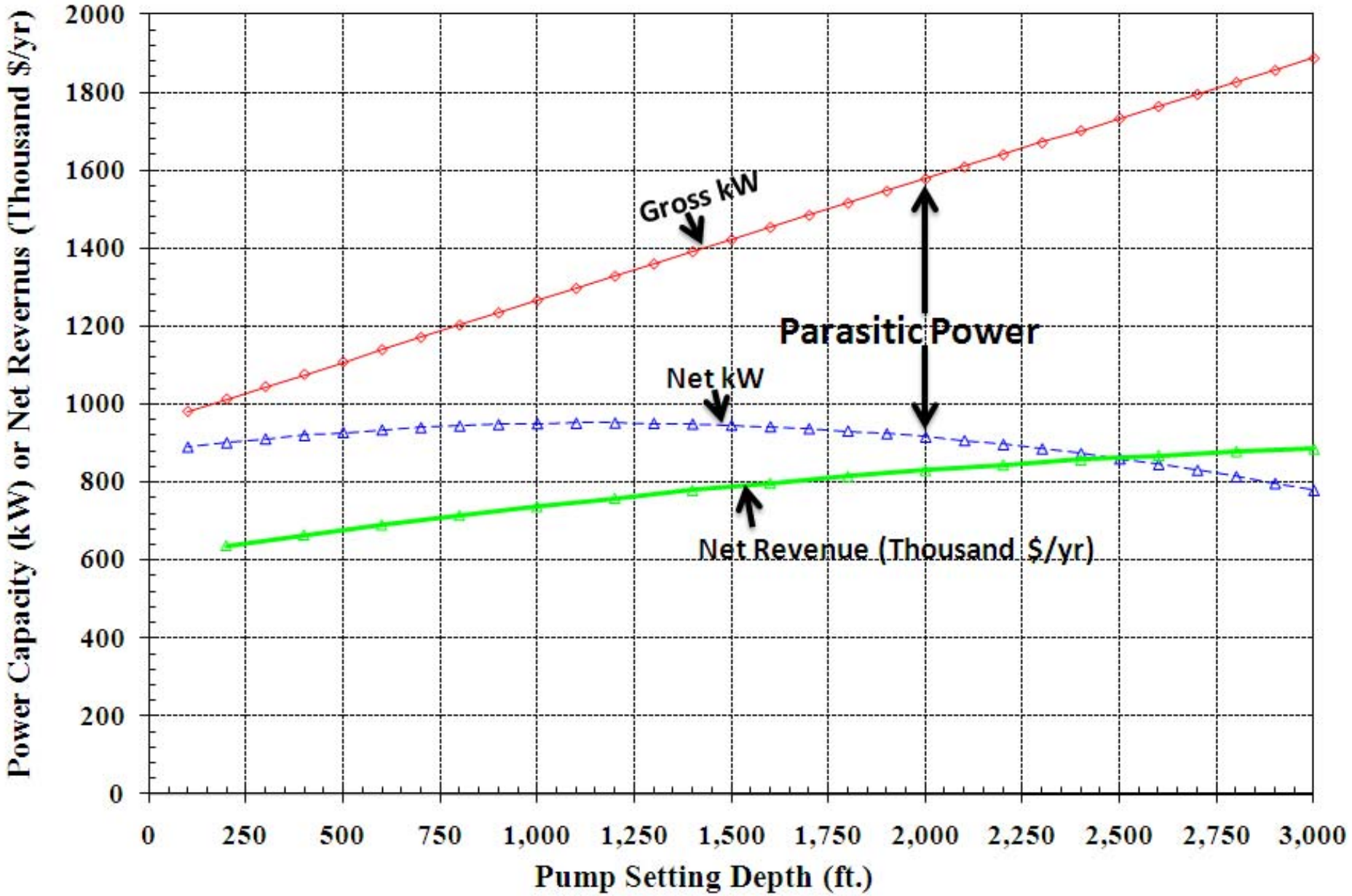
Case 2: Flow Characteristics of a Gas Well at Abandonment Condition



Case 2: Wellhead Flow Conditions of the Reworked Well



Case 2: Power Capacity of the Well if Pumped (no gas)

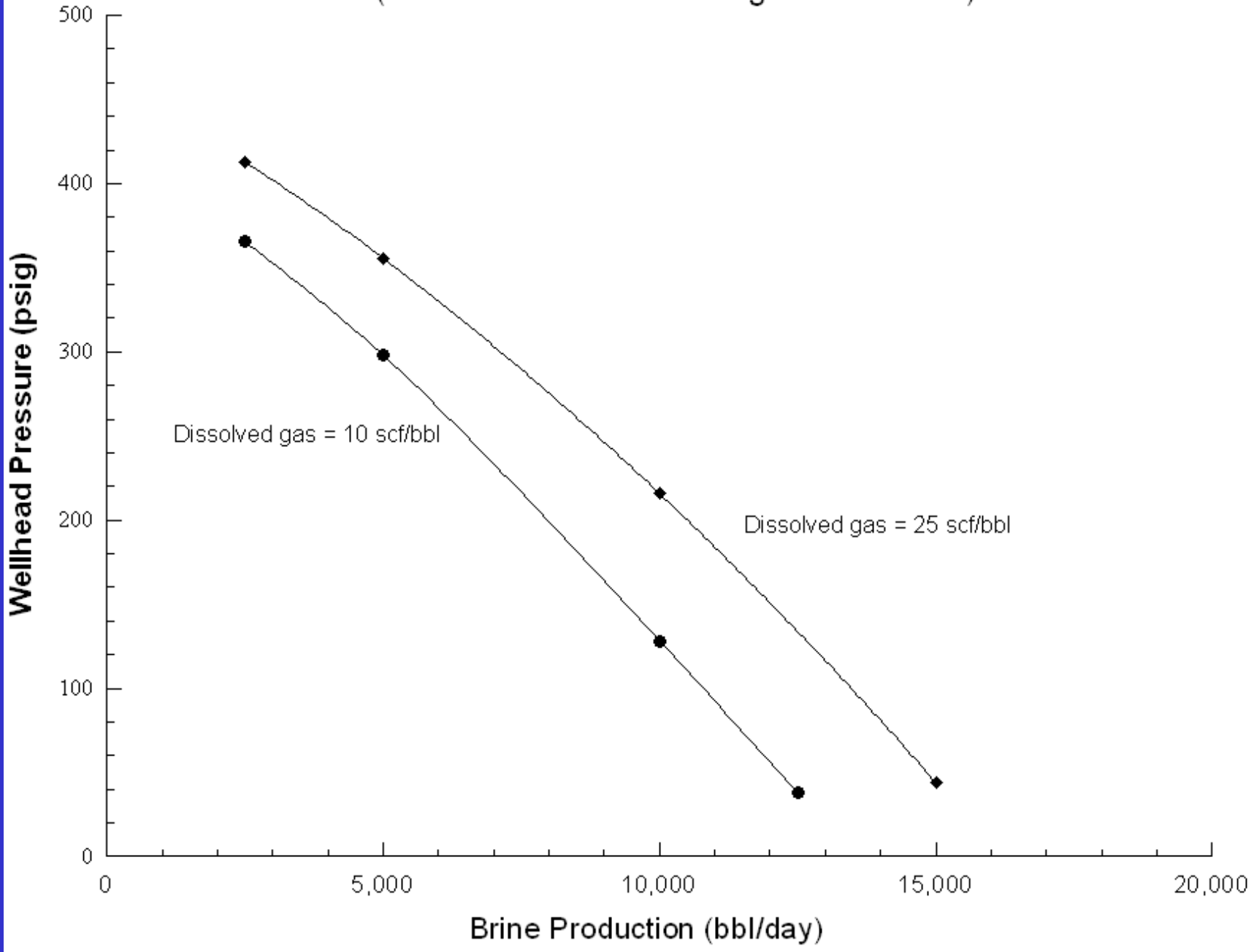


ECONOMIC ISSUES FOR CASE 2

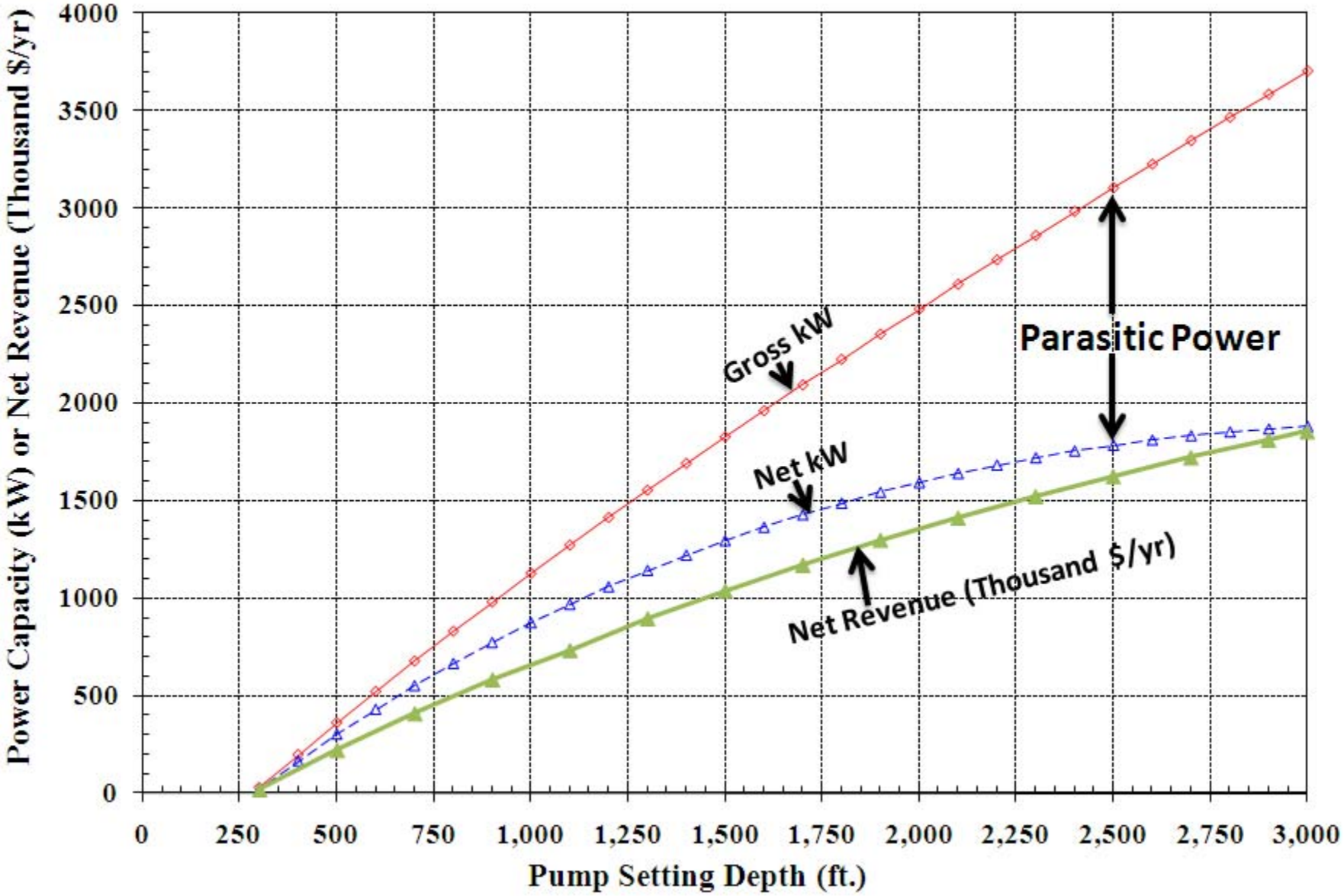
	Gas used for power generation	Gas sold to pipeline	Negligible gas / well pumped
Geothermal Power (kW)	340	340	1,340
Gas-derived Power (kW)	1,260	0	0
Production Pump Parasitic (kW)	-	-	390
Gas Sold (MCF/Day)	0	315	0
Well Workover Cost ($)	500,000	500,000	500,000
Production Pump Cost ($)	-	-	400,000
Total Capital Cost ($)	3,342,000	1,452,000	4,652,000
Unit Capital Cost ($/kW)	2,089	-	4,897
Net Annual Revenue ($)	611,800	525,000	762,300
Pay-Out Time (years)	5.5	2.8	6.1

CASE 3: Normal-Pressured 16,000 ft. Deep New Brine Well

(300°F and no reservoir gas saturation)



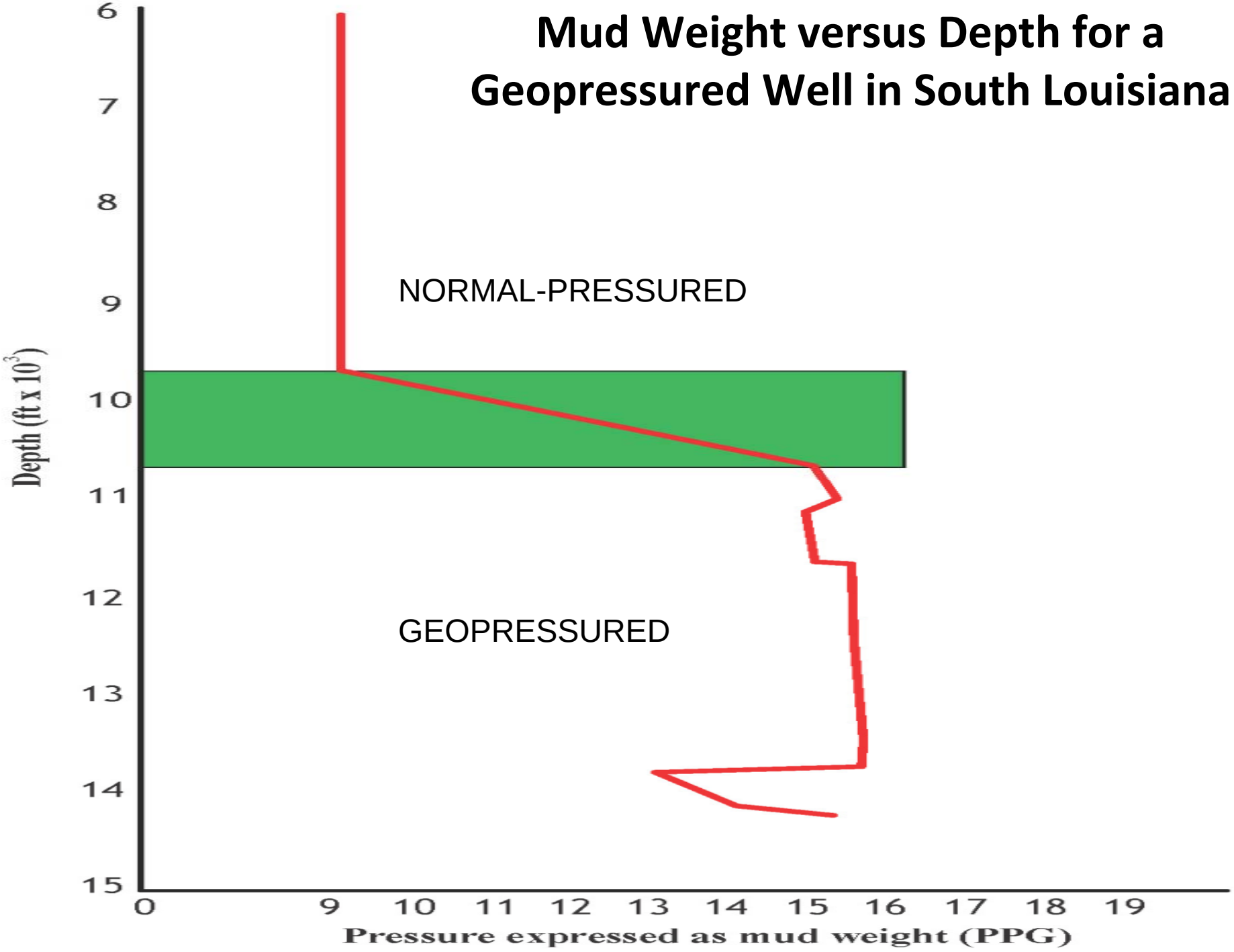
Case 3: Power Capacity of Well if Pumped



ECONOMIC ISSUES FOR CASE 3

	Self-flowing Well	Pumped Well
Geothermal Power (kW)	120	3,700
Gas-derived Power (kW)	250	1,850
Parasitic Power for Pumping (kW)	–	1,850
Production Well Drilling Cost ($)	7,000,000	7,000,000
Injection Well Drilling Cost ($)	5,000,000	5,000,000
Production Pump Cost ($)	–	700,000
Total Capital Cost ($)	12,711,000	23,060,000
Unit Capital Cost ($)	34,354	12,464
Net Revenue ($/year)	154,526	1,847,484
Pay-out Time (years)	82.3	12.5

Mud Weight versus Depth for a Geopressured Well in South Louisiana

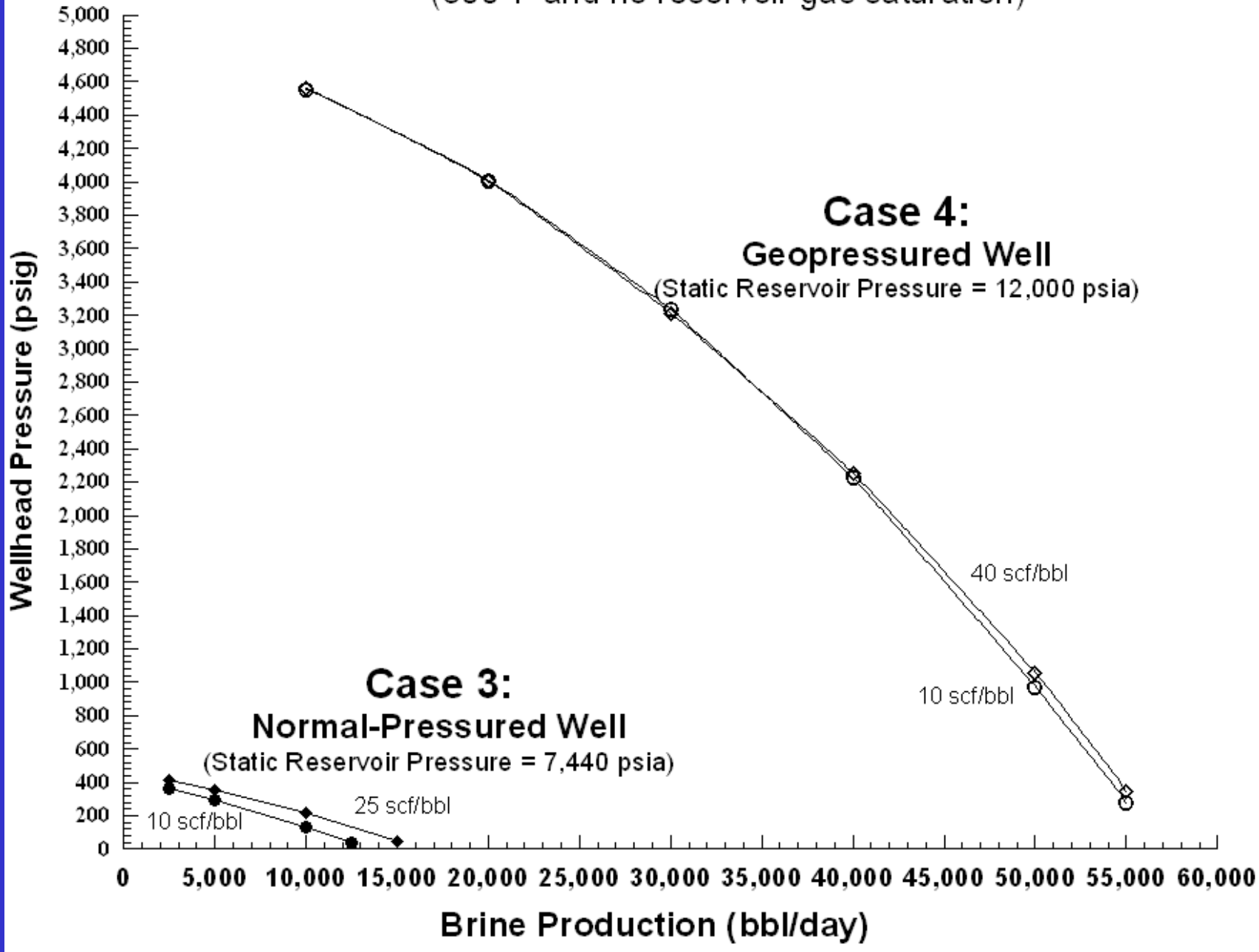


CASE HISTORIES OF TWO GEOPRESSURED WELLS

CHARACTERISTICS	CASE 4: New well drilled in Louisiana	CASE 5: Existing well in Texas
Depth (feet)	16,000	16,465
Tubing Diameter (in)	5 1/2	5 1/2
Pay Thickness (ft)	100	60
Porosity (%)	22	19
Permeability (md)	260	200
Bottomhole Pressure (psia)	12,000	9,800
Bottomhole Temperature (°F)	300	302
Solution Gas/Water Ratio (SCF/bbl)	20	24
Brine Salinity (mg/l)	130,000	127,000

Deliverability Curves of Deep Normal-Pressured & Geopressured Wells (16,000 ft.)

(300°F and no reservoir gas saturation)



ECONOMIC ISSUES FOR CASE 4 (20 SCF/bbl)

	Gas used to generate power	Gas sold to pipeline
Brine Flow Rate (bbl/day)	50,000	50,000
Gas Flow Rate (MCF/day)	1,000	1,000
Geothermal Power (kW)	2,400	2,400
Gas-derived Power (kW)	4,000	_
Parasitic Power (kW)	600	_
Total Net Power (kW)	5,800	1,800
Gas Sold (MCF/day)	0	1,000
Production Well Drilling Cost ($)	8,000,000	8,000,000
Injection Well Drilling Cost ($)	1,000,000	1,000,000
Total Capital Cost ($)	21,720,000	15,720,000
Unit Capital Cost ($)	3,745	_
Net Revenue ($)	2,357,000	2,120,800
Pay-out Time (years)	9.2	7.1

ECONOMIC ISSUES FOR CASE 4 (40 SCF/bbl)

	Gas used to generate power	Gas sold to pipeline
Brine Flow Rate (bbl/day)	50,000	50,000
Gas Flow Rate (MCF/day)	2,000	2,000
Geothermal Power (kW)	2,400	2,400
Gas-derived Power (kW)	8,000	–
Parasitic Power (kW)	600	–
Total Net Power (kW)	9,800	1,800
Gas Sold (MCF/day)	0	2,000
Production Well Drilling Cost ($)	8,000,000	8,000,000
Injection Well Drilling Cost ($)	1,000,000	1,000,000
Total Capital Cost ($)	30,120,000	15,720,000
Unit Capital Cost ($)	3,073	–
Net Revenue ($)	3,461,000	3,106,000
Pay-out Time (years)	8.7	5.1

ECONOMIC ISSUES FOR CASE 5

	Gas used to generate power	Gas sold to pipeline
Brine Flow Rate (bbls/day)	20,000	20,000
Gas Flow Rate (MCF/day)	480	480
Geothermal Power (kW)	960	960
Gas-derived Power (kW)	1,920	1,920
Injection Parasitic (kW)	240	240
Total Net Power (kW)	2,640	720
Gas Sold (MCF/day)	–	480
Well workover Cost ($)	2,000,000	2,000,000
Total Capital Cost ($)	7,568,000	4,688,000
Unit Capital Cost ($)	2,867	–
Net Annual Revenue ($)	1,031,200	974,400
Pay-out Time (years)	7.3	4.8

CONCLUSIONS

- Co-produced water hotter than 160°F can yield 6 kW (at 160°F) to 12 kW (at 212°F) per thousand bbl/day
- Whether an existing normal-pressured gas well, if reworked, can be an economic source of geothermal power and gas is a highly site-specific issue
- Drilling new wells to produce geothermal power from a normal-pressured aquifer without any gas saturation is unlikely to be economic for self-flowing wells but may be economic for pumped wells

CONCLUSIONS (continued)

- Gas-derived component of total power from a geopressured well is larger than the geothermal component; the kinetic energy component is minor
- Economic value of a geopressured well is sensitive to temperature and overpressure, and highly sensitive to gas content
- Geopressured systems are economic sources of geothermal power plus gas, if re-worked existing wells are used

CONCLUSIONS (continued)

- Geopressured systems can be economic sources of geothermal power and gas even if new wells are drilled
- Selling produced gas from a geopressued well becomes more attractive than making gas-derived power as gas price increases
- Economics of geothermal and gas-derived power from abandoned or new wells is sensitive to resource degradation rate, which cannot be generalized