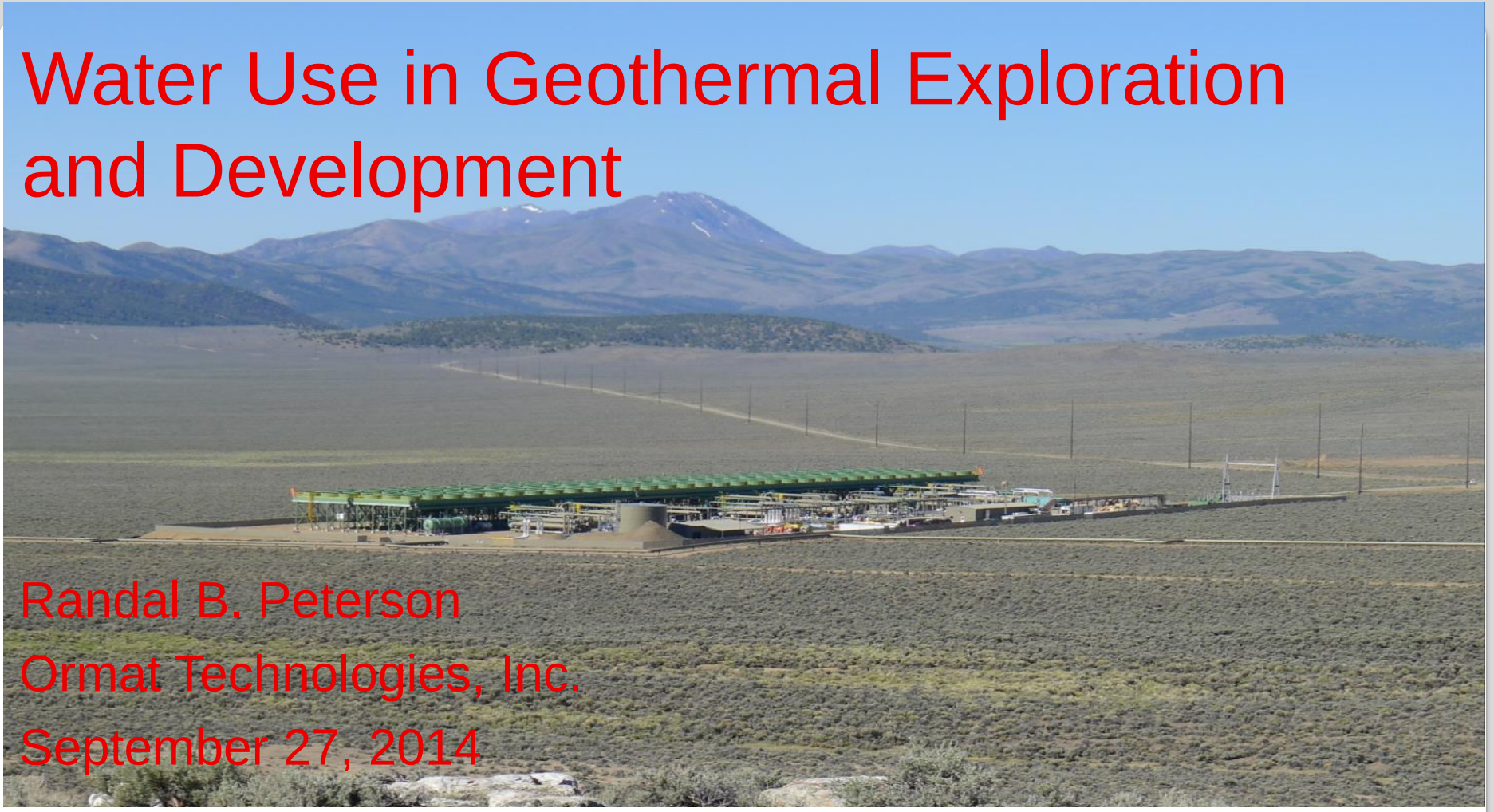
Water Use in Geothermal Exploration and Development



Randal B. Peterson
Ormat Technologies, Inc.
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What I'm going to tell you:

- Where water is consumed in exploration and development
- Who might care about your water use
- What these people may be concerned about
- Proactively managing their concerns
- Typical sources of water for your project
- Typical water consumption for exploration and development
- Geothermal fluid for drilling and cementing
- Case studies

Where is water consumed?

- Exploration:
  - Dust Suppression
  - Drilling
  - Flow Testing
  - Injection Testing
- Development
  - Dust Suppression
  - Construction
  - Cooling
  - Workover
  - Fire Suppression
  - Potable water
  - Reclamation

Who might care about your water use?

- BLM and Others with Environmental Oversight (Think NEPA – CEQA)
- Native Americans
- U.S. Bureau of Reclamation
- State Water Regulatory Agencies
- Farmers and Ranchers
- Non-Governmental Organizations (NGOs)
- Counties and Municipalities

What are their concerns?

- Environmental:
  - Impacts to (depletion or contamination of) fresh surface or ground water
    - Wildlife
    - Streams, springs, meadows, groundwater
    - Municipal supplies
    - Agricultural supplies
- Leverage Point:
  - Project opponents
  - Competitors
  - Speculators

Proactively managing concerns

- Project descriptions for purposes of environmental analysis should include water consumption estimates, sources or water, and water delivery methods
- Discuss alternatives with regulators, water brokers, ranchers, NGOs
- Be prepared to demonstrate that impacts will not be significant, or how impacts will be mitigated
  - Hydrologic studies
  - Baseline monitoring
  - Farm fallowing
  - Spring flow supplementation

Where will I get my water?

- Obtain temporary or permanent water rights and drill wells or create points of diversion (will require regulatory approvals)
- Ranchers (may require regulatory approvals)
- Commercial sources
- Municipal supplies
- Treated municipal waste water

For drilling and construction, consider Temporary Change in Manner of Use or Point of Diversion

- Using agricultural or stock water for other purposes
- Often necessary if purchasing water from rancher or other water rights holder for uses other that those originally permitted
  - Drilling
  - Construction dust suppression
  - Road maintenance
- Intra-basin change in point of diversion – from one well to another
- May not exceed one year
- May be denied if interferes with another water right
- Lender-Borrower or sale agreement required

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How Much Water Will I Need?

Exploration

- Well pad and access road construction: 30,000 gpd
- Drilling, full sized wells: 50,000 gpd

Construction

- Plant construction, grading: 50,000 gpd

Typical Project Totals

- Exploration & drilling (assume 7 wells): 40.0 Acre-feet
- Construction & development 17.6 Acre-feet
- Reclamation 13.6 Acre-feet

1 Acre-foot = 325,851 gallons

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Can I use geothermal fluid for drilling and testing?

- The simple answer: yes
  - If drilling with brine from the same reservoir, it can be argued that it is not consumed, just recirculated
  - Transporting water from another reservoir for drilling adds complications and invites intervention
    - Water quality issues – UIC
    - Consumptive use and water rights
    - NEPA-CEQA
  - Flow testing generally acceptable within the same reservoir
  - Injection testing may require additional authorizations

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Can I use geothermal fluid for cementing?

- The simple answer: with care
  - Without knowing exactly what the fluid constituents are, it can be risky. Work with an experienced cementer
  - Temperature, pH, CA, Cl-, TDS can all affect cure time, either accelerating or retarding

Property	Sample	Unit	Low	High	Affects on cement slurry
Tempeature (°F):	*N/A*	°F	40	90	High temp will accelerate, low temp will retard
pH:	*7.45*		5.5	9	High pH will accelerated, low pH will retard
Potassium (K^+):	*0*	ppm		1500	High Potassium will accelerate
Hardness (Ca^{+2}):	*450*	ppm		600	High Calcium will accelerate and cause gelation
Iron (Fe^{+2}):	*0*	ppm		300	High Iron will cause gelation
Chlorides (Cl^-):	*0*	ppm		3000	High Chlorides will accelerate
Sulfates (SO_4^{-2}):	*200*	ppm		1000	High sulfates will reduce compressive strength
Total Dissolved Solids:	*590*	ppm		2000	High TDS will accelerate

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What about evaporative cooling?

- No simple answer, each project varies with:
  - Technology; flash or binary
  - Thermal efficiency
  - Geothermal fluid temperature
  - Ambient temperature
  - Ambient humidity
  - Makeup water quality
  - Cooling water chemical treatment plan
  - Cooling tower efficiency and cleanliness

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Case Study: Fresh water for cooling

- Ormat's Galena 1 project; a 20 MW net, air-cooled, binary power plant located in Reno, Nevada

Hybrid cooling:

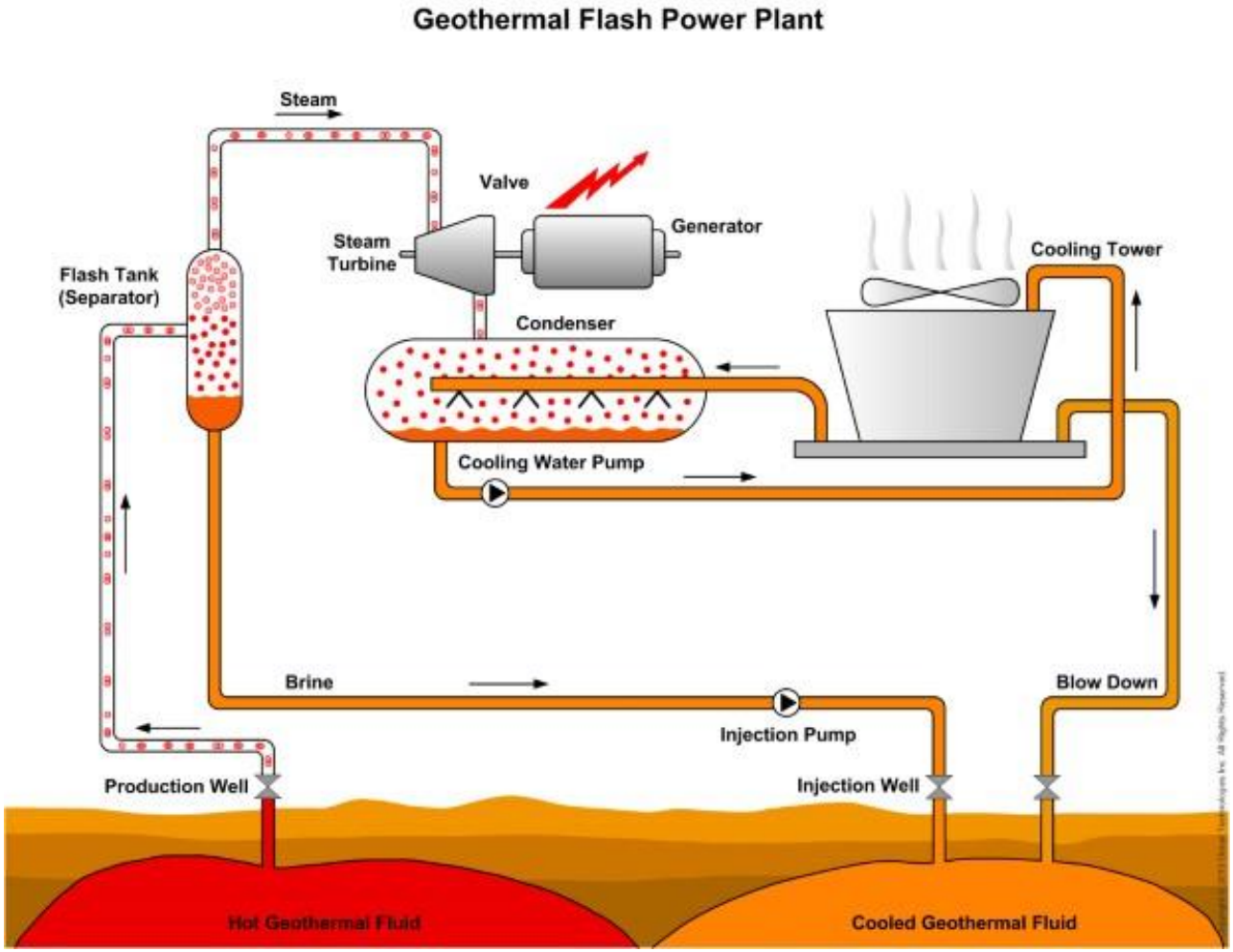
- Air-cooled technology with evaporative assist during hottest hours of day
- Much lower water consumption than conventional wet cooling
- Can be retrofitted to existing air-cooled power plants
- Can be switched on and off quickly to help balance grid

Fogging System at Work

Water Sources

- Ormat considered using geothermal condensate, tertiary treated effluent, agricultural (surface) water from the Steamboat Ditch
- Economic evaluation of capital and operational costs drove the selection of ditch water
- Ormat purchased water rights in the secondary market; existing water rights holders
- Converting from agricultural to industrial requires additional rights for return flows
- In low water years, water allocation may be restricted

Case Study: Geothermal condensate for cooling



Water source:

- Condensate from flashed geothermal fluid
- Submit application for appropriation of maximum estimated condensate evaporation
- Unlikely to be required to obtain existing water rights, assuming a completely different reservoir/aquifer from fresh water users
- Be prepared to defend appropriation: hydrologic and reservoir models to show no impact to other water rights holders, wildlife, or the environment
- Once granted, project must show consumptive beneficial use by metering production and injection, calculating evaporation
- Extensions for additional time to demonstrate beneficial use often granted

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For more information:

- Check recent NEPA – CEQA documents for discussions on water sources and consumption
- Nevada Division of Water Resources: http://water.nv.gov/index.cfm
- California Department of Water Resources: http://www.water.ca.gov/
- Oregon Department of Water Resources: http://www.oregon.gov/owrd/pages/wr/index.aspx
- Geothermal Energy Association http://geo-energy.org/ search: “cooling water consumption”

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