DIRECT USE GEOTHERMAL IN WASHINGTON STATE PAST, PRESENT, AND FUTURE

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ABSTRACT

Direct use geothermal resources have played a large and important role in Washington's history. Early hot spring development brought thousands of tourists and settlers in the early 1900s, and helped lead to the creation of two national parks. Renewed interest in geothermal development, spurred by the oil crisis of the 1970s, resulted in the identification of significant low-temperature potential and the development of the nation's first major geothermal heat pump project, a project that was widely replicated and helped create today's geothermal heat pump industry.

Recently completed investigations have tripled the state's thermal well database and, with renewed interest in renewable energy development by utilities as well as by state and federal government agencies, the future for accelerated widespread development seems almost assured.

PAST

The direct use of geothermal resources in Washington State had its modern beginning in the late 1800s, but its benefits had been enjoyed by the native Indians for centuries before. In the early 1880s, Theodore Moritz, a settler in the Quillayute Valley, was out hunting and came across an Indian who had broken his leg. Mr. Moritz took the injured man home and nursed him until be could travel. In gratitude, the Indian told him of some wonderful curative "fire chuck" (hot water) that bubbled from the ground where Indians had gone for years to cure their ailments. The Indian led Moritz to what is now Sol Duc Hot Springs, and Moritz later returned to build a cabin and file a claim with the U.S. Land Office. Word spread of the healing waters and mud, and people began making the two-day horseback trip from Port Angeles. In 1903, Michael Earles, owner of the Puget Sound Mills and Timber Company, accompanied a group of people to Sol Duc. Earles had been told by his doctor that he was dying and was advised by his doctor to travel to Carlsbad, but was too weak for the long journey. The mineral water at Sol Duc cured him, and in gratitude he decided to build a place to help others. In 1910, Earles bought the site from the heirs of Theodore Moritz and founded the Sol Duc Hot Springs Company with four other men as trustees. The company built a road to Crescent Lake, allowing guests to travel from Port Angeles by Stanley Steamers. The passengers then boarded the Betty Earles steamboat that carried them across the lake where more Stanley Steamers awaited to transport them the final 15 miles to the resort. Sol Duc soon became the most noted pleasure and health resort on the Pacific Coast. Michael Earles spent fully a half million dollars in creating the resort which was opened on May 15, 1912, and which, during its peak year, handled 10,000 guests from all over the U.S. and from as far away as Europe. One hundred sixty-five guest rooms, each with an outside view, had electric lights, telephones, hot and cold running water, and steam heat. The hotel was luxuriously furnished and had objects of art, including beautiful European tapestries. Several immense fir trees enameled white with gold trim served as pillars for the 110 x 90 ft. lobby that contained a gallery for musicians. Guests at the resort drank the mineral water and bathed in the water in tubs, showers, mud, or vapor. The temperature of the hot springs was 60°C, and contained sodium, potassium, magnesium, silicon, iron, and other minerals. It was believed the waters were particularly good for rheumatism, diabetes, ulcers, gout, blood disorders, skin infections, liver, kidney, and nervous diseases and other disorders. The mineral waters were also bottled and sold as delicious draught with marvelous healing qualities to be enjoyed at home. For several years, the Sol Duc Hot Springs Company had an office in Port Angeles to distribute the bottled water (Kellogg, 1975).

In addition to the hotel, there was also a three-story sanitarium complete with operating room, appliances for surgical cases, a laboratory, and an x-ray. The sanitarium had beds for 100 patients.

On May 26, 1916, after only 3 years of operation, the fabulous resort was destroyed by fire started when sparks from a defective flue lit on the roof of the main hotel building. Although the caretaker tried to put out the fire, he discovered that the water had been turned off for the winter (Kellogg, 1975).

The fire at Sol Duc did not, however, signal the end of the growing interest in hot spring resorts. Although Sol Duc was never again to achieve its earlier grandeur, it was modestly rebuilt and is now part of the Olympic National Park.

Nearby Olympic Hot Springs also saw considerable development only to be returned to its natural state by the Park Service in 1973.

Other resorts were built at Longmire and Ohanapecosh Hot Springs, now part of Mt. Rainier National Park, and at North Bonneville and Carson, both located in the Columbia River Gorge (Bloomquist, 1979).

Renewed interest in Washington's geothermal resource began in the mid to late 1970s as a result of the oil embargo of 1973 and oil crisis of 1979. The primary emphasis was on the discovery, evaluation, and commercialization of high temperature resources that could be harnessed to generate electricity. A majority of the activity was centered in the Cascade Range, where it was thought that high temperature geothermal resources would be most likely to occur. Investigations conducted during the late 1970s and early 1980s in the Cascades by the Washington State Department of Natural Resources, Division of Geology and Earth Resources (DNR) included description, sampling, and chemical analysis of thermal and mineral springs, and several episodes of heat-flow/temperature-gradient drilling. In addition, regional gravity studies were conducted in the Cascades along with geologic mapping and geochemical and soil mercury studies. Over a million acres were once under lease application throughout the Cascade Mountains of Washington, but due to environmental concerns, delays in completing environmental impact studies by the U.S. Forest Service, and a surplus of low-cost electricity throughout the 1980s, few leases were actually granted and no major exploration programs were completed by industry.

Direct use geothermal resources, however, were found to be abundant, widespread, easy to access, and increasingly cost effective. A detailed assessment program carried out by the DNR identified 338 warm water wells (wells at a temperature at or above 20°C throughout the Columbia Basin (Korosec, et al., 1981). The Washington State Energy Office (WSEO), working cooperatively with DNR, identified a number of promising development projects. In 1980, WSEO began the design of what was to become the nation's first major dual purpose geothermal heat pump project. The system was based on the use of an 30°C, 550 m, 140 sec., municipal well in Ephrata, Washington. In 1980, with assistance from WSEO and the Oregon Institute of Technology Geo-Heat Center, the city of Ephrata applied for a grant under the Department of Housing and Urban Development's Innovative Community Energy Conservation Program. The $468,000 grant allowed for the construction of the new geothermal heat pump plant designed to provide all of the heating and cooling requirements of the Grant County Courthouse and Courthouse Annex, the retrofit of the Courthouse complex, and a demonstration project in the June's Court low-income housing project (Bloomquist, 1983).

The heat pump system was designed to remove approximately 7.5°C from a 30°C city water well. The water was then returned to the municipal system. The two-stage heat pump was capable of supplying 52°C to 65°C water to the Grant County Courthouse's central heating system, resulting in an 80 percent decrease in energy consumption and an 85 per cent decrease in the Courthouse fuel bill. The June's Court project consisted of retrofitting a number of units to use geothermal heat pumps. Both projects were completed in 1983, and received national awards from the U.S. Department of Energy and from the American Society of Heating and Refrigeration Engineering (ASHRE). The uniqueness and importance of the system also resulted in commendations for the Governor and the Washington State Legislature. This project also marked the first acceptance by state health regulators of the secondary use of water that had passed through a heat pump, and served as the model for the acceptance of such systems throughout much of the U.S.

The project served as the catalyst for several additional projects, including the Yakima County Jail, Washington State Department of Social and Health Services Office in Yakima, several schools, including two community colleges, and numerous commercial and residential installations. Studies completed by WSEO and DNR initially identified 22 cities in central and eastern Washington with proximity to geothermal resources. Geothermal district heating feasibility studies were completed in six cities by 1985, using HEAT-PLAN, a new computer program developed by WSEO for this purpose.

However, 1985 also saw one of the most dramatic decreases in competing energy prices with natural gas dropping to less than half of projected levels. The low natural gas and oil prices, coupled with a significant surplus in electrical generation capacity, removed any economic incentive for the development of capital-intensive geothermal systems by developers or incentives for energy conservation by utilities. In addition, the Washington State Department of Ecology (DOE) found itself further and further behind in adjudicating water rights and, in many areas, a total moratorium on new water rights was put in place, often stopping projects that were still attractive from both an energy and economic perspective.

PRESENT

The 1990s have brought new interest in geothermal resources development in Washington State. California Energy Company has filed lease applications in both the northern and southern Cascades (McClain, 1993). Seattle City Light, the state's largest municipal utility, has begun a reassessment of its position on future geothermal development. Puget Sound Power and Light, the state's largest investor-owned utility, entered into an agreement to purchase electricity generated from geothermal resources in California. And the Bonneville Power Administration (BPA), with support from the Northwest Power Planning Council, initiated a program to demonstrate the technical, economic, and environmental acceptability of geothermal electric generation in the Northwest. In 1993, the CARES (Conservation and Renewable Energy Systems) was founded by a number of public utilities to pursue the development of renewable energy projects. However, by far the greatest interest remains in the development of the state's tremendous low-temperature geothermal potential found mostly in the Columbia Basin counties of Adams, Benton, Franklin, Grant, Walla Walla, and Yakima (Figure 1). This new interest stems from the fact that more and more of the state's electrical utilities are discovering that low-temperature geothermal, when coupled with new high efficiency water source heat pumps, can be an extremely attractive demand side measure. The installation of such systems not only reduces total energy consumption in comparison to electrical resistance or air-to-air heat pump heating system, but can reduce demand by up to 50 percent, thus significantly reducing the need to build new generation facilities. Water source heat pumps have also becomes a major element in many utility programs designed to maintain market share, being the only technology readily available to them that compares favorably with extremely cost-competitive natural gas. Many manufacturers of water source heat pumps claim COPs exceeding 4.5 and, when coupled with geothermal sources, may exceed 6.0. For example, the Ephrata Grant County Courthouse complex routinely achieves a COP of 5.8.

In order to further the development of the state's low-temperature geothermal potential, DNR and WSEO in 1993, under contract to USDOE, began a reassessment of the state's geothermal resources. Because of the limited funding available, the assessment relied primarily on a compilation of a bibliography and index of geothermal resources and development and a thorough review of existing data sources (Christie, 1994). However, 18 samples were taken for detailed chemical analysis. The analysis of these samples was performed by the University of Utah Research Institute. By far the most productive of the new or much-expanded sources of data are the unpublished water well reports held in the Yakima and Spokane regional offices of the Washington State Department of Ecology and the U.S. Geological Survey's WATSTORE database (Washington State Department of Ecology, April 12, 1993; Washington State Department of Ecology, May 3, 1993; Washington State Department of Ecology, January 18, 1994; U.S. Geological Survey, 1993). The current database includes 941 wells and 34 springs, spring systems, fumeroles, and warm lakes all with a temperature at or above 20°C (Schuster & Bloomquist, 1994). This represents an almost threefold increase in the number of wells since the completion of the last major assessment (Korosec, et al., 1981) that located and assembled basic data on 338 wells, 31 thermal springs, spring systems, fumeroles, warm lakes, and 29 mineral springs. In order to facilitate further assessment and development of geothermal resources in Washington, this database has been established on the geographic information system (ARC INFO) of the Washington State Energy Office. This will provide the ability to easily combine and evaluate the geothermal data with many other kinds of spatial data such as the collocation of wells and significant thermal loads, e.g., schools, government facilities, etc.

The first observation one would be likely to make upon studying the distribution of geothermal resources in Washington is that they are not randomly distributed. Thermal springs are largely confined to the Cascade Mountains (27 of 34 are in the Cascades), and most are spatially associated with a stratovolcano or a fault that probably provides for heating by means of deep circulation of water. Thermal wells, on the other hand, are strongly associated with the Columbia River Basalt Group and located in the Columbia Basin, including the various sub-basins that form the southwestern and southcentral parts of the Columbia Basin in Washington. Some 97 percent of the state's 941 thermal wells are located in areas underlain by rocks of the Columbia River Basalt Group or supra-basalt sediments. Moreover, within the Columbia Basin there is a strong tendency for thermal wells to occur in the western, southwestern, and south-central parts of the Washington portion of the Columbia Basin. The six counties so located (Adams, Benton, Franklin, Grant, Walla Walla, and Yakima) account for 786 (83.6 percent) of Washington's thermal wells. Yakima County alone contains 259 thermal wells, more than twice as many as the next highest county (Schuster & Bloomquist, 1994). Because of this, these six counties are clearly the most advantageous places to focus development efforts (Figure 1).

The Columbia River Basalt Group is a thick succession of theoleiitic basalt that has erupted from fissures in southeastern Washington, northeastern Oregon, and western Idaho between 17 million and 6 million years ago. There are more than 300 separate lava flows covering an area of 164,000 square kilometers, and with an aggregate volume of 174,000 cubic kilometers.

Within the Columbia River Basalt Group, flow bottoms are often pillowed, rubbly, or mixed with subjacent sediments, and flow tops are frequently rubbly, oxidized, vesicular, or scoriaceous. The interior parts of the flows, although usually joined, are often of low permeability. In contrast, the flow tops and bottoms and interflow sediments are generally quite permeable and porous, and make good aquifers. Because many of the flows are of great lateral extent, the associated aquifers are also of great lateral extent.

To the west in the Cascades, and to the east in the Palouse hills and the mountains of eastern Idaho, precipitation is higher than in the basin itself, and these areas provide the recharge areas for the basalt aquifers, both because of the higher precipitation and because the lower basalt units crop out in these areas.

The combination of basinal shape, laterally-extensive aquifers that are confined between relatively impermeable basalt flows, and high precipitation recharge areas to the east and west, means that the hydrologic gradients are sloping into the deepest part of the basin near Pasco and into the deeper parts of the sub-basins of the Yakima fold belt where deeper aquifers are often confined and under artesian pressure.

Low Temperature Geothermal in Washington

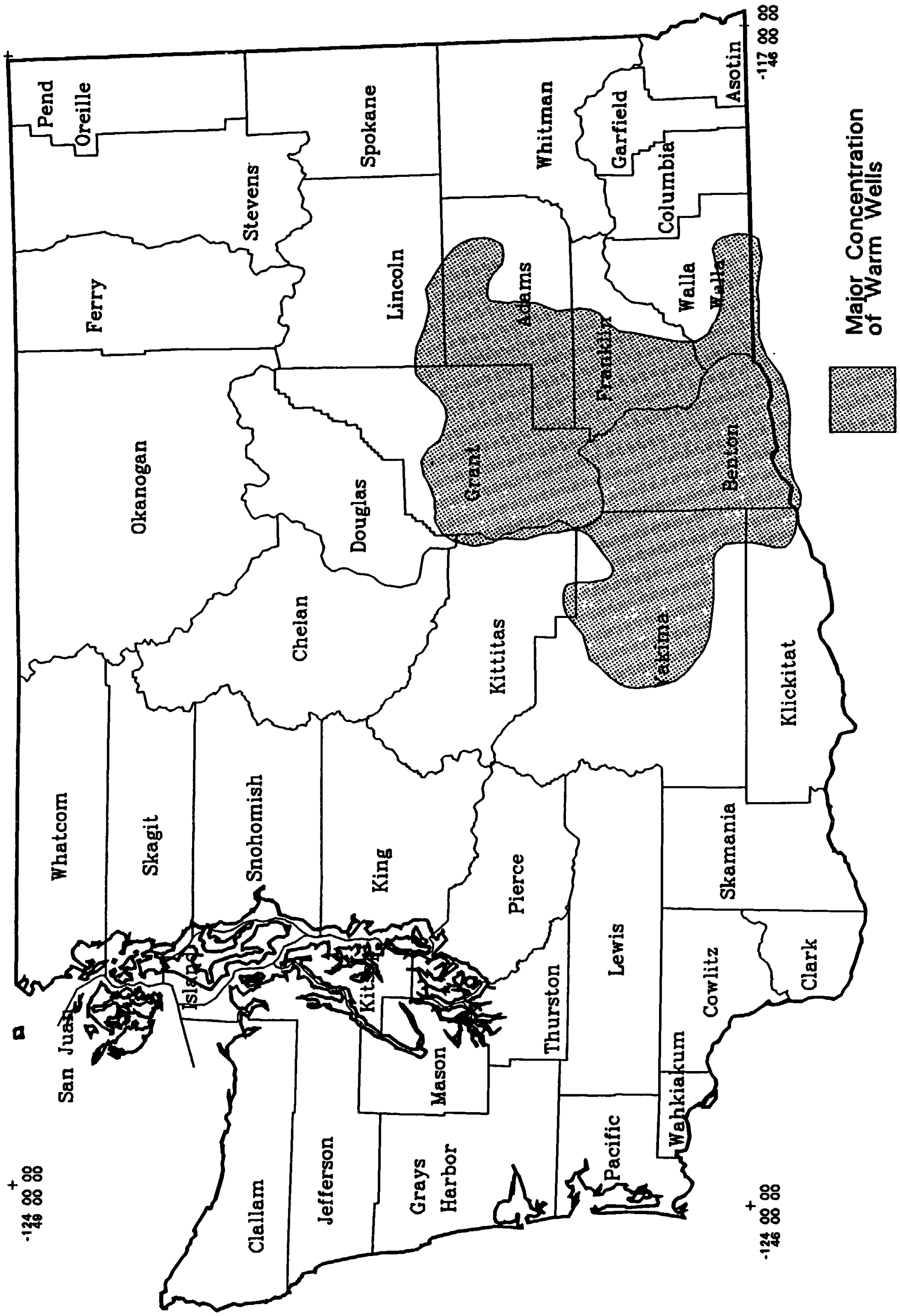

Figure 1

In addition to the attractive hydrology of the basin, equally important factors in the existence of a developable geothermal system are heat flow and temperature gradient. Compared to the northern Rocky Mountains province and the high heat flow zone of the Cascade province, the Columbia Basin does not have high heat flow (Table 1); in fact, heat flow in the Columbia Basin is approximately equal to the world-wide average. However, because the thermal conductivity of the rocks is low, the Columbia Basin has a higher than world-wide average temperature gradient. At 41°C/km it also has a higher temperature gradient than any other area in Washington except for the high heat flow zone of the Cascades. Assuming an average surface temperature of 10°C, that means that the 20°C isotherm can be reached in the Columbia Basin in a well only 250 meters deep, on the average.

Table 1

	Avg. Gradient	Avg. Heat Flow
Columbia Basin	41.1°C/km	61.1 MW/m^2
N. Rocky Mountains	26.0°C/km	74.9 MW/m^2
Cascades		
High heat flow zone	64.0°C/km	100 MW/m^2
Coastal Provinces	24.5°C/km	39.8 MW/m^2

Blackwell, et al., 1985

The favorable regional geothermal gradient, the extensive interflow aquifers of the Columbia River Basalt Group, the complex basin shapes with recharge areas at significant distance to the west and east that bring about deep circulation of groundwater and the relatively long residence time that allows the water to be heated all contribute to the establishment of one of the country's most favorable low-temperature geothermal resource areas. It is obvious to any visitor to the six-county area of the Columbia Basin (Adams, Benton, Grant, Franklin, Walla Walla, and Yakima counties) who is aware of the number and location of warm wells, the extensive agriculture and population centers, and alert to the many possibilities for development, that the area is rife with attractive opportunities for development of low-temperature geothermal resources for space and process heating, agriculture, and aquaculture developments.

FUTURE

The future for low-temperature geothermal development in Washington State must be seen as extremely positive, especially in light of the abundant and areally widespread occurrence of the resource and the new and increasing interest in renewable energy development by utilities and the state and federal government. In fact, the Clinton Administration's Global Change Action Item #26 gives considerable attention to the need and desirability of developing low-temperature geothermal heat. But probably most important is the renewed interest on the part of the state's public- and investor-owned utilities and an increasing desire on the part of state and municipal government to expand the use of renewable energy resources wherever technically and economically feasible. This common interest on the part of utilities and government provides a natural mechanism for targeting further assessment and development activities.

Because there are still significant problems associated with the obtaining of new water rights, development activities are being directed toward sites where thermal wells already exist, where such wells are under the control of a government entity, and where the water is used or usable year round, i.e., nonirrigation wells. Development is also being focused upon sites where significant new construction or redevelopment is or will be taking place, e.g., schools, correctional facilities, and institutions of higher education. For example, from a quick analysis of the database, 63 cities of 5,000+ population are found to be located within 8 kilometers of a geothermal well. Further analysis locates 24 schools that have construction or remodeling projects planned or underway, totaling ca 150,000 square meters and with an aggregate budget of over $100 million. These 24 schools have a total of 259 thermal wells within 8 kilometers, many of which are owned by the municipality, county, port district, state agency, or the school district itself. In fact, out of the 941 thermal wells identified, 250 are under government ownership.

But the availability of low-temperature geothermal resources and the collocation of a need for thermal energy is in no way a guarantee that development can or will take place. Decision-makers, as well as those who advise them, e.g., architectural and engineering firms, must be made aware of the availability of geothermal resources and the reliability of the use of geothermal water-source heat pumps. Regulators in the Department of Ecology and Department of Health must be convinced of the benefits and extremely low risk associated with installation that either reinject the water or use it in a secondary manner once it has passed through the heat pump. And, finally, mechanisms must be put in place that ensure that the generally high front end capital cost of these systems is not a deterrent to development. Many utilities are adopting incentive programs that encourage the development of geothermal heat pump systems, either in the form of rebates or long-term lease arrangements. The cost of such systems can also be significantly reduced through advancements in drilling technology and improvements in system efficiency.

CONCLUSION

Low-temperature geothermal resources have played an important role in Washington's history. Early developers at Sol Duc, Olympic, Longmire, and Ohanapecosh brought tourists and settlers to the state beginning in the early 1900s, and played a major role in the designation of both Olympic and Mt. Rainier National Parks.

Geothermal heat pump developments in Ephrata and Yakima in the early 1980s helped establish the present heat pump industry and led the way to numerous replications through Washington and the entire west.

Bloomquist and Schuster.

Renewed interest in renewable energy development by local, state, and federal government agencies and public and private utilities; significant decreases in the cost of installation and increases in system efficiency; and increased knowledge about the occurrence and widespread availability of the resource, all point to a bright future for low-temperature geothermal resource development in Washington State.

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