SUMMARY REPORT
CONCERNING WATER RESOURCES
AND WATER QUALITY IMPACTS
RELATED TO GEOTHERMAL ACTIVITIES
IN OREGON

BY

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ABSTRACT

This report provides a survey of Oregon's Known Geothermal Resource Areas (KGRA's) particularly in regards to regional water resource characteristics and 1979 geothermal development activities. Water use requirements were estimated from a projected 25 year development scenario for nine major geothermal resource areas in Oregon. The potential water use requirements significant include: the Alvord and Vale KGRA's, which reportedly have geothermal resources particularly suited for electrical power generation, and the Cascades' hot water resources, which have potential use in direct heating.

A review of the chronological account of geothermal activities and impacts was projected for each of Oregon's KGRA's. Water quality issues and concerns regarding prospective geothermal activities within the resource areas were identified and ranked. The major concerns were: potential surface water pollution and degradation, changes in the groundwater regime, both chemical, thermal and hydraulic, erosion and sedimentation, subsidence and land mass movements. Disparate concerns were associated with the region because of different prospects for resource development and the variety of topography associated with the sites.

Water quality baseline information was collated on Oregon's geothermal resources. The chemical attributes of Oregon's hot springs and wells were compared and considered as models for heated waters to be drawn for electrical power generation or direct use heating. On the basis of water quality standards, most of the thermal spring waters would be undesirable to discharge directly to surface waters following thermal recovery. A call was made for improving the (surface and subterranean) water quality data base, establishing meaningful monitoring of the potential of Oregon's geothermal energy resources.
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I. INTRODUCTION

The environmental issues which will determine the acceptability of geothermal resources utilization need to be resolved for exploration of Oregon's resources. Known hydrothermal reservoirs in Oregon need to be assessed and demonstrated by the state and industry to utilize hydro(geo)-thermal resources optimally in terms of economic and environmental constraints.

Environmental impact data relevant to geothermal resource development are sparse since there are only three sites in the world with a significant history of geothermal power generation. While electrical power production from geothermal power resources is a relatively new industry, geothermal hot water and steam have been used beneficially for centuries. Non electrical space and direct heat uses by industry have been manifest for decades. The growing shortage of oil and natural gas is expected to cause a rapid increase in the utilization of geothermal resources; concurrently there is an increased environmental consciousness regarding exploration, development and utilization of natural resources which brings us to examine the potential water resource and water quality impacts associated with the development of geothermal resources within the State of Oregon. Geothermal energy, like any other energy source, can be exploited to result in negative impacts on the water quality of an area.

However, hopefully through examination of available information on geothermal resources, the nature of geothermal fluid's chemical attributes, and improved technology for pollution control, there will be minimal impacts on Oregon's water resources. Accordingly, this report is to provide an in-depth perspective of the key water quality issues surrounding development of geothermal energy in the State of Oregon.

This report supercedes the March 1979 Oregon Geothermal Environmental Overview Workshop's water quality sessions' record, which is presented as Appendix I. This report expands on the workshop discussions and subsequent reviews. Additional bibliographic documentation has been provided concerning Oregon's environmental water data base and on
the water related impacts and water assessments of emerging energy technologies associated with the potential regional geothermal developments.

I.1. OBJECTIVES

The goals of this project parallel those of the overview workshop, which are:

+ Identify water quality issues of concern in the development of geothermal energy.
+ Prioritize these water quality issues.
+ Inventory and assess the available data on these issues.
+ Determine gaps in the data and information for clarifying water quality issues for Oregon's KGRA's.
+ Suggest needed water quality studies for Oregon's KGRA's.

In accomplishing these goals it was hoped to also satisfy some tasks associated with Oregon State University's Water Resources Research Institute's efforts with the Pacific Northwest River Basins Commission on providing a "Water Assessment of Emerging Energy Technologies" with a focus on geothermal activities in the State of Oregon, including:

+ selection of candidate areas for potential location of emerging (geothermal) technologies
+ compare siting criteria of geothermal energy technologies to siting characteristics in each water accounting unit
+ evaluate resource requirements of energy development patterns and water accounting unit's resource availability
+ quantify water deficits of emerging energy deployment patterns

I.2. SCOPE OF INVESTIGATION

The purpose of this reporting effort is to assess current and future water quality issues facing the State of Oregon as concerns the potential development of geothermal energy as a resource. A systematic statewide investigation of water resource and water quality information relating to potential geothermal activity has been made. Characteristics and potential activity for Oregon's known geothermal resource areas (KGRA) were identified. Estimates of water use for direct heat utilization and power production were compiled; combined Western Cascade use projections were the
largest of the systems considered, being as much as 40,000 l/s (1400 cfs) for supplying 2000 MWt direct heating.

A section of this report delineates regulations regarding concern for maintaining water quality during geothermal resource developments.

A comparison was made of recently reported water chemistry of the state's thermal springs and wells with accepted water quality standards for human, irrigation and livestock consumption. On the basis of present water quality standards, most of Oregon's thermal waters would be undesirable for disposition to surface waters.

A ranking of general environmental impacts (ecological, air, water, solids and noise pollution) was made for seven identified KGRA's of the state encompassing periods from pre-lease exploratory through field and operational stages of geothermal energy extraction. The scenario offered from the geothermal projections section was used for estimating water requirements of geothermal activities; a discussion on this matter was included because it was felt that the topic has not been seriously addressed in previous environmental reviews because of the lack of accurate information on particular geothermal site potentialities.

Available bibliographic materials regarding water resources and water quality for the Oregon KGRA regions were cross referenced. Limited information was found. Accordingly, baseline studies and geothermal monitoring studies emphasizing the gathering of water resource and water quality information were recommended.

Appendices were included which covered: the water quality session record of Oregon's Geothermal Environmental Overview Workshop, a general paper on geothermal development impacts on water quality, a summary of laws requiring or related to geothermal pollution control, administrative requirements for development of geothermal resources in the State of Oregon, the 1979 environmental protection stipulations of the Oregon Department of Geology and Mineral Industries, and water quality standards of the Oregon Department of Environmental Quality.

This reporting effort depended on receipt of available published findings and reports of others and was not intended to be original research. A discussion of geothermal resource types (hot water, dry
steam, geo pressured hot water, hot dry rock, and magma) was not included in this report as Oregon's geothermal resources are generally classified as hot water dominated. General clarification of geothermal resource types can be found in (27). Similarly discussions on production technology of various power from various geothermal resource types can be found in (86) and (76). Economic analysis of water resource and water quality impacts and waste water treatment technology were considered as beyond the scope of the work outlined for this reporting effort. Geothermal energy development pollution control technologies, including processes concepts and costs of waste water treatment and disposal are covered in a recent EPA publication, (36). It is recommended that this report is periodically edited and upgraded to include economic analysis of proposed geothermal projects waste water treatment as new information is made available regarding Oregon's geothermal sitings, and as baselines of water resource and water quality become better developed.

We are grateful for the information that has been made available for inclusion into this report and hope that those who have contributed to elements of the various sections will recognize their work or comments, whether or not it has been appropriately cited, and will understand our efforts and will accept our thoughts of appreciation.

We hope that by providing the information found in the subsequent sections that rational development of geothermal resources can progress whilst making a minimal or least negative impact on our environmental resources. Finally, we feel we have adequately identified the probable occurrence of water resource and water quality impacts associated with geothermal activities in Oregon's KGRAs; we wish to emphasize that the severity of the effects may be low even though the chance of occurrence might be ranked high.

II. OREGON GEOTHERMAL PROJECTIONS

II.1. OREGON'S (KGRAs) KNOWN GEOTHERMAL RESOURCE AREAS

Table I is a current compilation of regional known geothermal resource area (KGRA) reservoir temperatures, electrical power potentials,
TABLE I. OREGON KGRA POTENTIAL POWER CHARACTERISTICS AND ESTIMATED WATER USE.

<table>
<thead>
<tr>
<th>POTENTIAL AREA</th>
<th>SUBSURFACE TEMP °C</th>
<th>POTENTIAL MW (2)</th>
<th>COOLING WATER REQUIREMENTS (3) 1/S</th>
<th>CONVERSION CYCLE</th>
<th>DIRECT USE</th>
<th>3-5 yrs FLUID REQUIRED (5) (total) Mlt</th>
<th>5-25 yrs FLUID REQUIRED (5) (total) Mlt</th>
</tr>
</thead>
<tbody>
<tr>
<td>KLAMATH FALLS KGRA</td>
<td>130</td>
<td>No</td>
<td></td>
<td></td>
<td></td>
<td>60(6)</td>
<td>72(6)</td>
</tr>
<tr>
<td>- 50,300 acres</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>600 - 1200</td>
<td>720 - 1440</td>
</tr>
<tr>
<td>ALVORD KGRA</td>
<td>180 - 210</td>
<td>300</td>
<td>2500 - 5000</td>
<td>FLASH</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- 176,835 acres</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VALE KGRA</td>
<td>160 - 180</td>
<td>770</td>
<td>6141 - 12,830</td>
<td>BINARY/FLASH</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- 22,990 acres</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GLASS BUTTES</td>
<td>UNKNOWN</td>
<td></td>
<td></td>
<td>BINARY/FLASH</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>ONTARIO - URE IDA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LA GRANDE</td>
<td>120</td>
<td>No</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LAKEVIEW KGRA</td>
<td>160</td>
<td>123</td>
<td>1025 - 2050</td>
<td>BINARY/FLASH</td>
<td>.48 (4)</td>
<td>4.8 - 9.6</td>
<td>15</td>
</tr>
<tr>
<td>- 12,165 acres</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>150 - 300</td>
<td></td>
</tr>
<tr>
<td>MT. HOOD KGRA</td>
<td>170 - 200</td>
<td></td>
<td></td>
<td>BINARY/FLASH</td>
<td>2</td>
<td>20 - 40</td>
<td></td>
</tr>
<tr>
<td>- 8,671 acres</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CASCADES</td>
<td></td>
<td></td>
<td></td>
<td>BINARY/FLASH</td>
<td>100</td>
<td>1000 - 2000</td>
<td>2100</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>21,000 - 42,000</td>
<td></td>
</tr>
</tbody>
</table>

(1) Source - Bowen, R. G.  
    a. Geothermal Environmental Overview Study Workshop Presentation Mar 26-29, 1979  
    b. Personal communication July 1979  
(2) MW electrical for 30 years  
(3) Source - Environmental Readiness Document Sept. 1978 DOE/ERD-0005  
    upper bound; related to personal communication with Paul Lineau (OIT) July 1979  
(6) Personal communication with Paul Lineau (OIT) Aug 1979
FIGURE 1. OREGON'S KNOWN (KGRA) AND POTENTIAL (PGRA) GEOTHERMAL RESOURCE AREAS.
intended power cycle types and water utilization estimates associated with projected geothermal developments within Oregon. KGRAs and PGRAs for Oregon are delineated on Figure 1.

Because the site specific locations, depth of strata, resource quality and volume to be tapped of most of these potential geothermal developments are not firm; it is difficult to relate what aquifers and water courses might be specifically influenced by recovery and use of the available geothermal energy. Similarly, since the State's geothermal resources have not been fully assessed in terms of development character (liquid dominated, liquid dominated-binary, or vapor dominated), production type (electrical power vs. space heating), reservoir extent (strata depth, geologic formation, resourcequality and potential tapable volume), it is difficult to discuss geothermal exploration, development and production activities which would significantly impact water quality aspects of particular aquifers and watersheds. The lack of such information has been a failing of most Environmental Impact Statements (EIS) which have been written to date (1979) for the development of Oregon's geothermal resources.

In this report we too must deal with regional KGRAs rather than specified sites for discussing possible water quality impacts connected to exploration and development of geothermal energy within the state. There is limited information to share on possible water quality impacts which would be constituted as quantitative because the type of resource, its depth, quality and production characteristics at specific sites in the general KGRAs have not as yet been determined or announced. In other words, a scenario of projected development activities has been designated (Table I) for which we are to next consider the water resource (quality) issues of this speculative development. The scenario may be either an under or an over estimate of the possible developments in the State of Oregon.

II.2. RESOURCE APPLICATIONS AND ECONOMIC VALUE

II.2.1. Historical Applications of Geothermal Resources

Geothermal energy is the heat energy that exists within the earth's
crust. Geothermal energy is one of only a few energy resources indigenous to Oregon. Although identified geothermal resources in Oregon have lower temperatures than in some other areas of the United States, resource assessment and utilization is taking place in the state. It should be noted that Oregon has presently the most extensive geothermal direct utilization of any state, examples include greenhousing (Lakeview, Klamath Falls, Cove, Vale), agricultural applications and processing (Klamath Falls, Ontario, Vale), space heating (Klamath Falls, Lakeview, Vale, Hot Lake, Haines, Breitenbush Hot Springs, Ontario) and numerous geothermally heated spas and pools (32).

Geothermal utilization in Oregon pre-dates the white man. Indians used the hot springs for cooking and medicinal purposes, as did early settlers. The first large scale commercial use of geothermal was in Klamath Falls in the 1890's and early 1900's, in a large resort-spa on the site of Klamath Union High School (57). In 1928, Butler's Natatorium was constructed to take advantage of the hot water resource underlying the city. At present, over 400 wells serve more than 500 structures in Klamath Falls, including a hospital, city schools and the Oregon Institute of Technology. Other uses include milk pasteurization, concrete curing, highway snow removal, laundry hot water and heated swimming pools. Some locations utilize waste hot water discharged into storm sewers. Overall, about 60 megawatts thermal (MWt) of the present 61 MWt total of direct use geothermal energy is being utilized at Klamath Falls, see Table I.

Some geothermal operations at Klamath Falls have resulted in significant economic benefits. For example, Medo-Bel Creamery estimates its annual fuel savings at $20,000. At Oregon Institute of Technology's old campus, annual fuel costs were about $100,000 (at pre-inflation prices). At the new larger campus (440,000 square feet), OIT spends about $25-30,000 annually for its geothermal heating system; if oil were used it would cost $250,000 (11,000 bbls of equivalent oil). The economic value of the geothermal resource as energy can be computed on a site specific basis by comparing geothermal heating costs to conventional fuel costs. In most cases, the initial capital investment is higher for geothermal than for conventional fuel, but savings in fuel purchases
over the life of the project usually exceed this gap relatively quickly in cases of direct heat applications. As conventional fuel prices rise, the economic value of geothermal energy as a substitute of these fuels will also rise \(57\).

II.2.2. General Statewide Developments

It is probable that Oregon will eventually realize significant electric power generation from its geothermal reserves, but this is not a near term prospect.

Estimates of future direct use of Oregon's "beneficial heat" total \(3,232 \times 10^{18}\) J available. This resource would develop 3416 MWt for 30 years of exploitation or only 1025 MWt for a century of use \(53\). Similarly, the future electric power potential for the state is 2031 MWt for 30 years of exploitation or 677 MWt-centuries. Estimates of future electrical power potential from Oregon's geothermal sources are influenced by the optimism of estimators relative to consideration of the total resource development and expected technological break-throughs. The resource potential summed from \(53\) U.S.G.S. Circular 790 (dated 1978) is more conservative than offered in U.S.G.S. Circular 726 (dated 1975) and the corresponding estimates made by Bowen \(98\), as shown in Table I.

Direct use applications--especially in agricultural processing, greenhousing and district heating--hold the greatest immediate potential. For example, Ore-Ida Foods is converging its Ontario plant to geothermal process-heat. This facility processes about one million pounds per day of frozen potato and onion products. If successful, the geothermal conversion project will reduce fossil fuel consumption by half and result in a net annual savings of \$1 million. The new system is scheduled for operation in late 1979. Other potential agricultural applications include greenhousing, crop dehydration, alfalfa drying, beetsugar processing and mushroom growing. The Geo-Heat Utilization Center (OIT) has produced an assessment of "Agribusiness Geothermal Energy Utilization Potential of Klamath and Snake River Basins, Oregon" \(44\).

A three year geothermal resource assessment was initiated in 1976
at Mt. Hood. This cost-sharing project involves the Oregon DOGAMI, USGS, US-DOE and US-FS. Drilling at Timberline Lodge was completed in 1978, did not reach target depth and accordingly a suitable geothermal resource has not yet been identified for development of space-heating and snow removal systems.

Northwest Natural Gas Company (NWNG), continues to drill at Old Maid Flat on the west flanks of Mt. Hood. NWNG envisions a $50 million project involving a 43 mile (69.2 km) pipeline (48 inch diameter (1.22 m)) to major industrial users in the Portland area (including Oregon City and Caman, Washington) to supply geothermal district heating, pulp and paper processing industries.

Klamath Falls has received a DOE/DGE grant for a downtown geothermal heating district. The project Phase I is designed to provide heating for 14 city, county, state and federal buildings and is scheduled for operation by 1980. Total costs will be approximately $1.5 million of which approximately 75% will be contributed by DOE. Phase II will cover 11 city blocks by providing additional connections to adjacent building. Phase III will provide heating to 54 user blocks and will be completed in 3 to 5 years through a bonding program; the bonding will be repaid by connection and user fees. Subsequently Klamath Falls will examine its geothermal resources for additional applications.

As these examples indicate, Oregon is in the forefront of geothermal direct use development. Add to this Oregon's geothermal electrical potential and the contribution of the resource to the state's energy future appears highly significant. Additional information on geothermal resource development in Oregon is given in Section II.3. regarding the individual resource sites.

The narrative for some of this section was abstracted, updated and revised from (32) "Preliminary Geothermal profile, State of Oregon" Geothermal Policy Project, National Conference of State Legislatures, 1405 Curtis Street Suite 2300, Denver, Colorado, October 1978, pages 7-9 and personal communications, (20), (3), and (37).
II.3. WATER RESOURCE CHARACTERISTICS AND DEVELOPMENT ACTIVITIES OF OREGON'S KGRAs

Oregon's geothermal resources are primarily the liquid dominated type, as opposed to being vapor-dominated (dry steam) or geopressured. As noted in Table I, Oregon is blessed with moderate and low temperature liquid geothermal resources for development. A listing of the locations, temperatures, volumes, and energies of identified hot-water hydrothermal convection systems within Oregon are given in Table II, (53). Following this listing is a narrative of the water resource characteristics and activities of Oregon's KGRAs regions, including: Western Cascades, High Cascades, Brothers Fault Zone, Southern Basin and Range, Snake River Plain, and the Columbia River Region.

II.3.1. Western Cascades

II.3.1.1. Breitenbush Hot Springs KGRA (32)

Total KGRA acres: 13,445
Surface Temperature: 99°C
Estimated subsurface temperature: 150°C
Approximate number of hot springs: 60
Natural surface discharge: 56.66 l/s

Present Development Status Space heating in two resorts and pool heating. Temperature gradient holes have been drilled by the Sunoco Energy Co. and the Department of Geology and Mineral Industries. Sale to Sunoco of 5818 Acres in 4 parcels for geothermal development took place in 1979; 1 parcel received no bids (1,029 acres). Twelve non-competitive lease have been issues in 1979 covering 15,887 acres.

Interest has been shown in examining the resource to assess the feasibility for direct-use or electrical applications.

Surface Water (15) Streams in the Breitenbush Geothermal Area (BGA) drain into the North Santiam and Clackamas River systems. Among the larger tributary streams are the Breitenbush River, Collawash River, Whitewater Creek, Woodpecker Creek and Devils Creek.

The average discharge of the North Santiam River measured over a 48-year period at a gaging station 0.5 mile below Boulder Creek is 1,017 cubic feet per second (c.f.s.), or 736,800 acre-feet, per year. This
<table>
<thead>
<tr>
<th>Name of area</th>
<th>Latitude (°N)</th>
<th>Longitude (°E)</th>
<th>Estimates of reservoir temperature (°C)</th>
<th>Mean reservoir temperature (°C)</th>
<th>Mean reservoir volume (km³)</th>
<th>Mean reservoir thermal energy (10¹⁰ J)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Newberry caldera</td>
<td>43 43</td>
<td>121 14</td>
<td>180</td>
<td>230 ± 20</td>
<td>47 ± 16</td>
<td>27 ± 10</td>
<td>Reported hot springs appear to be drowned fumaroles which issue along the shores of East Lake and Paulina Lake in Pleistocene calderas. Reservoir temperatures are inferred and based on temperatures estimated for other Quaternary volcanoes.</td>
</tr>
<tr>
<td>Crump's Hot Springs</td>
<td>42 13.8</td>
<td>119 53.0</td>
<td>144 (I)</td>
<td>167 ± 9</td>
<td>7.2 ± 2.6</td>
<td>3.0 ± 1.2</td>
<td>Several hot springs and seeps and one geysering well; maximum well temperature 121°C at 201 m depth; sinter deposits.</td>
</tr>
<tr>
<td>Mickey Hot Springs</td>
<td>42 40.5</td>
<td>118 20.7</td>
<td>180 (A)</td>
<td>205 ± 10</td>
<td>12.8 ± 6.7</td>
<td>4.5 ± 3.5</td>
<td>Hot springs to 73°C discharging 100 L/min; mud pots; extensive sinter.</td>
</tr>
<tr>
<td>Alvord Hot Spring</td>
<td>42 32.6</td>
<td>118 31.6</td>
<td>140 (A)</td>
<td>181 ± 18</td>
<td>5.0 ± 2.1</td>
<td>2.2 ± 1.0</td>
<td>Several hot springs to 76°C discharging 500 L/min in area about 0.5 km².</td>
</tr>
<tr>
<td>Hot (Borax) Lake area</td>
<td>42 20</td>
<td>118 36</td>
<td>165 (C)</td>
<td>191 ± 14</td>
<td>0.3 ± 3.5</td>
<td>4.0 ± 1.7</td>
<td>Several springs to 96°C and one large pool (lake); total discharge 2500 L/min; sinter.</td>
</tr>
<tr>
<td>Vale Hot Springs</td>
<td>43 59.4</td>
<td>117 14.0</td>
<td>152 (A)</td>
<td>157 ± 2</td>
<td>117 ± 54</td>
<td>45 ± 21</td>
<td>Large area suggested by audio-magnetotelluric survey and heat flow anomaly. Hot springs in two groups to 97°C, but low flow rates. Another sulfate-water isotope determination gives 200°C.</td>
</tr>
</tbody>
</table>
**TABLE IIb. LOCATIONS, TEMPERATURES, VOLUMES, AND THERMAL ENERGIES OF IDENTIFIED HOT-WATER HYDROTHERMAL CONVECTION SYSTEMS 90-150°C.**

(For reservoir temperature estimates, first number is most likely value, subscript is maximum value, and superscript is minimum value. Letters indicate method used to estimate temperature, as follows:

- G. Amorphous silice
- H. Na-K-Ca, Mg-corrected
- I. Na-K-Ca
- J. Sulfate-water isotope
c- K. Sulfate-water isotope-corrected.
- L. Surface
- M. Reported well
- N. Mixing
- O. Renner, 1976

No letter indicates a subjective estimate. Mean values of temperature, volume, and reservoir thermal energy are followed by standard deviations. Temperatures given to three significant figures; in most cases volumes and energies are given to two significant figures. However, if the first digit is 1, three significant figures are given in order to approximate to more closely uniform percentage accuracy.)

<table>
<thead>
<tr>
<th>No.</th>
<th>Name of area</th>
<th>Latitude (%N)</th>
<th>Longitude (%W)</th>
<th>Estimates of reservoir temperature (°C)</th>
<th>Mean reservoir temperature (°C)</th>
<th>Mean reservoir volume (km³)</th>
<th>Mean reservoir thermal energy (10¹⁸ J)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Summer Lake Hot Springs</td>
<td>42 43.5</td>
<td>120 38.7</td>
<td>107 (0)</td>
<td>110 ± 6</td>
<td>7.8 ± 2.0</td>
<td>2.2 ± 0.8</td>
<td>Three springs to 43°C discharging 75 L/min. Sulfate-water isotope geothermometer gives about 190°C.</td>
</tr>
<tr>
<td>2</td>
<td>Lakeview area, Hunters and Barby Ranch Hot Springs</td>
<td>42 32.0</td>
<td>120 21.6</td>
<td>147 (1)</td>
<td>150 ± 3</td>
<td>15.3 ± 5.6</td>
<td>5.6 ± 2.0</td>
<td>Several springs to 96°C discharging 2500 L/min; travertine and sinter. Two geothermal exploration wells 189 and 1658 m deep; several shallow wells used for space heating.</td>
</tr>
<tr>
<td>3</td>
<td>Fisher Hot Springs</td>
<td>42 17.9</td>
<td>119 46.5</td>
<td>95 (0)</td>
<td>114 ± 7</td>
<td>3.3 ± 0.9</td>
<td>0.09 ± 0.26</td>
<td>Spring discharging 75 L/min at 68°C.</td>
</tr>
<tr>
<td>4</td>
<td>Young Hot Springs</td>
<td>44 00.0</td>
<td>119 30.8</td>
<td>99 (0)</td>
<td>108 ± 6</td>
<td>3.3 ± 0.9</td>
<td>0.04 ± 0.24</td>
<td>Spring discharging 40 L/min at 65°C. CO₂-rich water; geothermometers may be unreliable.</td>
</tr>
<tr>
<td>5</td>
<td>Harney Lake area</td>
<td>43 30.9</td>
<td>119 02.2</td>
<td>105 (3, J)</td>
<td>114 ± 7</td>
<td>3.3 ± 0.9</td>
<td>0.09 ± 0.26</td>
<td>Several springs to 68°C discharging 550 L/min. Reservoir may be larger than estimated.</td>
</tr>
<tr>
<td>6</td>
<td>Crane Hot Springs</td>
<td>43 28.6</td>
<td>118 38.4</td>
<td>99 (0)</td>
<td>117 ± 6</td>
<td>3.3 ± 0.9</td>
<td>0.04 ± 0.26</td>
<td>Two springs to 70°C discharging 550 L/min.</td>
</tr>
<tr>
<td>7</td>
<td>Riverside area</td>
<td>42 28.0</td>
<td>118 11.3</td>
<td>116 (1)</td>
<td>110 ± 10</td>
<td>3.3 ± 0.9</td>
<td>0.93 ± 0.28</td>
<td>Several springs to 63°C discharging 200 L/min.</td>
</tr>
<tr>
<td>8</td>
<td>McDermitt area</td>
<td>43 04.7</td>
<td>117 45.6</td>
<td>83 (E)</td>
<td>90 ± 8</td>
<td>3.3 ± 0.9</td>
<td>0.75 ± 0.22</td>
<td>Several springs to 52°C discharging 750 L/min.</td>
</tr>
<tr>
<td>9</td>
<td>Medical Hot Springs</td>
<td>45 01.1</td>
<td>117 37.5</td>
<td>116 (1)</td>
<td>96 ± 12</td>
<td>3.3 ± 0.9</td>
<td>0.73 ± 0.23</td>
<td>Several springs to 60°C in two groups discharging 200 L/min.</td>
</tr>
<tr>
<td>10</td>
<td>Little Valley area</td>
<td>43 53.5</td>
<td>117 30.0</td>
<td>118 (0, J)</td>
<td>127 ± 6</td>
<td>3.3 ± 0.9</td>
<td>1.31 ± 0.19</td>
<td>Several springs to 70°C discharging 550 L/min. Sulfate-water isotope geothermometer gives 215°C.</td>
</tr>
</tbody>
</table>

**OREGON**
<table>
<thead>
<tr>
<th>Name of area</th>
<th>Latitude (°N)</th>
<th>Longitude (°W)</th>
<th>Mean reservoir temperature (°C)</th>
<th>Estimate of reservoir temperature (°C)</th>
<th>Mean reservoir volume (km³)</th>
<th>Mean reservoir energy (10¹⁸ J)</th>
<th>Comments</th>
<th>Wellhead thermal energy (10¹⁸ J)</th>
<th>Beneficial heat (10¹⁸ J)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mount Hood area</td>
<td>45 22.5</td>
<td>121 42.5</td>
<td>122 ± 12</td>
<td>3.3 ± 0.9</td>
<td>0.96 ± 0.20</td>
<td></td>
<td>Fumaroles and acid-sulfate springs to 90°C; reservoir temperatures are speculative; may be a small vapor-dominated system.</td>
<td>0.24</td>
<td>0.054</td>
</tr>
<tr>
<td>Catar Hot Springs</td>
<td>45 01.2</td>
<td>122 00.6</td>
<td>104 ± 8</td>
<td>3.3 ± 0.9</td>
<td>0.80 ± 0.24</td>
<td></td>
<td>Several springs to 91°C discharging 950 L/min. Sulfate-water isotope geothermometer gives 181°C.</td>
<td>0.20</td>
<td>0.044</td>
</tr>
<tr>
<td>Breitenbush Hot Springs</td>
<td>44 11.9</td>
<td>121 38.5</td>
<td>125 ± 10</td>
<td>3.3 ± 0.9</td>
<td>0.99 ± 0.29</td>
<td></td>
<td>Several springs to 92°C discharging 1400 L/min. Sulfate-water isotope geothermometer gives 195°C.</td>
<td>0.25</td>
<td>0.059</td>
</tr>
<tr>
<td>Crater Lake Springs</td>
<td>41 11.6</td>
<td>122 03.2</td>
<td>113 ± 14</td>
<td>3.3 ± 0.9</td>
<td>0.88 ± 0.28</td>
<td></td>
<td>Several springs to 52°C discharging 200 L/min.</td>
<td>0.21</td>
<td>0.051</td>
</tr>
<tr>
<td>Belknap Hot Springs</td>
<td>44 11.9</td>
<td>121 12.9</td>
<td>109 ± 3</td>
<td>3.3 ± 0.9</td>
<td>0.85 ± 0.24</td>
<td></td>
<td>Three springs to 71°C discharging 300 L/min; may be part of a larger system that includes Catar Hot Springs.</td>
<td>0.22</td>
<td>0.053</td>
</tr>
<tr>
<td>Foley Hot Springs</td>
<td>43 09.0</td>
<td>122 05.9</td>
<td>99 ± 7</td>
<td>3.3 ± 0.9</td>
<td>0.76 ± 0.22</td>
<td></td>
<td>Four springs to 79°C; system may be larger and include Belknap Hot Springs 6 km to the northeast.</td>
<td>0.130</td>
<td>0.046</td>
</tr>
<tr>
<td>McCredie (Winona) Hot Springs</td>
<td>43 42.6</td>
<td>122 17.3</td>
<td>91 ± 4</td>
<td>3.3 ± 0.9</td>
<td>0.68 ± 0.19</td>
<td></td>
<td>Several springs to 77°C discharging about 75 L/min.</td>
<td>0.170</td>
<td>0.041</td>
</tr>
<tr>
<td>Umpqua Hot Springs</td>
<td>43 17.5</td>
<td>121 16.3</td>
<td>112 ± 7</td>
<td>3.3 ± 0.9</td>
<td>0.87 ± 0.25</td>
<td></td>
<td>Two springs to 46°C discharging less than 20 L/min; travertine. CO₂ rich water, geothermometer may be unreliable.</td>
<td>0.22</td>
<td>0.072</td>
</tr>
<tr>
<td>Klamath Hills area</td>
<td>42 09.0</td>
<td>121 44.5</td>
<td>124 ± 7</td>
<td>10.6 ± 3.8</td>
<td>3.1 ± 1.1</td>
<td></td>
<td>Several wells to 127 m; maximum temperature 93°C at 127 (7) m; 9 km² area of silicified rocks. Thermal water used in greenhouse operation.</td>
<td>0.18</td>
<td>0.007</td>
</tr>
<tr>
<td>Klamath Falls area</td>
<td>42 14</td>
<td>121 46</td>
<td>111 ± 7</td>
<td>114 ± 55</td>
<td>30 ± 15</td>
<td></td>
<td>Several wells ranging in depth from 40 to 550 m used for space heating; downhole temperatures as high as 113°C are reported.</td>
<td>7.4</td>
<td>1.74</td>
</tr>
</tbody>
</table>
TABLE IIc. AREAS FAVORABLE FOR DISCOVERY AND DEVELOPMENT OF LOCAL SOURCES OF LOW-TEMPERATURE (<90°C) GEOTHERMAL WATER. (53)

<table>
<thead>
<tr>
<th>Name of area</th>
<th>Wells considered</th>
<th>Thermal springs</th>
<th>Thermal gradients</th>
<th>Equilibration temperature</th>
<th>Dissolved solids</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>Depths (m)</td>
<td>Temperature (°C)</td>
<td>No. Temperature (°C)</td>
<td>Gradients (°C/km)</td>
<td>temperature (°C)</td>
</tr>
<tr>
<td>Belknap - Foley Hot Springs</td>
<td>2</td>
<td>150</td>
<td>14, 22</td>
<td>3</td>
<td>20-97</td>
<td>85-91</td>
</tr>
<tr>
<td>Willamette Falls</td>
<td>2</td>
<td>150</td>
<td>15, 21</td>
<td>3</td>
<td>41-71</td>
<td>80</td>
</tr>
<tr>
<td>Craig Mountain - La Grange</td>
<td>5</td>
<td>45-885</td>
<td>30-80</td>
<td>11</td>
<td>24-82</td>
<td>40-50</td>
</tr>
<tr>
<td>Oregon</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Western Snake River Basin</td>
<td>50</td>
<td>30-310</td>
<td>20-103</td>
<td>3</td>
<td>20-97</td>
<td>85</td>
</tr>
<tr>
<td>Glass Butte</td>
<td>3</td>
<td>60-220</td>
<td>18-48</td>
<td>---</td>
<td>120-190</td>
<td>---</td>
</tr>
<tr>
<td>Northern Basin</td>
<td>7</td>
<td>50-300</td>
<td>22-72</td>
<td>5</td>
<td>21-27</td>
<td>150</td>
</tr>
<tr>
<td>Southern Basin</td>
<td>20</td>
<td>30-160</td>
<td>22-25</td>
<td>15</td>
<td>20-68</td>
<td>75-140</td>
</tr>
<tr>
<td>Alvord Desert</td>
<td>4</td>
<td>35-95</td>
<td>16-22</td>
<td>10</td>
<td>36-97</td>
<td>47-300</td>
</tr>
<tr>
<td>Lakeview</td>
<td>15</td>
<td>15-300</td>
<td>40-94</td>
<td>3</td>
<td>72-94</td>
<td>60-150</td>
</tr>
<tr>
<td>Elamath Falls</td>
<td>400</td>
<td>20-550</td>
<td>15-95</td>
<td>8</td>
<td>16-87</td>
<td>30-1,000</td>
</tr>
</tbody>
</table>

1 Most thermal gradients reported in this study were calculated by subtracting mean annual air temperatures from maximum reported fluid temperatures in wells and test holes and dividing by the total depths of the wells. The resulting linear gradients do not reflect actual depths of occurrence of thermal waters or variations due to changes in thermal conductivity with depth, and they may be strongly influenced by convective flow in the wells and in the formations. At most places, therefore the gradients do not represent conductive thermal gradients in the earth's crust. "Cond." = probable conductive gradients, "conv." = affected by convection.

2 Temperatures of rock-water equilibration estimated by means of chemical geothermometers; mostly unreliable for low-temperature waters unless possible effects of minor interferences, high concentrations of dissolved solids, organic silt, and other factors are accounted for. Not considered reliable for determination of temperatures of low-temperature waters, especially in high gradients exceeding 30°C/km for continental crust rocks. Criteria are given in selecting and defining the favorable areas. Equilibrium is obtained by means of chemical geothermometers in high-gradient areas.


4 Thermal springs are defined for this report as those having surface temperatures at least 10°C above mean annual air temperatures. Thermal wells are also defined on the basis of minimum temperatures 10°C above mean annual air temperatures but, in addition, are required to have thermal gradients exceeding 30°C/km for continental crust rocks. Criteria are used in selecting and defining the favorable areas. Including the temperature and thermal gradients in the areas described above for thermal wells and springs. In addition, regional conductive heat flow measurements were given considerable weight, especially in a few areas for which hydrologic data suggested possible favorable temperatures but for which regional heat flow were high. Heat flow is generally greater than 80 mW/m² in most areas. The index of favorable areas can be defined as a basis for selection of favorable areas. Many continental high-temperature geothermal systems are not included in the areas listed. Although it may be assumed that conditions favorable for the occurrence of low-temperature waters exist in the vicinity of such high temperature systems, available data permit depiction of favorable areas only at a few such locations.
represents 63.94 inches of runoff per year.

Flow of the Breitenbush River has been gauged since 1932 at the station above Canyon Creek. During that period the average flow has been 533 ft³/second, or 422,400 acre-feet per year, which is equivalent to 74.69 inches of runoff per year.

The sediment yield of streams in the Willamette Basin is low because of favorable physiographic and climatic conditions. Soils derived from the basaltic, andesitic, and pyroclastic rocks underlying the western slope of the Cascade Range were generally quite resistant to erosion, but may be locally unstable. Further protection against erosion is provided by the trees, shrubs, and other plants that grow profusely in the moderate maritime climate.

The Willamette Basin Task Force report indicates that average annual yield of sediment in the High Cascades area is estimated to be 50-150 tons per square mile. The Western Cascades area yield is 150-300 tons per square mile. Median particle size of streambed sediments taken from the North Santiam at the Mehama sampling station is 120 mm compared to 0.6 mm in samples taken from the Willamette River at Portland. Weighted mean concentration of sediments measured at the same sites shows 45 ppm for the North Santiam and 71 ppm for the Willamette.

The Geological Survey has obtained temperature data for the North Santiam River below Boulder Creek since 1951. The highest temperature recorded was 19°C and the lowest was at the freezing point at several times during the winters of 1954, 1956, and 1974.

At the station Breitenbush River above Canyon Creek, the Geological Survey has stream temperatures since 1950. The measured highest temperature recorded was 18°C on July 27, 1973. Freezing temperatures have been recorded on several days in December 1972 and January 1973.

Waters in streams draining the BGA are of excellent chemical and biological quality. These waters have few colonies of coliform and streptococci and have low concentrations of dissolved constituents, including heavy metals. Concentrations of nutrients such as nitrogen and phosphorus also are low. Analyses of water from Breitenbush and North Santiam Rivers, shown on pages 38 and 39, are representative of
waters from streams in the area.

Streams in the area are tributary to rivers tapped for domestic water at the following recreation sites and urban areas:

<table>
<thead>
<tr>
<th>Site</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oregon City</td>
<td>Clackamas River</td>
</tr>
<tr>
<td>City of Estacada</td>
<td>Clackamas River</td>
</tr>
<tr>
<td>Whispering Falls C.G.</td>
<td>Unnamed tributary, N. Santiam River</td>
</tr>
<tr>
<td>Riverside C.G.</td>
<td>Unnamed tributary, N. Santiam River</td>
</tr>
<tr>
<td>Whitewater C.G.</td>
<td>Whitewater Creek (no developed source)</td>
</tr>
<tr>
<td>Cleator Bend C.G.</td>
<td>Breitenbush River (no developed source)</td>
</tr>
<tr>
<td>Breitenbush C.G.</td>
<td>Unnamed tributary, Breitenbush River</td>
</tr>
<tr>
<td>City of Detroit</td>
<td>Breitenbush River</td>
</tr>
<tr>
<td>City of Idanha</td>
<td>*Cabin Creek</td>
</tr>
<tr>
<td>Breitenbush Forks</td>
<td>S. Fk. Breitenbush R. (no developed source)</td>
</tr>
<tr>
<td>Recreation Resid. Tract</td>
<td>Devils Creek (no developed source)</td>
</tr>
<tr>
<td>Devils Creek Recreation Resid. Tract</td>
<td>Devils Creek (no developed source)</td>
</tr>
<tr>
<td>Breitenbush Hot Springs Resort (USFS permit)</td>
<td>Mansfield Creek</td>
</tr>
<tr>
<td>Villa Maria Lodge</td>
<td>Shallow Well</td>
</tr>
<tr>
<td>Chemeketans Cabin</td>
<td>Whitewater Creek (no developed source)</td>
</tr>
</tbody>
</table>

*Outside the area influenced by the BGA.

**Ground Water** (15). Little direct information is available concerning ground water in the BGA. The only known developed ground-water supply in the area is the well that supplies Villa Maria Lodge.

The volcanic rocks of the High Cascades, which occur in the topographically higher parts of the area, are generally considered to be highly fractured. They readily receive infiltration from precipitation and discharge water freely to maintain the dry-weather flow of streams. In most places, the regional water table in those rocks lies at a depth of at least a few hundred feet, reflecting the high permeability of the rocks and the depth of surface erosion. No wells are known to be drilled in these rocks in the BGA.

The alluvium along the Breitenbush River and the glacial deposits adjacent to local stream valleys consist of unconsolidated, poorly stratified and lenticular beds. Where these deposits have sufficient thickness and lie below the water table, they may contain ground water that could be used locally for domestic sources. Ground water in these deposits, immediately adjacent to streams, probably is in hydraulic
continuity with the stream. Thus, these deposits may receive some re-
charge from the streams when stream stages are high and may contribute
to streamflow during low-flow periods. To date, no wells are known to
tap these deposits.

The tuffs and older volcanic rocks of the Western Cascades occur
in the western and topographically lower parts of the BGA. They also
underlie the High Cascade volcanic rocks at least in the western edge
of the High Cascades. Breitenbush Hot Springs apparently issues from
these rocks, and they are tapped by a well reported to be a few miles
west of the BGA. Generally, these rocks have relatively low permeability
and yield water only slowly to wells. Therefore, the hot springs may be
associated with an unusual hydrologic phenomenon—perhaps a highly
fractured zone or a layer of abnormally high permeability. In the
Cascade foothills west of Willamette National Forest, these rocks yield
water in quantities adequate for domestic supplies to wells ranging
from about 100 to 600 feet in depth.

The only data available on ground water quality in the BGA is the
analysis of water from Breitenbush Hot Springs. (See Table IV.) That
water may rise from considerable depth, so probably is not representative
of water from shallower aquifers. Water from zones likely to be tapped
by wells should be similar to water from streams, but somewhat higher in
dissolved constituents. The ground water should be of excellent
quality suitable for domestic and other uses.

Stream classification. Breitenbush River and all its tributaries
are closed for industrial usage.

II.3.1.2. Carey Hot Springs KGRA (Part of Austin Hot Springs) (32)
(North of Breitenbush)
Total KGRA acres: 7,579
Total State and Private Acres: 160 (160 acres at Austin HS System
Surface Temperature: 86°C    being developed by PGE)
Estimated subsurface temperature: 125°C
Natural surface discharge: 15.83 liters/second

Present Development Status: Recreational bathing only. Two shallow
temperature gradient holes have been drilled in the vicinity in 1975 and
1976 by DOGAMI.
Leasing on the KGRA lands will not be considered until the Clackamas Land Management Planning process has been completed. The document is scheduled for release in late 1979. Noncompetitive leasing outside the KGRA is tentatively scheduled following receipt of Forest Service recommendation.

The potential for utilization of Carey Hot Springs is now well known at this point.

II.3.1.3. McCredie Hot Springs KGRA (South of Breitenbush) (32)

Total KGRA acres: 3659
Surface temperature: 73°C (164°F)
Natural surface discharge: 4.80 l/s
Estimated reservoir temperature: 75°C - 120°C

No geothermal development or leasing has taken place in the McCredie area. The draft environmental impact statement possible will be initiated in 1980 and leasing will not be addressed until the document is final.

All lease applications received for this KGRA have been withdrawn (97).

II.3.1.4. Belnap-Foley (McKenzie River area) (32)

KGRA acres 4706 EIS acreage 167,000
Surface Temperature: 71°C
Natural Surface Discharge: 75 gpm (5.7 l/s)
Estimated Reservoir Temperature: 149°C

Draft EIS in process of review (August 1979); leasing is expected to occur during late 1980 summer (97). Sunoco Energy Development Company applied for leases in area. Eugene Water and Electric Board (EWEB) working with various companies for future consideration for electrical power production (71).

The possibility of geothermal resources in the McKenzie River area is suggested by hot springs issuing from Intermediate Age rocks at Belnap, Foley and Bigelow. All of these hot springs emerge within a few hundred feet of the 1800-foot contour. It has been suggested that this may represent a regional water table. Whether the hot springs are directly over their heat source or find their way through vents from geothermal systems related to more recent volcanism of the High Cascades farther to
the east is a subject of conjecture. Some geologists suggest that the hot springs known at the surface may be recirculating relatively near surface waters, and that hot water or steam systems deeper underground may be effectively sealed off by relatively impermeable layers of silica derived from the abundant silica ash deposits of the Western Cascades. Chemical and trace element data collected and analyzed by the U.S. Geological Survey suggest thermal aquifer temperatures for Belnap Hot Springs ranging from a low of 56°C. to a high of 135°C. (88).

The Oregon Department of Geology and Mineral Industries has drilled two wells in the Belnap Foley area for temperature-gradient studies. One of these wells, drilled on the floor of Horse Creek Valley, yielded temperature-gradient measurements well above the 7°C/100m minimum often used as a guideline for economically attractive geothermal resources. The second well was drilled on the lower slope of a ridge about 1/2 to 3/4 mile northwest of Belnap Hot Springs. Measurements in this well suggested an above normal, but lower than economically attractive, temperature gradient. Temperature gradients listed for both wells have not been adjusted to correct for lateral movement of cool ground water, a factor than can influence temperature gradient measurements at intermediate depths (88).

Surface Water. (88)

Drainage Systems, Reservoirs, and Lakes - The Belnap Foley area is drained by the McKenzie and North Santiam River systems. Among the larger streams are Horse Creek, White Branch, Lost Creek, Deer Creek, Smith River, Parks Creek, Browder Creek, Lynx Creek, and Downing Creek. Also within the area are three reservoirs totaling 259 acres and eight lakes totaling 332 acres.

Trail Bridge, Smith and Carmen Reservoirs are components of a 90 megawatt hydroelectric project operated by the Eugene Water and Electric Board. A unique feature of this project is the diversion of part of the McKenzie River flow through a tunnel into Smith Reservoir, and then back into the McKenzie River at Trail Bridge Reservoir through a power tunnel and penstock.

Discharge - Average discharge of the McKenzie River at the Clear Lake outlet (32-year average) is 486 cubic feet/second (cfs) and 352,100
acre-feet/year. Minimum discharge during the same period at the Clear Lake outlet was 160 cfs. At the gaging station below McKenzie Bridge the average yearly discharge (66-year period) was 1,693 cfs and 1,227,000 acre-feet/year. Minimum discharge during the period of record of this gaging station was 805 cfs.

For the North Santiam River at the Boulder Creek gaging station over a 50-year period average discharge is 1,020 cfs and 739,000 acre-feet/year. Minimum discharge is 250 cfs, recorded in 1909.

Temperature - Average temperature of the McKenzie River at the McKenzie Bridge gaging station is 45.5°F., with a minimum of 40°F. and a maximum of 51.8°F. Temperatures measured at this station are the lowest in the McKenzie system. Low temperatures are attributable to the subterranean reservoirs, snowmelt, and glacier seepages comprising the source for this section of the river.

Temperature data have been recorded for the North Santiam River at the gaging station below Boulder Creek since 1951. The highest temperature recorded was 64°F. on July 27, 1973. Temperatures at the freezing point were recorded on several days during the winters of 1954, 1956, and 1974.

Sediment - Discharge of the McKenzie River at the Coburg gaging station is 18 percent of the Willamette River's streamflow at Portland. Sediment yield at Coburg is 9 percent of the yield at Portland. For the North Santiam River at Mehama, streamflow is 10 percent of the Willamette River streamflow at Portland, while sediment yield is 6 percent of the Willamette River sediment yield at Portland. Annual yield of sediment in the study area ranges from 50 to 300 tons per square mile.

Particle size of streambed sediments from the McKenzie River at the Coburg gaging station is 55 mm compared to 0.6 mm for the Willamette River at Portland. For the North Santiam River at the Mehama gaging station, particle size of streambed sediments is 120 mm.

Weighted mean concentration of sediments measured at the Coburg, Mehama, and Portland gaging stations respectively is 34 ppm, 45 ppm, and 71 ppm.
Domestic Use - Surface water from the McKenzie River is the domestic source for approximately 125,000 persons in the City of Eugene and unincorporated Glenwood, Oakway, and Santa Clara suburban areas. Exact figures are unavailable, but a substantial percentage of the 4,600 residents of the McKenzie Valley east of Springfield also rely on surface waters of the McKenzie River for domestic water supplies.

The North Santiam River is the domestic source for approximately 120,000 persons including residents of Salem, Stayton, Turner, Keizer, suburban east Salem, and the Jan Ree Water District.

Within the study area for the following sites utilize the McKenzie River or tributary streams for domestic water:
- Fish Lake Campground
- Clear Lake Day Use Area
- Clear Lake Resort
- Melakwa Boy Scout Camp
- Scott Creek Recreation Residence Site
- White Branch Youth Camp
- Eugene Water and Electric Board residences

No use is made of surface water from the North Santiam River and tributary streams within or adjacent to the study area.

Groundwater. Little is known about the groundwater conditions of the Western Cascade formations in the study area since there has been little or no drilling exploration of water well drilling. The occurrence of water is probably controlled by the joint and fracture pattern, as many of the sedimentary and pyroclastic rock units which comprise the bulk of the formation are lacking in porosity and are impervious.

The High Cascade formations of the Belnap Foley, McKenzie River area have an extremely complex groundwater system. The combination of extremely porous and broken lava flow units with relatively impervious fine grained interbeds have produced perched water tables and confined aquifers with very large volume flows. The open and porous nature of the lava formations as well as the glacial deposits retains the bulk of the precipitation and produces an even discharge into the McKenzie River. The upper McKenzie River is primarily spring fed with large volume flows. Many of the springs are not exposed but discharge directly into the bottom of the river. Tremendous flows of water were encountered
in the excavation of the Carmen-Smith diversion tunnel that required special design changes and increased cost of construction. The lava field and cinder blankets absorb the melting snow directly into the ground like a huge sponge.

The only utilization of groundwater in the High Cascades has been for water wells for public use at recreational developments. Water wells in the McKenzie River valley are usually shallow and probably tap near surface water. Deeper wells encounter fine grained lake sediments with little or no water yield. These deposits blanket the bedrock. Well drilling is difficult in the glacial and alluvial deposits due to the coarse boulders which makes advancing the casing difficult.

II.3.2. High Cascades

II.3.2.1. Mt. Hood (32)

Total KGRA acres: 8,671 All National Forest Land
The KGRA is in an area classified as Wilderness.
Surface Temperature: 90°C
Estimated Subsurface Temperature: 125°C

The only hot spring in the Mt. Hood area is Swim Hot Springs which flows at 1.58 l/s at 27°C. East and northeast of Crater Rock near the summit of Mt. Hood are at least 20 fumarolic vents with temperatures ranging from 50-85°C.


Mt. Hood Geothermal Assessment Project - current status
participants: DOGAMI, USGS

studies completed (C) or in Progress (IP):

DOGAMI: gravity study of Mt. Hood cone & flanks (C)
geology study of Columbia River basalts (C)
stratigraphy study of Old Maid Flat area (C)
geologic and geochemical survey of Mt. Hood andesites (C)
heat flow analysis of 13 area wells (C)
(11 drilled by DOGAMI, 1 by NWNG, 1 by NWGTH Corp.)
USGS: seismic reflection and refraction studies (IP)
spontaneous potential (IP)
aerial infra-red study of Mt. Hood cone & flanks (IP)
gradient well drilling for hydrological data (water quality, temperature, and depth) (IP)
audiomagnetotelluric (IP) - subcontracted to Lawrence Berkeley Laboratories

In association with the Northwest Natural Gas Co. (NWNG) exploration drilling by the NW Geothermal Corporation, in return for partial funding by USDOE of drilling at Timberline Lodge and Old Maid Flat, is continuing. Drilling took place at Timberline Lodge during 1976, 1977, and 1978. Difficulties hampered the drilling process as the gradient hole string twisted off at 1380 feet. Temperatures were isothermal to 600 feet and thence the thermal gradient was reported as 200°C/km. Drilling provided data for the Mt. Hood geothermal assessment program, however the drilling did not reach target depth and accordingly a suitable geothermal resource wasn't identified for development of space-heating and snow removal systems which had been proposed for the Mt. Hood Lodge area.

NWNG is interested in providing district heating for industrial users in the Portland area; for example, for the processing of wood and paper products. At Old Maid Flat on the west flanks of the slope, a hole was drilled to 4002 feet in August 1978; although the results were not conclusive, NWNG reports encouraging temperatures of approximately 79.4°C. Flow tests are being considered for this site. They are continuing during 1979 to explore on the west side of Mt. Hood, where twelve holes have been authorized; present drill sites receiving attention include one near highway 26 and another on McGee Creek.

There is some interweaving between interested agencies and developers regarding assessing Mt. Hood's geothermal resources. The USGS will cooperate on the drilling of two of NWNG's 12 holes. An additional eight holes are part of the continuing (1978-1979) drilling program coordinated by the USGS; presently (August 1979) they are on their 4th hole being drilled about the base of the mountain. Drilling will commence in August 1979 at the base of Poochie Ski Run. The target of these studies is the finding of a suitable reservoir and determining its extent as previously, only marginal temperatures for a quality geothermal resource have been
found on the west flanks of the mountain.

Regarding exploration impacts on water quality, the majority of the holes have been approved through the USFS environmental impact statement EIS and exploration permit process. To date, impacts on water quality have been minimal. Drill hole locations have been sited to satisfactory sites to minimize environmental concerns, including stream proximity. Above ground mud pits (steel basins) have been used instead of in-group sumps. Restrictions on use of foam in the drilling process has been maintained. (34)

**Hydrologic Setting** - (102) Mt. Hood lies along the axis of the Cascade Range, and receives most of its precipitation during the fall and winter from storms that originate in the north Pacific and move southward and eastward across the range. The average annual precipitation in about 102 cm at Portland and increases to the east, to a maximum near the crest of the range. Records of the National Weather Service show that at Government Camp the average is 230 cm. Precipitation decreases rapidly to the east and is only 25 cm within 50 km of the crest.

Precipitation falling above an altitude of about 1,500 m on Mt. Hood is inferred to be within a recharge area, and ground water tends to move downward. The transition from recharge to discharge area is manifested by a band around the mountain where springs tend to discharge, and below which perennial streams are common. Above the band, many streams are intermittent; in smaller channels there is runoff only during spring, from melting snow.

At depths ranging to at least 250m in the vicinity of Timberline Lodge, ground water occurs in perched zones between or within andesite flows. The warm water emanating at Swim Springs may have circulated deeper than some of the perched zones, probably originating at elevations higher than Timberline Lodge. The water comes to the surface at Swim, where there is an abrupt flattening of the topographic slope; Mt. Hood andesite flows tend to dip down the mountain, and some permeable zones may intersect the land surface here. The Swim area also lies near a contact between Mt. Hood andesite flows or andesite debris and pre-Mt. Hood andesite and basalts (Wise, 1968); these older rocks are less permeable and may tend to direct ground water to the surface.
Distribution of runoff of streams draining Mt. Hood corresponds that of precipitation. Records of a gauging station on Salmon River, 7 miles southeast of the summit of Mt. Hood (east of Trillium Lake near highway U.S. 26) show an average runoff of about 80 cm. per year for the drainage area above the gauge. Sandy River has a runoff of 178 cm. above a gauge 30 km west of the summit, and the West Fork of the Hood River has a runoff of 203 cm. above a station 26 km northwest of the summit. The greatest runoff in the Mt. Hood area is reflected at a station on Bull Run River, 29 km northwest of the summit, where the average is more than 305 cm. The component of any deeply-circulating ground water in most of the springs is probably very small because the runoff is large.

Recently, Lawrence Berkeley Laboratory, the U.S. Geological Survey, and the Oregon Department of Geology and Mineral Industries conducted a study of the geothermal resources of Mount Hood. The report of this study (90) published February 1979, and contained geochemical analyses of streams, warm and cold springs, gas samples from the fumaroles, and rock samples. Repeated sampling of Swim Springs Waters (Mt. Hood's only warm-spring area located on the south flank) showed little overall change in water chemistry between summer and winter. Oxygen and hydrogen isotope data and mixing calculations based on analyses of Swim Springs and numerous cold springs, indicated that a large component of the warm water at Swim is from near-surface (snow and glacier melt) runoff. It is hypothesized that snow and glacier-melt water near the summit of Mt. Hood passes in close proximity to the hot central "neck" of the mountain, becomes heated, migrates down-slope and mix with ambient cold water along its path with result that a small portion of the mixed warm water surfaces at Swim Springs. (102)

II.3.2.2. Newberry Crater KGRA (Cascades & Brothers fault zone) (32)

Total KGRA acres: 31,284
Paulina Springs: 57°C (135°F)
East Lake Springs: 66°C (150°F)
Estimated subsurface temperature: Chemical concentrations are too close to those of normal groundwater to apply geothermometry techniques.

Present Development: None at present (resort heating in past). promising area as best indicators are recent glass flows (1400 yrs) and
hot springs in both Paulina and East Lakes. An apparent problem is that heavy flows of cold ground water.

U.S. Geological Survey is continuing a gradient hole drilling program begun in 1977. USGS well #2 down to 1300' in lake sediments with no observed heat anomalies.

Lease applications appear to cover the entire area of the Newberry Volcano. Leasing on non-competitive lands may take place within the next 12 months (i.e. summer 1980). KGRA lease sale is speculatively scheduled by 1981.

In 1975 Oregon House Joint Resolution 31 directed the Energy Facility Siting Council to designate Newberry Crater and surrounding roadless areas as unsuitable for thermal power plants.

Most of the interest in Newberry has been for power generation. Considering the rapid growth rate in Deschutes County, direct-use applications may prove economically viable if the resource is located such that pumping out of the crater would not be necessary.

II.3.3. Brothers Fault Zone

II.3.3.1. Burns Butte KGRA (32)

Total KGRA acres: 640
Surface temperature: 68°C
Estimated subsurface temperature: 135°C
Estimated surface discharge: 9.17 l/s

No near term plans for the utilization of the resource are known.

Much of the precipitation falls during the winter months in the form of snowfall. July, August and September are the driest months with less than 10 percent of the annual total precipitation. Precipitation in this area is noted to increase at a rate of one inch for each 100 m (300 feet) gain in elevation. Mean annual precipitation at Burns is 15 inches.

Most of the runoff in the lease area occurs in winter and early spring and varies from 2.5 to 5.0 cm (one or two inches). Warm spring chinook winds cause rapid snow melt and consequently heavy runoff.

As typical of eastern Oregon, the evaporation rate is high with
pan evaporation varying from 102 mm (40 inches) in the forested areas to 152 mm (60+ inches) in the lower, open valleys.

Average annual sediment production is less than one-tenth acre-feet per square mile but varies widely according to geology, soils, amount of runoff, slope, land treatment practices and upstream watershed conditions. Many of the smaller streams have little or no flow except during periods of melting snow and high runoff. Water temperatures for many of these streams are commonly 21 degrees C (70 degrees F) or higher in late summer and near freezing from November to April. They are generally well aerated with dissolved oxygen concentrations near saturation levels, averaging 8 to 12 mg/liter.

Water quality of the perennial streams is good to excellent but decreases substantially in the downstream portions because of increases in mineral content. The amounts of calcium and sodium vary; calcium is usually predominant during high flow periods.

Coliform contamination is generally low in surface waters due to the low human populations density. The coliform counts are higher in the areas of animal concentrations and soil bacteria.

Ground water is usually found in alluvial deposits and some volcanic rocks at a depth of 18 to 180 m (60 to 600 feet). These volcanic rock aquifers are only moderately permeable but the annual recharge to these aquifers is very low. The quality of the ground water is fair to good. The main water source for the city of Hines is located in alluvial material adjacent to the lease area.

Several reservoirs are located in the geothermal lease areas, most of which are less than 3 acre-feet. The primary purpose of the reservoirs is to provide water for livestock, but also provide water for wildlife and habitat to the aquatic plants and amphibians. The availability of water in these reservoirs is adequate in most years. Projected needs for municipal, industrial, domestic, and livestock water will double by the year 2020. Ground water supplies are estimated to be adequate to meet the demand.

All of the streams flow into the Harney Basin which has no outflow. The Harney Basin watershed provides the all important habitat for waterfowl. However, the Malheur Lake levels fluctuate greatly from year to
In 1972, a high water year, 250 cubic hectometers (200,000 acre-feet) flowed into the lake. In 1973, only 90 cubic hectometers (75,000 acre-feet) flowed into Malheur Lake. During the high water year of 1972, the Donner und Blitzen River contributed 55 percent of the inflow, with the Silvies River, direct precipitation, and Sodhouse Spring contributed 28, 13, and 4 percent respectively.

In the drought year of 1973, the Donner und Blitzen River was again the principal contributor of water with 62 percent of the total inflow. The Silvies River, direct precipitation, and Sodhouse Spring contributed 1, 25, and 12 percent respectively.

Groundwater inflow, other than Sodhouse Spring, appears to be negligible. A large amount of the snowmelt runoff does not reach the Malheur Lake because the stream waters are diverted for irrigation use.

Most of the outflow from the lake is from evapotranspiration (81 percent in 1972 and 96 percent in 1973), but some surface outflow from Malheur Lake goes through the Narrows into Harney Lake. Groundwater outflow also seems negligible.

II.3.4. Southern Basin and Range

II.3.4.1. Alvord KGRA (32)

Total KGRA acres: 176,835
Surface temperature: 76°C
Estimated subsurface temperature: 200-210°C
Flow rate: 135 GPM 8.52 l/s approximate at Alvord Hot Spring
Present Development: None

Active area of exploration. Leases issued in 1976. Injunction delayed competitive sale. Speculation is that there will be a sale in January 1980. Approximately 60 gradient wells have been permitted for drilling in the Alvord Valley.

The Alvord Valley is remote with rough terrain. Utilization, if the resource proves capable, will likely be for power generation.

Lawsuits concerning rejected landlease bids and environmental concerns are pending.

Alvord Valley is a long north-south fault trough east of Steens
Mountain is one of the driest parts of Oregon. Alvord Lake itself is a
playa, or intermittent lake, usually dry every summer except for a small
pool known as Borax Lake, which is kept filled by a warm spring. Each
year is a very shallow pool or lake is created by rain and snowmelt,
chiefly runoff from Trout Creek, a spring-fed stream flowing out of the
mountainous area to the southeast. The alkaline waters of the lake are
not usable for irrigation, and the wide flats that are periodically flooded
are barren and do not support even the alkali-resistant plants.

Water

Hydrologic Cycle - Annual precipitation (for the Southern Basin
and Range) is about 8 inches, distributed rather evenly through the year
except for July and August, which together receive only 8 percent of the
annual moisture, mostly from thunderstorms. The Steens Mountain, border-
ing the study area on the west is an effective barrier and as the air
rises over the mountain, it loses much of its moisture. The entire
study area lies in this rain shadow of Steens Mountain. Annual snowfall
amounts to about 23 inches, with over 60 percent of this amount falling
in January and February.

These lands are located in a closed basin, the Alvord Desert Basin,
a north-south oriented structural valley. Water collects on the many
small playas through the area and on Alvord Desert and Alvord Lake, which
are both large playas. There it evaporates.

A number of perennial streams enter the study area from the west,
draining the east slope of Steens Mountain. These include Castle Rock,
McCoy, Mosquito, Willow, cottonwood, Big Alvord, Little Alvord, Pike,
Indian, Wildhorse, Carlson, and Bone Creeks. Other drainage ways on
the east slope of the mountain are intermittent, running water during
spring snowmelt and summer thunderstorms. Trout Creek heading in the
Trout Creek Mountains enters the study area from the south. Although
a perennial stream, most or all of the flow is diverted for hayland
irrigation upstream of the subject area or simply disappears in the
ground and water from Trout Creek reaches its ultimate destination,
Alvord Lake, only in the spring months of exceptional high water years.

There are three main areas of hot spring activity in the Alvord
Valley graben. The northernmost is Mickey Hot Springs in section 13, T.33S., R.35E., Mickey Hot Springs include fumaroles, several vents, clear pools 8 to 10 feet in diameter, sinter cones, and boiling mud pots. The hot spring system has built a siliceous sinter apron approximately 1,300 feet in diameter. The entire area surrounding the springs had a hollow sound when walked over and water can be heard underground. The flow from Mickey Hot Springs has been estimated at from 20 to 100 gallons per minute.

The central area of hot spring activity is the Alvord Hot Springs in section 32, T34S., R34E. Located there are a series of 6 to 8 springs aligned in a north-south direction that Russell (1903) describes as being situated along the Steens Mountain fault. These springs flow approximately 135 gallons per minute.

The southernmost area of hot springs activity is located in and around the old borax works in sections 11 and 14, T.37S, R.33E. There are several thermal springs in this area and they follow a linear trend that have mapped as a fault (Figures 4 and 5). This line of hot springs trends N. 20 W. from 2 to 2-1/2 miles south of Alvord Lake. At the southern end of this line of springs a large pool has been formed, called Borax Lake or Hot Lake. It is about 275 yards in diameter and discharges about 900 gallons per minute. The series of hot springs have built up a deposit of porous siliceous sinter, so that they now discharge above the present valley floor. Because the deposited sinter is porous, the static pressure of the springs causes slow seepage of spring water over a considerable surface. Just west of this line of springs there is an outcrop of cemented, fine-grained conglomerate. This is thought to be a crest of a fault block which has become almost submerged under the action of erosion and the accumulation of more recent detritus at its base. This probably dips westward, and the line of hot springs erupts from the fault along its eastern scarp.

Springs in Borax Lake are the water source for Borax Lake, Lower Borax Lake Reservoir, and other channels in this drainage.

Water flows out of Borax Lake through two channels, one on the west side and one on the south side. On October 24, 1974, most of this flow went into ponds northeast of the Lower Borax Lake Reservoir, by-passing
the reservoir. At other times most of the flow goes into the reservoir. If the Borax Lake were ever breached on the north and east sides, there would not be overland flow to the Lower Borax Lake Reservoir and channels downstream in T.37S., R.33E., sections 3, 10 and 15. Flow from this source is usually greater in the fall than in late summer, but no additional flow data is available.

At the north end of the Lower Borax Lake Reservoir is a dike and headgate that were built to control water for irrigation. However, there has been no irrigation here for 5 years. If the flow were adequate, the reservoir could cover 27 to 30 acres. The normal high water floods about 20 acres and the reservoir is 4 to 5 feet deep at its deepest part.

At times there is no overland flow into the reservoir. Then the only flow is accretion from the slightly higher areas to the east.

Channels north of the Lower Borax Lake Reservoir drain into Alvord Lake. During the summer this flow is about .01 cfs in places. The northerly part of this channel pools. In places there are flooded meadows 1 to 8 inches deep and 1 to 5 acres in size. In the fall, when the flow increases out of the Borax Lake, there is additional standing water.

Alvord Lake is ephemeral. Maximum water depth does not exceed a foot and it is usually dry by mid-summer.

Data in the files of Conservation Division, USGS, show that in 1959 a drill hole was made about a quarter of a mile east of the series of hot springs. It penetrated the porous sinter and produced steam when about 150 feet deep. The well was plugged off and abandoned.

There are a number of BLM owned shallow stockwater wells within or adjacent to the KGRA. Most are powered by windmills. Available data follows:

<table>
<thead>
<tr>
<th>T37S., R34E., W.M.</th>
<th>Calderwood Desert Well</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sec. 22: NE 1/4 NE 1/4</td>
<td>Total Depth 119 feet</td>
</tr>
<tr>
<td></td>
<td>Static Water Level 94 feet</td>
</tr>
<tr>
<td></td>
<td>27 GPM Bail Test with 5 foot drawdown.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sec. 31: SW 1/4 NE 1/4</th>
<th>Black Butte Well</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Depth 68 feet</td>
<td>Static Water Level 37 feet</td>
</tr>
<tr>
<td>No Test Data</td>
<td></td>
</tr>
</tbody>
</table>
T.32S., R.35E., W.M. Sec. 31: SW¼SE¼ Mann Lake Well
Total Depth 230 feet
No Other Data

T.34S., R.35E., W.M. Sec. 3: SE¼NW¼ Alvord Well No. 1
Total Depth 196 feet
No Other Data

Sec. 10: SW¼SE¼ Alvord Well No. 2
Total Depth 60 feet
No Other Data

Sec. 27: NW¼SE¼ Alvord Well No. 3
Approx. 25 GPM
No Other Data

T.35S., R35E., W.M. Alvord Well No. 4
Sec. 3: NW¼SE¼ Approx. 25 GPM
No Other Data

T.32S., R.36E., W.M. White Sage Well
Sec. 14: SW¼SW¼ Total Depth 160 feet
No Other Data

Only in recent years have private land owners in the area drilled irrigation wells. The fact that this is the sump area of a closed basin would indicate that a large quantity of water may be available. Several irrigation wells in the area reportedly yield from 1,000 to 3,000 gpm from total depths of 100 to 400 feet.

Sediment Load - There is no known data on sediment loads carried by the streams of the area, although peak loads are probably less than 150 ppm.

Dissolved Solids - The hot spring water within the area of the Alvord Valley are saline with total dissolved solids around 3,000 milligrams per liter. Boron and lithium are anomalously high. In fact, boron in the form of borax was actively produced from the Hot Lake area at the turn of the century. Samples taken by Libbey (1960) are summarized below.

Mickey Hot Springs - Sample taken from pool below main pool. Total solids in solution - 0.168 percent. B₂O₃ - 33 ppm.

Alvord Hot Springs - Sample taken in main vent. Total solids in solution - 0.298 percent. Spectrographic analysis of solids:
(1) Concentrations more than 10% -- Silicon, sodium
(2) Concentrations 10%-1% -- Potassium (high), Boron (low), Calcium
(3) Concentrations 1%-0.1%

II.3.4.2. Crump Geyser KGRA (East of Lakeview) (32)

Total KGRA acres: 85,663
Surface temperature: 78°C
Estimated subsurface temperature: 180°C
Flow rate: 0.073 l/s

Moderate amount of leasing activity and exploration.

Sale of 35,974 acres in 1975 went to Chevron. Reoffer of additional acres were taken by Chevron in 1976. Reoffer of additional lands in 1978 brought no bids. (97)

Very little is known about the Crump Geyser in hydrocycle. (51)

II.3.4.3. Klamath Falls KGRA

Total KGRA acres: 50,300
Surface temperature: 74°C
Estimated subsurface temperature: 120°C
Flow rate: 3.33 liter/second (Olene Gap Hot Springs)

Klamath Falls has the most wide spread use of non-electric geothermal applications in the U.S. Over 400 wells supply space heat to 500 structures, including a college campus and a hospital. It is estimated that total use of geothermal energy is 60 MWt. Apparently only a small portion of the area's potential is being used.

In the 1978 summer the city drilled some wells to supply a greenhouse within the college Industrial park adjoining OIT. Problems occurred with the drilling procedure, reportedly with drilling mud leakage. Temperatures were measured and were found unsatisfactory for development; there is speculation that a cross fault exists between the resource and the wells. Accordingly the Industrial Park's pursuit of a local well for its geothermal heat supply has been abandoned with the possible prospects of using surplus hospital and OIT waste heating water.

Klamath Falls is developing a municipal heating district for its central building area. This project is to provide heating for 14 city, county, state and federal buildings by 1980. Following its first year of operation there will be a second phase expansion whereby additional
connections will be made to adjacent buildings; this expansion will cover 11 city blocks. Phase III will be to provide services to 54 user blocks. Optimistic projections have been made for completing phase III in three to five years (by 1984). Phase III would be covered by bonding and repaid by connection and user fees. (20)

Water (11)

Hydrologic Cycle - Annual precipitation in the Klamath area totals 15 inches. Water in the Klamath Basin originates as precipitation with the majority of it falling during the period of October through March. December and January receive the maximum and minimum occurs during July, August, and September.

The juniper tablelands and pine plateau areas receive most of the precipitation in the form of snow. Mid-winter rains occur frequently at the lower elevations.

Precipitation can be divided into three categories once it has reached the earth's land surface: (1) surface runoff, (2) evaporation and transpiration losses and (3) seepage into the ground (recharge).

Surface runoff is by rivers such as Klamath River and Lost River. They are fed through snow melt, rain and discharge from springs.

Evaporation and transpiration occurs from lakes, from the soil and by vegetation. Evapotranspiration data on the vegetated areas has been estimated to be 1½ feet/year from large stands of pine trees, and less than 1 foot from sagebrush and low lying open lands.

The remaining precipitation that is not lost percolates into the ground water table. Ground water flows through spaces between rocks or fractures. These spaces are generally less than 1 inch in diameter. Ground water can be found in four different aquifers.

Sedimentary Aquifer - stream and lake deposited silt, sand, clay, gravel, peat, chalk, and ash, volcanic ejecta, thin basalt and andesitic lava flows. Specific capacities completed in this unit range from 0.01 to 5 gallons per minute per foot of drawdown and average 0.45 gallons per minute per foot. Some black sand and gravel layers may yield 2-10 gallons per minute per foot of drawdown.
Volcanic Centers Aquifer - moderate to highly fractured basaltic, dacitic and andesitic lava flows and pyroclastic material associated with eruptive centers. Specific capacities of wells completed in this unit range from less than one to over 100 gallons per minute per foot of drawdown and average approximately 25 gallons per minute per foot of drawdown.

Lower Basalt Aquifer - highly faulted and fractured series of basaltic lava flows separated by layers of scoria and cinders. Specific capacities of wells completed in this unit range from 35-500 gallons per minute per foot of drawdown and average about 145 gallons per minute per foot of drawdown.

Volcanic Ash Aquifer - massive beds of light colored rhyolitic and dacitic ash flows; minor amounts of basalt and volcanic sediments. Specific capacities are largely untested as well logs have not reported this unit within the Klamath Basin. This unit lies below lower basalt aquifer and at considerable depth.

There are many wells (reportedly ASO geothermal wells in 1979) located in the area, however, to date no serious decline in water levels has occurred. This is evidenced by observation wells. Annual water level fluctuations are greater in wells located in the recharge areas than those in the discharge areas.

Water quality is the highest in the recharge areas and declines in quality as if flows toward the discharge areas. Temperatures correspond to quality with the recharge area having the coldest water. Water in wells in the recharge areas have low temperatures of 40°F to 50°F and have small quantities of dissolved chemicals. (See tables for water quality.)

There are several localities within the Klamath River Basin that have geothermal groundwater. The larger more developed area is in northeastern Klamath Falls. In 1975 there were approximately 400 wells utilized for heating purposes. The depth of these wells range from 100 feet to approximately 1800 feet. Temperatures average less than 190°F.

Lost River Subbasin - The Lost River Subbasin is a naturally closed basin. The river originates at the outlet of Clear Lake in
northeastern California and drains the eastern 90% of the area considered in this analysis.

Lost River enters Oregon at the southeast end of Bryant Mountain flowing northwesterly on the west side of Langell Valley, continuing westward to the northern end of Poe Valley. It enters Klamath Valley through Olene Gap flowing southward along the east side of Klamath Valley and eventually discharging into Tule Lake in northeastern California.

Other main sources of water contributing to the Lost River drainage system are Gerber Watershed with an average runoff of 50,000 CFS and Bonanza Spring producing 100 cubic feet/sec. A diversion was made between Lost River and Klamath River for flood control and irrigation purposes. The Lost River Subbasin includes the following five valleys: Langell, Yonna, Swan Lake, Poe, and Kiamath. The regional water table of these valleys is generally the Lost River. The river apparently is the local base level for ground water moving beneath these valleys.

Perched water tables occur above the regional water table, are evidenced by springs in the juniper tablelands and pine plateaus area. Flow from these springs may vary from less than 1 gpm to several hundred gpm.

The primary use of water is for irrigation of croplands in the Klamath Project area.

Upper Klamath Lake - The Klamath River drains only a small portion (approximately 10%) of the area considered in this analysis. The river flows from Upper Klamath Lake southward through Link River to Lake Ewauna. It flows from Lake Ewauna along the northwest side of Klamath Valley over lava ridges near Keno, descending through a deep canyon into California. It eventually reaches the Pacific Ocean. The major water source for Upper Klamath Lake is the Williamson River (outside of the analysis area) and many springs beneath it. The portion of the area considered in this analysis contributes only a minor portion of the Klamath River flow.

Potential Pollutants - (27) The principal pollutant is heat; this is derived from all wells, whether heat-exchangers or direct consumers of geothermal fluid. Those holes involving heat-exchange do not discharge
any mineralized water, as none is produced from the wells. Only those few holes consuming geothermal reservoir fluid have any geothermal discharge.

**Water Pollution Potential**

**Summary of Baseline Water Characteristics** - Klamath Basin groundwaters fall into two main chemical groups. Cool wells and springs are of the calcium magnesium bicarbonate type with low TDS (about 55 ppm). The second type of water, occurring in warm and hot wells and springs mostly within the basins of the Klamath graben, is sodium bicarbonate chloride sulfate water with TDS averaging 700 ppm (and reported as high as 4,000 ppm). Boron and fluoride concentrations increase with temperature. For a detailed discussion of water characteristics of Klamath Basin, refer to Geonomics (in press).

Water pollution data are very scarce, incomplete and probably meaningless. They show principally that pulp and paper operations at Klamath Falls and agricultural irrigation discharge more pollutants and possibly toxic substances than the geothermal system can be shown to contain. Among these industrial and agricultural wastes are pesticide residue, various phosphate fertilizers, and sulfate and chloride ions. Partial analyses of water from Klamath Lake and Klamath River show indications of these.

**Potential Water Pollutants** - The principal pollutants from this discharge are chloride ions (perhaps 50 to 60 ppm, Table 4.1) and boron, with about 1 ppm on the average. In comparison, local cool surface waters average less than 1 ppm boron and 1 to 10 ppm chloride.

Other polluting constituents are not recognized from the scattering of partial chemical analyses available to this study. However, no data are available concerning metals or other trace element contents of these waters. When these additional data are obtained, the pollution potential may be altered.

**Potential Pollution Mechanisms and Pathways** - Direct discharge from thermal wells goes into local surface waters. Most wells do not directly produce the reservoir fluid, but utilize heat-exchanging in the well with cool, meteoric water supplied through the municipal water system. The
heated municipal water is discharged to the sewer system when depleted of its heat. Those wells (principally OIT and Klamath Hills) consuming reservoir fluid at the surface, dispose of the heat-depleted fluid in a similar manner.

Level of Potential Pollution - No reason is seen for an increase in pollutants, unless either:

1) New wells are allowed to discharge to the surface instead of being heat-exchanged with cool meteoric water; or
2) Wells are drilled into deeper aquifers (perhaps 900 m (3,000 ft) or deeper).

The latter seems unlikely in the near future, because of the cost of the deeper drilling, and the general lack of interest in exploration for a deep geothermal aquifer for generation of electricity. If it occurs, new studies of chemistry, heat content and pollutants will be required.

II.3.4.4. Summer Lake Hot Springs KGRA (32)

Total KGRA acres: 13,631
Surface temperature: 43°C
Estimated subsurface temperature: 140°C

Sale of acreages in 1976 was for 7.521 acres; however these were relinquished in 1979. Summer Lake Hot Springs is a recreation site with several campsites and a geothermally heated pool. The bathhouse has been heated with geothermal energy for close to 60 years.

(72) Summer Lake occupies the center of the floor of a basin bounded on the west by the bold scarp of forested Winter Ridge and on the east by gentler slopes covered only with desert vegetation. The lake water is shallow and saline. White crusts of crystalline minerals coat the dry part of the lakebed. In May and June 1941, the water surface was at 4,147.2 feet altitude and the greatest depth was found to be "less than 2.5 feet" by a survey party of the U.S. Bureau of Land Management. The lake is practically dry at times. The lowest recorded water level was measured by leveling as 4,144.86 feet on September 30, 1961. The highest recorded lake level occurred from February to April 1905 at 4,151.4 feet.
Most of the inflow comes from spring-fed Ana River. The springs appear at the head of Ana River about 4 miles north of the lake, beneath the water surface of a reservoir behind a diversion dam completed in 1923. The total flow of the springs has decreased from about 140 cfs, 1950-14, to about 90 cfs, 1951-63. The decrease is due in part to back pressure caused by submerging the springs and to diversions by wells from the same underground source of water.

The water of Ana River is used to irrigate meadowlands and to maintain a large refuge for migratory waterfowl. The decrease in spring flow coupled with increased use of water for irrigation and wildfowl propagation has caused less water to reach the lake; in recent year, therefore, the lake level has been consistently about 4 feet lower than it was from 1905 to 1912, and the concentration of dissolved mineral matter is correspondingly greater. The water of streams and springs entering the lake is relatively soft and is good for irrigation and domestic use.

A bed of silt and clay on the valley floor extends onto the foot of adjoining rock slopes for about 100 feet above the present level of Summer Lake. The high level of this alluvial deposit testifies to the previously much greater extent of Summer Lake. The clayey alluvium confines the extensive ground-water body in the volcanic bedrock. This ground water has a water table (pressure level) sufficiently high that the water will flow out over the clay confining layer at 50 to 100 feet above the level of the lake. Consequently, drilled wells and natural breaks in the confining blanket of clay allow the artesian ground water to flow from the lava bedrock. Numerous springs spill over the edge of the clay around the west and north sides of the basin, and a few rise in artesian fashion through the clay near the north end of the basin; Ana Springs is the largest of these.

II.3.4.5. Lakeview (32)

Total KGRA acres: 12,165
Majority of land in private ownership
Surface temperature: 96°C
Estimate subsurface temperature: 138°C
Flow rate: 600 gpm (37.85 l/s) Hunter's Hot Spring
Existing use: Commercial greenhouse and resort heating.
Activity: (19) City swim pool well cleaned out in 1979. Previously well had been rumored to be 200 feet deep but was found to be caved in. The restored well has been lined and logged for temperatures.

Hunter's well was until recently badly scaled up and less than a 3/4 inch stream was being emitted; following use of a cable tool for opening the well a geyser like flow resulted, having a 3" stream. The well has a concrete shaft to 40 feet depth and is connected by tunnel to gravity feed the lodge there. A pump installation for this facility is planned.

Planned Activity: A district heating system is being considered for Lakeview. The geothermal resource is presently unquestioned but additional gradient holes or wells are required before the regions subsurface temperature contours can be drawn. Approval for drilling tests have been given. Economic and engineering feasibility studies including hydrology, water quality, economics are being organized (1979) for serving the city with district heating.

A well to 660 feet is being used for observation purposes to determine permeability and resolve questions on the resource; this well may later be used as a possible reinjection site. Three blocks away the city uses a well (for fresh water) drilled to 550 feet but which has been plugged back to 230 feet because of the heat zone. This information is being evaluated by NWNG for selecting a reinjection strata for the district heating system it is considering. Temperatures for these wells have not yet stabilized (August 1979) thermally for establishing reinjection depths. Six additional holes are planned for assessing the resource.

II.3.5. Snake River Plain

The western Snake River basin is divided, for the purpose of discussion, into five subareas, including: Ontario, Nyssa, Adrian, Vale and Bully Creek. To date, there has been no production of geothermal waters in the region except for a few shallow wells near Vale Hot Springs. However, the presence of other hot springs and warm-water wells in the environs, along with the background knowledge of the subsurface geology from oil and gas tests drilled in the basin, indicate that the required conditions for non-electric utilization are present. The region has an
average geothermal gradient of about 85°C/km. Geothermal fluid temperatures in the range of 90° to 100°C are expected at 1 km. depth at the Grassy Mountain Basalt and from 140° to 165°C from deeper drilling into the Owyhee Basalt. Fault related geothermal waters are expected to occur from near the surface to depths of 1 km. A discussion of the individual thermal water occurrences is given in the accompanying sections.

Water

Surface Water - The two major rivers in this region are the Malheur River and the Owyhee River. Within the area of the EAR, the Malheur generally flows west to east, and joins the Snake River north of Ontario, Oregon. Major tributaries of the Malheuer within the geographical boundaries of the EAR are Bully Creek, Willow Creek, and the North Fork Malheur River. Thw Owyhee River flows south to north and joins the Snake River south of Nyssa, Oregon.

According to the Oregon Department of Environmental Quality (1975), most of Oregon's water quality problems are directly associated with deficiencies in water quantity. With respect to the current established water quality standards in Oregon, both the Malheur and Owyhee Rivers exhibit substantial partial or fulltime noncompliance of temperature, turbidity, and suspended solids parameters. This occurs mainly during low flow periods.

Seasonally high turbidity measurements are due to land runoff and irrigation return flows. High temperatures are not due to heated effluent discharges, but rather from solar radiation heating diminished flows.

Average annual discharge measured at the Owyhee River below the Owyhee Dam is only 252 cfs. Note that discharge values for the Owyhee River are obtained below Owyhee Dam, and do not reflect quantities of water which have been diverted from the reservoir to regions outside the river basin. Maximum flows for the 1970-1975 period was 22,900 cfs and the minimum flow was 1.8 cfs in 1973-1974, illustrating the variability of discharge in this region.

Low flow augmentation of the Malheur River would help improve the
water quality of this region. A proposal has been made to divert some water flowing into the Malheur Lake Basin (a closed basin without any natural outlets which adjoins the Malheur River Basin) to a reservoir which would be situated between the Malheur River and Malheur Lake Basins. This water would then be used to increase flows and water quality for either basin.

**Ground Water** - Shallow ground water is recharged annually from precipitation and infiltration. Due to the low precipitation rates in this area, ground water is not abundant, and occurrences are localized and utilized mainly for irrigation. In general, wells within the region produce less than 100 gallons per minute. Notable exceptions occur in gravelly alluvium along the Snake River, and the Idaho Formation. The cities of Nyssa and Ontario have wells which produce more than 1,000 gallons per minute from 40 foot thick gravels, and wells at a sugar refinery at Nyssa produce 200 to 300 gallons per minute from the underlying Idaho Formation.

Mariner, et al. (174), discusses the chemical characteristics of selected hot springs in Oregon. Three such springs are located within the area of interest, namely Mitchell, and Beulah Hot Springs, and an unnamed hot spring near Little Valley.

Present demand for water in the Malheur River basin is higher than the amount naturally available. More than one-half of the water stored in Owyhee Reservoir is diverted to the Malheur River Basin (Oregon State Water Resources Board, 1969).

Cow Valley (T.15S., R40E., and vicinity) had been declared a Critical Ground Water Area by the state in 1956 due to declining ground water levels (Bartholomew, et al., 1973). Since this declaration and resultant controls placed on ground water pumpage, withdrawals have stabilized to a point equal to the recharge, approximately 4,000 acre-feet per year. As long as ground water use remains below this figure, it is expected that the ground water table will remain stabilized (Bartholomew, et al., 1973). (13)

II.3.5.1. **Ontario ORE-IDA** (Near Ontario, Oregon)

Private Development Site Acreage: 200 Acres

43
Surface Temperature: No surface geothermal waters
Estimated Subsurface (7000 ft) Temperature: 149°C
Estimated minimum flow withdrawal rate: 800 gpm (50.5 l/s)
Existing uses: Ontario, OR: None
Planned Development: Commercial, Industrial direct heating

CH2M-Hill Boise office (3) provided engineering feasibility studies for ORE-IDA development on 200 acres. Regional oil well information related but restricted, wildcat hole information available for relating expected downhole temperatures and water availability for development.

Reinjection of spent geothermal resource waters can't be entirely decided until production well and ORE-IDA industrial heating is established. Estimated depth for reinjection will be between 3000 and 7000 feet to prevent potable water contamination.

Nearly all of the Ontario subarea lies within the bottomlands of the Malheur and Snake Rivers. With the exception of a small block of hill land in the northwest corner, this is all high-use agricultural, industrial or residential land. Ontario is the trading center of the study area, and probably 75 percent of the population is located in the Ontario subarea. Most of the area is covered with recent alluvium from the Malheur and Snake Rivers; underlying the alluvium are siltstones and claystones of the Chalk Butte Formation with a probably thickness of 1 to 1.5 km. A major northeast-trending geologic structure, the Malheur River fault (Bowen and Blackwell, 1975) appears to parallel the Malheur River from Vale to Ontario.

Waring (1965) reported a 73°C hot spring along the Malheur River three miles west of Ontario. A field check has failed to confirm this occurrence and local residents did not know of it. No other surface indications are known to be present. The only shallow target zone is inferred from measured well gradients and here above-normal temperature may be found; water volume may not be adequate. (44)

II.3.5.2. Nyssa Subarea (44)

This subarea is largely in the flood plain of the Snake River except for the northwest quarter which is rolling sagebrush-covered hills. Like other bottomlands in the region, high-intensity agriculture is the predominate land use and preishable high-value crops such as sugar beets,
onions, potatoes, corn and beets predominate. In the foothills dairying and cattle feeding are important industries. A fruit and vegetable can- nery and a sugar mill are important processors of local crops and pro- vide year-around employment in the region. The water for irrigation is supplied mainly from surface sources and delivered by ditches and pipelines. As surface water allocations are used up, groundwater is beginning to supply increasing amounts of irrigation water. Outside of the cities, most domestic water is from shallow wells.

Rocks underlying the subarea are fine-grained claystone, siltsone and sandstone of the Chalk Butte Formation. Terrace gravels cover the lower bench areas and fine-grained alluvium the flood plains of the Snake River. Two oil well tests show that the Grassy Mountain Basalt occurs at a depth of about 1 km and the Owyhee Basalt at about 2 km.

There are no geothermal manifestations known in this subarea; however, temperature gradients, both measured and those interpreted from water well logs, show geothermal gradients greater than 100°C/km at several locations. The most prominent geothermal anomaly is the Cow Hollow geothermal anomaly which extends into the southwestern edge of this subarea. Bowen and Blackwell (1975) have interpreted that this anomaly is caused by hot water or steam moving upward along the Willow Creek fault zone and that drilling to depth of 1 or 2 km should locate high-temperature water or steam. There is also a possibility that high-temperature fluids might be located by drilling near the strike slip fault interpreted by Couch (1977) as some measured gradients and water well data show above-regional gradients along the fault zone. The potential reservoir horizons, the Grassy Mountain Basalt and the Owyhee Basalt are probably nearer the surface in the western part of the sub- area so drilling there would not have to be as deep as in the eastern section. In the eastern part of the Nyssa subarea, it is expected that the same deep reservoirs discussed earlier are present, and at depths similar to those at Ontario.

II.3.5.3. Adrian Subarea (44)

This subarea lies along the transition zone between the Snake River Plain and Owyhee Uplands. Along the eastern edge are the flat bottomlands
of the Snake River. In the southwest corner of the Owyhee River has eroded a canyon several hundred feet deep. The presence of Mitchell Butte Hot Springs and Deer Butte Hot Springs within Owyhee Canyon, along with several more along this same trend in the Owyhee Basalt to the southwest suggest the presence of a major thermal zone. From geologists' reports it has been related that drilling to a depth of 0.5 to 1 km between the Owyhee Canyon and Adrian has a good chance of locating hot water between 50° and 100°C. After leaving the canyon the river meanders through a flood plain and joins the Snake River about 7 km north of Adrian.

Truck gardening takes place along the bottomlands of the Snake and Owyhee Rivers and the raising of hay, alfalfa and other grain crops in the adjacent foothills. In the upland areas cattle raising and dairying are the main land uses. Most of the population in the subarea is located near the eastern edge in Adrian and along State Highway 201 which leads north to Nyssa and Ontario. Farms are present throughout all of the region except in the higher hills in the southwest corner. Surface water provides most of the irrigation water while shallow wells provide most domestic water.

II.3.5.4. Vale KGRA (32)

Total KGRA acres: 23,998
Surface temperature: 73°C
Estimated subsurface temperature: 160-180°C
Surface discharge: 1.26 1/s
Present Development: Several local uses for space heating.
Planned Development: Geothermal heating and cooling for a mushroom growing facility.

The city is interested in a district heating system for publically owned buildings. The potential for non-electric applications for space heating and industrial processing (agribusiness) appears excellent.

The Vale subarea has been designated as a Known Geothermal Resource Area (KGRA) by the U.S. Geological Survey and geothermal leases on the federal lands within the block are offered for sale by competitive bidding. A total of 8,393 acres of the federal leases have been granted at prices ranging between $3 and $16.16 per acre. Geothermal leases have also been negotiated for much of the private land.
Vale Hot Springs, located on the east edge of the city of Vale, has a surface temperature of 97°C and a visible flow of 25 to 50 gallons per minute (1.50 to 3.0 l/2). Chemical analysis on the hot spring waters shows it has dissolved solids of 882 ppm. The alkali ratio indicates a minimum estimated reservoir temperature of 157°C (Mariner and others, 1975). A shallow well drilled 50 m east of the hot springs was reported to have temperatures of 110°C. Other shallow wells with temperatures slightly over boiling are located within a half mile of the hot springs, all on the south side of the Malheur River. On the north side of the river near Vale, just to the north of Rhinehart Buttes, shallow wells do not intersect the high-temperature zone located just south of the river, but a 320-m oil test in the SW 1/4 of sec. 21, T. 18S., R45E. shows there is also a high geothermal gradient of 147°C/km on the north side of the river. Warm-water wells and the high geothermal gradients along the Willow Creek fault zone, the west boundary of the Vale horst, indicate rising thermal waters to the southeast of Vale. (44)

The Vale subarea is made up mostly of rolling foothills of the Owyhee Uplands that form the western and southern boundary of the Western Snake River Basin. The Malheur River, one of the principal tributaries of the Snake, has cut a valley one to three miles wide and in places two to three benches or terraces have been formed by this erosion. Willow Creek, a tributary to the Malheur River, has also eroded a flat valley two to three miles wide and enters the Malheur Valley at Vale.

Farming activities and all of the homes are located within these two valleys and a few of their small tributaries. The uplands, consisting of rounded hills, are used for grazing. Land ownership patterns follow the topography, with nearly all of the valley land and near foothills under private ownership and the higher hilly land in federal ownership. The long growing season, nearness to processing plants and relatively abundant water had encouraged the development of large-scale farming within the valleys. Most of the water used for irrigation comes from ditches from nearby surface storage reservoirs.

Water quality of the Malheur River is low at present and intensive irrigation use degrades it further. This stream is seasonally warm, high in sediment and dissolved solids. Concentrations of basic nutrients,
nitrogen and phosphorous, are high; phosphorous concentrations are particularly high. High nutrient concentrations have stimulated heavy algal growth. Concentrations of dissolved solids in the Malheur average over 1,000 mg/l. Bacterial contamination of the Malheur also exists. Dissolved oxygen concentration fluctuate with low flows and algal activity. One in ten year low flow for the Malheur is a low as 32 cfs for a period of one month. Sediment and dissolved solid contributions to the Malheur from National Resource Lands within the area are reportedly insignificant.

Ground water - Several ground water aquifers exist within the area. Quality of water varies among the aquifers; some waters are not potable. Some deeper wells 500-600' produce warm water. Most potable wells within the town of vale are 20-40'.

The shallow wells are located in flood plain alluvium of the Malheur River. With few exceptions groundwater for irrigation is limited to shallow gravel zones near existing streams. Lesser amounts of groundwater for stock watering can sometimes be located in perched lenses at relatively shallow depths in the foothills.

II.3.5.5. Bully Creek Subarea (9) (44)

Geothermal manifestations in the subarea are Neal (Bully Creek) Hot Springs in the NW 1/4 of sec. 9, T. 18S., R. 43E., and an unnamed warm spring about one mile to the northeast of Neal Hot Springs. Neal Hot Springs has a maximum surface temperature of 87°C and water analyses indicate that minimum subsurface reservoir temperatures are 173°C to 181°C (Mariner and others, 1974). Two water wells on the east edge of the subarea show above-normal gradients. The Nelson well in sec. 34, T. 18S., R. 43E. has a reported water temperature of 21°C at a depth of 58 m, which indicates a geothermal gradient of 157°C/km. The BLM Vines Hill well in sec. 22, T. 19 S., R. 43 E., has a water temperature of 31°C from a 219-m depth, indicating a gradient of 94°C/km.

A prospective drilling target is along the western edge of the subarea. The Owyhee Basalt appears very close to the surface, probably covered only by a thin layer (0 to 1000 m) of Chalk Butte Formation. The high temperatures indicated by the geochemical analysis (Mariner, 1974) for Neal Hot Springs may given an indication of reservoir conditions.
A fault zone postulated by Couch (1977) from geophysical data appears to be the zone of leakage of the geothermal fluids. From the present indications further drilling along this zone appears to be warranted.

Water - The Bully Creek Subarea is located in the foothills of the Owyhee Uplands; the Malheur River has excavated a flat valley about 3 km wide through the middle of the area and Bully Creek, following a valley about 1-1/2 km wide, flows in from the northwest. Along the north side of the Malheur River is a broad gravel covered bench with Bully Creek Valley dividing it into what is known as East Bench and West Bench. As an intermittent tributary of the Malheur, Bully Creek usually carries a high sediment load.

Farming takes place in the valley and in the bench area and grazing in the rest of the hills. Most of the irrigation water is provided by surface canals that use water from the Malheur River and from Bully Creek Reservoir.

Ground Water - Bully Creek, north of the main stem of the Malheur, drains the east slope of lava rock ridge. A few irrigation wells in this area obtain yields of 500 gpm from the lava associated with the Idaho Formation, the Malheur River and Bully Creek flood-plains; more wells will probably be constructed as more is learned about the subsurface of the part of the basin. Several springs are within the area including some which produce warm or hot water. In the East and West Bench areas there is sufficient water for domestic wells in the gravel terraces. Away from the valleys a few stock wells produce small amounts of water from perched zones. Quality of water from these aquifers vary. At least one aquifer contains water with a high dissolved minerals content and is not potable.

II.3.6. Columbia River

II.3.6.1. La Grande (39)

Estimated important GRA acreage 19,200 acres.

<table>
<thead>
<tr>
<th>Temperatures</th>
<th>Site</th>
<th>Discharge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface</td>
<td>Underground</td>
<td></td>
</tr>
<tr>
<td>85°C</td>
<td>115°C Hot Lake Resort</td>
<td>Hot Springs 1700 gpm</td>
</tr>
<tr>
<td>79°C</td>
<td>Hot Lake Courtright</td>
<td>Well       30 gpm</td>
</tr>
<tr>
<td>60°C</td>
<td>Medical Hot Springs</td>
<td></td>
</tr>
<tr>
<td>57°C</td>
<td>109°C Radium Hot Springs</td>
<td>300 gpm</td>
</tr>
</tbody>
</table>
A Phase I examination of geothermal attributes for the area was initiated in 1975 and is compiled in (39). Economics of space heating of homes, industrial uses are being evaluated. Phase II plans for improved resource definition and feasibility analyses proposed for increased geothermal utilization. A potatoe alcohol plant is being considered for development Southeast of Hot Lake.

Water - The Baker and Grande Ronde Valleys are structural depressions produced by folding and faulting. Most of the geothermal springs in the area are associated with faults bordering the valleys. Over 31 warm water (>21°C) springs and wells in the area have been identified. (39)

II.3.6.2. Powder River (drainage past Baker) (44)

The Powder River rises in the Blue Mountains. The peaks beside the headwater reaches of the river are the highest in the range, many of them rising to altitudes of 8,000 to 9,000 feet. From these mountains a multitude of little streams tumble swiftly down the steep canyons. The growing river flows more gently through the round, open valleys near Baker, then more rapidly again through alternating canyons and small irrigated valleys, to join the Snake River at Robinette. The low-water flow of many of the streams is completely used for irrigation. The water of Rock Creek is used to develop electric power, and Goodrich Creek furnishes the municipal water supply for Baker.

There is as yet no upstream storage to control the floods that occur at rare intervals. Flooding along the Powder River is sometimes due, at least in part, to ice jams as the late winter rains swell the streams. The average flow of the Powder River is 247 cfs near Richland from a drainage area of 1310 mi².

The Powder River has a significant concentration of dissolved solids (190 to 200 ppm of which 30 ppm is silica). Where the river emerges into open valleys, it has deposited its bedload of gravel and sand to construct alluvial fans, such as the one on which Baker is located. These gravelly deposits yield moderate supplies of water to wells. A total of only a dozen wells are used for irrigation in Baker Valley and the heating area of the Powder River. Not over 2000 acres are being irrigated by wells in the Powder River Basin. The chemical
quality of the ground water of the basin is mostly good to excellent.

II.3.6.3. Grande Ronde River (flow past LaGrande) (44)

The large fault-block valley that lies between Union and Elgin became known to early French trappers as Grande Ronde, a name that soon was transferred to the river.

Rising in the snowbanks and springs of the Blue Mountains, the river meanders lazily through the large flat valley, much of the flow confined in a straightened cutoff channel known as the State ditch. In this valley reach, the principal tributary is Catherine Creek, which drains the southwest side of the Wallowa Mountains; it reaches the valley floor at Union, and from there it winds north through the valley to join the old channel of the Grande Ronde near Cove. The river has built a gravelly fan extending from its mountain canyon several miles eastward from LaGrande. Catherine Creek also flows across a gravel fan before reaching the Grande Ronde. From their confluence, the river meanders widely over a very flat part of the valley floor as far as the bedrock canyon carved through Pumpkin Ridge, below which the river enters the smaller Elgin Valley.

Economical supplies of water can be obtained from wells in the lava bedrock, in the gravelly alluvial-fan deposits, and in the sand and fine gravel beds within the valley alluvium. The water table stands close to the level of the valley floor, and springs flow from the bedrock and gravel aquifers around the edges of the valley. Springs rising along faultlines at Rot Lake contain water that is near boiling temperature.

The river drains 3,950 square miles, mostly mountainous and forested. Precipitation over the area is moderate (30 inches annually) annual runoff, would cover the basin more than 13 inches deep if it could be spread uniformly over it. The Grande Ronde River at LaGrande average discharge is 380 cfs (from a 678 mi² drainage area) and at Elgin is 660 cfs (from 1250 mi² drainage area). At Troy, where the drainage area is 3,275 square miles and the lowest streamflow measuring station is operated, the average flow is 3,200 cfs after the upstream needs have been taken out. The forests, meadows, and irrigated fields of the Grande Ronde basin consume or evaporate about 18 inches of water. This flow is
about twice the total net inflow contributed to the Snake River by all other Oregon streams although the drainage area at Troy is less than a fifth of the total of the combined Snake River tributaries in Oregon (19,150 sq. mi.).

Ground water in the alluvium of the Grande Ronde Valley ranges from soft to only moderately hard; it varies in chemical content temporally and spatially in accordance with adjacent surface runoff. Warm to hot water occurs along geologic faults in the Powder and Grande Ronde River Basins. This water carries large amounts of silica, sodium bicarbonate, chloride, and sulfate and is of poor quality.

III. WATER QUALITY

III.1. INTRODUCTION

This chapter covers delineations of Oregon's regulations regarding water quality, geothermal resource developments, and water quality issues and concerns related to proposed geothermal activities within the state.

Discussed in Section III.2 is the current understanding among state agencies for the coordinated action of the development of geothermal resources. This proceeds with the developer complying with the Department of Geology and Mineral Industries (DOGAMI) rules, regulations and environmental protection stipulations relating to exploration and development of geothermal resources in Oregon. State water quality standards, Forest Service management goals and federal pollution control requirements must be met in the process of development and operation of geothermal systems.

Environmental impacts anticipated with geothermal activities are projected for Oregon's developments in Section III.3 water related environmental issues to be considered in geothermal energy direct heat or electrical power project planning include: [104]

Water Quality One of the most serious water quality concerns is that geothermal fluids released to natural aquatic bodies will degrade water quality and result in negative impacts to fish and other aquatic organisms. These negative impacts can be avoided by simply preventing
geothermal discharges to aquatic bodies or by maintaining those discharges below harmful levels.

The disposal of toxic fluids is closely regulated in Oregon, with no discharges permitted. Direct heat projects should be designed to avoid or minimize equipment failure resulting in accidental releases of fluids to aquatic bodies. In areas where the geothermal fluids are potable or of irrigation quality, it may be possible to obtain permits for surface discharge or cascaded uses of the geothermal fluid (e.g., irrigation) after some of the heat is extracted.

Hot Springs: One of the most serious concerns associated with the withdrawal of geothermal fluid is its possible affect on hot spring activity. Geologic and hydrologic data are often insufficient to predict potential impact. As a result, the drilling of geothermal fluids in areas adjacent to hot springs is usually controversial and may be prohibited within a certain radius.

Subsidence: Land slides, liquefaction and mass earth movements may be a problem in any area if net fluid withdrawals exceed natural recharge or injection. The actual incidence of subsidence depends on the nature of the reservoir and the surrounding geologic formations -- in fracture permeability reservoirs, subsidence should be negligible, whereas in sedimentary reservoirs, subsidence could be a substantial problem. In this latter case, subsidence may be reduced through a well-planned program of injection of the geothermal fluids. Moreover, such injection also conserves the geothermal resource and would extend the reservoir's producing life.

Surface disposal of geothermal waters of similar quality of Oregon's thermal spring and well waters would presently be undesirable, based on water chemistry and current standards. Inter basin transfer, reinjection (or recirculation) of associated hydrothermal fluids will involve considerable flows which may significantly effect regional hydrology and must be ranked as a serious concern along with other water quality issues such as discharge of spent fluids to surface waters, erosion and sedimentation impacts, landslides and subsidence, resource depletion and ground water degradation.
III.2. REGULATION DELINEATION REGARDING WATER QUALITY AND GEOTHERMAL RESOURCE DEVELOPMENTS

The United States Geological Survey identifies the "geothermal resource base" as all of the stored thermal energy above 15°C to 10 km depth in the earth for the 50 states. Oregon's law establishes 250°F (121.1°C) and well depth greater than 2000 feet (609.8 m) for applying geothermal regulatory requirements under the aegis of the Department of Geology and Mineral Industries (DOGAMI). Wells cooler than 250°F (121.1°C) and shallower than 2000 feet (0.61 km) would be administered by the State of Oregon's Water Resources Department (DWR), whereby a water right would be required for "beneficial use" if industrial use exceeds 5000 gpd (0.22 l/s). It should be noted that development on federal land requires a federal lease (BLM or USFS) and compliance with USGS operating regulations. Drilling on federal land also requires state DOGAMI permits for both shallow and deep wells, and compliance with DEQ regulations. Development on state land requires a DSL lease, DOGAMI permits, and DEQ regulations compliance; and development on private land requires DOGAMI permits and DEQ compliance.

As noted in Table 1, Section II.1 and Table II.b,c Section II.3 some of the KGRA's reservoir waters have temperatures below 250°F (121.1°C). Characteristics of geothermal resources cannot be determined without drilling of deep wells, a process that existing regulations allow only after issuance of permits from DOGAMI. On the DOGAMI permits, copies of the applications to drill are distributed to all potentially interested state agencies (DOGAMI, DWR, DOE, DSL, F&W, Hwy. Comm., etc.) for consideration before a permit is issued.

DWR policy is that geothermal fluids (from wells producing over 5000 gpd (0.22 l/s) must be reinjected or subjected to subsequent water filings. Land disposal of geothermal fluids needs a DEQ (Department of Environmental Quality) permit; while beneficial use does not require a DEQ permit, a water right is needed. A condition of understanding among state agencies seemingly exists for coordinated action on the development of geothermal resources. That is, the commercial developer has been encouraged to follow DOGAMI's "Rules and Regulations ... Relating to Exploration and Development of Geothermal Resources in Oregon" and if
the resource is found with temperatures above 250°F (121.1°C) and deeper than 2000 feet, production would follow under DOGAMI's authority. If the resource does not fit this description, its regulatory disposition would be handled on a case by case basis with the pertinent interested agencies. For this reason the geothermal water quality impacts suggested in the workshop discussions and expanded upon in this report are generalized for both warm water near-surface (hydrothermal) systems and deep geothermal systems without concern for temperature or depth limitations.

A survey of environmental regulations applying to geothermal exploration development and use is found in (1) and a general guide for negotiating and obtaining regulatory approvals is given in (102). Detailed information on leasing, statutory responsibilities and legal definitions is also given in the appendicies of this reference.

A summary of Federal Pollution Control Laws Administered by the Environmental Protection Agency requiring or related to geothermal pollution control is presented in Appendix III, as abstracted from "Pollution control Guidance for Geothermal Energy Development" by Robert P. Hartley (36). The significant federal laws include those applying to all industrial developments, such as: the Federal Water Pollution Control Act Amendments of 1972 (PL 92-500), the Clean Air Act as amended (PL 91-604 and PL 95-95), the Safe Drinking Water Act (PL 93-523), the Resource Conservation and Recovery Act of 1976 (PL 94-580), the Noise Control Act of 1972 (PL 92-574), and the Toxic Substances Control Act (PL 94-469). Laws aimed principally at broad-scale encouragement of energy resource development include: the Geothermal Stream Act of 1970, the Federal Nonnuclear Energy Research and Development Act of 1974, and the Geothermal Energy Research and Development Act of 1974. Laws aimed principally at broad scale protection of environmental values include: the National Environmental Policy Act of 1969, the Fish and Wildlife Coordination Act, the Endangered Species Act of 1973, the Wilderness Act, and the Marine Protection, Research and Sanctuaries Act of 1972. Generally these laws, programs and acts have specific goals for maintaining environmental quality and standards, which must be met by commercial or industrial developments.

Oregon's concerns for geothermal development include meeting the
There are substantive and procedural requirements which developers are to follow in exploring and developing geothermal energy. Legal and institutional constraints to geothermal development along with a categorization of state laws in Oregon are presented in (56). The article "Administrative Requirements for Development of Geothermal Resources, the State of Oregon" (48) is enclosed as Appendix IV. This paper is not a step-by-step checklist of requirements but a guide for overcoming hurdles faced by the geothermal developer. It is noted in the enclosed article that Oregon's 1975 legislature vested all jurisdiction over geothermal wells in the Department of Geology and Mineral Industries.

The DOGAMI environmental protection stipulations (February 1979), applicable for exploratory drilling for geothermal energy resources, apparently supercede and make moot previous agreements with other state agencies for conditions which might affect water quality; the DOGAMI drilling stipulations are attached as Appendix V. It is noted that a developer can proceed with limited authoritative constraint during the period of resource exploration, providing sufficient care is taken drilling, operating and abandoning test wells and accordingly meeting DOGAMI's drilling rules. If the resource is found then a site specific EIS is required before development can proceed.

DEQ and other agencies review the EIS and provide comments on the planned geothermal development. Appendix VI contains a listing of water quality standards established by the Oregon Department of Environmental Quality (DEQ) and the Forest Service Stream Management Goals.

Generally, agency EIS review has involved resummarizing some environmental impact concerns and raising questions regarding federal enforcement of state environmental protection requirements by federal land managers. (31). It appears that existing state laws, regulations and agency agreements for fluid discharge cover geothermal exploration activities but are inadequate for fluid disposal from field development and operations.
III.3. WATER QUALITY CONCERNS AND ISSUES

III.3.1. Introduction

Early developments of geothermal activities in California (1960) had imposed stringent requirements on water quality limits. As developments progressed, condensate quantities and surface waste discharges grew with resulting degradation of water quality in nearby streams. Ammonia releases in the surface discharges were toxic to salmonids and boron posed agricultural problems. Reinjection of the effluent to lower aquifers provided resolve to the problem of direct discharge of condensate to surface waters. With reinjection the water quality problems associated with geothermal developments in these areas became more attributable to lax land management then from effluent discharges (i.e., erosion from road construction, failing sump pits and accidental breaks in condensate lines). Now associated requirements are sufficiently tight and methods of construction have become sufficiently improved that even the land management problems are minor. These experiences are important for the development of geothermal resources in Oregon because they show that problems can occur, problems can be mitigated and the resources can be successfully developed with present day technology without significant adverse impacts to regional water quality.

Water quality management actions within the regulatory system in Oregon will require measures to be taken to prevent geothermal waters from entering surface or ground waters of an area. For those suspecting some eventual degradation of water quality associated with geothermal developments will eventually occur, their concerns should eventually be tempered by a benefit-to-cost analysis related to the development and potential impacts, damage and losses. That is, the probability of the impact should be assessed, the expected harm or loss identified and quantified in terms of net value, and the cost of increased protection to prevent the accidental impact should be put into balance in terms of trade offs with the benefits of developing the resource for its energy supply.

Management of geothermal developments are important but are beyond the scope of this report, which is directed to identifying water quality issues, availability of water quality baseline information and information
needs. However, as geothermal energy developments progress, monitoring programs will be required to ensure the effectiveness of the program management. Information on stream and ground water quality will be necessary to evaluate impacts, if they occur. This report hopefully will supply identification of sources of available baseline information for geothermal developments now under consideration in Oregon. Monitoring programs should be planned to improve this meager data base and initially should be directed to resolve the issues and concerns mentioned in the next section and section III.3.4.

III.3.2. Identification of Water Quality Impacts

In the process of identifying possible water quality impacts associated with geothermal developments, the first step should be to identify the possible water contaminants that exist in regional geothermal waters of the KGRA and to document the baseline chemical composition of the waters of the area's hot springs and wells. Constituents deleterious to future water reuses should be identified. Information on the basic geothermal waters, condenser exchange waters, process wastes and cooling tower effluents should be found through exploratory drilling and projected process synthesis, analysis and design. Secondly, the probable impacts on surface runoff should be considered in terms of surface water degradation by geothermal plant effluents, drilling and testing runoff to streams, erosion and sedimentation of streams associated with road construction and site preparation, and land slides and subsidence contributions to stream sediment loads. Thirdly, probability of accidental spills, such as by well blowouts should be assessed. Fourthly, groundwater degradation and interference with nearby wells by leakage of the geothermal well should be considered, in addition to resource degradation and reinjection effects. Finally, cooling tower drift components should be considered regarding their possible chronic effects with possible isolated storm runoff of assembled deleterious constituents.

Baseline water quality information sources for Oregon's KGRA's are presented in the next paragraphs.

Water quality standards for drinking water (Oregon, recommended and mandatory (USPHS), irrigating water (threshold and limiting), and
livestock feeding (threshold and limiting) for numerous chemical elements and compounds are listed in Table III. A discussion of the environmental effects of known pollutants, identified through the chemistry of geothermal waters, is found in Appendix VII (36). Accordingly the limits for potable water are indicated on Figure 2. This information is for use in comparing the quality of Oregon's thermal springs and well water quality data with acceptable use standards.

Table IV is a summary of regional thermal spring and well water chemical analyses recently published in (89). Ranges of concentrations of elements and chemical compounds are listed in mg/l or ppm for each of the KGRA's of Oregon. Accordingly, the range of these concentrations found in Oregon's thermal springs and wells is indicated on Figure 2, along with the range accepted for potable waters.

It is noted that the chemical attributes of the waters of many of Oregon's thermal springs and wells exceed existing water quality standards, including many elements and total dissolved solids, as listed:

- Arsenic
  - all areas exceed (but LaGrande)
- Bicarbonate
  - all areas exceed (but Klamath Falls, Alvord)
- Boron
  - all areas exceed
- Bromide
  - exceeded by Belnap, Breitenbush, Klamath, Alvord
- Calcium
  - exceeded by Belnap, McCredie, Klamath Falls
- Chloride
  - all areas exceed
- Copper
  - all areas exceed
- Fluoride
  - all areas exceed
- Hydrogen Sulfide
  - exceeded by Mt. Hood (gas) and Alvord (water)
- Iron
  - exceeded by Klamath, Alvord, Vale
- Lead
  - all areas have <0.06 standard is 0.05 ppm
- Lithium
  - exceeded by Alvord, Belnap, McCredie, Greitenbush
- Manganese
  - exceeded by McCredie, Breitenbush, Klamath, Alvord
- Mercury
  - exceeded at LaGrande
- pH
  - exceeded by Klamath, Alvord, Burns, Vale, LaGrande
- Sodium
  - exceeded by Belnap, McCredie, Breitenbush, Klamath Falls, Alvord
- TDS
  - all areas exceed

No standards were found listed for Oregon's water for: Cesium,
### TABLE III. WATER QUALITY STANDARDS AND ACCEPTABLE LIMITS FOR DRINKING, IRRIGATION AND LIVESTOCK WATERS.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Drinking Water</th>
<th>Irrigating Water</th>
<th>Livestock Feeding</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Recommended USPHS</td>
<td>Mandatory USPHS</td>
<td>Oregon Limiting</td>
</tr>
<tr>
<td>Arsenic (As)</td>
<td>0.01</td>
<td>0.05</td>
<td>0.01</td>
</tr>
<tr>
<td>Barium (Ba)</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
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<tr>
<td>Bicarbonate (HCO₃)</td>
<td>range 25-550</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Boron (B)</td>
<td>range &lt;1-10</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Calcium (Ca)</td>
<td>range 3-150</td>
<td>500</td>
<td>500</td>
</tr>
<tr>
<td>Chloride (Cl)</td>
<td>250</td>
<td>25</td>
<td>100</td>
</tr>
<tr>
<td>Copper (Cu)</td>
<td>1.0</td>
<td>0.05</td>
<td>0.1</td>
</tr>
<tr>
<td>Fluoride (F)</td>
<td>1.7</td>
<td>2.2</td>
<td>1.0</td>
</tr>
<tr>
<td>Hydrogen Sulfide (H₂S)</td>
<td>0.002</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>Iron (Fe)</td>
<td>0.5</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Lead (Pb)</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>Magnesium (Mg)</td>
<td>range 8-55</td>
<td>250</td>
<td>250</td>
</tr>
<tr>
<td>Manganese (Mn)</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>Mercury (Hg)</td>
<td>0.002</td>
<td>0.002</td>
<td>0.002</td>
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<tr>
<td>Nitrate (NO₃)</td>
<td>45</td>
<td>10</td>
<td>200</td>
</tr>
<tr>
<td>Sodium (Na)</td>
<td>range 1.5-500</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Sulfate (SO₄)</td>
<td>250</td>
<td>200</td>
<td>1000</td>
</tr>
<tr>
<td>Potassium (K)</td>
<td>range</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>Aluminum (Al)</td>
<td>range &lt;0.25</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Bromide (Br)</td>
<td>range &lt;21</td>
<td>500</td>
<td>500</td>
</tr>
<tr>
<td>Strontium (Sr)</td>
<td>&lt;2</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Lithium (Li)</td>
<td>range 0.6</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Cesium (Cs)</td>
<td>range</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Rubidium (Rb)</td>
<td>range</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Iodine (I)</td>
<td>range</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Antimony (Sb)</td>
<td>range</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Ammonium (NH₄)</td>
<td>&lt;0.02</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Carbon Dioxide (CO₂)</td>
<td>range 50-800</td>
<td>500</td>
<td>500</td>
</tr>
<tr>
<td>Phosphate (PO₄)</td>
<td>100</td>
<td>500</td>
<td>500</td>
</tr>
<tr>
<td>Specific Cond. (S.C.)</td>
<td>20-400</td>
<td>20</td>
<td>600</td>
</tr>
<tr>
<td>Alkalinity (CaCO₃)</td>
<td>range</td>
<td>20</td>
<td>600</td>
</tr>
</tbody>
</table>

*Concentrations listed in mg/l (ppm)*

Major Source: Geonomics, Inc.; Subsurface Environmental Assessment for Four Geothermal Systems For Oregon; The Oregon Administrative Rules Chap. 340

Minor Source: Hammer, Mark J.; Water and Waste-Water Technology

More Sources: Geonomics, Inc.; Subsurface Environmental Assessment for Four Geothermal Systems For Oregon; The Oregon Administrative Rules Chap. 340

EPA; Quality Criteria for Water 1976

Maximum contaminant level specified in National Primary Drinking Water Regulations (EPA, 1976)

Maximum contaminant level specified in National Secondary Drinking Water Regulations (EPA, 1977a)

Acceptable Range for Potable Waters; Geonomics (Figure 4)
### TABLE IV. CHEMICAL ATTRIBUTES OF OREGON'S HOT SPRINGS AND WELL WATERS.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Western Cascades</th>
<th>Mt. Hood</th>
<th>Klamath Falls</th>
<th>Alvord</th>
<th>Burns</th>
<th>Vale</th>
<th>LaGrande</th>
<th>Lakeview</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Belknap</td>
<td>McCrezie</td>
<td>Summit</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arsenic As</td>
<td>.35</td>
<td>.08</td>
<td>.51- .54</td>
<td>&lt;.005</td>
<td>N-227</td>
<td>.037-2.5</td>
<td>.06</td>
<td>.001- .05</td>
</tr>
<tr>
<td>Bicarbonate HCO₃</td>
<td>17</td>
<td>142</td>
<td>21-1550</td>
<td>372-1250</td>
<td>49-128</td>
<td>127-198</td>
<td>62-64</td>
<td>62-208</td>
</tr>
<tr>
<td>Bicarbonate H₂CO₃</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bicarbonate H₂SO₄</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boron B</td>
<td>6.4</td>
<td>17.8-18</td>
<td>4.1-16-5.43</td>
<td>.32</td>
<td>.01-1.0</td>
<td>.09-36</td>
<td>.06-3.99</td>
<td>.5-14</td>
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<tr>
<td>Calcium Ca</td>
<td>210-455</td>
<td>460-500</td>
<td>90-100</td>
<td>13-60</td>
<td>1.2-180</td>
<td>.6-17</td>
<td>1-5</td>
<td>3.0-36.6</td>
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<tr>
<td>Chloride Cl</td>
<td>1300-1343</td>
<td>2200-2232</td>
<td>1170-1300</td>
<td>&lt;.2</td>
<td>1.8-170</td>
<td>24-780</td>
<td>5-38</td>
<td>5-360</td>
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<tr>
<td>Copper Cu</td>
<td>.01</td>
<td>.02</td>
<td>.01</td>
<td>&lt;.01</td>
<td>.01- .05</td>
<td>&lt;.01- .02</td>
<td>.01</td>
<td>N-.01</td>
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<tr>
<td>Fluoride F</td>
<td>1.2</td>
<td>2.68-2.7</td>
<td>3-4-4</td>
<td>.23</td>
<td>N-.17</td>
<td>6.5-17</td>
<td>.5-2.8</td>
<td>.7-9.4</td>
</tr>
<tr>
<td>Hydrogen Sulfide H₂S</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Iron Fe</td>
<td>.02</td>
<td>.02-1</td>
<td>.02</td>
<td>&lt;.05</td>
<td>N-.14</td>
<td>N-.12</td>
<td>.0-.05</td>
<td>&lt;.02- .4</td>
</tr>
<tr>
<td>Lead Pb</td>
<td>&lt;.06</td>
<td>&lt;.06</td>
<td>&lt;.06</td>
<td>&lt;.06</td>
<td>&lt;.06</td>
<td>&lt;.06</td>
<td>&lt;.06</td>
<td>N-.06</td>
</tr>
<tr>
<td>Magnesium Mg</td>
<td>1.2-13</td>
<td>.9</td>
<td>1.3</td>
<td>2.8-48</td>
<td>N-.47</td>
<td>N-.23</td>
<td>1.6-5.7</td>
<td>&lt;.05-14.7</td>
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<tr>
<td>Manganese Mn</td>
<td>.02</td>
<td>.05-1</td>
<td>.22</td>
<td>&lt;.05</td>
<td>N-.24</td>
<td>N-.1</td>
<td>&lt;.02- .06</td>
<td>N-.02</td>
</tr>
<tr>
<td>Mercury Hg</td>
<td>&lt;.0001</td>
<td></td>
<td>.0002</td>
<td>.0001- .0008</td>
<td></td>
<td></td>
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<tr>
<td>Nitrate NO₃</td>
<td>&lt;.02</td>
<td>N-.29</td>
<td>N-.25</td>
<td>N-.3</td>
<td>3.8</td>
<td>03-14</td>
<td>2-7.2</td>
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<tr>
<td>Sodium Na</td>
<td>266-690</td>
<td>910-1000</td>
<td>690-720</td>
<td>5.4-136</td>
<td>19-580</td>
<td>230-1040</td>
<td>30-157</td>
<td>148-192</td>
</tr>
<tr>
<td>Sulfate SO₄</td>
<td>168-170</td>
<td>240</td>
<td>96-164</td>
<td>77-205</td>
<td>.6-462</td>
<td>177-367</td>
<td>128-798</td>
<td>3.5-36</td>
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<tr>
<td>Potassium K</td>
<td>15-69</td>
<td>22-28</td>
<td>31-34</td>
<td>10-8-69</td>
<td>1.8-6.9</td>
<td>4.4-16</td>
<td>2.7-5</td>
<td>2.7-9.5</td>
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<tr>
<td>Aluminum Al</td>
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<td></td>
<td>.01</td>
<td>&lt;.01</td>
<td>0.0-3</td>
<td>N-.058</td>
<td>.008-28</td>
<td>N-.034</td>
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<tr>
<td>Bromide Br</td>
<td>33</td>
<td></td>
<td>5</td>
<td>.08</td>
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<td>.5</td>
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*Concentration ranges listed in mg/1 (ppm).
Source: USGS and DOGAMI "Chemical Analysis of thermal Springs and Wells in Oregon" open file report July 1979."
Figure 2. Oregon's Hot Springs and Well Water Chemistry.
FIGURE 2. (Continued)
Antimony, Carbon Dioxide, Sodium and Potassium, Phosphates, Uranium, Calcium Carbonates, Rubidium, Iodine, or Ammonia.

On the basis of water quality standards most of the thermal spring waters would be undesirable to discharge directly into surface waters. Accordingly, disposal of related geothermal waters of similar quality would have to be through ponding with evaporation or reinjection into subsurface strata. Alternatively, surface water transfer and recirculating schemes could be used incorporating down-hole heat exchangers, providing the economics of the situation justifies the development of the geothermal resource. Perhaps appeals could be made for permits to discharge spent direct heat fluid appropriated from one area to subsequently be released into regional streams, if it could be shown that the resultant mix of the waters would meet the acceptable water quality standards, and if energy recovery benefits would be substantial to serve as a justifiable tradeoff.

III.3.3. Ranking of Water Quality and General Environmental Impacts of Geothermal Activities.

Appendix I presents the water quality session record of Oregon's Geothermal Environmental Overview Workshop held March 28-29, 1979 in Portland, Oregon. The primary water quality concerns with geothermal developments for the state were shown in Appendix I, Table I as: hot water disposal to surface waters, surface water degredation by contaminants from the geothermal plant's effluent, erosion and sedimentation impacts associated with construction efforts, land slides and subsidence, groundwater degredation by lowering of phreatic surfaces and subsequent change or regional hot springs' output and resource depletion. These concerns were accordingly ranked jointly by the workshop participants for each of the KGRAs. Subsequent to the workshop a review of the chronological account of geothermal activities and impacts was made (64) for each of the KGRAs.

Information for accurate identification and quantification of possible geothermal activity impacts on water resources and water quality is not available at this stage of development of the geothermal resources in the State of Oregon. However, it is possible to estimate the
probability for occurrence (not severity) of effects. On a high-moderate-
low basis, the probability for possible impacts during various stages of
geothermal exploration, development and operation activities were esti-
mated and accordingly presented in Table II. These rankings were
assembled from reviewing of the Oregon Geothermal Environmental Overview
Workshop's draft Proceedings and available KGRA environmental assessment
reports (see Bibliographic Discussion Section III.4.1.). It should be
noted that this tabulation covers periods from pre-lease exploratory
operations through full field development and operational activities
and that the impacts for the Oregon KGRAs are summarized and ranked for
ecological considerations, air, water, solids and noise pollution con-
cerns.

Water Resources

Large quantities of energy underlie many of Oregon's geothermal
areas; however, to transfer this energy to the surface requires large
flows of water.

Fluid requirements for electrical power generation and direct use
operations for Oregon's potential geothermal developments are listed
in Table I, Section II.1. Assuming an average production per well per
day of 670,000 gallons of fluid and a total of 10 wells required to
supply a 50 megawatt power plant, a total of 6.7 million gal/day or
10.4 cu. ft./second or 294 l/s would be required to support each power
plant. This would result in reduction in streamflow from the area to
the extent that additional groundwater recharge would be induced to
replenish the water pumped. It is believed that most geothermal reservoirs
under economic utilization will be depleted in 25 to 50 years. It
is possible that the geothermal reservoirs in the Cascade areas contain
enough water to maintain production for as long as they are needed or
that they will be recharged by natural means. However areas of the
Southern Basin and Snake River plain may have insufficient waters for
long term geothermal energy production.

It is interesting to note that direct use of Breitenbush's and
Mt. Hood's geothermal waters is being promoted for community and commer-
cial heating with projected transport distances as far as 70 km from
the source fields. These associated water transfers for such direct use
heating are considerable when compared to tributary flows of streams in a watershed. That is, the maximum flow rate of 40,000 l/s (1412.4 cfs) (Table I) nearly matches the Cascade Range's Metolius River's average flow of 1479 cfs, which is almost entirely derived from spring flow. For comparison, the Sandy River near Bull Run has a mean annual average flow of 2,302 cfs, and the annual runoff for the Oregon Closed Basin (Burns, Harney, Hart Mountain, and Malheur Refuge) is 1650 cfs. The volume of these flow transfers was not seriously considered in the Breitenbush EIS (15) or the Oregon Geothermal Environmental Overview Workshop (See Appendix I) review of water quality issues related to the development of geothermal energy of Oregon. However, the Belnap-Foley EIS (88) gave adequate mention of the problem.

If the upper range of direct use fluid requirements (40,000 l/s) is appropriated from the High and Western Cascades for commercial heating in the Willamette Valley, then consideration on the changes of runoff from the groundwater and geothermal resource connection to stream supplies should be given. If pumping of groundwater for geothermal use is found to significantly affect streamflow, there could be some conflict with fisheries needs during periods of exceptionally low streamflow. Better information for analysis of this possible conflict will be obtained during test drilling and production testing. (88)

In the situation regarding the development of the hydrothermal resources of Mt. Hood, the resource has not become fully identified and accordingly the quality of the resource waters might be different from the region's thermal springs. From surface information the depth of the resource might be postulated to be at 1000 feet depth, when after exploration and assessment, it might be developed from 2000 feet. (80) At Mt. Hood, the developers, including NWNG (37) are seeding Columbia River Basalts which should contain waters of satisfactory quality for interbasin transfer, rather than the geothermal resources associated with deep circulation zones found along faults at other sites. If this resource can be established to provide fresh, clean well water then the transfer of direct heating waters to the Portland area would be useful domestic supply. Accordingly the disposal of spent hydrothermal fluids of acceptable quality would provide few problems. If the waters found
at the resource level are not of satisfactory quality for discharge after commercial heating use in the Portland area, then it has been suggested that a surface or water well supply near the geothermal development area be used for the heat exchanger fluids in down hole heat exchangers at Mt. Hood. Subsequently these waters would be transferred to the Portland area and used for industrial heating and then released for domestic use.

**Ground Water**

Pumping of 6.7 million gal/day (294 l/s) from a deep geothermal source would deplete the overall groundwater storage by the volume pumped unless an equal volume was reinjected. Deep sources can be expected to be confined aquifers. The effects of pumping from such aquifers commonly extend over great distances from pumping centers, particularly where the aquifers have relatively low transmissivity values, as would be expected from aquifers in the tuffs and older volcanic rocks. One effect of such development could be the decline in water levels and yields of wells in the affected area, which may extend several miles from the pumping centers. Another possible effect could be the reduction of flow from hot springs in the environs. If these springs are closely associated with the source of geothermal fluid, the flow may decline soon after production of geothermal fluid begins. (88)

Disposal of spent direct use fluids appropriated from a different area may have its advantages if the chemical quality of the receiving waters needs refreshing. On the other hand, central continuous reinjection of 40,000 l/s of poor quality fluids to subterranean aquifers would possible create problems such as ground movements, slides and uplifts of the upper strata, and affect regional aquifers, springs and seeps. Discharge of the geothermal waters directly into surface waters might have a negative impact if the thermal waters have elevated temperatures above those of the regional streams.

Until the High and Western Cascade resources are fully defined and the development options announced there is need to challenge the potential benefits of energy supply and water quality enhancement of the developments with the possible negative impacts. There is continued
<table>
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<th>TABLE V: CHRONOLOGICAL ACCOUNT OF GEOHERMAL ACTIVITIES AND IMPACTS</th>
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<td>X: Milwaukee</td>
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**Note:** The table likely contains detailed activities and their associated impacts, but the text is not fully legible due to the image quality.
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TABLE V. (Continued)
### TABLE V. (Continued)

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need to reflect on the volume of flows being considered for transfer, in event the High and Western Cascades were to be developed for geothermal direct heat use.

III.3.4. Water Quality Baseline Information Available on Oregon's Geothermal Resources

Only limited information was found in the process of evaluating water resource (hydrology and water quality) impacts associated with the progressive developments of recovering available geothermal energy in Oregon.

Table II of Appendix I was put together during the March 28-29, 1979 Oregon Geothermal Overview Workshop water quality session to tabulate: 1) the availability of site specific water baseline information within Oregon's geothermal regions, 2) ongoing or proposed projects which might offer water quality information, 3) the chances of finding adverse impacts for the regions which might limit geothermal developments, 4) suggested projects required to resolve impact concerns, 5) mitigation factors and regulation controls for limiting water impacts, and 6) the expected risks associated with geothermal development in the KGRA.

Several bibliographic searches were made through Oregon State University's Kerr Library computerized information retrieval terminal. Contacts were made with LIRS (Library Information Retrieval System), DOE Technical Information Center at Oak Ridge, Tennessee, and others. In general it can be said that there is limited documentation on Oregon's geothermal water resources; reference to relevant information, which was found for this survey, is given in Tables VI and VII.

Table VI cites reference numbers associated with those of the text's bibliography for specific topics (including: surface water, ground water, thermal waters, water quality standards and regulations, and KGRA environmental assessment reports).

Table VII provides a summary of the various available reports (totalling 68 in number) which were found relevant for relating water resource information needed for this project. The studies are listed according to type: B - Baseline water quality (before any geothermal developments were initiated), M - Monitoring studies (including discharge and well drilling events), I - Impact Studies (e.g., condensate
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effects on biota), R - Resource Studies (e.g., water use studies, etc.) and S - Source Studies (e.g., condensate chemistry cooling tower drift, etc.). The tabulator also includes the location of the regional watershed considered, the responsible publishing agency, the purpose of the study, periods of record, water quality parameters measured and comments.

Such cross referencing of information would be an important extension of the Oregon Geothermal Environmental Workshop's documentation efforts.

The U.S. Geological Survey at 12201 Sunrise Valley Drive, Reston, Virginia initiated or geothermal resources computer file (GEOTHERM) in 1976 (91). The computerized file is an "attribute or properties" file containing basic descriptive and numeric data records which describe and characterize various attributes of regional geothermal resources. Through computer searches one should be able to obtain information on a particular geothermal field or area, associated information on chemical analyses of geothermal effluents and specific information on the well and drill hole including: pressure, temperature, mass flow, volume flow, enthalpy, area, volume, heat, and heat flux. It would be most helpful to gain access to such information directly as geothermal resources are being explored in Oregon but little information is presently available because of the need for maintaining the information as proprietary. Commercial developer's well and drill hole information is maintained confidential by Oregon's Department of Geology and Mineral Industries (DOGAMI) for at least four years before releasing it to other agencies or reporting sources. Accordingly, the USGS GEOTHERM computer file can not be expected to be up to date.

The GEOTHERM information was recently used to create USGS Circular 790 Assessment of Geothermal Resources of the United States - 1978 (53) which was most helpful in preparation of this report. The USGS western region's GEOTHERM file is maintained at Menlo Park by Mr. Jim Swanson (415) 323-8111. Water resource, temperature and quality information on Oregon's hydrothermal systems is currently being reviewed and updated by the USGS offices at Menlo Park.
III.3.5. \textbf{Lack of Information on Geothermal Waters and Recommendations for Water Resource Monitoring Associated with Geothermal Developments}

There is a paucity of information relating the quality of deep (>2000 feet (0.61 km)) geothermal reservoirs in Oregon. The baseline chemical composition of surface hot springs and shallow wells of the KGRA are only indicative of what might be expected on commercial development of the geothermal resource at depth. (89)

Many states require observation wells as a permit requirement to provide baseline information on groundwater quality. Wells are needed for evaluating the geothermal resources and the groundwaters of the state; however even shallow holes are too expensive for the developer to consider unless exploration is to lead assuredly to development of the geothermal resource. It has been related that for a 4000 foot hole in Eastern Oregon a drill stem test would cost $30,000 (1979) and a 5000 foot well might cost $1,000,000. Such expense would be unjustified if the hole were only to be used for observational purposes on groundwater table drawdown, well interference studies, water quality analyses, and so forth when there is no assurance to the industry that the resource can be economically developed.

Industry relates that there is no problem in going from exploration wells to development wells, as long as preliminary information is adequate to make predictions of the resource. The developer obviously seeks to find whether a geothermal reservoir will be economically viable, based on whether there exists: sufficient temperature for its intended use (for electric power production temperatures should be 150. C or greater; for space heating temperatures 50 to 150 C are satisfactory, depending upon the particular use), sufficient volume of geothermal fluid in the reservoir to maintain production for 30 to 50 years or there must be hydrologic conditions that allow recharge of the reservoir, and the reservoir system has a natural means to accumulate fluids (e.g., via an impermeable barrier such as by faulting of geologic strata). Test holes are information producers and the data taken is held proprietary (beyond four years on submitting the information to DOGAMI) until the resource has been assessed and leases and claims filed by the developer. Thus considerable time might elapse and expenses accumulated
by industry before water resource and quality information might be released through public documents concerning possible environmental impacts. Initial flow testing only indicates the rate at which the well can be produced, not the life of the well or the ultimate reservoir capacity, nor if recharge potential exists. To determine if a reservoir has sufficient capacity to fulfill the needs of a major industrial or institutional user could require many years of production and long-term testing and monitoring.

After the exploratory and resource assessment period has passed, then some additional baseline information might ultimately be released regarding the water quality of a geothermal reservoir. Such information would be most beneficial on suggesting the water quality impacts of developing a KGRA but might be somewhat incomplete from the regulatory or environmental agency’s perspective, and thus additional observational wells might be required at the development stage, rather than at the time of exploration of KGRA.

The uncertainty of availability of geothermal water, and of its possible effects on the shallower groundwater in the areas can be resolved if the spent geothermal fluid is returned to the production reservoir. Observation wells might subsequently be needed also to monitor where reinjection fronts pass, once a geothermal field is developed.

As geothermal activities in the state progress, then the forms and amounts of hot water available for electrical power and direct heating use will become more precisely known. Accordingly, the well and production sites will become identified through sales and leases. Site specific baseline surveys of the hydrology and water quality of regional (stream and ground) waters will need to be advanced prior to geothermal field development and operations in order to evaluate and control the possibility of adverse impacts following siting. These studies will need to be concerned with the transient as well as the spatial variations of the geothermal and ground water reservoir variables such as: depth, pressure, temperature, mass flow, volume flow, enthalpy, reservoir area, reservoir volume, heat flux, total stored heat, total recoverable heat, reinjection flows, geohydrologic and geochemical information. Supplying

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transient flow information according to the requirements for reporting to GEOTHERM, and following a systems perspective as offered in (29) on Regulatory Water Qualtiy Monitoring would be helpful. Such information would be needed for numerical modeling of geothermal reservoirs which would be useful in optimizing operations of power or direct heat plants. Details for surface monitoring of geothermal areas with emphasis on subsidence research is given in (95). It is recommended that coordinated studies be initiated now to monitor the effects of development of Oregon's geothermal resources. Runoff from watersheds need to be gaged, stream sedimentation baseline established, ground water levels and quality monitored. This hydrologic and water quality information would serve as proper baselines for evaluating the impacts of geothermal water developments in Oregon.
EFFLUENT AND EMISSION MONITORING

Monitoring as described here is primarily for the purpose of determining the quantity of pollutants discharged to the air, surface water, and ground water. As such, monitoring must include sampling and analysis for contaminants at effluent and emission points. These measurements will be required as a part of permit conditions to ensure that permitted loading limits are in fact met.

Pollutant loading limitations may be based, as discussed earlier, upon effluent and emission standards when such are developed. In the interim, those limitations will be based upon calculations and judgments, by the permitting agency, as to loadings that will allow ambient air and water standards to be met. Also as discussed earlier, ambient standards may control limitations even after the development of effluent and emission standards, where the latter would allow ambient standards to be violated. Thus, ambient monitoring at receptor points will also be required, in most cases, in addition to effluent and emission monitoring.

This document suggests pollutant monitoring locations and frequencies. It does not describe actual sampling and analytical techniques. It recognizes that initial monitoring may be more cumbersome until the industry and a database have been sufficiently developed, and until geothermal specific monitoring methodologies have been developed. EPA's Environmental Monitoring and Support Laboratory-Las Vegas is currently engaged in methodology development.

AIR AND WATER POINT SOURCE MONITORING

Any planned waste liquid discharges or gas emissions resulting from materials used in the geothermal energy conversion process must be monitored by the operator in accordance with permit requirements. For liquid discharges, the required measurements may include volume, selected chemical constituents, suspended solids, temperature, pH, and radioactivity. Gas emission measurements will include volume and concentrations of regulated constituents such as hydrogen sulfide. Radiological analysis may be required. Any or all of the pollutants listed in Sections IV and V may require measurement.

Some planned direct discharges and emissions are likely to be intermittent, such as at wellheads, vents, and bypasses, while others may be continuous, such as at separators, mufflers, scrubbers, gas ejectors, cooling towers, and spent liquid drains. It is anticipated that, on the whole, continuous discharges, where permitted, will greatly exceed intermittent discharges in volume.
Monitoring of wastewater surface discharges and gas emissions should be conducted at each planned discharge site at a frequency commensurate with the character of discharge, e.g. less frequently for discharges of uniform character. Often, liquid effluents and gases will be combined and can be sampled simultaneously.

The frequency, duration, and method of sampling should be such that a calculated average constituent loading ± 50% will encompass the true average loading over any period of time.

In most cases, it is expected that discharges and emissions will be fairly uniform to the extent that they result from fluid consistently withdrawn from the geothermal reservoir. This would suggest that high frequency sampling is probably not demanded. The sampling frequency for continuous discharges might reasonably be monthly, with a sampling duration of 24 hours. For treated effluents and emissions, where treatment may not provide consistently predictable results, the required frequency may be weekly or more often. Planned, intermittent, direct discharges, where the content and volume are not known prior to release, should be sampled whenever they occur, for a duration proportional to that for continuous discharges, perhaps 1/7 to 1/30 of the total discharge time.

All discharge permits will require that monitoring be done by the operator, that records of measurements be maintained for inspection by the regulatory agency, that loading data for all releases be submitted periodically to the regulatory agency and that standard violations be reported. The regulatory agency may sample discharges to confirm operator monitoring results and to determine permit compliance.

AMBIENT AIR MONITORING

An initial ambient air sampling and analysis program should be established by the geothermal operator for all geothermal energy conversion facilities which require emission monitoring. Such a program can be expected to last at least until data accumulation is sufficient to show that ambient air quality standards are not violated or adverse impacts do not occur as a result of the emissions.

Ambient air monitoring should be designed on a case-by-case basis to ensure receptor protection (or to detect standards violations) at the facility's boundary with other private or public property or even within its boundaries if the property is accessible for public use. Monitoring sites should be selected to conform with principal directions of pollutant transport by increased sampling frequencies at those points.

Ambient monitoring sites should be established on the basis of a prior continuous sampling program at all compass octants from the production facilities or the geographic center of the production field. Sites should be at distances from the source(s) sufficient to delineate pollutant dispersion characteristics and to encompass any area where concentrations above ambient may be caused by such source(s). The continuous sampling program should be of sufficient duration to include characteristic weather variations throughout
the year. Sampling should be done within 5 meters (15 feet) of ground level, so that concentrations may be related to terrestrial receptor effects.

Where patterns are developed by the continuous sampling program, the same stations may be used for monitoring, with the sampling frequencies ascertained from an analysis of the concentrations vs. time distributions. The monitoring program might thus lie somewhere between the extremes of continuous sampling at all stations to no sampling at any stations. The latter would not be expected in most cases.

Any ambient air monitoring program will likely be subject to criticism, periodic reevaluation, and redesign to conform to expanded or reduced production or to natural factors not known at the time of program establishment. This may be particularly true for larger and expanding production facilities and/or those with relatively high non-condensible gas fractions in the raw geothermal fluid.

AMBIENT WATER MONITORING

In the past, it has been common to require industries to monitor discharges, but not surface receiving water quality. The bulk of those measurements have been made by regulatory agencies. Permits may require geothermal developers to monitor ambient water quality. Even if ambient monitoring is not required, voluntary monitoring will likely be to their advantage, particularly if discharge loading limitations are based upon water quality standards. Limitations, thus developed, are intended to prevent violations of concentration limits within the receiving waters under all flow conditions.

Monitoring points should be selected to ensure, as a minimum, that the quality of surface water be monitored where it is accessible to the use of others. In many cases, this may be at the downstream point of intersection of the developer's property line and surface drainage. However if the developer's property is leased public land, water quality and thus monitoring stations may be maintained within the leasehold, since all but operationally unsafe areas may still be publicly accessible.

Surface water quality monitoring may be required even if there are no planned surface water discharges. One of the reasons for this is air pollutants from geothermal operations may result in atmospheric "fallout" contamination. Another is that, if surface containment is employed, leakage may occur.

Water quality monitoring should include the same constituents and properties for which effluents are monitored.

The locations, frequency, and duration of surface water ambient monitoring should be determined after consideration of several factors such as:

- size, flow, and flow variability of the receiving water body
- stream mixing characteristics
• volume of the discharge
• chemical and physical characteristics of the discharge and the consistency thereof
• waste water treatment system characteristics
• air emission characteristics
• downstream water uses
• upstream pollutional discharges
• stream ecology

Despite the apparent complexity of the monitoring selection process, the resulting monitoring scheme would be expected to be relatively simple. One extreme might be represented by a uniformly low volume, low salinity discharge into a large flowing stream. Monitoring then might be one grab sample upstream and one downstream taken monthly at points of well-mixed stream flow. The other extreme might be represented by a high volume, high salinity, relatively nonuniform discharge into a low or variably flowing stream already contaminated by upstream users. In this case, much more frequent monitoring might be required at several upstream and downstream stations. Several cross-sectional grab samples might be taken, flows measured, and data composite.

In addition to determining constituent concentrations, effluent loadings may be confirmed.

Frequency of ambient water monitoring should be commensurate with variability in effluent characteristics and stream flow. However, it appears likely that in most cases, monthly sampling might be acceptable, because of the expected uniformity of discharge characteristics.

GROUND WATER MONITORING

Spent fluid is likely to be injected in many, if not most, cases to or below the geothermal reservoir to alleviate reservoir depletion and subsidence. Injection is also likely to be the most environmentally acceptable disposal method for high salinity fluids, if performed properly.

Subsurface injection may be the disposal method of choice, even if spent fluid cannot be feasibly returned to the geothermal reservoir. This is the case in known geopressed areas, where injection would probably be to shallower aquifers with similar chemical characteristics.

Injection in any case will have the potential, as a result of unplanned or accidental system disruption, of contaminating aquifers usable for other purposes, such as drinking water. Such contamination could have the most serious consequences. If such contamination occurs, it may be difficult, if not impossible, to return the aquifer to its original condition. Careful monitoring may be the only way to ensure that significant contamination does not occur with injection.
Because of the serious nature of potential ground water contamination, the Environmental Protection Agency is currently conducting a study to design an adequate ground water monitoring methodology for geothermal operations. Many other studies of geology, hydrology, scaling and corrosion, reservoir dynamics, etc. by other agencies will have direct bearing on injection technology and, in turn, monitoring methodology. Until monitoring methodologies are fully developed, interim requirements will necessarily be imposed, based upon state-of-the-art injection technologies.

The ground water chemical characteristics of all aquifers overlying the geothermal reservoir should be monitored. The monitored constituents should include all those that would be measured if the waste water were surface-discharged, and perhaps others, if chemicals are added to promote injection.

Methods, principally electro-chemical, are being researched to monitor by injection well instrumentation, the location and extent of migration of injected fluids. Until such methods are perfected, monitoring may require sampling from wells into each aquifer. Sampling, by fluid retrieval, of multiple aquifers from one well should not be encouraged because of potential mixing. Sampling wells should surround the geothermal operation, and all should be located within a few hundred yards of reinjection wells. The capability should exist to sample each aquifer at two or more points down-gradient from principal injection wells. Existing water supply wells may be used where determined appropriate.

The frequency of ground water aquifer sampling will depend principally upon the rate of injection and the quality characteristics of the injected fluid vs. those of the aquifer. Higher injection rates of more saline brines would probably demand higher frequency sampling than lower injection rates of "cleaner" fluids. In most cases, however, it is expected that a 30-day sampling frequency will be near the optimum. Various characteristics may demand more frequent sampling.

Simple grab samples should be sufficient for ground water monitoring.

LAND-DISPOSED WASTES

Land-disposed wastes requiring control by isolation are determined by chemical characterization. Monitoring of storage, treatment, and disposal sites under control of the geothermal operator will be required under state and Federal regulations to determine whether any constituents escape by leaching or percolation to surface and/or ground water. Monitoring requirements will be similar to those described above for ambient surface waters and for ground water. The most significant difference is that probably only the uppermost ground water aquifer may need to be monitored.

NOISE MONITORING

Monitoring of noise is accomplished by noise measurements at the property line or the boundary with other use areas, at points nearest the noise source. It is probable that a set monitoring schedule need not be established. Rather, measurements should be made upon a change in type or mode of operation.
Measurement methodologies have been developed for many specific noise sources and can be integrated to measure overall noise at the boundary site.

A noise monitoring program should be established by the operator to assure himself that violations of local, State and Federal regulations do not occur. Because noise cannot be ignored, it may be monitored frequently by regulatory agencies.

BASELINE AIR AND WATER MONITORING

Prior to geothermal energy production, the existing state and natural variations of air and water quality should be determined in detail by the developer in accord with the needs of regulating agencies. Baseline descriptions are in fact part of the requirement for environmental impact reports and analyses, which in turn are required for all projects on Federal lands and most on state lands. Baseline assessment may require long-term, detailed measurements to establish the basis for differentiating natural and operation-caused changes.

The U. S. Department of Interior's Geothermal Environmental Advisory Panel (GEAP) has prepared a document entitled "Guidelines for Acquiring Environmental Baseline Data on Federal Geothermal Leases." The document describes procedures for gathering chemical, physical and biological data for a one-year period prior to submission of a plan for production, as required by the Geothermal Steam Act of 1970. The data are submitted to the U. S. Geological Survey Area Geothermal Supervisor, who may alter the requirements according to specific needs.

The Department of Energy, Division of Geothermal Energy has developed general requirements for describing baseline data acquisition and evaluation methodology in environmental reports on DOE-sponsored geothermal activities. The U. S. Fish and Wildlife Service has prepared a handbook for gathering and assessing biological data, and for mitigating impacts. Each of the sources of information should be used by the developer in setting up a baseline monitoring program.

Baseline water and air quality monitoring should be viewed as setting the stage for later ambient monitoring during full-scale operations. Thus, it should include measurements of the same constituents that will be monitored later during construction and operation of the energy conversion facility. With this view in mind, it would be expected that the operational monitoring would utilize baseline stations established earlier. This of course requires coordination of planning throughout development.
IV. RECOMMENDATIONS AND CLOSURE

It is recommended that geothermal resource and water quality information be made available to the public as early as possible during the exploratory and development stages of the geothermal activity by industry. As geothermal projects become advanced, it will be recognized there will be but a limited amount of money available for basic environmental research, and that it should be spent where it will do the most to alleviate severe impacts to water quality. The research areas felt to be significant are: determining the hydrothermal reservoir characteristics and accurately projecting the potential water needs of the utility developing the site, ground water contamination, resource depletion, erosion, sedimentation and siltation, effects of transferring hydrothermal waters to other watersheds, and mass soil movements associated with subsidence.

Improved estimates of the magnitude of the resource, the type of heat-energy conversion method, and the size of industry to be served is urgently needed to provide an understanding of the potential water use of the facility. Once these sizes are narrowed, and a specific site selected, then more accurate estimates of impacts can be made. Careful planning to avoid environmental problems, coupled with appropriate mitigation measures for limiting the severity of the impact of problems which cannot be avoided can bring impacts to acceptable levels and at reasonable cost.

There is need for a well planned baseline program for providing water quality measurements in the environs of Oregon's hydrothermal recovery and disposal areas. To conserve and to achieve the greatest beneficial use of Oregon's geothermal resources and to protect the groundwater from damage due to excessive reservoir drawdown or improper disposal of the spent geothermal fluids, a program of reservoir management should be established at the time of initial reservoir development. Groundwater flow tracing and tagging of the geothermal reservoir's water will be important to resolve or allay fears of cross-connections, contamination and depletion of surface and groundwaters.

Records of transient operations of geothermal wells can be used for
determining the rate at which the geothermal well can be produced, not the life or the reservoir capacity, nor if recharge potential exists. Many years of production and long-term testing might be required to determine whether a reservoir has sufficient capacity to supply the needs of a large industrial user. Accordingly, monitoring and engineering studies need to be initiated early in the siting and development program. Monitoring of geothermal water chemistry as the resource is operated will be important if consideration of transfer of the waters to other areas is realistic. In areas where the geothermal fluids are nearly potable or of irrigation quality, it may be possible to obtain permits for surface discharge or cascaded uses after some of the heat is extracted.

Many of Oregon's geothermal sites have high erosion potential and significant sedimentation problems might result from field activities associated with bringing a plant on to line. Although there are concerns with sediment runoff into adjacent streams associated with clear cutting and road construction for logging, Oregonians seemingly accept the trade-offs of the impacts with industrial "progress". It is questioned that development of geothermal resources of Oregon's KGRA's would provide worse impacts than the logging industry. It is recommended that areas of highly erodible soils of the specific sites be carefully mapped and that sediment loading of the streams be monitored to provide baseline information on possible impacts following operation of the geothermal development.

The primary emphasis of this report has been on the environmental effects that could result from geothermal resource development in the State of Oregon. The environmental effects considered were potential surface water pollution and degradation, changes in the groundwater regime, both chemical and hydraulic, subsidence and induced seismic events, which may in turn affect the ecology and socioeconomic conditions of a site.

The limits to development for specific Oregon KGRA's tied to water resource interests include:

Alvord (300 MWe) water may not be available in sufficient quantities for development and cooling water
may have to be transported to site, economics of transmission distances need to be seriously considered. Area disturbance and erosional effects are of high concern regarding geothermal development, reinjected if used would be (med-high) concern.

Vale (770 MWe) most water is already committed for irrigation, groundwater degradation of (medium) concern.

Mt. Hood recreational and wilderness area, accordingly would be closed to power development; transfer of waters from region to other watersheds for utilization disposal would need to be resolved. High concern for surface and ground water, hot springs and resource degradation, reinjection if used would also be a prime concern.

Newberry Caldera closed to development

Burns groundwater degradation potential of (medium to high) concern

Klamath principal concern is heat degradation and water level degradation of the resource as currently being used; concern is for hot springs and resource degradation and the attendant effects of downhole heat exchangers and reinjection

Western Cascades principal concerns regarding hot springs and resource degradation; reinjection effects; area disturbances, erosion and landslides; and surface and ground water degradation

Breitenbush near Mt. Jefferson Wilderness and Breitenbush River; accordingly closed to power and industrial uses; transfer of waters to other watersheds for utilization and disposal need to be resolved

LaGrande hot springs and resource degradation of prime concern if geothermal developments proceed at large scale; groundwater degradation of (medium-high) concern

Lakeview water quality, reinjection and contamination of resource

Crump little known about Crump Geyser hydrocycle

Ore-Ida water availability and reinjection and contamination of groundwaters of concern.

Environmental impact data relevant to developments of the geothermal resources of the above mentioned areas (with the exception of Klamath Falls) are sparse. It may be related that as the data base is improved then increased benefits on utilization of Oregon's geothermal resources can be achieved through a program of reservoir management. With an
improved data base, careful planning can avoid some of the above mentioned concerns and provide appropriate mitigation measures to reduce the severity of the adverse effects to achieve acceptable benefit to cost limits.
This is to thank the participants of the water quality session of the Oregon Geothermal Environmental Workshop, held in Portland, Oregon during March, 1979, for their ideas, time and efforts in contributing to the workshop. Comments and suggestions of the draft reporting of the session's proceedings by participants were most helpful in revising the final reporting of the workshop (Appendix I) and for stimulating the bulk of this volume. Special acknowledgements are due numerous persons in industry, state government, federal agencies, and universities for their endeavors in setting activities and records straight, and for their contributions of reports and materials for review and inclusion in this document. Some of these individuals are identified in the bibliography under "person communication"; others deserve more credit but for reason of space limitations they must be collectively acknowledged just with "thanks".

Funding for this study was through the Oregon Graduate Center's contract with the Lawrence Livermore Laboratory for conduct of the Oregon Geothermal Environmental Workshop and through Oregon State University's Water Resources Research Institute's (WRRI) contract with the Pacific Northwest River Basins Commission for an "Assessment of Energy Technologies". Dr. John Cooper, of the Oregon Graduate Center, is thanked for his help on this project and for his patience in awaiting completion of our reporting efforts. Dr. Peter C. Klingeman, of OSU's WRRI, is similarly acknowledged for his efforts on the PNRBC Project on "Assessment of Energy Technologies".

Maureen Sergent is due much of the credit for assembling the many tables and related contributions to this report. Mrs. Debbie Noble provided information regarding economic aspects of the state's geothermal resources and served as a source contact with several state agencies. Brenda Broadsword of OSU's WRRI is thanked for her typing.
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VII.2.1. Geothermal Energy Data Base, Oak Ridge, Tennessee

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<td>AICHE STMP SER NO 136, PP 782-787, 1974 (V 70) (&quot;WATER--1973&quot;)</td>
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<td>TI</td>
<td>WASTE DISPOSAL IN SALINE AQUIFERS AFFECTED BY GEOTHERMAL HEATING</td>
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<td>HENRY H R; KOHOUT F A</td>
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<td>AAPG &amp; USGS UNDERGROUND WASTE MANAGE &amp; ENVIRON IMPLICATIONS SYMP F A</td>
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<td>HYDROLOGICAL PROBLEMS ASSOCIATED WITH DEVELOPING GEOTHERMAL ENERGY SYSTEMS</td>
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<td>ALFUEL; ENERGY SOURCES; ANOMALY; AQUIFER; AQUIFER RECHARGE; CHANGE; DEVELOPMENT; DISPOSAL; ECONOMIC FACTOR; &quot;ENERGY SOURCE&quot;; ENGLISH; &quot;FLUID FLOW&quot;; GEOLOGIC STRUCTURE; &quot;GEOLOGY&quot;; GEOTHERMAL ANOMALY; &quot;GEOTHERMAL ENERGY&quot;; GROUND WATER; &quot;HYDROLOGY&quot;; &quot;HYDROTHERMAL FLUID&quot;; LEGAL CONSIDERATION; NATURAL STEAM; NORTH AMERICA; &quot;POWER&quot;; RESERVOIR; 'RESERVOIR FLUID FLOW; STEAM; STEAM WELL; THERMAL ANOMALY; UNITED STATES; WASTE MATERIAL; WASTE WATER; WATER; WASTE DISPOSAL; WATER VAPOR; WELL</td>
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AN - 25698
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AU - ROBINSON J L
SO - NEW ZEAL J SCI V 20, NO 1, PP 27-29, MARCH 1977 (AO)
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AU - SCHEY M L
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AU - AILEGRE C J; STETTLER A
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AU - LEE T C
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FT - 1965
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TI - LAND DISPOSAL OF WASTEWATER WITH SPRAY IRRIGATION BY SMALL MICHIGAN MUNICIPALITIES: AGRICULTURAL, INSTITUTIONAL, AND FINANCIAL CHARACTERISTICS
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TI - SULFUR EMISSION CONTROL FOR GEOTHERMAL POWER PLANTS
AU - WILKER, JOHN A.; AXMANN, ROBERT C.
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TI - ABSTRACTS OF PAPERS
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TI - DISTILLATION I
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AN - 73-4314
TI - USGS REQUESTS MORE THAN $156 MILLION IN 1974 BUDGET
SO - USGS NEWS RELEASE JAN 73 (4)
TI - THE ESSENTIAL ROLE OF ISOTOPES IN STUDIES OF WATER RESOURCES
SO - IAEA B, FEB 77, V19, N1, P59 (12)
AV - MICROPICHE AV, FROM EIC
DT - FEATURE ARTICLE
CC - RENEWABLE RESOURCES-WATER
IT - *RADIOISOTOPIC TRACERS; *SURFACE WATERS; *GROUNDWATER; HYDROLOGY; FLOW MEASUREMENT; AQUIFERS; LATIN AMERICA; AFRICA; *WATER SAMPLING; U N INTL ATOM ENERGY AGENCY; LAKES; GEOTHERMAL ENERGY EXPLORATION
AB - ISOTOPES TECHNIQUES HAVE COME TO PLAY A MAJOR ROLE QUALITATIVELY AND QUANTITATIVELY ASSESSING WATER RESOURCES. IN STUDIES OF SURFACE WATERS, ISOTOPES ARE USED TO MEASURE RUNOFF FROM RAIN AND SNOW. FLOW RATES OF STREAMS, LEAKS FROM LAKES AND RESERVOIRS, AND DYNAMICS OF WATER BODIES. STUDIES OF GROUNDWATER RESOURCES ARE VIRTUALLY UNTHINKABLE WITHOUT ISOTOPE TECHNIQUES. IAEA PROVIDES NATIONS WITH ASSISTANCE IN HYDROLOGICAL APPLICATIONS. FIELD STUDIES IN LATIN AMERICA, AFRICA, AND IN SEVERAL NATIONS IN OTHER REGIONS ARE DESCRIBED. (7 PHOTOS)

TI - DRAFT ENVIRONMENTAL IMPACT REPORT: GEOTHERMAL PROSPECTING PERMITS W 9369, W 9529, W 9539, W 9592
SO - CALIFORNIA STATE LANDS COMMISSION REPORT EIR-211, UNDATED (37)
AV - MICROPICHE AV, FROM EIC
DT - SPECIAL REPORT
CC - ENERGY
IT - "ENVIRONMENTAL IMPACT STATEMENT"; "GEOTHERMAL LEASING"; "CALIFORNIA"; "GEOTHERMAL ENERGY EXPLORATION"; GEOTHERMAL DRILLING; DESERT PLANTS; DESERT WILDLIFE; GROUNDWATER; WATER ANALYSIS; HYDROLOGY; GEOLOGY; NOISE LEVELS; COUNTIES; SEISMOLOGY

AN - 86-8673C
TI - THE USE OF ENVIRONMENTAL ISOPTOE TECHNIQUES TOGETHER WITH CONVENTIONAL METHODS IN REGIONAL GROUNDWATER STUDIES
AU - SIGSBJARNARSON, GUTTORMUR; THEODORSION, PALL; APNASON, BRAGI
CS - UNIVERSITY OF ICELAND
SO - HYDROLOGY, 1976, V7, N2, PS1 (14)
DT - TECHNICAL REPORT
CC - RENEWABLE RESOURCES-WATER
IT - "GROUNDWATER; "DEUTERIUM; "TRITIUM; DRAINAGE; GEOTHERMAL RESOURCES; RADIOISOTOPIC TRACERS; LAKES; ICELAND; VOLCANOES; HYDROELECTRIC POWER; GEOLOGY; HYDROLOGY; RIVER BASINS
AB - REGIONAL HYDROLOGICAL INVESTIGATIONS AND GEOLOGICAL EXPLORATION OF THE SUTHERAN AREA AND GEOLOGICAL EXPLORATION OF THE NORTHERN PART OF THE VOLCANIC PLATEAU HAVE BEEN CARRIED OUT. ENVIRONMENTAL ISOTOPES (DEUTERIUM AND TRITIUM) PROVED DECISIVE IN FINDING THE GROUNDWATER FLOW PATTERN, IN SEPARATING THE DIFFERENT GROUNDWATER SYSTEMS, AND IN EXPLAINING LOCAL DEVIATIONS AS SARIES AND PERCHED AQUIFERS. THE REGIONAL GROUNDWATER FLOW DEPENDS (AT LEAST SLIGHTLY) ON THE TOPOGRAPHY, BUT HIGHLY ON THE GEOLOGICAL CONDITIONS, AS IT IS LOCATED UNDER MOUNTAIN RANGES AND UNDER THE TUNGNAFJALLA RIVER. (2 GRAPHS, 4 MAPS, 15 REFERENCES)
AN - 74-00403
TI - GASTHERMAL ENERGY-RESOURCE S TECHNOLOG
SO - REPORT HSE COMM SCIENCE ASTRONAUTICS SEP13, 73 (22)
AV - MICROFICHE AV. FROM EIC
CC - ENERGY
IT - GASTHERMAL ENERGY; HYDROLOGY; U S DEPT INTERIOR

AN - 73-11067
TI - DRY GEOTHERMAL WELLS, PROMISING EXPERIMENTAL RESULTS
SO - SCIENCE OCT 5, 73 V182 N4127 P43 (2)
CC - ENERGY
IT - GASTHERMAL ENERGY; ECONOMIC ENV; MONTANA; PERMEABILITY; HYDROLOGY

AN - 72-02148
TI - CHEMISTRY OF BROADLANDS GEOTHERMAL AREA NEW ZEALAND
AU - FINLAYSON, JAMES B.; MAHON, WILLIAM A.J.
SO - AMER JOURN SCIENCE JAN 71 V272 N1 P8 (21)
AV - MICROFICHE AV. FROM EIC
CC - ENERGY
IT - GASTHERMAL ENERGY; HYDROLOGY; LI'EOLOGY; NEW ZEALAND

AN - 75-02752
TI - GEOLOGY OF GEOTHERMAL TEST HOLE GT-2 FENTON HILL SITE, JULY 1974
AU - PURTYMUN, W.D.; WEST, F.G.; PETTITT, R.A.
CS - LOS ALAMOS SCIENTIFIC LAB
SO - NTIS REPORT LA-5760-MS, NOV 74 (17)
AV - MICROFICHE AV. FROM EIC
DT - SPECIAL REPORT
CC - ENERGY
IT - GASTHERMAL ENERGY; GEOLOGY; NEW MEXICO

AN - 72-03091
TI - ENVIRONMENTAL EFFECTS OF GEOTHERMAL WASTE WATER ON THE NEAR-BY RIVER SYSTEM
AU - NAKAHARA, H.; YANAGURA, M.; MURAKAMI, Y.
OS - TOYOTA METROPOLITAN UNIV, JAPAN
SO - JAPAN, R. 15145, N1, 21 (10)
DT - RESEARCH REPORT
CC - WATER POLLUTION
IT - RIVERS; WATER POLLUTION EFFECTS; GASTHERMAL POWER PLANTS; WASTEWATER OUTFALLS; JAPAN; GASTHERMAL ENERGY-HOT WATER; WATER ANALYSIS; TRACE ELEMENTS; ACTIVATION ANALYSIS, NEUTRON; SEDIMENT; GEOTHERMAL WELLS; GASTHERMAL ENERGY-STEAM
AB - GEOTHERMAL POWER FACILITIES IN SOUTHERN JAPAN HAVE BEEN DISCHARGING GEOTHERMAL WASTEWATER INTO A NEARBY RIVER SYSTEM. ORDINARY CHEMICAL ANALYSIS AND NEUTRON ACTIVATION ANALYSIS OF THE RIVER'S CHEMICAL CHARACTERISTICS INDICATE THAT SERIOUS EFFECTS (SALINITY AND TRACE METAL PRESENCE) OF PAST HIGH DISCHARGE RATES CAN STILL BE DETECTED. PARTICULARLY IN RIVER SEDIMENTS. CHEMICAL POLLUTION HAS BEEN GREATLY ALLEVIATED SINCE REINJECTION PROCEDURES WERE BEGUN; THE CURRENT DISCHARGE RATE OF 90 TON/HR OF GEOTHERMAL HOT WATER DOES NOT SEEM TO CAUSE SERIOUS PROBLEMS. ARSENIC AND CESIUM ARE THE BEST CHEMICAL SPECIES TO TRACE THE LONG-TERM EFFECTS OF GEOTHERMAL WASTEWATER DISCHARGE USING NEUTRON ACTIVATION ANALYSIS. (3 GRAPHS, 1 M.P, 5 REFERENCES, 7 TABLES)
A9 - 78-27732
TI - REMOVING H2S FROM GEOTHERMAL STEAM
AU - COURTY, G.E.; VORUM, M.
CS - COURTY AND ASSOC, COLO
SO - CHEMICAL ENGINEERING PROGRESS, SEP 77, V73, N9, P93 ($)
AV - MICROFICHE AV. FROM ZIC
DT - TECHNICAL FEATURE
CC - AIR POLLUTION
IT - *HYDROGEN SULFIDE; *GEOTHERMAL STEAM; WASTEWATER DISPOSAL
CC - CHEMICALS; ENV-AIR; NITROGEN COMPOUNDS; PH HYDROGEN ION CONCENTRATION
COOLING TOWERS; SCRUBBERS; WET SULFUR COMPOUNDS
AB - HYDROGEN SULFIDE GAS IS A MAJOR SOURCE OF AIR POLLUTION RELATED TO THE
UTILIZATION OF GEOTHERMAL STEAM TO PRODUCE ELECTRICITY. IN THE
PROCESS DESCRIBED, THE H2S IS ABSORBED IN AN AQUEOUS SOLUTION OF COPPER SALTS BY
PRECIPITATING COPPER SULFIDES. SINCE GEOTHERMAL INSTALLATIONS ARE PLACED
IN REMOTE LOCATIONS, DISPOSAL OF WASTE WATER CAN BE A SERIOUS PROBLEM. IT
MAY BE NECESSARY TO DISPENSE OF COOLING TOWER FLOWDOWN BY INJECTION INTO
DEEP WELLS TO A COOL UNDERGROUND FORMATION. THE H2S REMOVAL TECHNIQUE IS
DESIGNED TO USE PART OF THE COOLING TOWER FLOWDOWN STREAM AS MAKEUP
WATER, SO AS TO DISSOLVE THE AMMONIUM SALTS FOR DISPOSAL. A SINGLE
GENERATING PLANT WITH A CAPACITY OF 52MW IS ANALYZED. H2S ABSORPTION,
REGENERATION, NEUTRALIZATION OF ACIDS PRODUCED, AND DESIGN CRITERIA ARE
EXAMINED. THE ECONOMICS OF THE REMOVAL TECHNIQUE DESCRIBED APPEAR
COMPARABLE TO THE RELATIVE COST OF FLUE GAS DESULFURIZATION SYSTEMS FOR
FOSSIL FUEL-FIRED BOILERS. (1 DIAGRAM, 3 GRAPHS, 6 REFERENCES; 4 TABLES)

A9 - 79-01581
TI - ENVIRONMENTAL ASSESSMENT OF GEOPRESSED WATERS AND THEIR PROJECTED USES
AU - WILSON, J.S.; HAMILTON, J.R.; MANNING, J.A.; MUEHLBERG, F.E.
CS - DOW CHEMICAL CO, TEX
SO - NTIS REPORT PB-268 299, APR 77 (99)
AV - MICROFICHE AV. FROM ZIC
DT - SPECIAL REPORT
CC - ENERGY
IT - *GEOTHERMAL ENERGY-GEOPRINE; *ENV CONSTRAINTS-GEOTHERMAL ENERGY;
SALTWATER INTRUSION; WASTEWATER DISPOSAL; LOUISIANA; TEXAS; LAND
SUBSIDENCE
AB - A POSSIBLE SOURCE OF ALTERNATIVE ENERGY FOR THE U.S. IS BELIEVED TO EXIST
IN THE DEEP GEOPRESSED RESERVOIRS FOUND IN THE TEXAS AND LOUISIANA JULF
COAST SEDIMENTARY BASINS. THE POTENTIAL USES OF THE GEOPRESSED
GEOTHERMAL RESOURCE AND THE ENVIRONMENTAL ASPECTS OF THOSE USES ARE
EXAMINED. ECONOMICS OF POWER PRODUCTION ARE ESTIMATED AS AN AID TO
ASSESSMENT OF PRIORITY R&D IN THE AREA. PRINCIPAL ENVIRONMENTAL IMPACTS
OF ANY OF THE PROPOSED USES WILL RESULT FROM THE WASTE FLUID STREAMS AND
FROM POSSIBLE SUBSIDENCE OF THE WELL FIELD. DISPOSAL OF THIS LARGE VOLUME
OF SALINE FLUID WILL REQUIRE REINJECTION, CATALYzing TO A SALINE WATER
BODY, OR SOME MORE IMAGINATIVE METHOD. THE AREA IS ONE OF NATURAL
SUBSIDENCE THAT MAY BE ACCELERATED BY DEEP FLUID WITHDRAWAL.

A9 - 79-09169
TI - THE EFFECT OF THE BROADLANDS GEOTHERMAL POWER SCHEME ON THE WAIKATO RIVER
AU - WILLIS, D.J.
CS - NEW ZEALAND ELECTRICITY DEPT
SO - GEOTHERMAL ENERGY, JUN 78, V6, N6, P25 (13)
AV - MICROFICHE AV. FROM ZIC
DT - TECHNICAL REPORT
CC - WATER POLLUTION
IT - *WATERS; *NEW ZEALAND; *GEOTHERMAL POWER PLANTS; *WATER POLLUTION
EFFECTS; WASTEWATER ANALYSIS; WASTEWATER DISPOSAL; CHEMICAL TREATMENT;
GEOTHERMAL PLANTS-WATER; GEOTHERMAL PLANTS-TEMPERATURE; BORON; ARSENIC; AMMONIUM; COOLING
TOWERS
AB - THE BROADLANDS GEOTHERMAL POWER SCHEME DEVELOPED BY THE NEW ZEALAND
ELECTRICITY DEPT. MAY RELEASE GEOTHERMAL WASTES IN THE FORM OF AMMONIA,
ARSENIC, BORON, AND OTHER CHEMICALS, AND HEAT. RELEASE OF WASTES INTO THE
WAIKATO RIVER WOULD RESULT IN UNACCEPTABLE RIVER TEMPERATURE INCREASES, NOXIOUS SULFURIZATION OF THE HYDRO LAKES IN THE RIVER SYSTEM,
AND SIGNIFICANT DECREASES IN WATER QUALITY OF THE RIVER. DISPOSAL
ALTERNATIVES THAT WOULD VIRTUALLY ELIMINATE HEATING AND POLLUTION OF
RIVER WATER INCLUDE COOLING TOWERS FOR CONDENSER COOLING, AND DISPOSAL OF
THERMALLY HOT BORE WATER BY INJECTION. THESE PREVENTIVE MEASURES ARE CERTAIN TO
BE ADOPTED IN THE POWER SCHEME. (1 DIAGRAM, 1 MAP, 6 REFERENCES, 1 TABLE)
AN - 77-06171
TI - GEOTHERMAL RESOURCES OF THE TEXAS GULF COAST: ENVIRONMENTAL CONCERNS ARISING FROM THE PRODUCTION AND DISPOSAL OF GEOTHERMAL WATERS
AU - GUPTAVSON, THOMAS C.; KREITLER, CHARLES V.
SO - UNIV OF TEXAS BUREAU OF ECONOMIC GEOLOGY REPORT 76-7, 1976 (39)
AV - SPECIAL REPORT
CC - WATER POLLUTION
IT - TEXAS; GEOTHERMAL ENERGY; BRINE; WASTEWATER DISPOSAL; HEAT POLLUTION; SURFACE WATERS; ENVIRONMENTAL PROTECTION; BORON; SALINITY; RESERVOIRS; URBAN-RURAL COMPARISONS; NATURAL DISASTERS
AP - DISPOSAL AND TEMPORARY SURFACE STORAGE OF SPENT GEOTHERMAL FLUIDS AND SURFACE SUBLIMATION AND FAULTING ARE THE MAJOR ENVIRONMENTAL PROBLEMS THAT COULD ARISE FROM GEOPRESSURIZED GEOTHERMAL WATER PRODUCTION. GEPRESSURIZED GEOTHERMAL FLUIDS ARE MODERATELY TO HIGHLY SALINE AND MAY CONTAIN A SIGNIFICANT AMOUNT OF BORON. DEPOSIT OF HOT SALINE GEOTHERMAL WATER IN SUBSURFACE SALINE AQUIFERS WILL PRESENT THE LEAST ENVIRONMENTALLY HAZARDOUS MEANS OF DISPOSAL. IT IS NOT KNOWN, HOWEVER, WHETHER THE DISPOSAL OF AS MUCH AS 54,000 CU M/DAY OF SPENT FLUIDS INTO SALINE AQUIFERS AT THE PRODUCTION SITE IS TECHNICALLY OR ECONOMICALLY FEASIBLE. OVERLAND FLOW OR TEMPORARY SURFACE STORAGE OF GEOTHERMAL FLUIDS MAY CAUSE NEGATIVE ENVIRONMENTAL IMPACTS AS THE RESULT OF PRODUCTION OF LARGE VOLUMES OF GEOTHERMAL FLUID. RESERVOIR PRESSURE DECLINES MAY CAUSE COMPACTION OF SEDIMENTS WITHIN AND ADJACENT TO THE RESERVOIR. THE AMOUNT OF COMPACTION DEPENDS ON PRESSURE DECLINE, RESERVOIR THICKNESS, AND RESERVOIR COMPRESSIBILITY. THE MAGNITUDE OF ENVIRONMENTAL IMPACT OF SUBLIMATION AND FAULT ACTIVATION VARY WITH CURRENT LAND USE. THE GREATEST IMPACT WOULD OCCUR IN URBAN AREAS, WHEREAS RELATIVELY MINOR IMPACTS WOULD OCCUR IN RURAL, UNDEVELOPED AGRICULTURAL AREAS. GEOTHERMAL RESOURCE PRODUCTION FACILITIES ON THE GULF COAST OF TEXAS COULD BE SUBJECT TO A SERIES OF NATURAL HAZARDS: HURRICANE- OR STORM-INDUCED FLOODING WINDS FROM TROPICAL STORMS, COASTAL EROSION, OR EXPANSIVE SOILS.
(6 DIAGRAMS, 2 GRAPHS, 17 MAPS, 60 REFERENCES, 7 TABLES)

AN - 77-05393
TI - THE ROAR FROM AN EMERGING RESOURCE
AU - ARMSTRONG, ELLIS L.
SO - RECLAMATION ERA AUG 1971 V57 N2 P1 (7)
AV - MICROFICHE AV. FROM EIC
CC - ENERGY
IT - ELECTRIC POWER; ENERGY PLANNING; GEOTHERMAL ENERGY; SIC 491;
ELECTRIC CO; WASTEWATER DISPOSAL

AN - 79-02691
TI - ENVIRONMENTAL EFFECTS OF GEOTHERMAL WASTE WATER ON THE NEAR-BY RIVER SYSTEM
AU - NAKAHARA, H.; TANAKURA, M.; MURAKAMI, Y.
SO - TOKYO METROPOLITAN UNIV, JAPAN
SO - J RADIOANALYTICAL CHEMISTRY, 1979, V45, N1, P25 (11)

AN - 76-02509
TI - PRACTICAL GEOTHERMAL PUMPING STATION
SO - COMBUSTION, MAY 75, V46, N11, P24 (4)
AV - MICROFICHE AV. FROM EIC
CC - ENERGY
IT - GEOTHERMAL ENERGY; HOT WATER; GEOTHERMAL WELLS
AB - HOT WATER GEOTHERMAL DEPOSITS ARE ONE OF THE WORLD'S MAJOR UNTAPPED ENERGY SOURCES. THE EXTREMELY CORROSIVE DEPOSITS ARE LOCATED AT DEPTHS OF FROM 1000-2000 FT, AND UNTIL NOW HAVE BEEN CONSIDERED UNEXPLOITABLE DUE TO A LACK OF SUITABLE TECHNOLOGY. HOWEVER, THE SPERRY RAND CORP. HAS INVENTED A UNIQUE DOWNWELL PUMPING SYSTEM TO TAP THESE RESOURCES AND HAS RECEIVED A $300,000 NSF GRANT TO HELP BUILD AND INSTALL THE SYSTEM AT A GEOTHERMAL SITE BY MID-1975. (6 DIAGRAMS)
<p>| AN | 79-32547 | TI | EAST MESA GEOTHERMAL TEST SITE | AU | FERNEILIS, WAYNE A.; FULCHER, MARTIN K. | CS | USBR, NV | SO | J ENY ENGINEERING DIV-ASC; FEE 79; V125, N1, P13 (22) |
| AN | 79-22699 | TI | EFFECTS OF GEOTHERMAL ENERGY DEVELOPMENT ON FISH AND WILDLIFE | AU | SUTER, GLENN W. | OS | ORNL | SO | US FISH &amp; WILDLIFE SERVICE REPORT FWS/OBS-76/206, OCT 76 (22) |
| AN | 79-22121 | TI | BALANCING ENERGY AND THE ENVIRONMENT: THE CASE OF GEOTHERMAL DEVELOPMENT | AU | ELLICKSON, PHYLLIS L.; BREWER, SAUNDRA; KNIGHT, KATHLEEN | CS | RAND REPORT 2274-DOE, JUN 78 (152) |
| AN | 77-25949 | TI | THE PRODUCTION OF WATER FROM GEOTHERMAL RESERVOIRS: SOME ECONOMIC CONSIDERATIONS | AU | VAUX, H.J. | OS | UNIV OF CALIFORNIA, RIVERSIDE | SO | WATER RESOURCES 3, JUN 77, V13, N3, P659 (12) |
| AN | 79-22308 | TI | ENERGY FROM THE WEST: A PROGRESS REPORT OF A TECHNOLOGY ASSESSMENT OF WESTERN ENERGY RESOURCE DEVELOPMENT: VOL. 1 SUMMARY | AU | HART, JOHN; JASBY, ALAN | OS | US LAWRENCE BERKELEY LAB, CALIF | SO | ANNUAL REVIEW OF ENERGY, 1975, V3, P101 (46) |
| AN | 79-22892 | TI | ENERGY TECHNOLOGIES AND NATURAL ENVIRONMENTS: THE SEARCH FOR COMPATIBILITY | AU | - | OS | | SO | |
| AN | 79-32235 | TI | ENVIRONMENTAL ASSESSMENT OF GEOPRESERVED WATERS AND THEIR PROJECTED USES | AU | WILSON, J.S.; HAMILTON, J.R.; HANKS, J.A.; MUEHLBERG, P.E. | OS | DOV CHEMICAL CO, TX | SO | NTIS REPORT PB-268 289, APR 77 (93) |
| AN | 79-35565 | TI | ENERGY/ENVIRONMENT TECHNOLOGY AREAS TO BE DEVELOPED | AU | REZNIK, STEVEN R. | OS | EPA | SO | PRESENTED AT IES 24TH ANNUAL TECHNICAL MEETING, FORT WORTH, APR 18-20, 78, P1 (7) |</p>
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<td>SCIENCE, MAR 7, 75, V187, N4179, P795 (9)</td>
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<td>GEOTHERMAL ASPECT OF RADIOACTIVE WASTE DISPOSAL INTO SUBSURFACE</td>
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VII.2.4. Environmental Periodicals Bibliography, Environmental Studies Institute, Santa Barbara, California

865924
Drill-hole drilling can increase productivity
Prestwich, S. M.; Miller, L. S.
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Kiel, Herbert E.
Energy Conversion, 1978 VOL. 18, NO. 1, p. 17

721178
Multielement X-Ray Fluorescence Analysis of Natural Waters by Using a Preconcentration Technique with Ion Exchange Resins
Figarte, G. E.; Cesareo, R.

719388
Liquefaction Analysis of Horizontally Layered Sands
Chabrussi, Jamshid; Nikrmen, S. Umit

709683
Energy Production in Hot Water
Chemistry, 1978 VOL. 51, NO. 1 (January/February), p. 25

709585
A View of Iceland
Cook, C. Sharp
Science and Public Affairs/Bulletin of the Atomic Scientists, 1978 VOL. 84, NO. 3 (March), p. 34

416544
Practical Geothermal Pumping System

427148
Investment in a Ethiopian valley
Walker, P. C.
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403272
Reclamation's geothermal story
Sueoto, Susumu; Ferrelius, Kayne
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APPENDIX I
OREGON'S GEOTHERMAL ENVIRONMENTAL OVERVIEW WORKSHOP WATER QUALITY SESSION RECORD

OREGON'S GEOTHERMAL ENVIRONMENTAL OVERVIEW WORKSHOP WATER QUALITY SESSION RECORD

March 28-29, 1979
Portland, Oregon

Larry S. Slotta
Professor of Civil Engineering
Oregon State University
Corvallis, Oregon

Prepared for
Oregon Graduate Center
Beaverton, Oregon
ABSTRACT

The purpose of this section is to relate the key water quality issues related to the development of geothermal energy in the State of Oregon as discussed at the March 28-29, 1979 Oregon Geothermal Environmental Overview Workshop. This brief report lists the workshop participants' views of the current water quality data base for several potential geothermal areas in Oregon. Regional site developments for geothermal power are presently hindered for lack of a resource and an environmental data base. A format for collecting sources of available environmental data is listed for encouraging exchange of field information.

INTRODUCTION

Water quality issues were discussed in sessions of the March 28-29, 1979 Oregon Geothermal Environmental Overview workshop. These concerns were prioritized for regional known geothermal resource areas (KGRA) under consideration for development within the state. The geothermal resource and water resource (environmental and water quality) information bases were noted to be lacking for proper assessment of geothermal potentials and impacts.

Leo Deffarding, Project Manager of Battelle Pacific Northwest Laboratories, made a major presentation, in the introductory session, which altered the workshop participants to the key potential water quality issues surrounding geothermal development. Deffarding's presentation is appended.
Interactions among the natural systems that affect surface and subsurface water quality and the physical components within a typical geothermal plant are schematically shown in the systems analysis chart of Figure 1. (Figure 1 was abstracted from the Draft Proceedings of the LLL/GRIPS Geysers-Calistoga KGRA Water Quality Workshop, Jan. 1978, edited by K. Pimentel.) The issues and concerns discussed in the water quality sessions at the March 28-29, 1979 Portland geothermal workshop pivoted about the interactions noted in Figure 1 but with site specific considerations. Sites included: Klamath Falls; O-re-Ida Development and Vale in the Western Snake River Plain; Mt. Hood in the High Cascades; McCredie, Belnap, Austin Hot Springs and Breitenbush in the Western Cascades; Alvord in the Southern Basin and Range; and La Grande. The attributes of Lakeview are considered similar to Klamath Falls and the attributes of Burns to be like those of Alvord. Figure 2 illustrates the regional KGRA (Known Geothermal Resource Areas) of Oregon.

PRIMARY ISSUES

A tabulation of primary issues associated with regional geothermal development in Oregon is given in Table 1 as generated in the workshop discussion sessions. Concerns (ranked as high, medium, low or chronic) included:

- **H** hot water disposal into surface waters with resulting thermal degradation
- **H** drawdown and degradation of ground water and hot springs
- **H** potential negative reinjection aspects affecting intermediate ground water zones
- **H** chemical degradation of surface water
- **H** degradation of surface waters from construction related (roads, clearcuts, building pads, etc.) erosion and sedimentation
- **H** land settlement, subsidence and landslides
- **L-M** degradation of surface waters from well drilling, and testing activities
- **L** accidental releases associated with blowouts
- **C** cooling tower plume releases of trace metals that ultimately could become bio-accumulated
- **C** ecosystem damage
Figure 1. Water Quality Systems Model of Geothermal Impacts.
Figure 2. Known Geothermal Resource Areas (KGRA) of Oregon.
### Table 1

**Water Quality Issues and Concerns**

**Oregon Geothermal Workshop 1979**

<table>
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<th>Issues &amp; Concerns</th>
<th>General</th>
<th>Klamath</th>
<th>Ore-Ida</th>
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<td>H</td>
<td>L</td>
<td>L</td>
<td></td>
<td>L-M</td>
<td>L-M</td>
<td></td>
<td>L</td>
</tr>
<tr>
<td>Accidental Spills</td>
<td>L</td>
<td>LL</td>
<td>ML-HL</td>
<td>Possible interception of gas, boron release on agriculture.</td>
<td>ML-HL</td>
<td>H</td>
<td>HL</td>
<td>L</td>
</tr>
<tr>
<td>Ground Water Degradation</td>
<td>H</td>
<td>M-H</td>
<td>M</td>
<td>6000'</td>
<td>L</td>
<td>M-H</td>
<td>M-H</td>
<td>M</td>
</tr>
<tr>
<td>Réinjection Effects</td>
<td>M</td>
<td>M-H</td>
<td></td>
<td>L</td>
<td>H</td>
<td>H</td>
<td>M-H</td>
<td>M-L (1)</td>
</tr>
<tr>
<td>Cooling Tower Drift</td>
<td>C</td>
<td>C</td>
<td></td>
<td>C</td>
<td>C</td>
<td>C</td>
<td>C</td>
<td>C</td>
</tr>
</tbody>
</table>

**Key:**
- H = High
- M = Medium
- L = Low
- C = Chronic

**Footnotes:**
1. Could be problematic due to inherent high water quality. Currently of low potential due to strict regulation.
2. Numerous springs in area associated with fault scarts
3. Significant water quality problems expected if hot water were to be discharged to Grande Ronde R. Downhole heat exchangers recommended with geothermal exploitation.
Rankings were assigned regarding the water quality concerns for seven regional sites, as well as overall concerns for the projected geothermal development within the State of Oregon.

Environmental problems associated with geothermal energy recovery include waste heat disposition, brackish water disposal, reinjection and reservoir depletion. There is associated concern with regard to casing requirements of the geothermal wells.

The disposal of thermal groundwater from wells into surface streams, and the resultant thermal pollution of the receiving waters was recognized as a problem in the southern part of the state. Both the Department of Environmental Quality and the State Water Resources Department rules and regulations discourage large scale discharges of this type. However, the existing rules do not adequately address the discharge of small amounts of thermal groundwater, (less than 5,000 gpd); these smaller discharges are primarily responsible for the existing thermal pollution problems. Programs are being considered by the state that would encourage or require the use of down-hole heat exchangers as a means of resolving this problem.

It was recognized that secondary utilization of geothermal fluids can be accomplished through their use as irrigation water, provided they do not contain substances harmful to crops. Trace metal impurities incorporated in the discharge stream was of concern to the water quality workshop group. The opportunities available for other secondary uses of geothermal water, including drought relief and waterway enhancement, and aquaculture, were discussed and their development encouraged. Correspondingly, concern was expressed regarding the possible over development of hot water aquifers.

Concerns were raised about reinjection of excess condensate as affecting subterranean pressures, chemical and thermal fronts. There are problems with injecting large flows, and with trace impurity buildup in the aquifers. With reinjection there is a real lack of monitoring methods for determining resultant strata fracturing, subsidence, trace impurity buildup and aquifer contamination.

It was recognized that satisfactory sewage-type treatment of excess condensate bearing contaminants or high levels of dissolved solids before subsequent release would be expensive; in some cases the return of these waters to intermediate levels would be an acceptable disposal concept.
Problems with erosion and sedimentation in mountainous terrain were discussed. It was recognized that clearing and grading operations necessary for construction of access roads, well pads, power plants and/or processing plants could result in sedimentation of adjacent surface waters. It was brought out, however, that logging and forestry operations are successfully carried out within the State by applying mitigating measures, such as: soundly constructing roads and construction areas, providing open drainage on water courses, and restoring vegetation to protect the natural setting. In many cases, access roads to geothermal sites would be on improved logging roads and the associated impacts would be limited to that which has been acceptable to the State's economy over the years.

Well blowouts were practically dismissed by the water quality workshop discussion group because well-drilling technology has sufficiently advanced that blowouts can be limited or controlled by responsible operators working with quality equipment. State rules regulating exploration of geothermal resources in Oregon adequately address the problem of blowout prevention.

Cooling tower drift, the atmospheric transport of water containing trace contaminants, was considered to be difficult to predict (or to ultimately measure). Nonetheless, it was considered an issue and would be listed as a potentially chronic negative impact.

In general the potential impacts at Oregon sites presently would be constituted as variable because each Oregon site is hydrogeologically unique. Disposal problems will therefore be site specific. In view of the possible water quality and other environmental risks, there are benefits that warrant siting of geothermal demonstration projects at an early date.

DATA GAPS

The water quality discussion group next attempted to identify data gaps and to give recommendations for studies to lead to the practical utilization of geothermal energy. In general it was recognized that little is documented about Oregon's geothermal water resources. The forms and amounts of hot water that geothermal plants would have available for generation is not presently precisely known. Baseline surveys of the hydrology and water quality (for springs, streamflow and groundwater) of
prospective geothermal fields are not available. These surveys need to be established prior to geothermal field development in order to evaluate the possibility of adverse impacts following siting. Little is known about the variation of the characteristics of Oregon's ground/geothermal waters with space or time. Continued withdrawal of geothermal fluid could reduce the amount of heated reservoir water and thereby change the temperature and chemical characteristics of nearby springs. In most geothermal areas, data on rock porosity, permeability, and storage are insufficient to assess the hydrologic nature of the reservoir. To assess impacts on water quality, data should be collected not only on standard water quality parameters but also on the local hydrologic systems and the characteristics of geothermal water that would disclose their impacts on surface and ground waters.

Table II is a tabular summary of discussions which occurred in the 1979 Oregon geothermal water quality workshop sessions regarding barriers to regional geothermal developments. The subject heading include:

- Hydrology & Water Quality State of Knowledge
- Chance of Finding an Adverse Impact to Technology Development
- Mitigation Requirements (controls)
- Period of Program Delay Resulting from an Adverse Finding
- Environmental Risk of Proceeding with Technology Development

It was recommended that coordinated studies be initiated now to monitor the effects of development of Oregon's geothermal resources. Watersheds need to be monitored, stream sedimentation baselines established, and pertinent hydrologic and water quality information generated for potential geothermal sites. Presently there are few water quality-quantity baselines for evaluating the effects of hot water development in Oregon.

It was reported that water quality information from mid-depths wells will exceed $2000 to $30,000 per water sample. Wells are drilled primarily for production and not for formation tests. It was suggested that developers be encouraged to gather and share as much hydrogeologic information as possible during exploration drilling for later environmental impact assessments.

CONCLUSIONS

The delay of geothermal development could be reduced with clarification of existing water quality, resource recovery, and discharge regulations and standards. State laws and regulations for fluid discharge cover geothermal exploration activities but are inadequate for fluid disposal from
**TABLE II. WATER QUALITY DATA STATUS: AVAILABILITY AND REQUIREMENTS FOR ASSESSMENT OF POTENTIAL ENVIRONMENTAL IMPACTS BY GEOTHERMAL ACTIVITIES IN OREGON.** (SOURCE OREGON GEOTHERMAL ENVIRONMENTAL OVERVIEW WORKSHOP, 1979).

<table>
<thead>
<tr>
<th>GENERAL</th>
<th>BURNS</th>
<th>U.S. 30A</th>
<th>JAMESTOWN</th>
<th>WEST CASCADES</th>
<th>MALMEND</th>
<th>LA GRANDE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AVAILABILITY OF SITE SPECIFIC WATER BASINE REPORTS WITHIN GEOTHERMAL AREAS</strong></td>
<td>Very limited information available.</td>
<td>Considerable data on surficial geology available. Little on geothermal resources.</td>
<td>Little information available.</td>
<td>Eventual deep wells in 400' Shallow water in Bremerton basin.</td>
<td>Little information available.</td>
<td>May granted by area to area.</td>
</tr>
<tr>
<td><strong>ACTIVE OR IN PROGRESS RESEARCH TO GAIN WATER QUALITY INFORMATION</strong></td>
<td>Limited.</td>
<td>District heating &amp; association projects.</td>
<td>Oregon's well</td>
<td>USGS-004 at Mt. Hood.</td>
<td>Oregon's well</td>
<td>City of La Grande's project.</td>
</tr>
<tr>
<td><strong>SURFACE WATER SUPPLY IMPACT TO TRENCH DEVELOPMENT</strong></td>
<td>Surface &amp; groundwater quality and C.H. depletion biggest concern.</td>
<td>Surface and shallow geology have low quality.</td>
<td>Oregon's well</td>
<td>Oregon's well</td>
<td>Oregon's well</td>
<td>Oregon's well</td>
</tr>
<tr>
<td><strong>SPECIFIC PROJECTS REQUIRING TO RESERVE DELIVERY APPROVAL</strong></td>
<td>Field studies and exploratory wells supply proprietary information.</td>
<td>Evaluations of discharge waters if deep heat exchangers are not used.</td>
<td>Evaluation of site needed.</td>
<td>Groundwater models required and groundwater tracers recommended.</td>
<td>Groundwater models required and groundwater tracers recommended.</td>
<td>Evaluation of site needed.</td>
</tr>
<tr>
<td><strong>RESIDENTIAL MIGRATION COSTS SUBJECT TO REGULATION</strong></td>
<td>Double injection required to further reduce the problem.</td>
<td>Economics of heat exchangers and groundwater availability.</td>
<td>None expected.</td>
<td>None expected.</td>
<td>None expected.</td>
<td>None expected.</td>
</tr>
<tr>
<td><strong>ENVIRONMENTAL RISK IN POTENTIAL DEVELOPMENT</strong></td>
<td>High temperature at ground surface.</td>
<td>No detrimental effects to date.</td>
<td>Remote areas cause ground water.</td>
<td>Emissions from geothermal water.</td>
<td>Emissions from geothermal water.</td>
<td>No environmental concern.</td>
</tr>
</tbody>
</table>

- 11, Surface & groundwater quality threats. Other hazards include: (1) surface & groundwater quality threats. (2) Potential for geochemical hazards. (3) Emissions from geothermal water. (4) Aesthetic degradation.
field developments. The disposal of geothermal fluids on land currently requires a Department of Environmental Quality permit. If, however, these fluids are put to a beneficial secondary use a Department of Environmental Quality permit may not be necessary; but a water right, issued by the State Water Resources Department, may be required.

Discussion was held on the "flexible" Oregon geothermal law in which 250°F was established as the minimum temperature for applying geothermal regulatory requirements. Presently most geothermal prospecting in Oregon has returned with water below 250°F resulting in some confusion for developers regarding regulatory restrictions. Representatives of Oregon's Department of Geology and Mineral Industries, and the State Water Resources Department both felt they could "flexibly" operate under the current rules toward progressive development of geothermal energy in the State.

Encouragement was given in the water quality session for some near term geothermal site demonstration studies within the State for proper utilization of hot water as a viable alternative energy resource.

ACKNOWLEDGEMENTS

Participants of the water quality session are listed according to the following roles: R=Regulatory; D=Developer; E=Data Collector or Evaluator; and M=Modeler. Their contributions to the workshop discussions on water quality issues and concerns are gratefully acknowledged.

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Information on geothermal sites in Oregon for completing a final report on Oregon's geothermal water quality environmental concerns, data sources and recommendations is requested according to the following format:

- geothermal issues - water quality - hydrology
- type of study
- party or agency responsible
- descriptor - purpose
- location, watershed & no. of stations
- frequency of measurement
- period of record
- parameters measured
- reports
- status of project
- comments on projects
- evaluations prepared regarding site

Agency and individual response providing such data for Oregon's geothermal areas will be most sincerely appreciated.

L. S. Slotta, Reporter
APPENDIX II

GEOTHERMAL DEVELOPMENT
IMPACT ON WATER QUALITY

APPENDIX III

SUMMARY OF LAWS REQUIRING OR RELATED TO GEOTHERMAL POLLUTION CONTROL

APPENDIX IV
ADMINISTRATIVE REQUIREMENTS
FOR DEVELOPMENT OF
GEOTHERMAL RESOURCES
THE STATE OF OREGON

AGENCY MEMORANDA: Oregon Department of Geology and Mineral Industries
memo dated February 28, 1979 by Vernon C. Newton, Jr.
APPENDIX VI

WATER QUALITY STANDARDS
OREGON DEPARTMENT OF ENVIRONMENTAL QUALITY

APPENDIX VII
ENVIRONMENTAL EFFECTS OF KNOWN POLLUTANTS