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SUMMARY AND RESULTS OF THE COMPREHENSIVE ENVIRONMENTAL MONITORING PROGRAM AT THE INEL'S RAFT RIVER GEOTHERMAL SITE

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R. A. Mayes, T. L. Thurow,[a] and L. S. Cahn[b]
EG&G Idaho, Inc.
Earth and Life Sciences
Idaho National Engineering Laboratory
Idaho Falls, Idaho

ABSTRACT

The Raft River Geothermal Program at the Idaho National Engineering Laboratory (INEL) was a research project designed to demonstrate that moderate temperature (~150°C) geothermal fluids could be used to generate electricity and provide an alternate energy source for direct-use applications. Development of the geothermal reservoir began in 1975 and the environmental program was initiated soon after drilling began. The major elements of the monitoring program were continued during the construction and experimental testing of the 5-MW(e) power plant.

The monitoring studies established pre-development baseline conditions of and assessed changes in the physical, biological, and human environment. The Physical Environmental Monitoring Program collected baseline data on geology, subsidence, seismicity, meteorology and air quality. The Biological Environmental Monitoring Program collected baseline data on the flora and fauna of the terrestrial ecosystem, studied raptor disturbances, and surveyed the aquatic communities of the Raft River. The Human Environmental Monitoring Program surveyed historic and archaeological sites,considered the socioeconomic

a. Current address: Department of Range Science, Texas A & M University, College Station, TX 77843

b. Current address: 373 4th Street, Idaho Falls, ID 83401

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environment, and documented incidences of fluorosis in the Raft River Valley.

In addition to the environmental monitoring programs, research on biological direct applications using geothermal water was conducted at Raft River. Areas of research included biomass production of wetland and tree species, aquaculture, argricultural irrigation, and the use of wetlands as a treatment or pretreatment system for geothermal effluents.

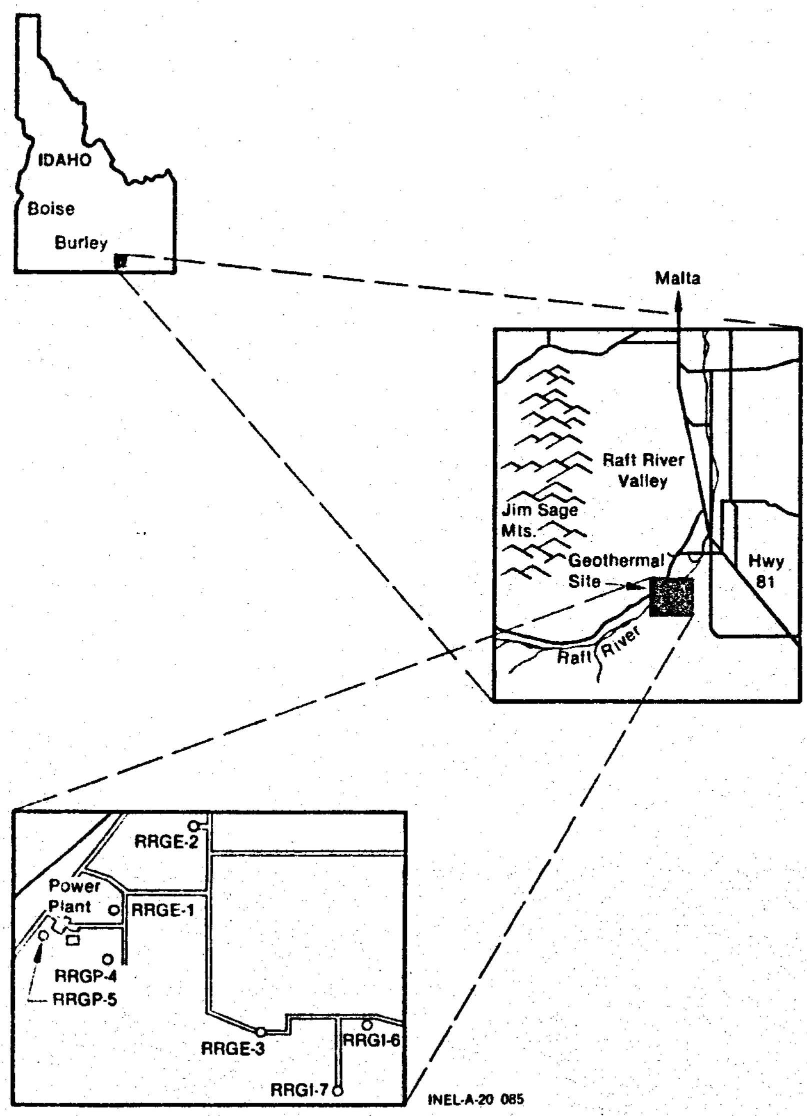
INTRODUCTION

Geothermal energy may be used either for the production of electricity or for direct-heat applications. Compared to some other energy technologies, the environmental effects of geothermal energy production are generally considered small. There may however be measurable impacts associated with the exploration, testing, and production phases of a geothermal resource. Several overviews of potential environmental impacts resulting from geothermal development have been published (Pimentel, 1978; Strojan and Romney, 1979; Suter, 1978; Tucker and Tanner 1978; O'Banion and Layton, 1981; Layton et al., 1981; and Spencer et al., 1979). Among the environmental concerns identified are: loss or modification of fish and wildlife habitat; potential socioeconomic impacts (particularly in sparsely populated areas of the western U.S. where many geothermal resources are located); gaseous emissions (primarily carbon dioxide and hydrogen sulfide and, to a lesser extent, mercury and radon); water use; land subsidence; induced seismicity; discharges to surface waters of geothermal fluids high in total dissolved solids; and effects of accidental spills and blowouts.

These general issues and other site specific concerns were considered during the environmental monitoring program at the Raft River Geothermal Site. The monitoring program was designed to: (1) provide baseline data with which to assess future impacts of development; (2) collect monitoring data during operations; and (3) serve as an example of how an environmental program associated with a larger-scale geothermal development might be conducted. The last item was an important objective of the environmental program.

FACILITY DESCRIPTION AND HISTORY

The Raft River Geothermal Site is located in southeastern Idaho in the Raft River Valley (Figure 1). The presence of a moderate temperature (~150°C) resource in this area had been reported by the U.S. Geological Survey (USGS). A joint effort between the U.S. Atomic Energy Commission (a predecessor to the Department of Energy), the Idaho Department of Water Resources, and the Raft River Rural Electric Co-op, was undertaken to develop this resource. Between 1975 and 1978, 5 production wells (depths from 1497m to 1994m) and two injection wells (depths of 1176m and 1185m) were drilled.



Location of Raft River Geothermal Site and exploration (RRGE), production (RRGP), and injection (RRGI) wells.

The Raft River Basin was declared a critical ground-water area by the Idaho Department of Water Resources in 1963 and the area was closed to further ground-water development. Because there was concern that injection of geothermal waters in the intermediate depth aquifer could affect the quality of water in the shallow aquifer used for irrigation and culinary water, seven monitor wells were drilled. Monitoring results from those and existing wells in the area are reported by Allman et al., 1982. Changes in ground-water quality observed were negligible. Short transient pressure responses were noted as a result of geothermal production and injection. The geology, geophysics, hydrology, and geochemistry of the Raft River Geothermal Site have also been described (Dolenc et al., 1981; Tullis and Dolenc, 1982; Russell, 1982; and Hull, 1982).

A major portion of the Idaho National Engineering Laboratory (INEL) work at Raft River was directed toward the design and construction of a binary cycle pilot plant with a nominal rating of 5MW(e). The principal objective of the pilot plant was to demonstrate the technical feasibility of generating electric power from a moderate temperature geothermal resource in an environmentally acceptable manner. In the binary cycle plant, geothermal fluids are used to heat a secondary working fluid (isobutane) which expands through a turbine-generator to produce electricity. The working fluid is then condensed and reheated in a closed system. Heat is removed from the isobutane by circulating cold, treated geothermal water through a heat exchanger. This heat is then dissipated in a wet evaporative cooling tower. Plant startup testing occurred during August to November, 1981. During the week of October 28, the plant was brought up to its full thermal power of 45MW(t). Testing and operation of the 5MW(e) facility continued through mid-June, 1982. More complete descriptions of the 5MW(e) plant and its water treatment system are provided by Whitbeck and Stiger, 1982 and Suciu et al. 1982.

ENVIRONMENTAL MONITORING AND RESEARCH PROGRAM

The environmental monitoring and research activities at the Raft River Geothermal Site were conducted during the period from 1975 to 1982. The monitoring program was established to characterize the existing environment prior to development and to measure changes in environmental parameters as a result of geothermal development. In addition, research regarding biological direct applications of geothermal fluids was conducted to identify other potentially beneficial uses associated with geothermal development.

These monitoring and research studies required the cooperation and participation of not only Department of Energy and EG&G Idaho personnel, but also individuals from numerous local groups, State and Federal agencies, universities, and private contractors. The many studies which made up the environmental program are summarized in detail (with the exception of ground-water monitoring which is reported separately) in a final report (Thurow and Cahn, 1982). That report forms the basis for this summary and should be consulted for details.

PHYSICAL ENVIRONMENT

Physical aspects of the environment may affect entire ecosystems. A physical environmental monitoring program was established to detect changes in the physical environment and to indicate potentially adverse results from geothermal development.

Geology

The Known Geothermal Resource Area (KGRA) is located at the southern end of the Raft River Valley. The valley, 60 km long and 20 to 24 km wide, is bounded by the Black Pine Mountains, the Jim Sage Mountains, the Raft River Range, and the Snake River Plain (Figure 2). The Raft River meanders northward through the basin from the southern end of the Jim Sage Mountains.

The geologic structure of the Raft River basin near the KGRA has been studied extensively and is described in detail in other reports (Dolenc et. al., 1981; Thurow and Cahn, 1982). The geothermal reservoir in the KGRA occurs near the Horse Well and the Bridge fault. A USGS analysis of the thermal fluids in the reservoir suggests the fluid is at least 60 to 70 years old. Static water levels in the thermal reservoir are about 100m above the land surface.

Seismicity

The possibility of inducing earthquakes as a result of fluid withdrawal or injection is of concern during geothermal development. At Raft River, a seismic network was established (initially in July, 1974) to collect baseline data and monitor microseismic activity during geothermal field testing, production, and injection.

The low level of background seismicity found in the vicinity of the KGRA indicates a low-stress environment. It is unlikely that earthquakes would be triggered by geothermal activities in the low-stress environment near the Raft River facility and, to date, no increase in seismic activity has been detected.

Subsidence

Excessive groundwater withdrawals from unconsolidated or poorly consolidated aquifers may cause land subsidence and fracturing. Areas in the northern Raft River Valley (about 40 km from the geothermal site) have subsided over 0.9m in the last 20 years because of excessive groundwater pumping for irrigation. A detailed surveying grid was established in 1975 at the Raft River geothermal well field to monitor potential subsidence caused by geothermal fluid withdrawal. The grid was surveyed again in 1978 and 1980. The grid was expanded in 1979 after completion of all wells to periodically include elevation checks at specific wells during production and injection tests.

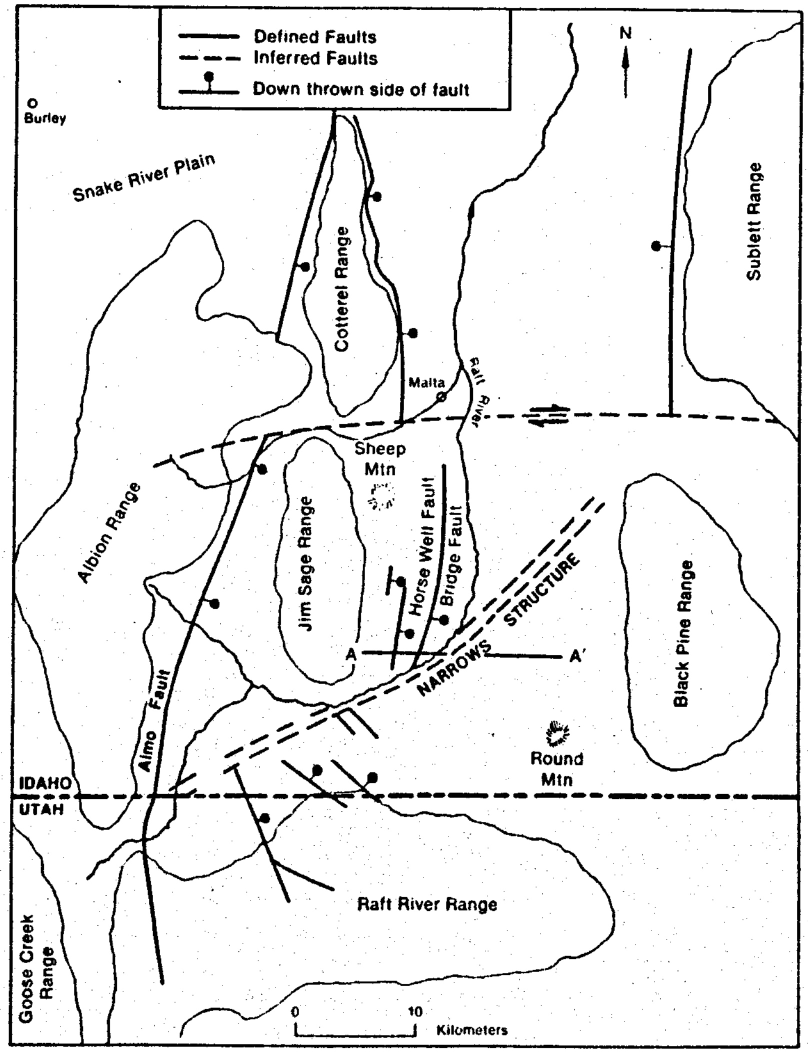


Figure 2. Major structural features of the southern Raft River Valley.

With the exception of five points located in cultivated fields where elevation changes were due to farming activities, all changes in elevation measured during the subsidence surveys were within the experimental error. No detectable changes in elevation occurred as a result of geothermal development at Raft River.

Meteorology

Meteorological data are important to a monitoring program because wind speed and direction, temperature, and precipitation may have direct effects on components of the ecosystem and influence air quality data. A weather station was established near the geothermal site in 1975 to monitor wind velocity and direction, precipitation, ambient air temperature, and dewpoint temperature.

The mean annual temperature in the valley is 8°C, and the extremes are -30°C and 40°C. Rapid cooling during clear evenings creates night time inversions, but winds and morning heating of the ground usually clear the inversions before afternoon. Because of a high frequency of windy days, dispersion characteristics at the site are good. Precipitation data are quite variable from year to year and month to month. The annual average precipitation during the period of geothermal development was 255 mm.

Air Quality Monitoring

Based on experience from the Geysers development in California, one of the environmental concerns at Raft River was the emission of H_2S. It should be noted that the Raft River plant [5MW(e)] is small compared to the generating capacity at the Geysers project [>900 MW(e)]. Particulate emissions from construction and operation activities, and from the drying of mists emitted from the cooling towers were identified as concerns also. Original plans called for the use of a chromate corrosion inhibitor in the cooling tower, but a phosphate and zinc sulfate mixture was used instead. All measurements were made in accordance with standard Environmental Protection Agency (EPA) reference methods (40CFR 50).

The baseline air monitoring program was initiated in 1975 and expanded in 1980. Total suspended particulate (TSP) data were collected at four locations around the geothermal site after 1980. On April 28 and 29, 1982, the emissions from the cooling tower were sampled to determine fluoride, sulfate, hydrogen sulfide, zinc, and particulate emissions.

The annual average TSP concentrations are well below the primary National Ambient Air Quality Standard (NAAQS) of 75 $\mu g/m^3$ and the secondary NAAQS of 60 $\mu g/m^3$ (Table 1). All samples except those taken on June 30, 1976 and June 19, 1981 were also below the primary 24-h standard (260 $\mu g/m^3$) and the secondary 24-h standard (150 $\mu g/m^3$). The cause for the 1976 exception was wind-raised dust from bare fields near the sample station. The 1981 exception was caused by a road maintenance crew working

TABLE 1. GEOMETRIC MEAN TOTAL SUSPENDED PARTICULATE (TSP) CONCENTRATIONS

Sampling Period	A[a]	B	C	D
10/80 to 12/80	10.7	14.5	12.7	16.4
01/81 to 03/81	4.7	6.7	6.7	7.6
04/81 to 06/81	11.3	19.5	17.2	16.1
07/81 to 08/81	34.6	41.1	45.7	45.1
10/81 to 12/81	6.4	7.9	6.2	6.7
01/82 to 03/82	5.5	6.0	5.5	5.2
04/82	9.5	13.5	12.0	12.2

a. Station A is the upwind or background location.

on an unpaved road near Station B. TSP concentrations were higher during the dry summer months and lower during the wetter periods of fall and winter. Values were also lower when a snow cover existed. The largest number of TSP values were in the range of 0 to 10 $\mu g/m^3$. The TSP concentrations during the 1980-82 sampling period ranged from 0.3 to 388.8 $\mu g/m^3$ with the average being about 19 $\mu g/m^3$. TSP values at Station A (background) were generally 30-50% lower than sites located near unpaved site access roads and plant construction activities.

The cooling tower emmissions tests revealed that most of the measured parameters (sulfate, fluoride, phosphate, suspended solids, total particulates and hydrogen sulfide) were below the limits of detection for the methods used. Zinc was present at an average of only 11 $\mu g/m^3$.

The U.S. EPA conducted tests of radon gas emissions in March 1976. Radon-222 concentrations in the geothermal fluids were about 390pCi/L, a relatively low concentration.

It was concluded that TSP levels at the site result mainly from agricultural activities and from construction and traffic at the geothermal facility. Ambient levels were well below standards. The impacts on air quality of site activities, plant operation, and cooling tower emissions were minimal.

BIOLOGICAL ENVIRONMENT

Effective environmental management requires an understanding of the diversity and population interactions of the biotic community. At the

Raft River Valley, baseline data on aquatic and terrestrial flora and fauna have been collected. These baseline studies have significantly improved the understanding of the ecology of the valley. Due to programmatic changes, the power plant did not operate as long as originally intended. Therefore, no ecological impacts due to operations were observed. However, these studies provided much-needed data about plant and animal populations and their natural variations. This information will be useful for assessing impacts of any future development in the valley and provides a good example of the type of information needed to assess impacts. The raptor studies demonstrate how such information can be used to minimize ecological impacts.

Raptor Ecology and Disturbance

Raptors are important biological indicators of environmental perturbations and as such may reflect changes occurring within an ecosystem. Data from this study provide baseline information for south central Idaho which can be used as a reference for similar habitats typical of the Great Basin.

Twenty-one raptor species were present in the Raft River Valley. Golden eagles, Swainson's hawks, ferruginous hawks, and several species of owls were most common. A total of 181 active raptor nests were found in the valley during 1978 and 1979. The limited land disturbance and increase in human activity associated with the Raft River geothermal development did not have an observable effect on raptor populations. Observed declines in large raptor nesting success (i.e., golden eagle and ferruginous hawk) were associated with the natural cyclic trend in the jackrabbit population. Jackrabbit population cycles were studied extensively as part of this program, and without those data, the change in raptor nesting success would have been more difficult to interpret.

The ferruginous hawk, the largest hawk in North America, is prone to nest desertion from disturbance and its numbers are apparently declining nationwide. The Raft River Valley has one of the most stable ferruginous hawk populations remaining in the country (Thurow *et al*., 1980).

During 1978, 1979, and 1980, nests were disturbed by several means to simulate noises common to development of a geothermal site (e.g. vehicles, small gasoline engines, investigator approaching on foot). Flushing distance and fledging rates were used as measures of response to the disturbance. The study concluded that nesting success of the ferruginous hawk in Raft River Valley was not impaired by geothermal development and associated human activity as long as buffer zones (approximately 0.6 km) were not violated.

HUMAN AND CULTURAL MONITORING PROGRAM

Developing the geothermal resources of the Raft River Valley could provide local residents with many benefits and opportunities; however, some undesirable alterations could also result. The high fluoride levels sometimes associated with geothermal development were of concern in the Raft River Valley. A program was established to identify potential socioeconomic changes that could accompany development of the geothermal resource.

A survey was conducted in the Raft River Valley to document the existence of historic and archaeological sites. The development had no impact on known sites and no undiscovered sites were located during construction activities.

A socioeconomic evaluation of Cassia County and potential impacts that could be associated with development at the Raft River Site was conducted from 1976 through 1980. Many benefits resulted from development of the geothermal site. Many locals were employed during development and wages at the site were generally higher than average wages in the county. Geothermal development increased tax revenues and reduced unemployment. There were no significant land use impacts.

Water with a high fluoride content can cause chronic fluoride poisoning (fluorosis) in humans and animals. Because fluorosis in a nearby community had been linked to high fluoride levels in the water supply, an investigation of the incidence of dental fluorosis in the Raft River Valley was undertaken. The incidence of dental fluorosis in Valley residents appeared to be abnormally high. However, fluoride levels in drinking water were low and no cause for the higher than normal incidence of fluorosis was found. The fluorosis was not associated with development of the geothermal resource.

BIOLOGICAL DIRECT APPLICATION RESEARCH

Research designed to test the feasibility of using energy expended geothermal fluid for beneficial biological uses was conducted at the Raft River site. The most common method of disposal of energy expended geothermal water is injection. However, in the arid west where water supplies are limited, some geothermal waters might be suitable for irrigation or other purposes. Survivability and productivity of various agricultural, aquacultural, rangeland, and tree species were tested at the Raft River facility. Studies were also conducted to assess the potential of biological systems such as wetlands for water purification. These studies are described by Thurow and Cahn, 1982 and by Breckenridge et al. 1982.

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