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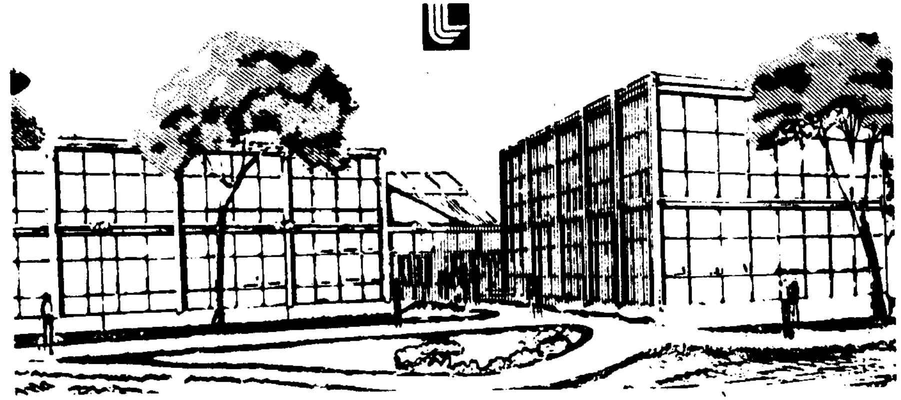

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WATER SUPPLY DILEMMAS OF GEOTHERMAL

DEVELOPMENT IN THE IMPERIAL VALLEY OF CALIFORNIA

David W. Layton[1]

ABSTRACT

There are four known geothermal resource areas in the Imperial Valley that have a combined potential of over 4,000 megawatts of electrical energy for 25 years. The water resources available to support geothermal energy development are imported Colorado River water, agricultural waste waters, Salton Sea water, and ground water. In addition, geothermal power plants can produce their own cooling water in the form of steam condensate. Nevertheless, the relatively high water requirements of geothermal facilities along with a series of real and potential constraints may cause water supply dilemmas involving both the acquisition and use of cooling water. Important constraints are institutional policies, water supply costs, technical problems, and impacts upon the Salton Sea. This paper examines these constraints and related dilemmas in light of relevant information on the valley's water resources, geothermal resources and energy technologies, cooling water requirements, and water supply options. (Key terms: water supply dilemmas; geothermal power plants; water requirements; water supplies; Imperial Valley)

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INTRODUCTION

Recent estimates of the energy potential of geothermal reservoirs underlying the Imperial Valley of California indicate that they could sustain between 4,000 and 5,500 megawatts (mw) of electrical power generation for 25 years (Towse, 1975; Nathenson and Muffler, 1975). To sustain 5,500 mw of energy production, more than 300,000 acre-feet (af) of fresh water would be required for wet cooling towers, or about 10% of the water annually diverted to the valley from the Colorado River. The water resources potentially available to meet the requirements of future geothermal projects are Colorado River water, agricultural waste waters, the Salton Sea, ground water, and condensate from geothermal steam.

During the initial stages of geothermal development when total water requirements are relatively low, water supply problems will probably be minor. However, as greater levels of energy are produced, dilemmas may emerge that hinder future projects. The expected dilemmas would not only involve difficulties in acquiring adequate sources of cooling water, but also the consequences of using a particular water supply. Formation of these dilemmas will be determined by the characteristics of the water and geothermal resources, the prospective geothermal energy technologies and their requirements for cooling water, the available water supply options, and a set of real and potential constraints.

WATER RESOURCES

The Imperial Valley is located in one of the more arid regions of the United States. It receives, on the average, less than 3 inches of annual rainfall. Yet the importation of water from the Colorado River has turned

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the valley into a productive agricultural area that includes over 450,000 acres of irrigated lands. Historic inflows of irrigation water shown in figure 1 have averaged nearly 3 million af/yr below drop No. 1 on the All-American Canal (see figure 2) and are distributed within the valley by the Imperial Irrigation District (IID). This imported water is part of California's 4.4 million af allotment of Colorado River water. Agricultural and municipal wastes of less than 120,000 af/yr flowing across the border from Mexico in the New and Alamo Rivers are another source of inflow.

Water deliveries to the valley depend on the irrigation demands that are highest during the months of April and August-September when the summer and winter crops are planted (Kaddah and Rhoades, 1976). Demands for irrigation water are based on the evapotranspiration requirements of crops, the efficiencies of irrigation methods, and the water required to leach salts out of the root zone. To facilitate the leaching of the valley's soils, the IID has installed a tile drainage system that encompasses over 83% of the agricultural land (shaded in figure 2). Effluent flows from the irrigation system (excluding waters from Mexico) have averaged over 1 million af/yr since 1951 (figure 1) and represent 37% of the inflows to the system. Approximately 75% of the effluent water is considered to be tail water with an additional 5 to 10% contributed by sewage discharges and canal spillage (Kaddah and Rhoades,1976).

The predominant water quality problem in the valley is the salinity of the Colorado River, which contains nearly 1.2 tons of salt/af of water. Waste waters from the drainage system carried away in the New and Alamo Rivers contain 3.7 tons of salt/af, or about 2,700 ppm total dissolved solids (TDS)

(IID, 1975). Concentrations of dissolved solids in drainage ditches sometimes exceed 4,000 ppm TDS (Pimental, 1976).

Brackish waste waters from both the Coachella and Imperial Valleys end up in the Salton Sea, California's largest inland body of water. It has a surface area of almost 235,000 acres and is completely land-locked. Evaporation from the sea is as high as 5.8 ft/yr (Hely et al., 1966) and in some years the total evaporation has actually exceeded the flows of agricultural waste waters, causing the sea's salinity to rise. The sea now has water that is approaching 40,000 ppm TDS. In recent years the inflows to the sea have been greater than the evaporation rate, thus producing increases in the sea's surface elevation and area displayed in figure 3. Drainage and flooding problems resulting from the rising of the sea have been a source of much concern to riparian property owners. Through the prompting of those property owners, a water conservation program has been adopted by the IID (Imperial Valley Press, 1976) that is designed to reduce the inflows to the sea by encouraging the more efficient use of water by the valley's farmers. Annual reductions in waste water output, nevertheless, would have to be greater than 100,000 af to begin decreasing the sea's elevation.

Fortunately, previous efforts at water conservation have shown that waste flows can be curtailed by large amounts. During the years 1964-1965 when allocations of Colorado River water to lower basin users were cut back because of the filling of the Glen Canyon Dam, water conservation was given a high priority by the irrigation district, and waste water output from the drainage system represented only about 33% of the inflows. In 1975 waste flows from the district rose to 37.6% of the 3,001,207 af imported from the Colorado River (IID, 1975). If flows had been curtailed to the 1964-1965 rate, a reduction of over 137,000 af could have been realized.

Another water resource is the ground water contained in the sediments underlying the valley. The amount of ground water having a salinity less than 35,000 ppm TDS is estimated by Dutcher et al. (1972) to be 1.1 billion af. The most promising area for ground water extraction is the East Mesa region (see figure 2) where recharge from the unlined All-American and Coachella Canals has amounted to well over 7 million af since 1950 (Loeltz et al., 1975).

GEOTHERMAL RESOURCES AND TECHNOLOGIES

There are six known geothermal resource areas (KGRAs) in the Imperial Valley. Their locations and acreages are shown in figure 2. An assessment of the geothermal resources in the United States by Nathenson and Muffler (1975) indicates that four of the six KGRAs have significant amounts of recoverable energy. The Salton Sea KGRA has the greatest energy potential with 3,344 mw for 25 years, followed by 1,168 mw at the Heber KGRA, 584 mw at the East Mesa KGRA, and the Brawley KGRA with 400 mw. The geothermal reservoirs associated with those KGRAs are liquid dominated as opposed to the dry-steam or vapor dominated type found at The Geysers in northern California. When a well is drilled into one of the valley's geothermal reservoirs, part of the fluid entering the well flashes to steam, resulting in a two-phase flow to the wellhead. In the Salton Sea KGRA steam represents between 10 to 20% of the wellhead flow (Palmer, 1975).

Temperatures and salinities of the geothermal fluids vary a great deal among the KGRAs. The Salton Sea KGRA, for example, has down hole temperatures in some wells as great as 572^{o}F (Palmer, 1975), while wells in the East Mesa KGRA have temperatures generally below 392^{o}F (U.S. Bureau of Reclamation, 1974). Fluids produced from the Salton Sea field contain 200,000 to 300,000 ppm dissolved solids compared to under 2,500 ppm for the majority of East Mesa wells (U.S. Bureau of Reclamation, 1974). Because of the variations in the geothermal fluids, the energy conversion technologies implemented in the valley may differ according to the fluid properties of each reservoir.

For reservoirs having geothermal fluids with salinities less than 3% TDS, a proven energy conversion technology is the flashed steam method (Austin and Lundberg, 1975). In this technique, steam is separated from the liquid-steam mixture coming from a well field and is then sent to a turbine that runs a conventional generator. The geothermal fluids are then either reinjected in a geothermal reservoir or discharged to evaporation ponds. A 75 mw facility using the flashed steam method is already in use south of the Imperial Valley in Cerro Prieto, Mexico. One problem connected with this conversion approach is the corrosion of turbine components resulting from the carry over of salts in the steam (Austin and Lundberg, 1975). Power plants using a binary system avoid this problem by transferring heat from brine-steam well flows to a secondary fluid such as isobutane that expands through a turbine. A third energy conversion method is the total flow system being developed at Lawrence Livermore Laboratory (Austin et al., 1973). Instead of sending processed steam through a turbine or transferring geothermal heat to a secondary working fluid, the entire two-phase flow from a geothermal well is sent through nozzles that are directed toward a specially constructed turbine that can withstand a highly corrosive brine-steam flow.

No matter how well-designed the geothermal energy conversion systems are, they still suffer from thermal inefficiencies caused by low reservoir temperatures. The lower the thermal efficiency of a power plant, the higher the amount of waste heat produced per unit of electrical output and the greater the need for cooling water.

COOLING WATER REQUIREMENTS

The basic types of cooling water requirements are consumptive use by evaporative cooling systems and withdrawals for once through cooling. The amount of water consumed or withdrawn by a geothermal power plant depends primarily on the ratio of power output to condenser heat rejection. Elliott (1975) has calculated the power to heat rejection ratios of a single stage flashed steam process, the total flow system, and a one-stage flash binary system to be 0.21, 0.18, and 0.15, respectively, based on a 572°F reservoir temperature. By assuming a 20°F condenser rise and an evaporation rate of 2% of the circulating flow in a mechanical draft wet cooling tower (Leung and Moore, 1969), the single stage flash steam design would provide the most efficient water use per megawatt of capacity at 52 af/mw/yr. Next in water efficiency would be the total flow system consuming 61 af/mw/yr and the least efficient is the single stage flash binary system at 73 af/mw/yr. A decrease in the reservoir temperature to 302°F would essentially double these water requirements. The consumptive uses of other evaporative systems

would compare to mechanical draft wet towers in the following manner: cooling ponds > mechanical draft cooling towers > spray ponds > natural draft cooling towers > wet-dry cooling towers (Edmonds et al., 1975). Withdrawal rates of the representative conversion systems when operating at 100 mw and using once through cooling would be 260,000 af/yr for the flashed steam method, 306,000 af/yr for the total flow approach, and 367,000 af/yr for the flash binary system.

WATER SUPPLY OPTIONS

The primary water supply options for geothermal facilities in the Imperial Valley are Colorado River water, agricultural waste water, and geothermal steam condensate. The use of imported river water and waste waters in evaporative cooling systems is shown schematically in the top portion of figure 4. Cooling towers or ponds receive water of about 1,000 ppm TDS from an irrigation canal. After evaporation increases the salinity of circulating water by about 4 times, excess salts are discharged via blowdown water into a drainage ditch. If waste waters are used in a wet cooling tower, the concentrating effect of evaporation would result in saline blowdown waters that exceed waste discharge requirements established by the Regional Water Quality Control Board (1975). Two possible ways of disposing of the blowdown would be by reinjection or discharge into a lined evaporation pond. Besides its use in evaporative devices, waste water could be used for once through cooling.

Use of geothermal steam condensate represents a third supply of cooling water (see figure 4). At The Geysers all the power plant cooling water is supplied by condensate, and surplus water is reinjected (Matthew, 1973).

Geothermal facilities in the valley could also rely on condensate for make-up water in cooling systems unless high evaporation rates or blowdown discharges made it necessary to supplement the condensate flow with irrigation or possibly waste water.

The remaining water supplies available for energy projects are Salton Sea water or ground water. Sea water could be used as a source of once through cooling water, or it could be used as make-up water in salt water cooling towers. Ground water, in contrast, would only be suitable for use in evaporative cooling systems.

CONSTRAINTS AND DILEMMAS

The ability of the various water supplies to meet the requirements of geothermal development will depend on constraints comprising institutional policies, the costs of certain water supplies, technological problems, and impacts on the Salton Sea. Acting together these constraints will define the types of dilemmas that may accompany future geothermal energy projects.

Institutional Policies

Imported Colorado River water is the most desirable water for use in power plant cooling systems since it is the freshest water in the Imperial Valley. However, water distributed in the valley by the IID already supports irrigated agriculture. It appears unlikely that substantial quantities of irrigation water would ever be shifted to nonagricultural uses, especially since the irrigation district's board of directors is elected by residents of the district who depend primarily on agriculture for their livelihood. Despite the favorable position of agriculture, the district is empowered by Section 22121 of the State Water Code to make special appropriations of

water for power production. Water may be available for such appropriations if the water conservation program started by the IID saves water that would normally be wasted. At least 100,000 af/yr could be provided for geothermal projects through successful conservation measures; yet even more water may be needed to support the total development of the valley's geothermal resources. Therefore, at some future time geothermal developers could be faced with the dilemma of having to select other less desirable water supplies.

An alternative to irrigation water is the brackish waste water contained in the New and Alamo Rivers and in the drainage structures of the irrigation district. According to a policy adopted by the California State Water Resources Control Board (1975), the use of brackish water is encouraged for power plant cooling rather than fresh water because of the dwindling fresh water supplies in the state. The potential dilemma of this water use policy involves the disposal of saline blowdown waters resulting from the use of brackish waters in cooling towers. Since the discharge of high salinity blowdown waters into drainage ditches in the Imperial Valley would not be allowed under present regulations, a possible solution would be to dispose of the wastes in lined evaporation ponds. However, the land requirements for ponds may conflict with planning standards of Imperial County (1971) that are designed to reduce the amount of arable land disturbed by geothermal projects. Moreover, salts stored in the ponds would ultimately have to be removed to a Class I waste disposal site (California State Administrative Code, Title 23, Section 2531) and none currently exist in the region.

A second policy of the control board that will affect the selection of cooling water options concerns thermal discharges. The board's policy is that thermal discharges from once through cooling are prohibited unless it can be shown by the discharger that "such a practice will maintain the existing water quality and aquatic environment of the State's water resources" (California State Water Resources Control Board, 1975). Chances are remote that geothermal power plants with their high heat rejection rates could use once through cooling and still preserve existing water qualities and aquatic environments.

Institutional policies aimed at the prevention of subsidence caused by the withdrawal of fluids from the valley's geothermal reservoirs could also influence the selection of cooling water for geothermal facilities. Natural subsidence is occurring in the valley and increases resulting from geothermal development could disrupt the tile drainage system that supports irrigated agriculture. As a consequence, state and county policies (California State Administrative Code, Title 14, Section 1971; Imperial County, 1971) already require geothermal well sites in Imperial Valley to tie into a subsidence detection network. If increased subsidence does occur with geothermal projects, new policies may be established that require complete reinjection of the geothermal fluids extracted from a reservoir. A policy of total reinjection would mean that additional water supplies would have to be acquired to replace the condensate used as make-up water in cooling towers operated with flashed steam systems (Goldsmith, 1976).

<u>Technical Problems</u>

The operation of wet cooling towers with brackish waste waters or Salton Sea water involve technical problems that may reduce the acceptability of those water supplies. The basic problems are related to: (1) the

corrosion and fouling of tower components exposed to circulating water (Roffman, 1973) and (2) the control of drift from towers to prevent possible crop damage. A problem that is just as important is the disposal of high salinity blowdown waters. Injection to a geothermal reservoir is an attractive solution, but the technical feasibility of doing so still needs to be resolved. If blowdown waters cannot easily be injected and if the disposal to lined evaporation ponds is impractical, the use of saline water supplies would no longer be possible unless other technical solutions were devised.

<u>Water Supply Costs</u>

Developers of some geothermal power plants may find that one or more of the water supply options are economically infeasible. Geothermal facilities in the Heber and East Mesa KGRAs, for example, could have special dilemmas caused by the costs of collecting and transporting irrigation drainage waters because those resource areas are at the borders of the drainage system where the waste water flows are comparatively small. The economic feasibilities of using Salton Sea water and ground water as sources of cooling water are also questionable. In the case of sea water, the pumping and conveyance costs of bringing it to KGRAs not in the proximity of the sea could make that water more expensive than other supplies. Similarly, the expenses of developing and operating a well field for ground water recovery could result in water that is economically unattractive.

<u>Salton Sea Impacts</u>

Future levels of geothermal energy production in the Imperial Valley could produce increases in salinity and reductions in the surface elevation of the Salton Sea by consuming substantial amounts of agricultural drainage waters that normally flow to the sea. Any significant increases in salinity, however, would conflict with past efforts directed towards the development of salinity control plans whose purpose was to protect the sea's sport fishery from adverse impacts. Reductions in surface level, on the other hand, would be consistent with more recent concerns over the impacts of continued sea level rises. In estimating the impacts of geothermal projects on the Salton Sea, Goldsmith (1976) has shown that a waste water diversion of 60,000 af/yr to support a generation capacity of 1,000 mw would result in a decline of 2½ ft in the sea's elevation and a salinity rise of 3,500 ppm greater than the expected value.

CONCLUSIONS

The process of selecting sources of cooling water needed for power plant cooling may eventually be complicated by dilemmas resulting from constraints that affect the acquisition and use of water supplies. Acquisitional constraints will be mainly determined by the quantity of irrigation water the IID will allocate to geothermal energy projects and potential subsidence control policies. Critical water supply problems could be created if inadequate water allocations occurred along with a subsidence policy that necessitated the reinjection of an amount of water equivalent to the steam condensate consumed in evaporative cooling devices. In that situation geothermal developers would have dilemmas associated with the selection of alternative cooling water supplies that have adverse water quality impacts, technical problems, or less favorable economics. Ultimately the timing and

severity of future dilemmas will depend on the rate of geothermal development, the types of energy technologies implemented, and the nature of the constraints that evolve.

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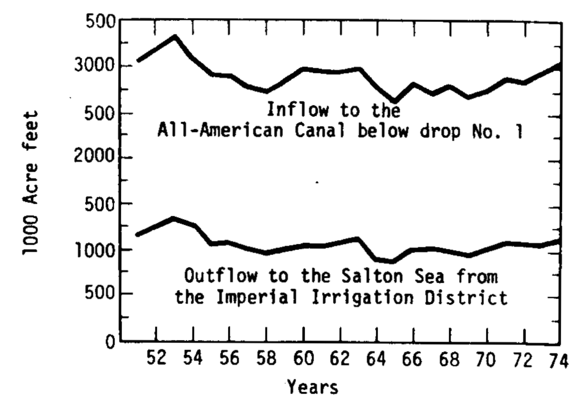

Fig. 1. Water Inflows and Outflows of the Imperial Irrigation District.