THERMAL POLLUTION

PROBLEM--AND SOLUTIONS

By

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INTRODUCTION

Thermal pollution, or excessive heat, is one environmental problem that man must resolve if he is to maintain the quality of his environment. The extent of the problem varies throughout the world as it does within our continental borders.

Biologists, engineers, politicians, and others with an interest in the environment have been concerned for some time about the problem of thermal pollution. More recently, the "unflappable" meteorologists and climatologists are becoming concerned. Although man is finding short-term solutions to the problem (Rainwater, 1970), it is now imperative that we carefully review thermal pollution on a long-term basis. Jaske (et al, 1970) has predicted that energy release rates in the Boston-Washington megalopolis will exceed 30% of the incident annual solar energy by the year 2000 and that the time has come for a serious examination of our national energy policy on a broad front. He proposed a change from a national policy of conspicuous consumption to policies of values based on thrift of resource usage.

Meteorologists point out that temperature increases of our oceanic water masses of 1°F will melt polar icecaps--which would result in the flooding of continental land areas adjacent to these waters. They also point out that a decrease in air temperature of 4°F could trigger an expansion of the polar ice caps. Thus, the layman is continually made aware that this earth is in a delicate state of energy balance with our solar system.

The problem of thermal pollution has many potential solutions, but they can be implemented only through a realistic recognition of the potential seriousness and magnitude of the problem. It is generally agreed that the heart of the problem is directly attributable to the tremendous expansion of the electric power industry which has doubled production to meet demands each decade since 1920.

Thus, with the source of the problem identified, it is my objective here to review the extent of the problem nationally and on the Pacific Coast; to briefly relate electrical demand and cooling water use to the effects on aquatic organisms found in estuarine and coastal waters; and, lastly, to point out some existing and potential avenues for solutions to this problem.

THE PROBLEM

Electrical power use and demand is a significant part of the total energy requirement in the U.S., and has been predicted to be near 50% of demand by 2000 (Figure 1). It is also evident that more energy from electrical production is wasted than is converted to electrical production and consumed. Electrical power use and future demand can be shown to double each decade (Eastland and Gough, 1969) superficially as a result of a better standard of living; however, the major factor for increasing electrical demand is growth of the U.S. population.

Electrical production techniques have improved rapidly, and thermal electric production has taken the front position. Turbine size at thermal plants has increased from a maximum of 1.5 Megawatts (MW) in 1900 (Federal Power Commission, 1964) to 1200 MW in 1970. Basically a thermal electric plant converts heat energy from fuel into electrical energy. The efficiency of this system today on a national average is only 32%--which means that for each unit of heat that is converted to electrical power, two units of heat are wasted to the environment.

The advent of nuclear powered steam plants magnified the problem of thermal pollution. Nuclear plants became competitive with fossil fuel plants in 1966. Nuclear plants are less efficient than fossil fuel plants, so they must be larger than fossil plants to be competitive. Unfortunately,

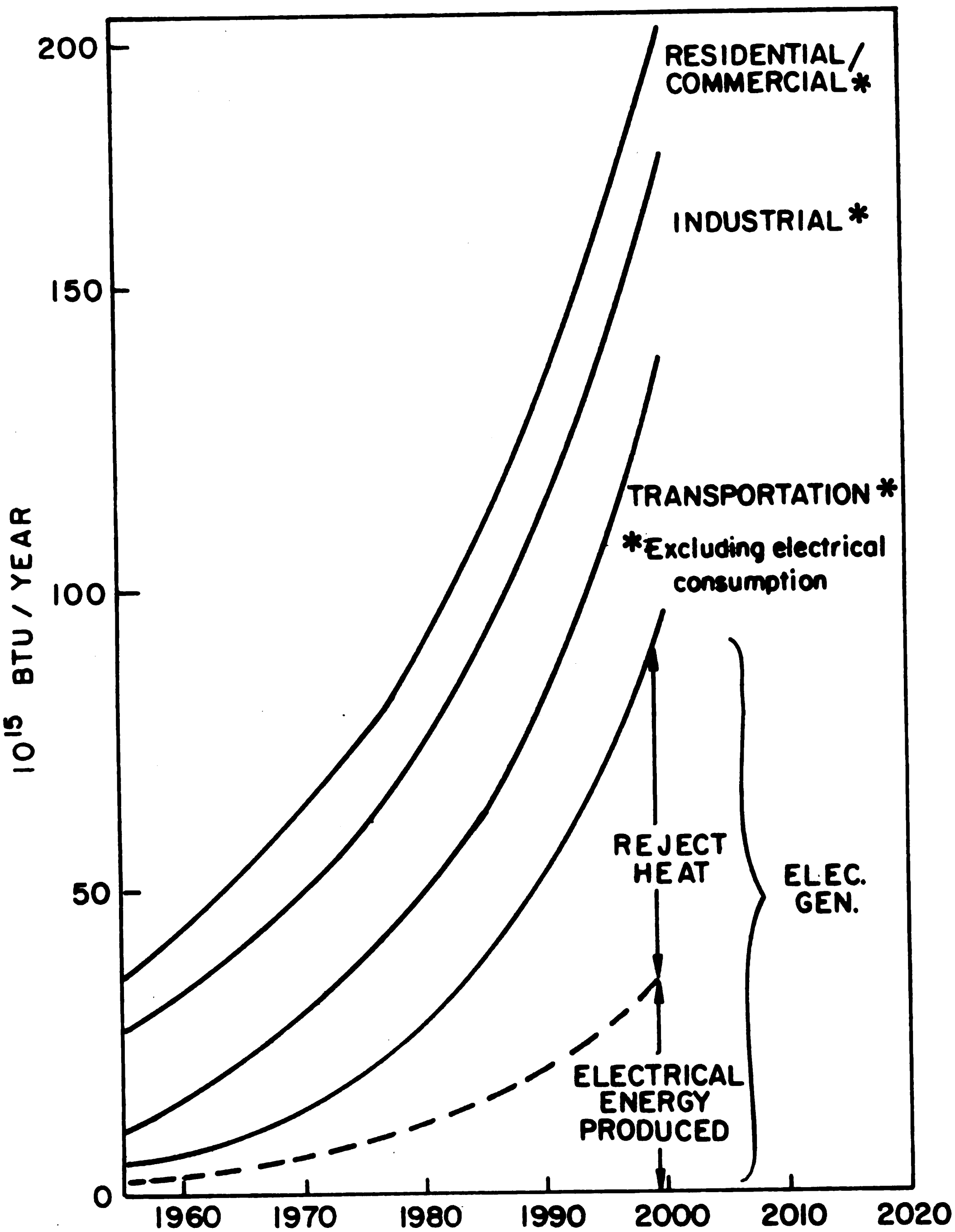

Figure 1. Predicted total energy demand in the United States (from Jaske, et al., 1970).

unless special means of cooling are included in plant design, larger plants result in more heat being ejected into our aquatic environment through larger cooling water systems.

Nationally, electrical demand has been projected to double each decade to 2000, and then double again in two decades (Eastland and Gough, 1969). Discharged heat is predicted to increase tenfold between 1967 and 2000 (Hauser, 1969). If direct cooling were utilized to cool the condensers of all thermal plants, by 2000 over two-thirds of the entire average annual run-off in the U.S. would be needed. Resulting heat loads, when accompanied with low flow conditions, would produce numerous sterile aquatic systems. Off-stream cooling facilities, such as towers and ponds, pose a consumption problem. Jaske, et al. (1970) puts this in a perspective: --if the total national energy requirement from 1970-2000 had to be served by off-stream cooling facilities, this would require the consumption of a quantity of water equal to twice the entire flow of the Colorado River basin annually.

In the last decade utilities have looked toward large river systems, large lakes and estuaries as natural heat sinks. Larger bodies of **water, estuaries, and coastal areas are and have been carefully scrutinized by developers of future plants. However, problems with heated discharges are occurring in these areas** that just several years ago seemed impervious to considerations of adverse effect from thermal pollution. The most notable recent examples are Chesapeake Bay (Foerster, et al., 1970), San Francisco Bay, and Lake Michigan (Great Lakes Fishery Laboratory, 1970). In the case of Lake Michigan, it has been estimated that by the year 2000, over 1% of the total volume of water contained within the 30-foot perimeter of the lake will be passed daily through cooling water condensers of thermal electric plants.

Because of the potential ecological damage to freshwater systems from heated effluents, it has become evident that alternate cooling systems will have to be employed. Developers are also giving more attention to siting possibilities in the estuaries and coastal zones. This has been the past trend in the United Kingdom.

On the Pacific Coast, production will increase from 19.3 MW in 1970 to 222 MW by 2000 (Department of Interior, 1970; State of California, 1970). More important, this expansion will be centered near high density population centers such as San Diego, Los Angeles, Santa Barbara, San Francisco, Portland, and Seattle (Figure 2).

If direct cooling of the condensers is employed at these plants, and this appears to be the trend in California, and estimated 330,000 cfs of water would be utilized by the Pacific Coast plants by 2000 (Figure 3). If this quantity of water was spread along the coast line, it would probably have limited effect on the environment, but the reverse could be true if these plants are centralized at load centers.

Hauser (1969) stated that our country faces a very real and serious problem in disposing of rejected heat and suggested that the problem cannot be solved, in the long run, by increasing allowable temperature limits for natural bodies of water or by permitting special deviations from established thermal regulation standards.

EFFECTS ON AQUATIC ORGANISMS

The most publicized aspect of the thermal pollution problem related to the maintenance of a quality biota for aquatic organisms. These effects have been stated in extremes from the complete destruction of most flora and fauna to actual benefits (Gaucher, 1968). Uncontrolled releases of heat can destroy, dislodge, or debilitate portions of the

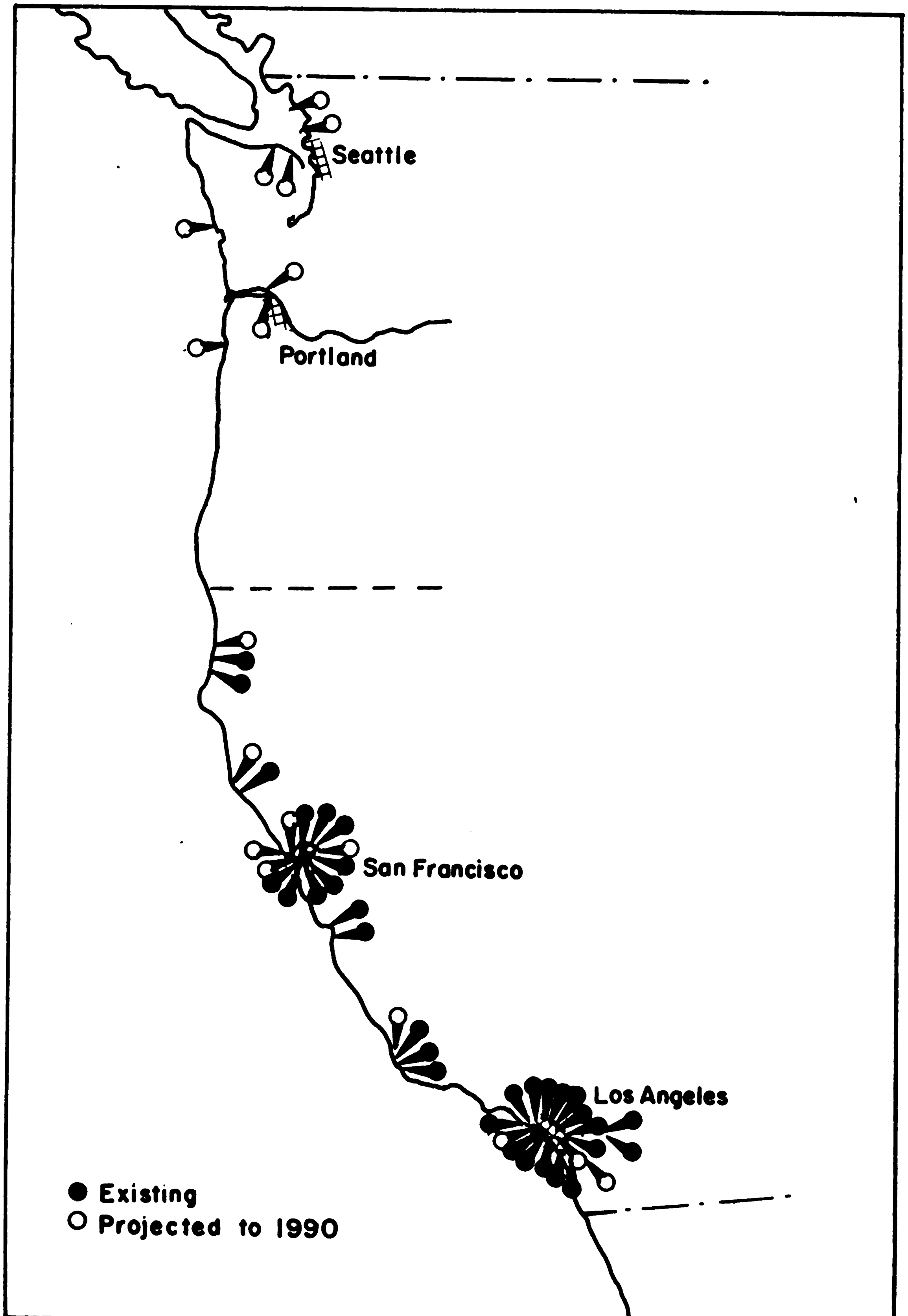

Figure 2.--Existing and projected* thermal electric plants on the coast and estuaries of the Pacific Ocean, U.S.A. (*From State of California, 1970

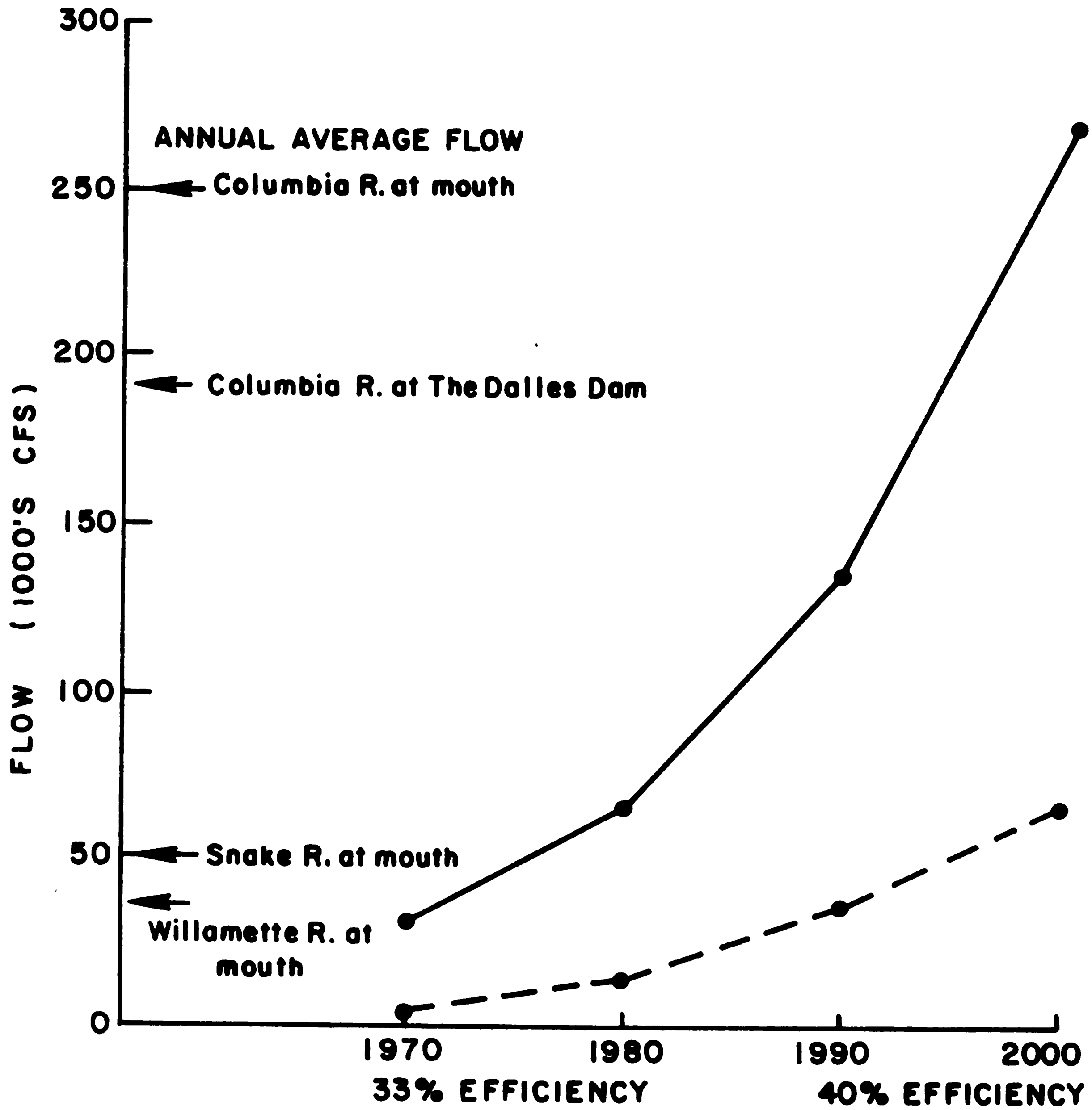

Figure 3.--Estimated quantity of cooling water needed* for thermal electric production at plants on the Pacific Coast, 1970-2000. (* Direct salt-water cooling assumed).

aquatic biota; controlled releases of heat in canals, etc., however, may benefit some desirable organisms.

Although the discussion here is centered on thermal pollution, it is well to emphasize at this point that thermal electric plants divert and utilize large quantities of water. The average 1000 MW nuclear plant would utilize 1500 cfs and increase temperatures of intake water by 20°F. In addition to problems from the discharge of waste heat, plants that divert water of this quantity can also have the following problems:

1) intake screening
2) mechanical damage to organisms from pumping
3) organisms passing through condensers where sharp temperature increases occur
4) chemical effects on organisms through use of algicides, fungicides, and buffering solutions

Thermal pollution can effect aquatic organisms directly, indirectly, and synergistically. In a review of past and present work on the effect of thermal plants on marine and estuarine organisms, it was evident that many experiments represented only a quick survey or a single experiment (Adams, 1968; Zeller and Rulifson, 1969). However, more comprehensive studies are presently being conducted or are in the planning stages and conclusions are not available at this time.

In generaly, the effect of heated discharges has been to reduce numbers of species native to the area, normally those at the edges of their specific g eraphical ranges, especially cold-water species. Although most of my research has emphasized effects of water temperatures on species of aquatic organisms in fresh water and estuaries, I am concerned with the lack of knowledge on the effect of temperature increases on organisms found in the saline waters of our Pacific Coast environment. For example, little is known on the thermal tolerance of our economically important migratory species once they are in the estuarine and coastal environment.

I am not going to dwell on this subject, but I would like to urge that cooperative research programs be initiated now to determine the effect of heat on coastal organisms. We must determine the temperature criteria of coastal and marine species if we are to provide a realistic base for temperature standards of and industrial development guidelines for marine waters.

Obviously, much more, **research is needed. Recently a cooperative** between FWQA, NMFS, and AEC was initiated to determine the temperature criteria for anadromous fish in the Columbia River. The program has been tremendously successful. This cooperative approach between industry and environmentalists should be duplicated for our estuarine and coastal waters.

One other point: On-site research is needed. This fact cannot be over emphasized. Researchers need to investigate the impact that potential plants will have on the aquatic environment at the site prior to the time a "go" or "no-go" decision for plant construction is made. Studies by the National Marine Fisheries Service in the Columbia River have shown that thermal tolerances at specific locations vary. For example, thermal tolerance levels of chinook salmon tested in the Columbia River water are lower than those of chinooks tested in British Columbia waters. The synergistic effect of N_2 supersaturation is suspected to have contributed to this difference, but not consistently (Snyder, Craddock, and Blahm, 1970).

SOLUTIONS

We need to encourage development of technology that will provide solutions to the national problem of thermal pollution. We now have regulations at the State and Federal levels that will aid in the evaluations of proposed sites and that provide for protection of the freshwater environment. These regulations need to be strengthened with biological facts concerning the thermal tolerance of organisms found in the marine and estuarine environments.

Short-term solutions obvious to us now are off-stream cooling facilities. If we do not discharge waste into water, aquatic organisms will not suffer; but this aquatic solution causes higher consumptive losses than would occur from direct cooling and could drain surface (fresh water) supplies that will be needed for domestic use. At our present state in technology, we should carefully evaluate each proposed plant, conduct meaningful on-site studies, and consider all alternatives carefully before construction is undertaken.

The long-term approaches, however, must be very carefully reviewed; we must encourage participation by a variety of technological fields. Some possible long-term approaches are:

1) change the national policies on federal subsidy of energy systems (from conspicuous consumption to thrift);
2) encourage development of higher efficiency in our existing systems;
3) accelerate development of new energy production systems;
4) develop projected land-use plans that will distribute plants along our coasts rather than clustering them at load centers;
5) encourage the acceleration of research on long-distance energy transmission systems;
6) renew interest in underwater and underground placement of future energy systems;

7) encourage aquaculture and agriculture systems development in conjunction with waste heat discharge;

8) and finally--and most interesting to me--develop alternatives to the disposal of waste heat into waters or the atmosphere.

At this point in time, we have developed technology only for the disposal of waste heat in the atmosphere and the hydrosphere; there appears to be a third alternative. Tsongas, et al. (1970) have proposed the disposal of heat in space--an idea that I feel is very worthy of considerable development. The authors suggest that waste heat can be converted to long wave radiation in "radiators" and be dissipated through the 8-12 micron wave length earth "window" into space.

In the past, industries were not confronted with restrictions on the discharge of waste heat to the aquatic environment. Heat absorption was considered a "proper use" of our nation's waterways. Recently, however, a strong awareness and concern about the present level and the potential expansion of thermal pollution has been expressed by the public, and State and Federal water resource agencies. In conclusion, wholesale disposal of heat into the aquatic environment must be either reduced, or stopped. It is hoped that through a recognition of the magnitude of the problem, the development of solution technology can be encouraged.

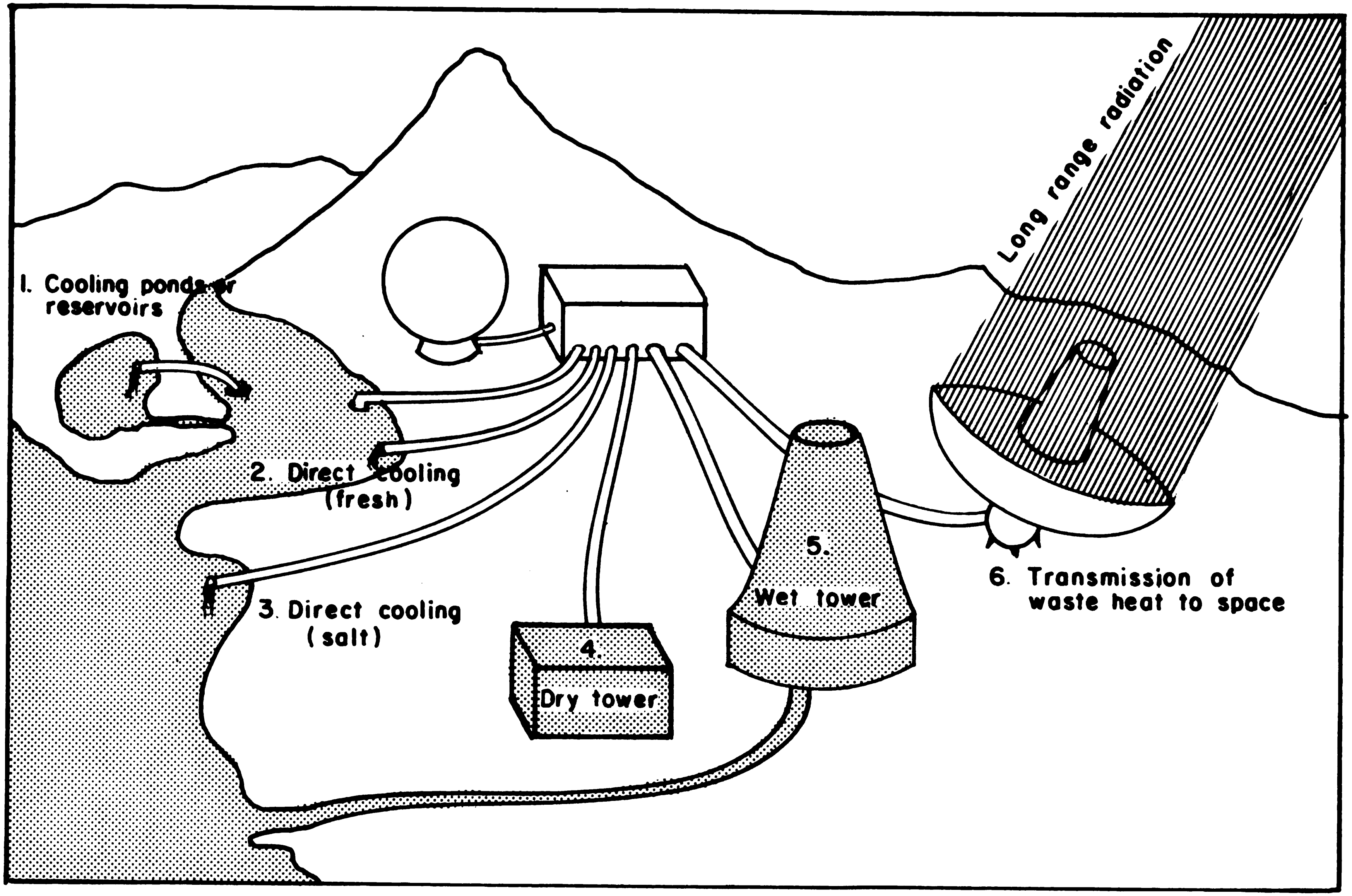

Figure 4.--Existing and potential methods of heat dissipation from thermal electric plants.

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