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Mid-Columbia

NUCLEAR POWER

Proceedings of a Conference
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Hermiston, Oregon, February 1971

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INTRODUCTION

Proposals for nuclear power development in the Mid-Columbia region of Oregon have generated considerable interest among the local communities. Realizing that such development would have significant effects upon both the economic situation in the region and the quality of their environment, representatives of community interests initiated a program to educate area residents about the advantages and disadvantages of such deveoopment.

The Mid-Columbia Nuclear Power Educational Committee was formed to work with Oregon State University Cooperative Extension Service personnel in developing an appropriate agenda for a conference on nuclear power development. Experts in each field were invited to speak and meet with the public. The conference was brought before the people on February 16, 1971 at Hermiston, Oregon.

On the same day, the joint Federal State Nuclear Power Siting Task Force for the Mid-Columbia area appointed by Govenor McCall met in Hermiston as part of their assessment of the environmental impact of nuclear power development in the region. Mr. L. B. Day, the chairman of the task force, gave the keynote address at the conference. The task force has since published their recommendations for the region in a report entitled *Environmental Aspects of Nuclear Power Development - Mid-Columbia Area of Oregon*.

The proceedings of the conference are reported here to bring the information disseminated by the speakers to people in the Mid-Columbia area and other areas of the state who were not able to attend. Much factual and technical information on an issue of great public concern was presented and explained there in a manner easily understood by most citizens. The educational value of such material will remain significant as nuclear development in the Pacific Northwest proceeds.

KEYNOTE ADDRESS

L. B. Day

The Federal-State Nuclear Power Siting Task Force (Technical) was created to evaluate the effect upon the environment of nuclear power plant construction in the Mid-Columbia area. To be most effective their evaluation must take into consideration the potential for using plant cooling water effluent in irrigation of nearby lands.

Plant siting and irrigation have received a considerable amount of attention in the Mid-Columbia area. Various community leaders, including representatives of the Umatilla and Morrow County Port Districts, have for some time been drawing attention to the possibility of building a nuclear power plant in this general vicinity. Numerous studies of irrigation potential have been undertaken by both public and private groups and, indeed, a significant amount of land has been brought under irrigation. Certainly, all those who have pioneered in these matters have made a very real contribution and we are grateful to them.

In observing the various programs--both on plant siting and irrigation--that have been undertaken in this region, it became apparent to me that a coordinated effort was needed. I therefore discussed the matter with Governor McCall, who concurred. The result was the creation of the Federal-State Technical Task Force which is meeting here today.

Studies to date, including the Bureau of Reclamation's study of the Cold Springs project, the Boeing Company's proposal for study of the Boardman bombing range, and various other public and private efforts, indicate that there is a good potential for irrigation in many parts of this district.

The development of this irrigation potential is not only vital to this area but will serve the general public by furnishing additional agricultural products. As an example of the tremendous economic boost agriculture can give to an area, the 1970 Umatilla County potato crop brought in $840 per acre, according to the county agent's figures. Subtracting the 42 percent value added by handling as fresh pack, the farm gate value is $500 per acre. If this $500 per acre crop is processed locally into frozen potato products, the value is tripled to $1,500 per acre (Oregon State University Special Report 183).

Ten thousand acres of potatoes could bring $5 million at the farm gate and $16 million in direct economic activity into the area. How many potentially valuable acres are there in this area? The study of Oregon's ultimate water needs completed in 1967 indicated that there are 1.2 million acres in the Umatilla Basin susceptible to irrigation. The Bureau's Umatilla Basin study projects the irrigation of some 100,000 acres. Morrow County has upwards of 200,000 acres that could be irrigated. Even partial development of this area's irrigation potential would bring in a staggering dollar volume from new local business benefiting us all.

The area is well worth considering as the site for one or more nuclear power plants. The most obvious resource is the enormous amount of water available from the Columbia River. Some of the objections which have arisen in other areas of the state would be automatically avoided because of the sparse population in this area. The general political climate, the apparent willingness or even eagerness of the local populace to have plants built in the region, is also very important.

However, a preliminary reconnaissance survey is imperative to determine if these advantages would be precluded because of hazards to the environment. During the next three days the task force will more clearly identify the resources and the potential. The construction of a nuclear power plant and the development of irrigation are thought by many to go hand in hand; however, we must be realistic and recognize that there are certain problems:

(1) The potential for irrigation is immediate. Some of the land can be developed promptly and, indeed, is being developed in various privately-financed projects. Some of the other more extensive programs may depend upon further development by the U.S. Bureau of Reclamation.

(2) The hydro-thermal program has cast plant development plants through most of the 1970's. Therefore, at the very earliest we probably cannot expect a nuclear plant to be built in this area until the 1980's. It might be short-sighted to tie irrigation solely to the reality of the nuclear plant. Rather, while the feasibility of the area for a nuclear plant site is being explored, development of irrigation should go forward. Both of these activities should be programmed so that later, if feasible, they can be welded together.

(3) While low population and high public acceptance are two very desirable qualities in choosing a nuclear plant site, there are a number of more technical questions dictated by safety and economic considerations to be studied and evaluated. The U.S. Atomic Energy Commission is charged with protecting the health and safety of the public as concerns nuclear power plants. They are hard taskmasters, zealously guarding a perfect record; no one has ever suffered radiation injury from a power reactor. They require painstaking examinations of meteorology, seismology, and hydrology before site approval is granted. Seismology and geology bear directly on the economics of structural design.

Other considerations include cost of transmission to load center and type of cooling system and its effect on efficiency. For a 1100-MW plant small increments of fuel cost can be quite significant (0.1 ml/kwh - $750,000/year). Provisions for emergency cooling, site access, and transportation of heavy equipment must also be studied. After the safety and feasibility of a site have been established, the economic considerations can be brought to bear in evaluating the mutual benefits of irrigation and power systems.

(4) There has been a considerable amount of confusion and misunderstanding over the means by which a nuclear plant might be financed.

Various proposals have been put forth by port districts, for the construction of a nuclear power facility with the use of the cooling water effluent for irrigation. To arrive at a means by which the construction of a nuclear plant in this area could be utilized for irrigation as well as power, we can benefit by eliminating the ways in which this cannot be done.

First, according to a 1970 opinion of the Attorney General of Oregon (34 Op. AG 927), the port district itself is prohibited from entering into the business of supplying electric energy to the public. According to that opinion (ORS 777.130 [13]), the law specifically limits the port district to supplying electric power for its own use and prohibits the operation of a power plant in competition with other suppliers. Hence, the port district could not construct, own, and operate a nuclear power plant and sell the output to others although it is authorized to produce power for its own use.

The same opinion of the Attorney General concluded that the port district does have authority to construct and lease to private utility a nuclear-powered electric generating plant. Thus, the port district could finance the construction of a nuclear power plant and lease it to a privately-owned utility or any other entity authorized to lease and operate such a plant and sell power to the public.

However, the effect of the industrial bond legislation included in the Revenue and Expenditure Control Act of 1968 (Public Law 80-364; 82 Stat. 251) must be considered. The effect of this legislation is that the interest on bonds issued by a political subdivision of the state, such as an Oregon port district, will not be tax exempt if all or a major portion of the proceeds of the bond issue are used to finance the construction of a nuclear power plant which is then leased to a private corporation or any other nonexempt person. Nonexempt persons are any corporations or entities other than governmental units and certain types of charitable organizations. The Treasury Department has issued no regulations on what constitutes a "major portion" of the proceeds of a bond issue, but there is some indication that tax exemption on bond interest would be lost if over 25 percent of the facility in question were used directly or indirectly by a nonexempt person. While the port district is apparently empowered by its own statute to construct a nuclear power plant and lease it to a privately-owned utility, it would have to finance such a plant with taxable bonds. The applicable interest rate on such bonds would be at least as high as that currently paid by private corporations on their own bonds, and the participation of the port in such a transaction would serve no purpose.

Facilities used for "local furnishing of electric energy" are exempt from the industrial bond restrictions of the federal tax laws. The Treasury Department has issued no regulations defining what is covered by "local furnishing." However, Senator Long, Chairman of the Joint Committee on Internal Revenue Taxation, in a March 1970 letter to the Secretary of the Treasury stated that in view of his committee, "local furnishing" was not intended to include regional supplying of electric energy. Rather, it was intended to limit the facilities under this exemption to a single locality, meaning a municipality or county, or at most, two contiguous counties. Obviously, power distribution from a large nuclear plant in this area would not come within this exemption.

The powers of a port district to distribute water for irrigation purposes are contained in a 1969 amendment to the port district law. According to an opinion of the Attorney General of Oregon issued December 8, 1969 (34 OP. AG 895), the port districts in counties named in the 1969 amendment (including Morrow and Umatilla) have authority to distribute water for irrigation purposes, but this authority is limited to distribution of water previously used for treatment of industrial waste including prior use of the water as a coolant for a nuclear energy facility. It would seem, therefore, that under appropriate arrangements with the owners of a nuclear energy facility, a port district could take the cooling water effluent of such a facility and distribute it for irrigation purposes.

Recognizing that even if irrigation and power generation potential are complementary, development timing is not immediately compatible, I have explored with various individuals and groups methods by which we might progress.

Because of their interest in the area, one of the organizations which I contacted was Pacific Power & Light Company. The potentials for both irrigation and power generation have been discussed with Pacific by various individuals on a number of occasions, and the company has expressed a desire to help in any way possible. If the necessary studies in the area determine a desirable site that can be licensed for a nuclear power plant where the surrounding terrain would permit an irrigation project to be tied to the plant, then, as a participant in the plant, the company would be willing to advance to the irrigation project prior to construction any net savings that would be realized by once-through cooling. Reservoirs that would be developed would serve the needs of both the irrigation project and the plant cooling requirements. By its willingness to contribute potential net savings in advance, Pacific would make possible the timely pursuit of the irrigation program as well as assuring orderly construction of the plant at such a time as it would be scheduled into the Northwest hydro-thermal program.

By your presence here today, each of you has indicated his interest in this area, his concern for the necessity of identifying nuclear power plant sites, and his recognition of the potential for irrigation development. Your task force is anxious to secure as much information as possible from each of you. We would also solicit your cooperation in properly relating the sometimes difficult problems to the unquestionably vast resources of the Mid-Columbia area. Let us jointly and cooperatively, then, move forward with the work of our task force.

NUCLEAR POWER PLANTS— A COMING REALITY IN THE PACIFIC NORTHWEST

Alan H. Robinson

Beginning in 1974 we will need one nuclear power plant every year until 1985 to meet our electric power needs in the Northwest. For many years the Pacific Northwest has relied on hydropower suppled by dams. These dams produce electric power for about 2 mills per kilowatt hour. No thermal power plant can yet make power that cheaply. However, we have almost run out of dam sites. There are now over 100 dams on the Columbia River system. The present installed capacity of the Bonneville Power Authority is about 9000 megawatts (MW). This is equal to the output of nine new nuclear power plants. The total capacity in the Pacific Northwest is about 20,000 MW.

The demand for electricity is doubling every ten years. Thus, by 1981 we will need twice the present installed capacity. Part of this need will be met by increasi the electrical producing capacity of the present dams and building a few new ones. After that, the only way to make additional power is with fossil fuel or nuclear fuel thermal power plants. I hope that they will be nuclear because they are cheaper and cleaner.

Figure 1 shows a diagram of a coal-fired fossil fuel plant. The heat from the burning coal is used to boil water. The steam is then passed through a turbine which turns a generator, thus producing electric power. After the steam leaves the turbine it is condensed back to water and returned to the boiler. During the condensing process a large amount of heat is removed from the steam. This heat is then put into the cooling water and winds up as thermal pollution in the environment.

Only part of the heat from the coal is converted to electricity. About 38 percent goes into producing electric power. The rest is rejected to the cooling water. Thus, for every 1000 MW of power,nearly 2000 MW of heat is put into the environment. The effect of this waste heat can be minimized by using cooling towers or ponds. In some cases beneficial use of the heat can be made.

The coal-fired plant has some undesirable features. It requires about 10,000 tons of coal a day, or about 300 train loads a year, each train having 100 cars full of coal. A coal-fired plant is a major contributor to air pollution. New York City reported that for the years 1967-68 over 80 percent of the oxides of nitrogen, sulphur dioxide, and particulate matter (three of the major air pollutants) came from the burning of fossil fuel to make electricity and heat buildings. Coal-fired plants also release the small amount of radioactive material that is contained in the coal. In a study done by the U.S. Department of Health, Education and Welfare it was reported that a Tennessee Valley Authority coal-fired plant gave a greater radiation

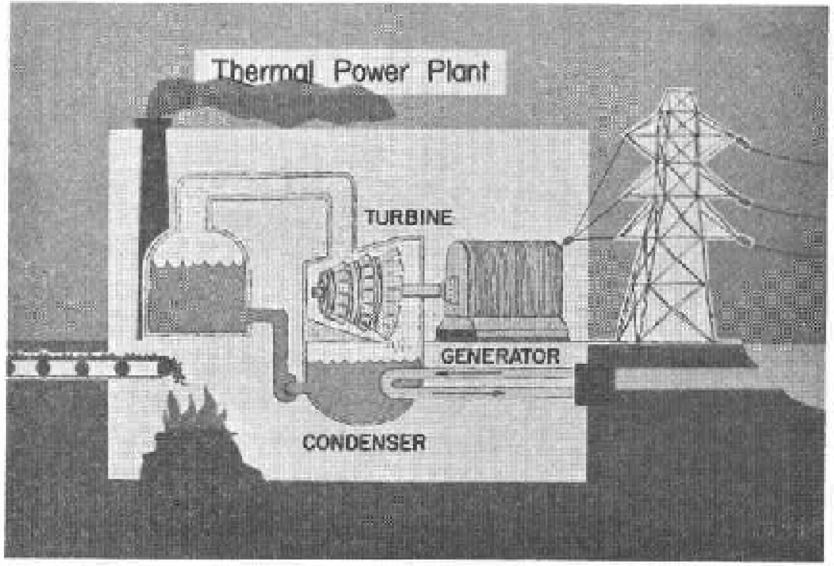
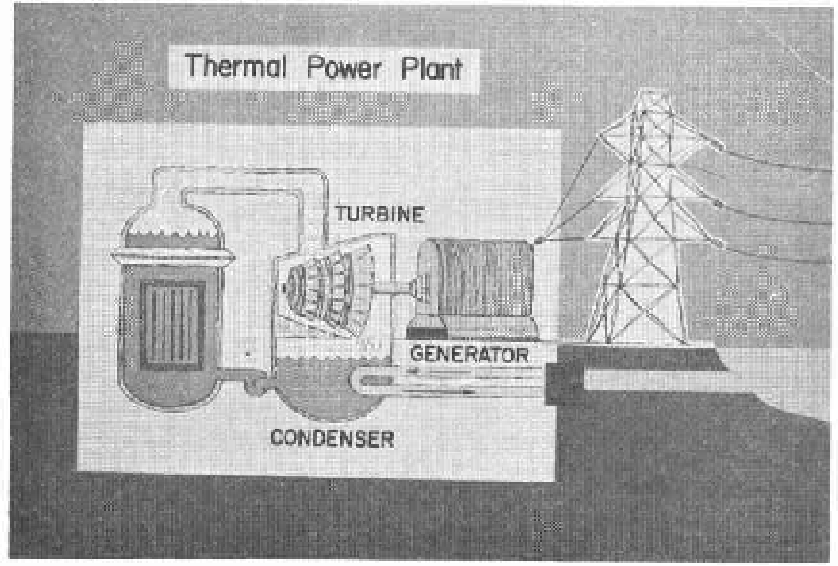


fig.1



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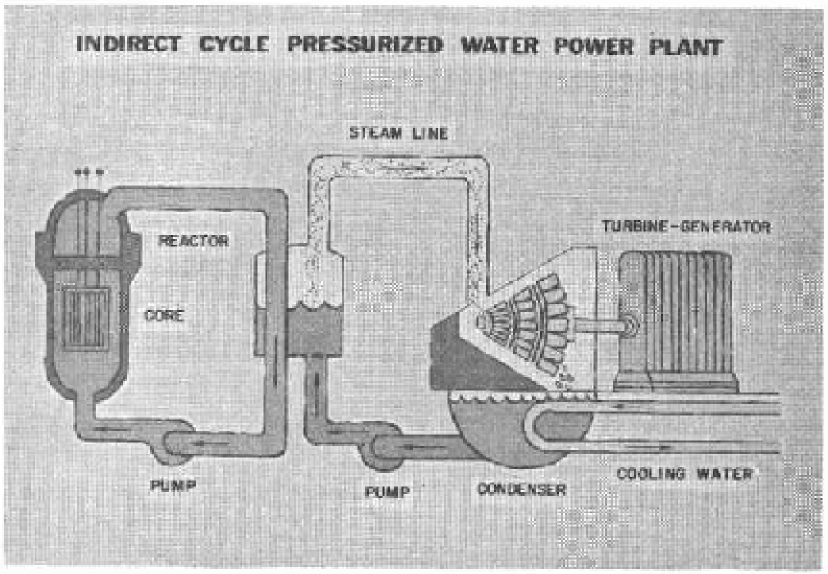

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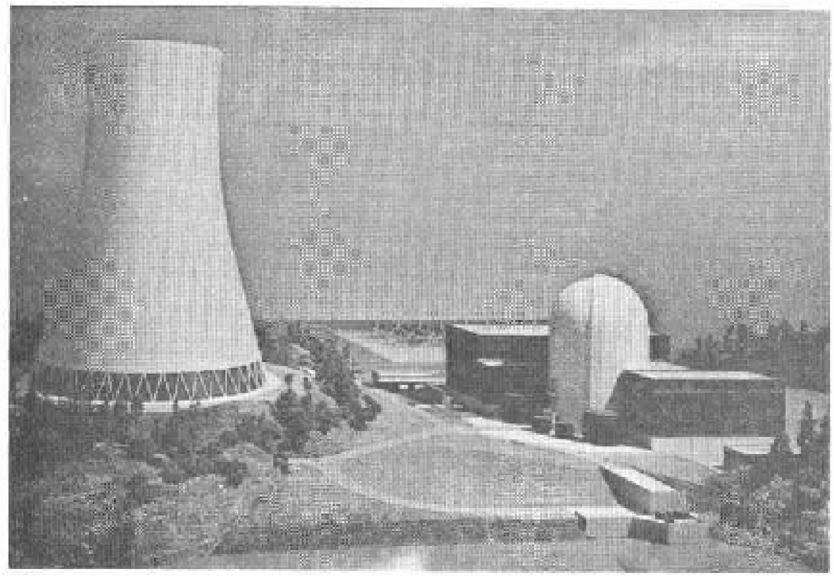

fig.4

dose to the environment than a pressurized water reactor (Power, April 1970). The cost of power from a new coal-fired plant is about 5 mills per kilowatt hour (kwhr).

Figure 2 shows the diagram of a nuclear reactor power plant, known as a boiling water reactor (BWR). The main difference between the nuclear plant and the coal plant is that the water is boiled by using the heat from nuclear fuel. The rest of the cycle is essentially identical. Thus, the steam produced from the nuclear reactor passes through a turbine which turns a generator, producing electricity. As in the coal plant, the steam is condensed back to water and returned to the reactor to be reheated again.

The nuclear power plant cycle is less efficient than the coal plant. In a nuclear power plant about 33 percent of the heat from the reactor is converted to electricity. The remaining 67 percent is rejected to the environment.

The nuclear power plant, which consumes four ounces of uranium oxide daily per megawatt of electricity, is cleaner than a coal-fired plant because the nuclear plant does not give off any air pollution. It will produce electric power for about 3 to 4 mills per kwhr.

A variation of the nuclear power plant called the pressurized water reactor (PWR) is shown in Figure 3. In this cycle the water in the reactor is under 2000 pounds per square inch (psi) pressure and does not boil. The water from the reactor passes through a heat exchanger (steam generator) and causes the water in the secondary side to boil. Steam from the heat exchanger then passes through the turbine as before. The rest of the cycle is the same as the boiling water reactor power plant.

The efficiency of the PWR plant is also about 33 percent and it produces electricity for about the same cost as a BWR. The Trojan nuclear plant to be built by the Portland General Electric Company is an example of a PWR. A picture of the model of PGE's plant is shown in Figure 4.

All thermal power plants will release heat to the environment. About 1 million gallons of water per minute are required for cooling the condenser. In the future this water, which is normally heated to about 20°F above the ambient water, may be used to grow greenhouse crops such as lettuce and tomatoes. The most promising beneficial use of the water in the near future is for irrigation. A 1000-MW plant can provide enough water to irrigate about 200,000 acres. When sprayed into the air, the cooling water loses most of its heat value.

To pump 1 million gallons per minute up 500 feet from the Columbia River will require 90.4 MW of power. At 10 mills/kwhr this means the water pumping cost will be 1.5¢ per 1000 gallons at 500 feet above the river and double that at 1000 feet up.

In order to use the water for irrigation it will be necessary to have a distribution system and a canal system to return the water if irrigation is not required. If the reactor is built near a reservoir, return canals would not be required. The reactor could use the reservoir as a cooling pond and also pump water from the river to the reservoir. Irrigation water could then be taken from the reservoir as required.

In addition to the heat released, all nuclear power plants release small amounts of radioactive material. This material consists mostly of the radioactive gases; argonne, xenon, krypton and iodine. Liquids containing tritium and radioactive iron and zinc are also released. The dose of radiation from the reactor plants to people in the area is very low. The average dose at plants operating today is less than 5 millirem (mrem) per year. In many cases the dose to the public is actually well below 1 mrem per year. To put this in perspective let's compare it to other sources of radiation in the environment.

The natural radiation or background in the environment is about 125 mrem per year, over 25 times as much as a reactor might add. An average chest X-ray gives about 200 mrem. A set of four dental bitewing X-rays gives over 1000 mrem. In mile-high Denver, Colorado the background is about 250 mrem per year.

There are many ways one can get 5 mrem of radiation instead of standing next to a reactor power plant. Each of the following will give you about 5 mrem of radiation.

(1) Flying by jet from Portland to New York and returning at 35,000 feet. (Dose from cosmic radiation)

(2) Vacationing for 10 days at a mountain resort above 6000 feet.

(3) Going skiing five weekends above 6000 feet.

(4) Living across the street from the U.N. building. (Dose from the earth materials used in construction).

In summary, nuclear power is the cleanest and cheapest form of thermal power we can build. Additionally, it offers the possibility of irrigating large areas of land.

YOUR RADIATION INVENTORY

The release of low level radioactive effluents from a nuclear power plant into the environment and the subsequent effect on people is a major issue. But as we in the nuclear industry know, all of us live in a radioactive world. Radiation is all about us. It is part of our natural environment. To put the radiation issue in perspective, you can get a general idea of the amount of radiation you are exposed to every year--and how much more a nuclear power plant might add to that exposure--by filling in the form below.

The radiation inventory below is expressed in terms of millirems per year. A mrem is a measure of the biological effect of absorbed radiation. "Milli" is 1/1000th, and "rem" is an acronym for Roentgen-Equivalent-Man. You could increase your annual radiation exposure one mrem per year by: moving to an elevation 100 feet higher than where you presently live; increasing your diet by four percent; watching one additional hour of TV; or taking a week's vacation at mile-high Lake Tahoe.

Common Sources of Radiation	Your Annual Inventory
WHERE YOU LIVE:	
Location: Cosmic radiation at sea level	45
(add 1 for every 100 feet of elevation. Typical elevations are San Jose Airport; 50 feet; Saratoga-Los Gatos and Livermore Airport: 400 feet). 1 x ____ =	____
House construction (based on 3/4 time factor): Wood, 50; Concrete, 70; Brick, or Stone, 100.	
Ground (based on 1/4 time factor): U.S. average	____
WHAT YOU EAT DRINK AND BREATHE:	
Water and Food: U.S. Average	25
Air: U.S. Average	5
HOW YOU LIVE:	
Jet airplanes: # of 6,000 mile flights ____ x4 =	____
(Jet crew members use 300 flights).	
Radium wristwatch dial add 2	____
Television: # hours per day ____ x 1 =	____
X-rays (dental, chest, etc.): U.S. Average	55
SUBTOTAL (mrem per year):	____
Compare your exposure to U.S. Average of 220.	
HOW CLOSE YOU LIVE TO A NUCLEAR POWER PLANT: (pick one)	
At site boundary: # of hours per day ____ x 0.2 =	____
One mile away: # of hours per day ____ x 0.02 =	____
Five miles away: # hours per day ____ x 0.002 =	____
GRAND TOTAL (mrem per year)	____

The following figures should help you judge the severity of your grand total. The maximum permissible exposure to a member of the public according to the U.S. Atomic Energy Commission standards is 500 mrem per year. It takes an acute exposure of 25,000 mrem for routine medical detection of biological effects in your body. And statistically, 50 percent of the people who receive an acute exposure of 500,000 mrem will die within 30 days. If the latter two acute exposures were protracted over a year's time, the figures would be accordingly higher.

CRITERIA FOR THE SITING OF NUCLEAR POWER PLANTS

C. H. Wang

The Pacific Northwest (PNW) Joint Power Planning Council, in a conference dated December 1970, indicated that by 1990 large thermal plants capable of producing 17, 600 megawatts electric (MWe) will have to be installed in the region to meet the forecasted power requirement. Assuming an average generating capacity of 1,100 MWe for a modern power plant, this would mean approximately 16 giant thermal power plants will be constructed within the next two decades. As many as 8 of them could be built in the state of Oregon to meet the forecasted total power loads amounting to 13,510 MWe in the Portland area and 7,550 MWe in the Willamette Valley area. As fossil fuel is not readily available in Oregon, and an air pollution problem is associated with fossil-fuel-fired plants, it is likely that these projected thermal power plants will utilize nuclear fuel.

Siting of nuclear power plants is a complex issue. Safety aspects and environmental impact must be taken into primary consideration. To accommodate the projected large number of nuclear plants in Oregon, detailed plans must be carefully made to insure that energy resource development will be orderly, aiming at the preservation of the quality of both life and environment. As pointed out in the report on "Considerations Affecting Steam Power Plant Selection" (The Energy Policy Staff, Office of Science and Technology, 1968), the plans for siting of a nuclear power plant should consider the following elements:

(1) Compliance with the safety criteria for nuclear power plants as prescribed by AEC,

(2) Compliance with air pollution criteria and standards and water quality standards as established by federal and state agencies,

(3) Opportunities for public recreation at plant sites,

(4) Aesthetic values of the plant and its associated facilities,

(5) Rural development plan,

(6) Lead time requirement for reliability of service,

(7) Security aspects,

(8) Transmission problems,

(9) Plant size with respect to projected bulk power need,

(10) Multiple use of the facilities.

A statutory set of criteria for siting of nuclear power plants has not yet been developed by either the federal or state agencies. However, AEC in its rules and regulations (Title 10, Code of Federal Regulations, Part 100) spelled out principles underlying site evaluation with regard to distance between plant site and population center and other parameters. More recently, several states have developed informal sets of siting criteria, although these guidelines are primarily concerned with the issue of environmental impact.

Analysis of various considerations underlying site selections reveal that specific principal criteria can be categorized as technical, environmental, and economic factors. These factors are elaborated in some detail in the following:

TECHNICAL FACTORS

Proximity to population density

The reactor site criteria described under AEC rules and regulations (Title 10, Code of Federal Regulation, Part 100) stipulated that a nuclear reactor should be located in a low population zone of adequate size and a population center distance of at least 1 1/3 times the distance from the reactor to the outer boundary of the low population zone. Guidance in developing the exclusion area, the low population and the population center distance is provided in a technical document, TID 14844, published in March, 1962.

The closer the reactor is located to the population center, the more elaborate is the design required for the reactor containment. The general trend at the present time is to locate a power reactor at least 20 miles from a population center. However, in the future, power reactors with more adequate containment designs may be located in suburban areas, thereby permitting the use of waste heat for central heating and central refrigeration.

Unlike coal-fired power plants which require up to 1,200 acres for plant and fuel storage, nuclear fuel power plants will require only 200 to 400 acres depending on the site of the plant.

Geology and Foundation

Siting of a nuclear power plant requires the same geologic formation as other major construction. Information needed includes depth to bedrock, character of the bedrock formation, attitude of the bedrock formation, indications of land slides that may suggest instability of the formations, and general geologic history.

It is most important to determine if a satisfactory foundation for the plant structure is available. Possible ground variation due to differences in foundation conditions must be carefully evaluated.

Seismology

The presence of faulting could present foundation problems such as instability of rock foundations during an earthquake. As stipulated in the AEC regulation (Title 10, Code of Federal Regulations, Part 100), no facility should be located closer than 1/4 mile from the surface location of a known active earthquake fault.

Hydrology

Consideration should be given to such issues as depth to ground water and indications of ground water flow directions. Grading for a plant should be set above the elevation of the greatest flood that may reasonably be expected, based on actual storm and flood records and particularly on possible disasters such as the collapse of a giant dam.

The cooling water source should be made dependable for all conditions in which the plant is expected to continue operation and for the removal of decay heat after the reactor shutdown. In addition, an independent source of cooling water for emergency reactor shutdown must be assured.

Access

Access to the plant should be carefully evaluated taking into consideration the nature of the construction task, transport of very heavy equipment, and fuel transport. Good highway access is essential for a nuclear power plant. Rail or water access is very desirable for delivery of heavy equipment such as assembled reactor facilities, although field assembly is becoming more common.

Transmission Provisions

The transmission lines connecting a typical 1,000-MWe nuclear power plant into the existing transmission system at 500 kilovolts would occupy right-of-way totaling 100 to 150 acres for each mile. Consequently, the availability of an existing or planned transmission network is one of the most important factors in siting selection.

ENVIRONMENTAL FACTORS

Thermal Pollution

Data on stream flow, temperatures, stratification and depth must be examined in connection with the size of the container and pumping facilities to insure that the temperature of the body of water receiving the cooling water discharge will not exceed the thermal criteria set by state and federal regulatory agencies.

Meteorology - Air Pollution

Detailed meteorological data must be gathered on a seasonal and annual basis at the proposed site. These data are of great importance in designing the air pollution control features of the plant. Air pollution problems associated with nuclear power plants are:

(1) Emission of radioactive gases which have to be diluted drastically to a level below the permissible level at the boundary of the plant site.

(2) Emission of an enormous amount of water vapor when waste heat is removed by means of a cooling tower. The possibility of fogging and other alterations of atmospheric conditions must be evaluated.

Radiation Pollution

Release of radioactive materials either in gaseous or liquid form by nuclear power plants must be at a level below the permissible air and water concentration levels set forth by the AEC. Experience gained in operating the existing modern nuclear power reactors indicates that the level released is generally only 2 to 3 percent of the permissible limit. The AEC recently stipulated that the level of radiation release must be kept as low as practicable, and recent technological advances may make the radiation pollution from a nuclear power plant an insignificant issue.

Nevertheless, due consideration should be given to the meteorological and hydrological conditions to insure that maximum dilution of radiation release can be ascertained. It is also advisable to collect ecological data in the vicinity of the proposed site, thereby providing a better understanding of the fate of the released radioisotopes in the ecosystem.

In addition, access routes should aim at minimizing radiation hazards associated with the transport of spent nuclear fuel.

Chemical Pollution

To control corrosion, mineral deposits, and biological growths in the various water cycling systems of a nuclear power plant, addition of chemicals is necessary. The chemicals discharged by a nuclear power plant in operation include sulfates, polyphosphates, chromates, hypochlorites, amines, borate, zinc, iron and lithium hydroxide. In general, the levels of chemicals released are very low and hence not expected to cause any significant harmful effects. Nevertheless, consideration should be given to possible synergistic action of chemical and thermal pollution upon biological species in the ecosystem.

Recreational Facilities

The plant and its operation may have an effect on existing or potential recreational facilities nearby. It is often possible to enhance or create recreational facilities through ingenious planning of a plant site.

Aesthetics

The impact of the plant and associated transmission lines on the appearance of the surrounding area must be considered. Design of the plant and such associated facilities as a cooling tower should be aimed at maximum blending into the natural environment. Similarly, the appearance of overhead transmission lines can be improved by the use of aesthetic tower designs.

ECONOMIC FACTORS

Proximity to Load Centers versus Transmission Costs

It is not presently advisable to build a nuclear power plant immediately next to a load center. However, with improved technology and increased experience in construction, design and operation, it will be possible to site a nuclear power plant adjacent to a load center such as a giant industrial complex. The trend is clearly indicated by the concept of nuclear agro-industrial complexes developed by the Oakridge National Laboratory. In fact, planning is underway in Sweden and other European countries to locate nuclear power plants next to a population center and use waste heat for central heating and central refrigeration.

Naturally, the transmission cost is proportional to the distance between the plant site and the load center. It includes the cost of construction of transmission lines and procurement of right-of-way, as well as the cost of energy loss in long distance transmission. Transmission cost should be carefully balanced with the safety parameters and other economic factors since any additional costs will eventually be borne by consumers.

Multiple Uses of the Cooling Water

Removing the waste heat from a 1,100-MWe nuclear power plant by once-through cooling requires more than 2,000 cu. ft. per sec. (900,000 gallons per minute) of water, which could be reused to great advantage. The use of reactor cooling water for irrigation offers the greatest potential. In fact, the benefits derived from such an arrangement may outweigh the economic disadvantages of locating a nuclear power plant on a remote site.

Utilization of Waste Heat

Thermal power plants are largely inefficient, discharging into the environment 2/3 of the heat generated. In the absence of a technological breakthrough for power generation, a means of using the low-grade waste heat must be developed. Plans have been devised and tested in the use of waste steam for industrial processing and for desalination. Benefits derived from the utilization of waste heat may constitute a major economic factor in the overall cost evaluation of a nuclear power plant at a given site.

Plant Cost

Plant cost is heavily dependent on the nature of the proposed plant site. Whenever other factors are equal or similar, plant cost considerations may be the determining factor in choosing a site.

LAND USE POLICY FACTORS

Rural Development

The establishment of a giant thermal power station can presumably affect both the surrounding environment and the local economy, particularly in the rural area. In choosing plant sites, America should not be treated as a place of refuge from environmental controls, but rather the contribution that a power plant can contribute to the full development of the nation should be emphasized. A giant thermal nuclear power plant could be the start of a new community with its own economic base. Since a large part of the land area of rural America receives its electric service from rural electric cooperatives, conflicts and competition for retail sales and large industrial customers should be avoided. Coordination of rural units is essential in devising a regional plan. The supply of employees during the construction phase and during the operation phase as well as the long-range economic growth of the area, must also be taken into consideration.

Population Density

In states like Oregon there exists a sharp contrast in population density among various geological areas. A long-range land use policy must be established to insure an orderly development with respect to environmental preservation.

utilization of natural resources and economic development. Only by implementation of such a plan can overcrowding and unbalanced growth be avoided.

Economic Development

Economic development of the state must be maintained at a healthy rate to accomodate normal population growth and to improve the quality of life. Controlling industrial growth is of primary importance in preserving environmental quality. Careful siting of giant nuclear power plants can be one means of achieving these goals.

RELEASE OF RADIOACTIVE SUBSTANCES AND THEIR ENVIRONMENTAL EFFECTS

Peter J. Mellinger

The release of radioactive effluents to the environment is inherent in the practical operation of all nuclear and fossil fueled power plants. There is no such thing as a "zero release plant." Dissolved, particulate and gaseous fission products accumulate as a direct consequence of the fission process in reactor fuel elements. In addition, the primary coolant and its metallic piping are activated as a result of neutron bombardment to a greater or lesser extent. Leakage into the coolant from defects in individual fuel elements is unavoidable. The need to continually renew a portion of the primary coolant results in the accumulation of both liquid and gaseous wastes during normal reactor operation. Demineralization and ion exchange procedures remove all but a small fraction of the dissolved radionuclides but none of the tritium from the liquid wastes. Both fossil fuel and nuclear power plants release small quantities of radioactivity from their stacks. Fossil plants also release sulfur, nitrous oxides, mercury and particulate matter. Filtration can remove particulates and certain elements but not the noble gases from the gaseous wastes of nuclear reactors.

Radioactive effluents are released to the environment from nearly all other uses of radioactivity, such as university research, medical diagnosis and therapy, and industrial tracers. In the Pacific Northwest, radionuclides have been released on a large scale into the Columbia River from plutonium production at the Hanford operations in Washington for a quarter of a century. More importantly, organisms have been living with naturally occurring radioactivity since they first appeared on earth. In short, environmental radioactivity is neither a recent nor novel phenomenon. Because the atomic age was officially ushered in with the mushroom cloud over Hiroshima, much discussion of environmental radioactivity is still shrouded in irrational fear and failure to comprehend realistic degrees of hazard.

The purpose of this report is to evaluate the likely ecological effects of the normal radioactive effluents from nuclear power plants and to make comparisons with the estimated radioactive effluent of the Trojan plant planned for Columbia County, Oregon. Many groups have demonstrated understandable concern over the Trojan project because of the important and economically valuable fishery resources of the lower Columbia River. A realistic perspective on the very low concentrations of radionuclides that may be released will hopefully serve to allay these fears. No consideration will be given here to thermal effects or the presence of water treatment chemicals in the plant effluents.

Unless otherwise noted, all data on the identity and amount of Trojan plant effluents and the nature of the discharge system are taken from the Portland General Electric Company's Preliminary Safety Analysis Report and its amendments (1969-1970). My primary concern will be to predict radioecological effects given these radionuclide releases in this environmental setting. These predictions will be based on analysis of the past effects of environmental radioactivity in the lower Columbia River and consideration of the mass of laboratory and field studies in radioecology conducted during the last three decades.

When a pollutant is identified as being potentially harmful, conservative discharge limits based on naturally occurring levels, are imposed to keep the concentration below any calculated hazardous level. Radioactivity should be treated in the same manner.

MAXIMUM PERMISSIBLE CONCENTRATION

The biological effects of radiation have been well documented in scientific literature. Standards for public protection against radiation hazard are found in publications of the Federal Radiation Council (FRC, 1960; 1961; 1964), Atomic Energy Commission Regulations (AEC, 1965), National Council on Radiation Protection and Measurements (NCRP, 1959; 1971) and the International Commission on Radiological Protection (ICRP, 1960).

Maximum permissible concentrations (MPC) of various radionuclides in air and water (AEC, 1964) are designed to prevent an individual from receiving more than the maximum permissible dose (MPD) of 500 millirems per year (mrem/yr).

Maximum permissible doses have been largely based on exposure data collected from studies on the New Jersey radium dial painters and subsequently supported by a large collection of additional human exposure data. Before the hazard was known, it was common practice in the manufacture of luminous instruments and watches for dial painters to use their mouths in forming fine brush points, thus many of these painters ingested large quantities of radium. Many of these women died as a result of their radiation exposure, but many others have not shown any significant radiation effects during the 30-40 years that followed. The dividing line seems to be that if less than 1.0μCi of radium was deposited in the bone there was no significant radiation effect. Thus, the permissible dose to bone has been established to equal the energy released in the bone by 1.0μg ^{226}Ra plus the decay products which result from a radiation exposure of 29,000 mrem/yr (NCRP, 1959). There is a built-in safety factor of 10. The permissible occupational whole body exposure of 5,000 mrem/yr is based largely on this permissible bone dose, but with an additional reduction of about 6.

When exposure from nuclear power plants is considered, the occupational MPD of 5,000 mrem/yr contains an additional reduction factor of 10 resulting in the public MPD of 500 mrem/yr (Smith, unpublished paper). Thus, between a yearly dose which might cause injury and the public MPD, there is an overall safety factor of 600. Based on that limit, MPC's have been defined for each radionuclide which reflect its physical and biological behavior, i.e., physical half-life, absorption through gastrointestinal tract, target organ, excretion rate and other factors. The limits for radionuclide concentration in air and water at a reactor site boundary are 10 percent of the ICRP or equal to the public MPD.

Waste disposal operations in commercial nuclear power plants are controlled so that the actual dose delivered to any person outside the plant property does not exceed 5 mrem/yr or 1.0 percent of the permissible 500 mrem/yr. The neighbor of a nuclear power reactor will typically receive an exposure of only 1.0 mrem/yr or less, based on experience of other nuclear plants.

NATURAL BACKGROUND RADIATION

We live in a sea of natural radioactivity that has high and low tides. This naturally occurring background of radioactivity varies with geology, elevation, latitude, diet and materials used to house and clothe the population.

Exposure from Cosmic Radiation

The intensity of cosmic radiation changes with latitude and to a greater extent with altitude. The minimum cosmic radiation is found at the equator and then climbs to a maximum at about 50° N and S latitude and extends almost constant to the poles. As shown in Table 1, the cosmic radiation at 40° N and S varies from 45 mrem/yr at sea level to about 3,800 mrem/yr at the jet aircraft altitude of 35,000 feet.

Table 1. COSMIC RADIATION AND ALTITUDE

40°N,S Latitude (feet)	Dose (mrem/yr)
Sea Level	45
3,280	80
6,560	150
9,840	260
35,000	3,800

(Smith, unpublished paper)

The average cosmic ray exposure to residents of the continental United States is 50 mrem/yr. In mile-high Denver, Colorado, it is about 150 mrem/yr (Smith, unpublished paper). Commercial jet aircraft crews spend about 0.1 of the year at 35,000 feet and thus receive an occupational exposure of 300-400 mrem/yr. A passenger on a jet flight from Portland, Oregon to New York City and back would receive a total radiation dose of about 4 mrem (Smith, unpublished paper).

Exposure from the Earth

The earth itself contains a variety of naturally occurring radioactive elements, including uranium and thorium with their decay products, ^{40}K and ^{14}C. These radionuclides produce an exposure dose in the continental United States of 23 to 90 mrem/yr with an average of about 70 mrem/yr. Granite gives an exposure 4 times higher than sedimentary rock. There are a number of geologic hot spots in the world where exposure doses are much higher, largely due to near-surface thorium deposits. Hundreds of thousands of people live near such deposits and receive annual dosages of from 1,000 to 1,600 mrem with no observable biological damage. These levels are 200 to 320 times higher than the designed allowable exposure at reactor site boundaries and over 1,000 times the observed exposure from operational commercial reactors.

Building materials also contain various amounts of radioactivity. A wooden house may give a radiation dose rate of 50-65 mrem/yr, while concrete and brick may give 70-100 mrem/yr and stone construction may reach as high as 90-130 mrem/yr.

Exposure from Internal Emitters

The uranium and thorium decay products found in the ground each contain the radioactive gas radon which has a radioactive half-life of 3.8 days. This element with its decay products yields a world average exposure to the whole body of 5 mrem/yr. The inhalation of this gas and the deposition of its radioactive decay products in the lung may give a lung dose of 25-250 mrem/yr. (Pertsov, 1964).

Another naturally occurring radioisotope is ^{40}K. It occurs in almost all foods and liquids and is in our bodies from the time of conception. The individual internal exposure from ^{40}K ranges from 17-19 mrem/yr. Carbon-14 in the body contributes about 0.7-1.7 mrem/yr to internal exposure (Folsom, 1957 and Pertsov, 1964).

RELEASE OF RADIOACTIVE SUBSTANCES AND THEIR ENVIRONMENTAL MODIFICATIONS

Dilution and Concentration Factors

Immediately upon introduction of radioactive materials into water, certain factors interact to dilute and disperse these materials, while simultaneously other factors tend to concentrate the radioactivity.

RADIOACTIVE WASTE
Water

Dilution and Dispersion

1. currents and turbulence
2. isotope dilution
3. biological transport

Concentration

Biological

1. uptake directly from water
2. passage through food webs

Chemical & Physical

1. absorption
2. sedimentation

(Rice, 1964)

Isotopes entering the environment as small suspended particles may dissolve or remain as particles while those entering in the dissolved state may be attracted to particulate matter, such as silt or clay particles, and fall to the bottom or may remain in solution. Both particulate and dissolved radionuclides can enter into the biological cycles of the marine and fresh water environments.

Plants and animals play an important role in the cycling of radionuclides not only through metabolism, but also through the process of decomposition, after death. Dead tissues are attacked by bacteria and other organisms and decomposed into their component elements. These elements then become available as nutrients for the production of new organic material.

Each radionuclide tends to take a characteristic route and has its own rate of movement from component to component prior to coming to rest in a temporary reservoir (Rice, 1964).

Concentration Factors

Aquatic organisms are capable of concentrating many elements from the very dilute solutions in which they are immersed. In fact, without this physiological ability, aquatic life as we know it would be impossible. The level to which an isotope is concentrated by any organism varies with season, geographic location, concentration, specific activity and physical form of the isotope in the water.

The concentration factor (C_f) is a useful unit for expressing an organism's ability to concentrate a given element. It is defined as follows:

$$C_f = \frac{\text{concentration of the element (or radionuclide) in the organism}}{\text{concentration of the element (or radionuclide) in the aqueous medium}}$$

Concentration values vary with such factors as the element, the species of aquatic organism, the chemical and physical form of the radionuclide and the age of the organism. C_f values may be expressed for the whole body of the organism in question or for separate portions or tissues. In the latter case wide variations can be anticipated. Thus, for the lobster *Homarus vulgaris*, the C_f for strontium is 180 for the hard shell and only 1 for the muscle tissue (Polikarpov, 1966).

Thousands of concentration factors for hundreds of different species and radionuclides have been determined. The standard text in this field by the Soviet radioecologist G. G. Polikarpov (1966) includes page after page of tabulated C_f values. Many individual technical articles (Weaver, 1967; Freke, 1967; Harvey, 1964; Chapman, Fisher and Pratt, 1968) have appeared listing ranges of C_f values for specific organisms or groups of organisms. This is a well-documented area of knowledge with a sufficiently broad base of data to allow reasonable predictions of C_f values where they have not been experimentally determined.

Concentration factors are often determined by controlled laboratory experiments in which an organism is immersed in a solution of a specific radionuclide of known concentration. The organism is periodically removed and its radioactive content assayed. When equilibrium is virtually established, it is a simple matter to calculate the C_f value. In such a case, uptake of the radionuclide is strictly a result of direct exposure to the radionuclide solution. Since many aquatic organisms have gelatinous or mucus-covered surfaces, it is not always possible in such studies to differentiate between radioactive material, especially in a particulate form, that has been physically adsorbed to the body surface and that which has been metabolically incorporated by absorption. On occasion excessively high C_f values are reported which are due more to adsorption than absorption.

From a radioecological standpoint, the C_f values derived from analyses of organisms chronically exposed to radionuclides in their normal environmental setting are more meaningful. Such values allow a more realistic view of radionuclide uptake both directly from the water and through the food chain. Large differences in environmental C_f values for different species are commonly observed, particularly when plant species are compared to animal species. In this regard, Davis and Foster (1958) of the Hanford Laboratory have noted that adsorption and absorption are of major importance in plant uptake of radioisotopes but are apparently of less importance than the food chain in uptake by aquatic animals.

There is a common lay misconception that if the primary plant food (algae) highly concentrates a given radionuclide, the plant-eating organisms will have a higher body concentration, and their predators will have a still higher concentration. Furthermore, if man then eats these predators (usually fish) he will obtain a yet higher body radionuclide concentration. Fortunately, environmentally determined C_f values have shown quite the opposite to be true. In general, C_f values decline as materials are passed up the food chain. For example, Freke (1967) cites the following C_f values for radioactive iodine: algae - 10,000, crustacea - 100, fish - 20. This phenomenon is due to several factors, one being the radioactive decay occurring during the interval of time required for food chain transfer. Another important reason is that many radionuclides are deposited in either inedible or indigestible tissues and not assimilated by the predator. Davis and Foster, (1958, p. 534) have concluded that "In a flowing stream, the specific activity of a radioisotope will diminish along the food chain".

This is particularly pertinent in relation to food chain transfer of radioactivity to fish. However, the food chain of edible mollusks is much shorter. In addition, since the mollusks are filter feeders they may show very much higher C_f values when the radioactive material is particulate or in colloidal suspension. Weaver (1967) has tabulated a range of expected concentration factors and maximum permissible concentrations of radioactivity in shellfish tissue for thirteen important radionuclides. These values will be used to assess the relative hazard to man from eating shellfish exposed to the ^{131}I released from the proposed Trojan plant. Iodine-131 was selected because it represents the highest level of radionuclide release (796 µCi/yr) where reconcentration is a factor:

(1) The highest concentration factor cited by Weaver for ^{131}I will be used, i.e., C_f = 10,000.

(2) Since the estimated mean river concentration of ^{131}I after complete mixing (Appendix A) is 9.5×10^{-15} µCi/ml, the maximum concentration in shellfish tissue would be 9.5×10^{-11} µCi/g.

(3) The Federal Radiation Council lists a maximum permissible intake of ^{131}I as 1.00×10^{-4} µCi/day which after reaching equilibrium in the body would expose an individual to the maximum permissible dose of 0.5 mrem/yr (FRC, 1961).

(4) Thus, an individual would need to consume 2,400 lbs/day of this shellfish to reach the maximum permissible level of ^{131}I intake.

These case calculations should demonstrate just how low the levels of the estimated Trojan plant releases actually are. Note that the value calculated pertained to shellfish reconcentration (usually considerably higher than for vertebrate fish) and to the radionuclide subject to reconcentration which will be released at the highest concentration. Weaver (1967, p. 493) concludes, "Under circumstances in which the concentrations in shellfish remain well below the guidance values, there is no need for public health concern."

Since the end of World War II, Columbia River water has been used as primary coolant for the plutonium production reactors at the Hanford Atomic Products Operations. This usage has resulted in the release of more radioactivity into the Columbia River than into any other known body of fresh water in the world. However, physical decay of short-lived nuclides, dilution by tributary inflow, biological uptake and sedimentation rapidly reduced water concentrations.

In 1965, the residents of Richland, Washington, below the Hanford reactors received a calculated maximum annual dose of 35 mrem, assuming a daily intake of about 1 1/4 quarts of municipal water. About 2/3 of this exposure was from ^{76}AS (radioactive arsenic), and most of the remainder was from ^{239}Np, ^{51}Cr, ^{64}Cu and ^{24}Na. Pasco, located 13 miles downstream from Richland, received a lower dose because of the additional decay of short-lived nuclides. Residents there received a dose to the gastrointestinal tract of about 13 mrem/yr (Foster and Soldat, 1966). None of these isotopes are likely to be discharged from a commercial pressurized water reactor or boiling water reactor.

The major radioisotopes remaining in the Columbia River at Richland prior to municipal treatment are shown in column 1, Table 2. The fraction of the MPC_w for public consumption of these individual radioisotopes appear in columns 3 and 4 (Corley, 1970).

Table 2

FRACTION OF MPC_w REMAINING IN COLUMBIA RIVER AT RICHLAND, WASHINGTON

Isotope	10 CFR 20 MPC Public (μCi/ml)	Practice of MPC 1967	1969
^{24}Na	3×10^{-5}	0.087	0.053
^{32}P	2×10^{-5}	0.0095	0.0036
^{46}SC	4×10^{-5}	0.0015	0.0018
^{51}Cr	2×10^{-3}	0.0016	0.00036
^{56}Mn	1×10^{-4}	0.0052	0.01
^{64}Cu	2×10^{-4}	0.01	0.0085
^{65}Zn	1×10^{-4}	0.0022	0.00072
^{76}As	2×10^{-5}	0.020	0.015
^{122}Sb	3×10^{-5}	0.005	0.003
^{239}Np	1×10^{-4}	0.011	0.011
		0.1530	0.1069

The average radioactivity in the Columbia River at Richland was 15.30 percent of MPC_w in 1967 and decreased to 10.69 percent of MPC_w in 1969 due to further reactor shutdowns.

By the time the river water mass reaches the Trojan site, only three radionuclides of biological importance are readily detectable from the Hanford input--^{51}Cr, ^{65}Zn and ^{32}P. Although these nuclides will not be among those released from the Trojan plant, it is pertinent to examine their average concentrations from 1961 to 1967 in the river at Goble, Oregon (Tombs and Cutler, 1968) and calculate the fraction of their MPC_w for public consumption.

Nuclides	Concentration ($\mu Ci/ml$)	MPC_W ($\mu Ci/ml$)	Fraction of MCP_W
^{32}P	3.3×10^{-8}	2×10^{-5}	0.00165
^{51}Cr	1.3×10^{-6}	2×10^{-3}	0.00065
^{65}Zn	3.6×10^{-8}	1×10^{-4}	0.00036
			0.00266

Therefore, the river concentration is less than 1 percent of the MPC_W at Goble, Oregon.

Repeated long-term studies have failed to demonstrate any biological hazard to downstream users of the Columbia River or its fish and wildlife resources (Davis and Foster, 1958; Foster, 1963; Foster, n.d.) due to Hanford operations. In fact, the presence of these trace levels of radioactivity in the river as it empties into the Northeastern Pacific Ocean has had at least one positive benefit in that it has enabled oceanographers from Oregon State University and the University of Washington to trace the plume of the river for over 100 miles from its mouth as it interacts with the ocean water mass (Osterberg, 1965). These studies have greatly enhanced knowledge of marine food webs in this important ocean area (Osterberg, Pearcy and Curl, 1964). An even clearer contrast is seen when the fractions of MPC's from the Trojan plant are compared to the Hanford values at Goble:

Source	Fraction MPC_W
Hanford Operation (1961-67)	0.00268
Trojan effluent canal*	0.00480
Trojan after river mixing*	0.000000264

*Calculations are presented in Appendix A.

The Hanford concentration is some 10,200 times that of the Trojan plant, although, with the shutdown of many of these reactors in the past few years, the values for Hanford are now significantly less. Thus, the radioactivity released from the Trojan operation will be negligible in comparison to that which has been constantly discharged from the Hanford reactors for over 25 years.

Extensive studies of the concentration of the Hanford-produced radionuclides in aquatic organisms of the lower Columbia River have been made. From data available for the alga *Cladophora sp.* collected at Goble from 1963-67 (Weaver, 1967), the following concentration factors were calculated:

Nuclides	C_f
^{65}Zn	2,400
^{51}Cr	8,600

As expected, algal concentration factors at other points along the lower Columbia River varied both above and below these values, but seldom by more than one order of magnitude (10x). Concentration factors for ^{65}Zn in mollusks were typically higher--usually in the range of 25,000 to 30,000 (Weaver, 1967). These values are in the normal range for these nuclides as reported by Polikarpov (1966) and Weaver (1967). Game fish in the lower Columbia had relatively low concentrations of these radionuclides in their tissues (usually 1-2 x 10^{-6} μCi/g wet weight) (Foster, n.d.). Significantly higher concentrations of ^{65}Zn were observed in edible portions of the resident sturgeon population as compared to the nonfeeding spring-run Chinook salmon (Tombs and Cutler, 1968).

HAZARDS TO MAN FROM TROJAN RADIONUCLIDES

Twenty-three radioisotopes of 13 different elements are included in the list of estimated releases from the proposed Trojan plant (Appendix B, column 1). These will be examined to assess their relative radioecological hazards to man.

Radionuclides Subject to Biological Reconcentration

Thirteen of the radionuclides (^{54}Mn, ^{56}Mn, ^{60}Co, ^{59}Fe, ^{89}Sr, ^{90}Sr, ^{91}Sr, ^{90}Y, ^{91}Y, ^{132}I, ^{140}Ba, ^{140}La, ^{144}Ce) will have estimated annual releases of less than 2 μCi. Mean river concentrations of these nuclides after complete mixing will be so minute (10^{-17} to 10^{-19} μCi/ml) that even the possibility of the most extreme reconcentration by aquatic organisms imaginable ($C_f = 10^6$) could not conceivably result in any detectable biological hazard. Let us assume that the entire year's discharge of ^{89}Sr (highest release level of this group of radionuclides) occurred in just one day, instead of over 290 days. Of course such a discharge would not be allowed because the accompanying ^3H release would greatly exceed 10 CFR 20 limits. The river concentration after complete mixing of this discharge would be only 9.6 x 10^{-11} μCi ^{89}Sr/ml, 31,000 times smaller than the maximum permissible water concentration for this isotope. Thus, the contribution of these low level radionuclides is removed from any serious consideration of hazard.

Four additional radionuclides (^{99}Mo, ^{133}I, ^{135}I, ^{132}Te) have half-lives measured in hours. Physical decay would very rapidly further reduce the already low river concentrations of these isotopes. Within one day after release their radioactivity levels will have declined respectively to 78, 44, 8 and 81 percent of the initial river concentrations. The environmental effect of these nuclides would decrease rapidly with increasing distance or transit time downstream and through any food chain. The two longer-lived nuclides in this group (^{99}Mo and ^{132}Te) are not readily metabolized by aquatic organisms, and extensive reconcentration is unlikely. Fish have a C_f of only about 10 for these two elements (Freke, 1967). The two isotopes of iodine are indeed readily reconcentrated, but their very low mean river concentrations preclude any consideration of hazard.(See pg. 22)

The remaining six radionuclides (^{58}Co, ^{131}I, ^{134}Cs, ^{136}Cs, ^{137}Cs, ^3H) are all biologically significant and, except for tritium, are subject to varying degrees of reconcentration by aquatic organisms. Cobalt uptake has been extensively studied because of the large-scale release of ^{60}Co in nuclear weapons tests. Large numbers of cobalt C_f values for a wide variety of organisms have been reported (Polikarpov, 1966; Weaver, 1967; Freke, 1967; Harvey, 1964; Wiser and Nelson, 1964). The following are representative values:

Organism	C_f Range
Algae	100-1,000
Crustacea	100-10,000
Mollusks	100-10,000
Fish	100-1,000

Simple calculations will show that using the highest C_f value and the mean fully mixed river concentration of ^{58}Co following release (7.8×10^{-17} μCi/ml), maximum edible tissue levels could reach only 7.8×10^{-13} μCi/g. At this tissue concentration a man would have to eat 200 million lbs/day of such shellfish or crustacea to reach the maximum permissible daily intake of ^{58}Co (Weaver, 1967). Such an impossible intake value clearly reveals the infinitesimal hazard from this level of ^{58}Co release.

Iodine-131 will be discharged at the highest radioactivity level (796 μCi/yr) of any of the radionuclides subject to reconcentration. This is offset by its reasonably short half-life (8.05 days), which will lead to a reduction in water concentration of 8 percent per day due to radioactive decay alone. Radioactive iodine from terrestrial fallout can pose a considerable health hazard because of the potentially short food chain to man (grass-cow-milk) and the fact that iodine is highly concentrated in the thyroid gland. No such case exists in the aquatic situation, where the highly soluble iodine is neither extensively concentrated, nor is there a short food chain leading to man. The calculations on page show the impossibly high level of shellfish consumption required to even approach maximum permissible daily intake values of ^{131}I.

Routine clinical tests of thyroid function involve oral administration of up to 100 μCi of ^{131}I to the patient. Most of this activity is excreted in the patient's urine during the first day. Because over 200 such tests are performed in just one of the Portland medical centers each year (Plath, personal communication) the treated sewage discharge of ^{131}I into the Columbia River from that city alone greatly exceeds the estimated amount for the Trojan plant effluent.

The three radioisotopes of cesium (^{134}Cs, ^{136}Cs, ^{137}Cs) deserve closer attention both because their estimated annual releases are significant and their half-lives are fairly long. If the hazard of ^{137}Cs, which has the longest half-life (30 yrs) and the highest level of estimated discharge (319 μCi), can be shown to be negligible, the other two isotopes may likewise be dismissed. As one of the major long-lived fission products, ^{137}Cs has received extensive radioecological study (Harvey, 1964; Bryan, 1961; Hasanen, Kolehmainen, and Miettinen, 1966). Cesium, an alkali metal, is chemically and biologically similar to potassium in its environmental behavior. Its salts are highly soluble and it is not highly concentrated in any particular tissue of the body. Polikarpov (1966) reports that the concentration factors for radioactive cesium are considerably higher (100 to 1000 times) in fresh-water organisms than in marine organisms. Since the stable cesium concentration of sea water is much higher than that of most fresh water, this can be easily understood as simply an effect of the marked differences in specific activity.

The highest C_f for fresh-water fish reported by Polikarpov (1966) is 9500 for the muscle tissue of the sunfish *Lepomis gibbosus*. Applying this C_f value to the mean mixed river concentration of ^{137}Cs (3.7×10^{-15} μCi/ml), a fish muscle concentration of 3.5×10^{-11} μCi ^{137}Cs/g would be possible. In this worst case situation, a man would still have to consume 950,000 lbs of fish to reach the maximum permissible body burden of ^{137}Cs. Thus, food chain concentration of radioactive cesium from the proposed Trojan plant effluents can scarcely be considered hazardous to man.

Tritium

The level of estimated tritium release (4,770 Ci/yr) from the Trojan plant great exceeds the total release of all other radionuclides. At first glance this disproportionately high level might appear quite ominous. In fact, the environmental and radiobiological impacts of tritium are incomparable to the previously considered fission product discharges. This difference is well recognized by the national and international agencies which set radioactivity standards. For example, the maximum permissible whole body burden for tritium is 66 times that for ^{137}Cs, and the maximum permissible drinking water concentration is 150 times as great (Public Health Service, 1970).

The reduced hazard from tritium results first from the fact that its disintegration energy is the lowest of any radionuclide (a maximum energy of 0.018 MeV and an average of 0.006 MeV) and that decay is solely by beta emission; therefore, the dose to tissue from tritium is one of the lowest from any nuclide, allowing one of the highest permissible concentrations. Because tritium is a very weak beta emitter, it poses no hazard to organisms from external radiation. Secondly, it is present in the environment almost exclusively in the form of tritiated water. In an aquatic system the dilution by normal water molecules is enormous, producing an exceedingly low specific activity (ratio of radioactive molecules of a compound to total molecules of the compound).

Most significantly, tritiated water behaves just like ordinary water in any organism. Upon ingestion or absorption it is rapidly and uniformly distributed throughout the body (Bond, 1970). However, it is also excreted rapidly with a biological half-life of only 12 days in man. Tritium atoms on most biochemical compounds in the body, like stable hydrogen atoms, are freely exchangeable with those on body water molecules. To a much smaller extent tritium atoms, like stable hydrogen atoms, can be incorporated into nonexchangeable positions in certain biologically important molecules, such as carbohydrates, proteins and nucleic acids. Chronic exposure to constant tritium concentrations results in a small percentage of organically bound tritium in body tissues (Thompson and Ballou, 1956).

Organically bound tritium is evenly distributed throughout the body and not selectively concentrated in certain tissues (Pinson and Longhorn, 1957). The fact that tritium is not reconcentrated in body tissues leads to the conclusion that it poses no environmental hazard from food chain concentration. An aquatic organism could have a body concentration of ^{3}H approaching that of the ambient water. Human intake of tritium through eating such aquatic animals would thus be limited by the river concentration, and the C_f value of tritium along the food chain is unity.

In regard to estimated tritium releases from the proposed Trojan plant, fully mixed Columbia River concentrations of ^{3}H are calculated to be 5.6×10^{-8} μCi/ml. Fish chronically exposed to this level of tritium would likely attain tissue concentrations of the same magnitude. A man would have to eat 79 million lbs of such fish to reach the maximum permissible body burden of tritium (Public Health Service, 1970). The impossibility of such an intake emphasizes the very low level of hazard posed by the estimated tritium releases from the Trojan plant.

Some individuals have become unduly alarmed upon learning that tritium may be incorporated as a part of DNA molecules in body cells. Several key experiments have been performed to evaluate the relative radiobiological effects in cells of tritium as water and as a portion of DNA (introduced as the DNA precursor, tritiated thymidine). Bond (1970, p. 1377) summarizes the results, "All experiments of this type to date, on somatic and genetic effects in mammals, showed approximately the same degree of biological effect whether or not the tritium was incorporated into DNA, i.e., the tritium showed no additional effect by virtue of its having been incorporated into DNA."

Since tritium incorporated in certain positions of the DNA molecule is relatively nonexchangeable or fixed, there appears to be a potential for food chain accumulation of ^{3}H through nucleic acids or their nucleotide precursors. Bond (1970, p. 1376) states, "Higher organisms, including man, also synthesize their own building blocks, e.g., purine and pyrimidine nucleotides, and are not dependent on preformed nucleotides derived from food. A large percentage of nucleic acid precursors given orally are broken down before absorption." It appears that there is no likelihood for increased incorporation of tritium into DNA as a result of the ingestion of tritiated DNA through the ascending levels of the food chain.

It is estimated that the resulting buildup of all reactor produced tritium will increase exponentially until it reaches the level of cosmic ray produced environmental tritium in the late 1980's. Around the year 2000, it will be equal to the residual tritium from the hydrogen weapons tests of the last two decades. At that time the planetary exposure to the world population from all sources of tritium would then be 0.0002 mrem (Price, 1969).

It appears that no significant environmental hazard to man will result from the conservatively estimated ^{3}H releases from nuclear power plants.

GASEOUS RADIOACTIVITY

Nuclear vs. Fossil Fuel

A comparison of the radioecological hazards of fossil-fueled and nuclear-fueled power plants is very difficult due to the nature of their gaseous effluents. Nuclear plants release predominantly noble (biologically nonreactive) gases, which produce whole body exposures, while fossil-fueled plants release soluble and insoluble radioisotopes associated with fly ash (fine particulate material). Soluble forms are long-lived bone seekers and insoluble ones lead to radiation exposure of the lungs.

Radioactivity From Fossil Fuel Power Plants

Trace quantities of uranium and thorium and their radioactive products are released to the environment in the form of fly ash from fossil-fueled plants.

If the nuclides in fly ash are soluble, bone is the critical organ; if insoluble, the lung is the critical organ. For bone the most significant nuclides in fly ash are ^{230}Th, ^{228}Th, ^{232}Th, ^{226}Ra and ^{228}Ra; for the lung they are ^{230}Th, ^{232}Th, ^{238}U, ^{228}Th and ^{228}Ra.

For bone, continuous 50-year exposure to the MPC for air in unrestricted areas would be required to reach the body burden and a dose rate equivalent of 0.01 mg of radium or 2.91 rem/yr (Martin, Harward and Oakley, 1969).

For lung exposure the MPC for unrestricted areas corresponds to a dose rate of 0.71 mrem/hr or 1.5 rem/yr after sufficient time has elapsed for an equilibrium concentration to occur in the lung tissue. This comparison was based on the dose limits and exposure concepts for various critical organs recommended by the International Commission on Radioecological Protection (1960).

Public whole body exposure of individuals from noble gases is limited to 0.5 rem/yr (500 mrem/yr); bone dose from long-lived bone seekers is limited to that from 0.01 mg of radium or 2.9 rem/yr; and lung doses from insoluble particles are limited to 1.5 rem/yr (Martin et al.).

Gaseous discharges from the pressurized water reactor (PWR) are several orders of magnitude below that of the boiling water reactors (BWR). The main reason for this difference is that PWR's have the designed ability to store gaseous wastes for 45-60 days prior to discharge, whereas BWR's discharge short-lived gases after only about 30 minutes holdup.

Comparing a new coal plant of 1000-MWe (megawatts electric) size, possessing efficient air-cleaning equipment and one 800-foot stack with the Connecticut Yankee PWR, and the Dresden I BWR, both assumed to be of typical current design, the calculated dose rates as fractions of ICRP limits per MWe showed that the coal plant is 5 times higher than the PWR, but 14,000 times less than the BWR. Since the BWR's in operation at this time produce exposure dose rates off-site that are only 1-3 percent of FRC guidelines, the comparisons made above are only relative, and such radiation exposure rates are of negligible public health significance (Martin, et al., 1969). In comparing these three power plants, the single parameter with the greatest significance is the height of the gaseous effluent stack. The higher stacks diffuse the effluent over a larger area and thus result in exposures to more people at a lower rate. In order to account for the variation due to stack height, Martin et al. (1969) gave the coal plant a hypothetical 300-foot stack and recalculated the fraction of the ICRP dose/MWe. The results of this comparison show that the coal plant, as a fraction of ICRP recommendations, is 400 times higher than the PWR and 180 times less than the BWR.

Radioactivity From Nuclear Power Plants

Since the majority of the 24 radionuclides of krypton and xenon produced in the fission process are short-lived, ^{85}Kr is the radioactive gas of greatest long-range public health interest in stack emissions from nuclear power plants. Unlike tritium, krypton is unreactive biologically and does not enter into organic molecules; therefore, human exposure is principally to the skin, involving a dose 20 times greater than that to other tissues (Sagan, unpublished paper).

Current dose rates from environmental levels of ^{85}Kr are calculated to be about 0.04 mrad/yr to the skin and 0.005 to the whole body. Even though levels will continue to increase as nuclear power plants multiply, radiation exposure calculations indicate that by the year 2000 the dose will be less than 1.0 percent of permissible levels (Larsen, 1970).

Eisenbud and Petrow (1964, p. 289) compared the relative biological significance of their data on fossil fuels with emission data from nuclear plants of equal size and concluded that "an electrical generating station that derives its thermal energy from such fuels discharges relatively greater quantities of radioactive substances into the atmosphere than many power plants that derive their heat from nuclear energy.

The fundamental assumption in this conclusion is that the relative biological effect of radium and thorium emitted by fossil-fuel plants is higher than ^{131}I and ^{85}Kr emitted by nuclear plants because:

1. radium isotopes give rise to a number of radioactive daugher products,

2. some of the isotopes in the decay chains emit alpha particles,

3. the radium isotopes are relatively long-lived and their energies are greater than those associated with the decay of ^{131}I or ^{85}Kr.

CONCLUSIONS

The present radioactive releases of modern pressurized water reactors and boiling water reactors are exceedingly small in comparison to both naturally occurring radioactivity levels and the considerable input from the Hanford reactors.

No aquatic organisms with known concentration factors could reconcentrate any of the released radionuclides to anything even remotely approaching hazardous levels.

The discharge of tritium at very much higher levels than all the other radionuclides poses no special hazard due to its chemical form (tritiated water), its exceptionally low specific activity in river water, and the absence of reconcentration in the aquatic environment.

The rapid and very extensive dilution of the gaseous discharges from fossil and nuclear power plants will reduce the concentration to well below measurable levels in most cases.

DISCUSSION

Q: How would you compare the problem of accumulative DDT to the problem of radiation?

A: Personally, I think environmental levels of pesticides and heavy metals are much more important to look at than radioactivity from the normal operation of nuclear activities.

There have been numerous studies which show subtle detrimental effects of accumulated pesticides in birds from present environmental levels. Heavy metals such as mercury and cadmium, which I am working on for my Ph.D. dissertation, have been shown to reach lethal levels through the marine food chains of Japan where 47 persons have died from eating contaminated fish and shellfish. Numerous additional toxicities attributed to these two metals have occurred all over the world. By contrast, there have been no reliable studies which show any detrimental effects of the present low levels of radioactivity being released to the environment from the nuclear activities in the U.S.

Q: Do you have any data on the comparisons of radioactive concentrations in coal that might be used in the Western plants and that used back East?

A: No, I don't. On a tour of Centralia I asked what the radium and thorium content was and the engineer had no idea. The hazard would probably come not from the radioactive content, but from the sulphur and nitrous oxide and mercury. In 1968, the U.S. burned 550 million tons of coal which released about 1800 tons of mercury to our environment.

A: Does coal constitute a significant hazard?

A: My comparison of fossil fuel with nuclear fuel was not meant to express significant hazard. I wanted to emphasize that radioactivity doesn't only occur in nuclear power. Life on earth has lived and evolved with radioactivity present from the onset of time. If these low levels of environmental radioactivity are indeed mutagenic, than you and I are the results of these mutations.

APPENDIX A Fraction of MPC_w to Public From the Trojan Nuclear Power Plant

Isotope	Maximum Estimated Mean Discharge Concentration (μci/ml)	10 CFR 20 MPC_W Public Soluble (μci/ml)	Fraction MPC_W Public In Discharge Canal	Fraction MPC_W Public 12,000' Downstream
Manganese-54	4.4×10^{-14}	1×10^{-4}	4.4×10^{-10}	2.5×10^{-14}
-56	2.1×10^{-15}	1×10^{-4}	2.1×10^{-11}	1.2×10^{-15}
Cobalt-58	1.4×10^{-12}	1×10^{-4}	1.4×10^{-8}	7.8×10^{-13}
-60	4.2×10^{-14}	5×10^{-5}	8.4×10^{-10}	4.6×10^{-14}
Iron-59	5.9×10^{-14}	6×10^{-5}	9.9×10^{-10}	5.5×10^{-14}
Strontium-89	3.2×10^{-13}	3×10^{-6}	1.1×10^{-7}	6.0×10^{-12}
-90	9.7×10^{-14}	3×10^{-7}	3.2×10^{-7}	1.8×10^{-11}
-91	2.5×10^{-14}	7×10^{-5}	3.6×10^{-10}	2.0×10^{-14}
Yitrium-90	6.3×10^{-15}	2×10^{-5}	3.1×10^{-10}	1.7×10^{-14}
-91	3.4×10^{-14}	3×10^{-5}	1.1×10^{-9}	6.3×10^{-14}
Molybdenum-99	1.2×10^{-10}	2×10^{-4}	6.0×10^{-7}	3.3×10^{-11}
Iodine-131	1.7×10^{-10}	3×10^{-7}	5.6×10^{-4}	3.2×10^{-8}
-132	5.1×10^{-14}	3×10^{-6}	1.7×10^{-8}	9.7×10^{-13}
-133	1.3×10^{-10}	4×10^{-6}	3.2×10^{-5}	1.8×10^{-9}
-135	1.3×10^{-11}	4×10^{-6}	3.2×10^{-6}	1.8×10^{-10}
Tellerium-132	1.6×10^{-11}	3×10^{-5}	5.3×10^{-7}	3.0×10^{-11}
Cesium-134	1.2×10^{-11}	9×10^{-6}	1.3×10^{-6}	7.5×10^{-11}
-136	1.7×10^{-12}	9×10^{-5}	1.9×10^{-8}	1.3×10^{-12}
-137	6.7×10^{-11}	2×10^{-5}	3.3×10^{-6}	1.8×10^{-10}
Barium-140	1.7×10^{-14}	3×10^{-5}	5.7×10^{-10}	3.2×10^{-14}
Lanthanum-140	4.4×10^{-14}	2×10^{-5}	2.2×10^{-9}	1.3×10^{-13}
Cerium-144	2.3×10^{-13}	1×10^{-5}	2.3×10^{-8}	1.3×10^{-12}
Unidentified	4.2×10^{-10}	1×10^{-7}	4.2×10^{-3}	2.3×10^{-7}
Fraction MPC_W			0.004801	0.0000002643

APPENDIX B — Estimated Releases of Dissolved Radioisotopes And Their Subsequent Dilution

Isotope	Half-life	Estimated Annual Release (μCi) (1)	Estimated Mean Discharge Concentration (μCi/ml)	Estimated Mean River Concentration After Complete Mixing (μCi/ml)
Manganese-54	303 d	0.21	4.4×10^{-14}	2.5×10^{-18}
-56	2.57 h	0.01	2.1×10^{-15}	1.2×10^{-19}
Cobalt-58	71.3 d	6.67	1.4×10^{-12}	7.8×10^{-17}
-60	5.2 y	0.20	4.2×10^{-14}	2.3×10^{-18}
Iron-59	45.6 d	0.28	5.9×10^{-14}	3.3×10^{-18}
Strontium-89	52.7 d	1.53	3.2×10^{-13}	1.8×10^{-17}
-90	27.7 y	0.46	9.7×10^{-14}	5.4×10^{-18}
-91	9.67 h	0.12	2.5×10^{-14}	1.4×10^{-18}
Yttrium-90	64 h	0.03	6.3×10^{-15}	3.5×10^{-19}
-91	58.8 d	0.16	3.4×10^{-14}	1.9×10^{-18}
Molybden-99	66.7 h	566	1.2×10^{-10}	6.7×10^{-15}
Iodine-131	8.05 d	796	1.7×10^{-10}	9.5×10^{-15}
-132	2.26 h	0.24	5.1×10^{-14}	2.8×10^{-18}
-133	20.3 h	628	1.3×10^{-10}	7.3×10^{-15}
-135	6.68 h	61.3	1.3×10^{-11}	7.3×10^{-16}
Tellurium-132	77.7 h	76.2	1.6×10^{-11}	8.9×10^{-16}
Cesium-134	2.05 y	59.1	1.2×10^{-11}	6.7×10^{-16}
-136	13.7 d	8.27	1.7×10^{-12}	9.5×10^{-17}
-137	30.0 y	319	6.7×10^{-11}	3.7×10^{-15}
Barium-140	12.8 d	0.08	1.7×10^{-14}	9.5×10^{-19}
Lanthanum-140	40.22 h	0.21	4.4×10^{-14}	2.5×10^{-18}
Cerium-144	284 d	1.11	2.3×10^{-13}	1.3×10^{-17}
Unidentified	--	1,990	4.3×10^{-10}	2.3×10^{-14}
Total non-tritium		4.5×10^{3}	9.5×10^{-10}	5.3×10^{-14}
Hydrogen-3 (Tritium)	12.26 y	4.77×10^{9}	1.0×10^{-3}	5.6×10^{-8}

Assumptions in Estimated Annual Release (Column 3)

1. These values are taken from Table 11.1-3 of the Preliminary Safety Analysis Report (Portland General Electric Company, 1969-1970). They appear to be conservative based on experience with other pressurized water reactors (PWR).

2. These releases will come primarily as a result of small defects in and diffusion of fission products from the enriched uranium fuel elements. A one percent fuel failure is assumed in calculating the releases indicated. This appears to be a high value from experience with other PWR installations.

3. The unidentified isotopes making up 44.2 percent of the nontritium release will most probably be composed of the same isotopes listed, in approximately the same proportions. Since these will be from nonrecurrent sources (laundry wastes, equipment drains, etc.) it is not possible to identify them more precisely in advance of operation.

Assumptions in Calculation of Estimated Mean Discharge Concentration (Column 4)

1. The minimum voluem of liquid discharge from the Trojan plant will be 3,000 gallons per minute, derived from the cooling tower. Actually, the average value is expected to be more nearly 5,000 gpm, thus providing greater dilution than indicated.

2. Discharge will occur at a constant rate during 290 days each year. Actually discharges will be made on a batch basis, so that the values in column 4 are mean values. However, from a radioecological standpoint, they are the values of significance, since they represent the maximum sustained standard concentrations to which organisms in the immediate vicinity of the discharge pipe could be exposed.

Assumptions in Calculation of Estimated Mean River Concentration After Complete Mixing

1. The mean discharge concentrations (column 4) will be mixed with a minimum Columbia River flow of 120,000 cubic feet per second (5.39' x 10^7 gpm) at the Trojan site. This is a conservative figure as river flow measurements made very near the Trojan site indicate a mean yearly flow of 238,000 cubic feet per second (FRC, 1964).

2. Complete mixing of the Trojan effluents and the river mass wi-l occur at a mean point 12,000 feet downstream from the release point (FRC, 1964). The influence of the tidal cycle will have a recurrent, but very temporary effect on complete mixing. Again, the values listed in column 5 are important radioecologically, since they represent the maximum sustained radionuclide concentrations to which organisms downstream from the Trojan plant will be exposed.

3. No consideration is given to the physical decay of radionuclides as the water mass moves downstream. Since a substantial portion of the total radionuclide

release is due to short-lived isotopes (^{99}Mo, ^{131}I, ^{133}I, ^{135}I, ^{132}Te), the radionuclide concentration in the river due to the Trojan releases will decline sharply before it reaches the Pacific Ocean.

4. No consideration is given to further downstream dilution resulting from the entrance of water from tributaries below the Trojan site. With the possible exception of the Cowlitz River, most of these are quite modest in flow compared to the Columbia itself. However, the total effect will be to further reduce these calculated concentrations.

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EFFECTS OF THERMAL DISCHARGES ON AQUATIC COMMUNITIES

Wayne K. Seim

The title of my talk is somewhat misleading as I will talk mostly about effects of warmed water on fish, primarily salmon, and make only scant reference to the other members of the aquatic community. In addition, the suggestion that anyone might know with very much certainty the final outcome of small thermal changes on most aquatic ecosystems is rather optimistic. However, there are perhaps 1600 references in the literature to effects of temperature and many laboratories, including our own in Corvallis, are placing major emphasis on thermal studies. A brief description of the magnitude of the problems involved in predicting effects of heat on aquatic communities may enable you to more readily understand some of the reasons why both environmental agencies and the public are focusing so much attention on these problems and why so many biologists are unable to formulate definitive answers about temperature effects.

In 1948 Huntsman discussed the concept of a biocrisis in nature. According to this idea individuals of a species constantly confront crises as they respond to their environment. They must grow and develop, escape predators, migrate, survive disease epidemics, consume food, defend territories and reproduce. The success of each individual in meeting these demands determines the distribution and abundance of that species in nature. Temperature, directly or indirectly plays an important role in the ability of organisms to successfully meet these environmental demands. The effect of temperature change on an organism depends on the size, amount and rate of the temperature change and the age, condition, previous thermal history, and rate of food consumption of the organism. The influence on the community with which this organism interacts is also an important factor. Much is presently known about many of these effects and interactions, but much more must be learned and understood as we continue to place greater demands on our aquatic resources.

Fish remove oxygen from the water by pumping their blood into close contact with the surrounding water at the gill surface. This rapidly exposes internal tissues to the temperature of the habitat. Fish cannot regulate their body temperature and must exist at the same temperature as the water. Altering water temperatures may cause lethal or sublethal effects. Lethal effects are imposed directly on the organism, causing dysfunction of physiological processes and subsequent death. Lethality due to heat or cold is modified by a number of factors including the organism's previous history. Fishes acclimate to increasing temperatures much more quickly than to dropping temperatures. Examples of upper lethal temperatures at which 50 percent mortality occurred for juvenile salmon acclimated to 20°C (68°F) are: coho salmon - 25°C (77°F), chinook salmon - 25.1°C (77.2°F), sockeye salmon - 24.8°C (76.1°F), and chum salmon - 23.7°C (74.3°F) (Brett, 1952).

Salmon eggs are less tolerant. Combs and Burroughs (1957) defined levels of survival and normal development for chinook embryos between 5.8°C (42.5°F) and 13.5°C (57.5°F) and for sockeye embryos between 5.8°C (42.5°F) and 12.7°C (55°F). This suggests that warming of winter waters too cool for normal development and survival may increase egg survival and speed development. Less information is available on lethal temperatures for adult salmon although some evidence suggests they are less tolerant than juveniles.

While lethal temperatures can be determined rather easily in the laboratory, their application to nature is restricted because the specific water quality and biotic conditions of a body of water have such a great effect on lethal limits. In most cases, disease, starvation, predation or interactions with other water quality parameters such as nitrogen gas or dissolved oxygen concentrations might be expected to cause mortality before actual heat death occurs. Also, it is unlikely that fish will experience lethal temperatures in the waste streams of thermal electric plants in Oregon. The Oregon Department of Environmental Quality has already created temperature standards which should reduce or eliminate the possibility of direct thermal death. For instance, Oregon law states in the special water standards for the Columbia River that no unnatural temperature increases shall be permitted when river temperatures are at or greater than 68°F (20°C), and no more than 2°F increases will be permitted when temperatures are 66°F or less. This law has apparently eliminated the option of once-through cooling for thermal electric plants to be constructed on Oregon's inland streams. Thermal plants locating inland will probably have some method of off-stream cooling for condenser discharges. Therefore, lethal effects do not appear to be the most important aspect of the influence of thermal discharges.

Sublethal effects are less understood, but perhaps more important. Effects on growth, directive effects, and changes in community composition will be discussed.

Brett et al. (1969) studied the growth of young sockeye salmon held at temperatures ranging from 1° to 24°C and at several different feeding levels. He found that optimum growth occurred at 15°C (59°F) for high feeding levels. This optimum shifted to lower temperatures as the ration was decreased. At the low ration, 1.5 percent of body weight per day, the optimum growth rate was at the low temperature of 5°C (34.6°F), and no growth occurred at 15°C (59°F). At the higher temperatures there are increased metabolic costs which must be satisfied before any growth can occur. The amount of food required merely to maintain a constant body weight is called the maintenance ration. Below this level of consumption fish begin to lose weight. For sockeye, the maintenance ration increased rapidly above 12°C (53.6°F) and at 20°C (68°F) the maintenance ration equaled 2.6 percent of the body weight per day. At 21°C (69.8°F), growth was zero for a 3 percent ration. At 23°C (74.3°F) no growth took place even when excess food was present. At 24°C (75.2°F) feeding activity stopped and at 25°C (77°F) heat death occurred.

What do all these numbers suggest? First when food is plentiful, increasing the temperature may increase growth rates of sockeye at temperatures below about 15°C (59°F), and some growth may occur to almost 23°C (74°F). Also when the food supply in nature is low, any substantial increase in temperature may reduce growth and survival of sockeye salmon. Some experimenters have fed their test fish all they could consume and have erroneously concluded that temperature increase always increased fish growth.

A recent study of the influence of warmed water on juvenile coho salmon is nearing completion at our laboratory. This two-part study includes an aquarium experiment in which groups of juvenile coho were fed different rations and exposed to naturally fluctuating temperature regimes incrementally increased 3.5° and 7°C above the controls, and a model stream experiment. Results of the aquarium studies indicate that the ration necessary for zero growth during spring and summer experiments increased from about 2 percent of body weight per day at 15°C (59°F) to 5.5 percent per day at 22°C (71.6°F). At low and moderate feeding levels, fish at control and intermediate temperatures had greater growth rates than did fish exposed to the highest temperature regime. At the highest ration levels growth was generally not greatly different at the various test temperatures. The increased requirements for maintenance resulted in reduced growth rates at high temperatures especially during warm summer months. The size of the coho smolt, which is the seaward bound migrant, has been shown from hatchery releases to be positively related to the number of returning adults. Typical coho smolts migrating from a natural stream in April and May were found to be about 15.9g in weight and 115 mm long. In comparison, fish held at control temperatures in aquaria were 15.9 g and 102 mm by April. Fish exposed to the two higher temperatures were well below average migrant size. Somewhat higher growth during October and November in the warmer water did not compensate for spring and summer reductions in growth (Everson, 1971).

In the model stream experiments one of the two streams was heated 5°C above the control temperature regime. Young salmon fed on insects and other invertebrates produced in the stream itself. During the first fall-winter period there was slightly greater salmon production in the warmer stream than in the control. This was apparently because of increased food density in the heated stream. During spring and summer, production of salmon in the control stream was much greater than in the heated one. The control stream had a maximum temperature of about 17°C (62.6°F), and the heated stream had a maximum of 22°C (71.6°F). Substantial increases in the spring and summer food density in the control stream along with reduced fish maintenance costs resulted in increased productivity of the cooler stream for salmon. One mayfly species, a major salmon food organism, was found in reduced numbers in the warm stream (Iverson, R. A., unpublished data).

These data suggest that an increase in the biomass of food organisms may occur in winter because of increased temperatures, but during spring and summer, the important growth period for juvenile salmon, a reduction in the biomass of food organisms and increases in fish maintenance costs may reduce the annual production of coho salmon in streams where temperature is significantly increased.

Charles E. Warren, Director of the Pacific Cooperative Fisheries Laboratory, has proposed a bioenergetic approach to study the effects of the environment on growth of fish (Warren and Davis, 1967). In this approach the energy budget of fish is described. Biologists measure the food consumption of fish and determine the amount of this food energy needed for metabolism, how much is wasted, how much is used up in activity, and how much energy is left over for growth. Averett (1968) used this rationale in measuring the energy relations of juvenile coho salmon exposed to different constant temperatures during different seasons. The range of temperatures at which maximum efficiency of food utilization for growth occurred changed with season and depended upon the range of consumption rates. The most efficient growth, within consumption ranges estimated to occur in nature, was at the temperatures of 5°-14°C in early spring, 11°-14°C in early summer, 14° - 17°C in late summer, 11° - 17°C in fall, and 5° - 8°C in late winter. Efficient food utilization for growth sometimes occurred at higher temperatures, but only at consumption rates thought to be well beyond those usually existing in nature.

Temperature may also have a directive effect. Some fishes can respond to temperature changes of less than 1°C and will follow a temperature gradient to a preferred level. Preferred temperatures for most juvenile salmon are between 12° and 14°C (Brett, 1952). Juveniles of all salmon species apparently will avoid temperautes above 15°C when a gradient is present. Migrating fish are thought to avoid thermal plumes associated with heated discharges. Some evidence suggests that the upstream migration of adult salmon and steelhead has an increased tendency to be inhibited at temperatures above 21°C (70°F). Burrows (1963) suggests that the optimum temperatures for migration of salmon adults are between 45° and 60°F; however, Columbia River temperatures normally exceed 60°F during summer migration periods.

The response of algal and invertebrate populations to temperature increases is perhaps the least understood aspect of the problem. It has been generalized that diatoms form the major part of aquatic communities at relatively low temperatures (below 30°C), green algae predominate at intermediate temperatures (30°-35°C), and blue-greens at high temperatures (over 35°C). The effects of small temperature changes on the species composition of aquatic communities are not well documented, and the importance of diversity changes to the rest of the aquatic community is not clear. Blue-green algae are considered to be a poor food source for herbivores and in some cases are classed as nuisance forms. Rates of photosynthesis have been shown to increase at temperatures up to 18.5°C when adequate light is present (Phinney and McIntire, 1965) which suggests that some increases in plant biomass may result from heated discharges.

The influence of temperature on the invertebrates which are important as fish food has not been well defined. There is some evidence indicating that some aquatic insects, particularly the midges, are more tolerant of thermal increases than the cold water salmonids. Wurtz (1960) lists 22-hour lethal temperatures ranging between 84.2 and 101.8°F for seven midge species. Other studies have shown that species compostiion may change as temperature rises, with the more heat tolerant species replacing the less tolerant. Unfortunately no definitive answer can now be given to describe the extent and importance of changes in the invertebrate community which may result from thermal addition.

Temperature may also act as an accessory factor, interacting with biotic or physical-chemical factors in the environment and altering their effects on aquatic organisms. For instance, from the literature it is apparent that most salmon disease organisms are more virulent at warm temperatures. Laboratory studies and field observations have shown that elevated temperatures drastically increase the occurrence of such fish deseases as kidney disease, furunculosis, vibrio disease and columnaris disease (Ordal and Pacha, 1963). Burrows (1960) defines the critical water temperature for disease development in chinook and sockeye salmon as 60°F. Temperature may modify also the effects of water quality parameters such as dissolved gas concentrations. Recent measurements of nitrogen gas at supersaturated concentrations in Columbia River water has raised concern about a possible danger to fish life. These gases may evolve as bubbles in fish body fluids, causing death by interruption of blood circulation, a condition known as gas-bubble disease. Increased temperatures reduce the solubility of gases and may therefore increase the danger to fish. The effects on fish of low dissolved oxygen concentrations and of certain toxicants are more severe at elevated temperatures.

In general, the excess temperatures may be considered a form of stress loading that may reduce the success of aquatic organisms in facing other stresses.

Burrows (1963) has postulated these temperature requirements for maximum production of salmon in fresh water:

For upstream migration	45°-60°F
Spawning and egg deposition	42.5°-55°F
Egg survival after the 128-cell stage	32°-55°F
Productivity of the fingerling stage	50°-60°F

Although biologists have not yet developed temperature requirements for salmon to a high level of definition, Burrow's findings along with results of studies previously mentioned suggest that streams with modified temperature characteristics, such as the Columbia River, already have marginal water quality conditions for salmon during some months of the year. Further increases in temperature during these periods can be considered detrimental to maintaining salmon populations at high levels of production.

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RELEASE OF CHEMICAL ADDITIVES IN COOLING WATER—PART I

Norman H. Cutshall

We will be concerned today with two types of biological changes in the environment that may be brought about by the chemical effluents from nuclear power plants: (1) the stimulation of certain species to grow more abundantly and, (2) inhibition of other organisms.

Nuclear power plants use water and add chemicals to the water for a number of reasons. The most abundant and greatest number of chemicals are added for corrosion control in the plumbing system and heat exchanger. Somewhat related to this is the control of pH or acidity in the waters. Some chemicals are added in order to prevent algae and other organisms from fouling and plugging up the plumbing. Finally, at least one, boron, is used partially to assist in the control of the nuclear reaction itself within the reactor.

The power plant itself is but one portion of chemical operations related to nuclear power. Some other operations which have chemical effluents are mining, milling of the ore and fuel fabrication. After the reactor is through with the fuel, there are chemicals used in the reprocessing and these plants have chemical effluents. Finally, the management of wastes may, possibly, produce chemical effluents.

Although eventually we must take into consideration all of these aspects, today we're talking just about the power plant, specifically the Trojan plant because this is one for which we have readily available up-to-date numbers. Different types of power plant systems release different amounts of water. The total amounts of chemicals may vary slightly, but probably not greatly. The nature of the chemicals involved is rather uniform from plant to plant. In Table 1 the expected discharge of water from the Trojan plant is shown. The amounts will run from 1.5 to 8 million gallons per day. I have converted a fairly representative flow rate for the Columbia River at McNary from thousands of cubic feet per second (cfs) to millions of gallons per day in order to compare it with the Trojan plant effluent. Concentrations of chemicals in the water are, of course, at a maximum when you have a minimum amount of water for dilution; thus, we use the lower figures for comparison of concentrations. I divided one by the other in order to show that the Trojan effluent is only a small fraction of the flow of the Columbia River.

Table 1. Volume Comparison for Trojan Plant Discharge and Columbia River Flow at McNary Dam

Trojan Plant	1.5-8 million gallons per day
Columbia River at McNary Dam (1961-2)	75-450 thousand cubic ft per second (48,000 - 290,000 million gallons per day)
Flow Ratio $\frac{\text{Trojan}}{\text{Columbia}}$	= 0.0000312 for low river flow

Table 2 shows several chemicals and associated numbers. These numbers are at first somewhat unfamiliar and hard to compare, but are necessary to approach a quantitative assessment of what we can expect from a plant. In the first column on the left, the maximum release concentration of the chemicals in the Trojan effluent water is shown in parts per million in weight units. The second column, in the same units, gives the mean concentration of chemicals in the Columbia River at McNary Dam, with the exception of the phosphate number which is taken from the lower river for which we had more available data. In the fourth column, I have divided the maximum concentration of the chemical in the Trojan effluent by the mean concentration of the Columbia River at McNary. Note that the Columbia River at McNary varies from 48,000 to 290,000 million gallons per day discharge. This is one of the aspects of natural change. We go through annual or seasonal cycles of several-fold variation in just the discharge alone.

Table 2. Chemical Concentrations in Trojan Plant Effluent and Columbia River Water

Chemical	Trojan (maximum)	Columbia (mean)	Trojan / Columbia
Sulfate	824 ppm	20 ppm	41
Phosphate	25 "	0.025 ppm	1000
Chromate	14 "	0.005 "	2800
Zinc	2. "	0.02 "	100
Boron	0.48 ppm	0.03 "	16
Chlorine	1.5 "	?	?
Volatile amines	0.1 "	?	?

Chlorine is shown to be, at maximum, 1.5 parts per million in the Trojan plant effluent. There are no data to my knowledge on chlorine in the Columbia River but, for reference, municipal drinking water supplies operate with chlorine concentration of about one part per million. The concentration of the volatile amines is rather low. The three chemicals for which the numbers are largest are chromate or chromium, phosphate and zinc. Concentrations are perhaps most meaningful to the species that live in the river and experience them first hand. These concentrations will vary. From the maximum right at the outfall, they will be rapidly diluted to a much lower level after complete mixing in the river. The larger the volume of water, the greater the mixing and the lower the concentration will be. The volume of the river in which the maximum concentration occurs is very, very small.

A percent increase over the natural river levels is shown in Table 3 for chromium, phosphorus, and zinc, three elements added as corrosion inhibitors. These were calculated somewhat roughly and fairly conservatively by assuming mean Columbia River chemical concentration with minimum flows. Rather than dwell upon the absolute magnitudes of these, as they are rather high estimates of the actual percent increase expected, I want to emphasize the relationship between them. The percent of increase of chromium is about three-fold greater than the increase of phosphorus and, again, there is about a three-fold difference between the phosphorus and the zinc.

Table 3. Selected Chemical Characteristics

Chromium (9% increase)---	Two chemical forms, chromate = oxidized, soluble Cr (III) = reduced, insoluble A moderately toxic metal.
Phosphorus (3% increase)-	Two chemical forms in effluent, 80% polyphosphate 20% orthophosphate Biologically essential, may stimulate growth
Zinc (1% increase)-------	Initially released in dissolved form, tends to be rapidly adsorbed to sediments in river. Biologically essential at low concentrations, toxic at high concentrations

Chromium will be released as chromate, an oxidized chemical form which is quite soluble in river water. It happens to be the chemical form in which ^{51}Cr is being released to the river by the Hanford operation. We followed the ^{51}Cr through the system for several years and found that the chromate tends to remain in solution all through the river. Even after it reaches the ocean, it floats along the surface for hundreds of miles at sea until eventually it is diluted beyond any detection. If it reaches an environment which is very low in oxygen or high in organic matter, it may be converted to a reduced chemical form which is very much less soluble and eventually become incorporated into sediment. In the Columbia River most of the chromate just flows on into the ocean.

Phosphorus, which is 25 parts per million in the effluent, is comprised of two chemical forms of phosphorus, about 80 percent polyphosphate and about 20 percent orthophosphate. Orthophosphate is more readily utilized by the phytoplankton in the water, but the polyphosphate may also be used. Phosphorus is a requirement for organisms and is used to fertilize plants.

Zinc is distributed between the dissolved zinc chemical form and a chemical form that is adsorbed onto particulate material. We think that zinc absorbs the sediment and is less available to organisms, particularly those which live in the water. By tracing the radionuclide ^{65}Zn from Hanford in the system, we found that although it was initially introduced in the dissolved form, within a few tenths of miles the bulk of the zinc becomes associated with particulate material. A good deal of it then goes into bottom sediment and at the mouth of the river about 80 percent of the zinc has become associated with particulate material.

RELEASE OF CHEMICAL ADDITIVES IN COOLING WATER—PART II, BIOLOGICAL CONSIDERATIONS

Richard S. Caldwell

Dr. Cutshall has discussed some of the chemicals that may be found in reactor cooling water and which, depending on the system employed, may find their way into the Columbia River ecosystem. I would like to extend his discussion to provide some indication of the possible effects that these wastes may have on the aquatic biota. In order to avoid misunderstanding, I feel compelled at the outset to state that with the present level of biological knowledge, it is virtually impossible to predict with any certainty the eventual biological outcome of chemicals added to the river. Instead I hope to impart a feeling of how chemicals affect organisms and indirectly affect biological communities along with some understanding of the complexity of interactions and the resulting uncertainty of predictions.

For purposes of discussion, I will assume that discharged chemicals will be of the same type and quantity as those to be discharged by the proposed Trojan nuclear plant which employs a cooling tower. The maximum discharge data (U.S. Atomic Energy Commission, 1970) are listed in Table 1. The proposed Trojan discharge rate is 7 cubic feet per second, which compares to a minimum Columbia River flow of about 100,000 cubic feet per second (Battelle-Northwest, 1967). The resulting dilution factor is, therefore, greater than 10,000. This figure will be used subsequently in calculations.

Table 1

Trojan Plant's Chemical Discharge Limits

Chemical	Concentration (parts per million)
Polyphosphate	21
Free residual chlorine	1.5
Sulfate	824
Chromate	14
Zinc	2
Orthophosphate	3.9
Volatile amines	0.1
Boron	0.48
Lithium	0.002
Sodium	172

There are three primary ways by which dissolved chemicals may affect fish and aquatic organisms. These are: 1) by deoxygenation of receiving waters, 2) through environmental effects of nontoxic salts and 3) by direct toxic action (Hyns, 1963).

DEOXYGENATION OF RECEIVING WATERS

Deoxygenation of receiving waters, a problem usually associated with organic wastes, occurs as a result of the oxidation of these complex molecules in the presence of suitable microorganisms. Such wastes are said to exert a biological oxygen demand. Oxidation of inorganic chemicals or other reducing agents may also occur in the absence of microorganisms. Since the concentration of organic chemicals will be very low in cooling waters and since the inorganic chemicals are already in a highly oxidized state, deoxygenation caused by dissolved chemicals is not likely to be a significant factor in this case.

DISSOLVED NONTOXIC SALTS

The dissolved nontoxic salts include such forms as sodium, calcium and magnesium along with the anionic chlorides, carbonates, sulfates, nitrates and phosphates. These chemicals can generally be tolerated by fresh-water organisms at fairl high concentrations, the upper levels set more by osmotic effects than by a specific toxic effect. The National Technical Advisory Subcommittee on Water Quality Criteria for Fish, Other Aquatic Life and Wildlife (1968) recommended that dissolved materials not exceed 50 milliosmoles, which is equivalent to about 1,500 parts per million of sodium chloride. Initial concentrations of dissolved materials in the Trojan waste are less than half the recommended maximum level, and after dilution they are less than 1/20,000 (0.00005) of that level. Clearly then, the osmotic effects under these circumstances are negligible.

On the other hand, the addition of dissolved chemicals may stimulate the growth of plankton by providing nutrients that had been lacking. Some growth stimulation might be desirable since more food would be available for invertebrates and fish, but excessive growth could lead to oxygen depletion and other undesirable effects. The Trojan waste chemicals most likely to stimulate growth are the phosphates. Current phosphate levels in the Columbia River are reported to be about 20 parts per billion (Battelle-Northwest, 1967). Addition of Trojan wastes would increase that level to 21 or 22 parts per billion. The National Technical Advisory Subcommittee (1968) recommended that total phosphorus not exceed 100 parts per billion in flowing streams or 50 parts per billion in lakes or reservoirs. Since the present level is already 1/5 (0.2) of the recommended maximum level, further additions should be considered with care even though they may only increase river phosphate by a few parts per billion.

TOXICITY

Finally, let us consider the possibility of exposure to highly toxic chemicals, those which may be lethal at only a few parts per million or less. Tc begin with, let me review a few principles. Pollution biologists have customarily assessed the toxicity of a chemical to a particular species by determining the concentration of that chemical, dissolved in water, which results in mortality to 50 percent of the test animals in a specified period of time. Since the time period specified is usually 96 hours, the concentration is referred to as the 96-hour median tolerance limit or 96-hour TL_m. Obviously the 96-hour TL_m is an unacceptable concentration in a river if it is to maintain a constant population level. What is needed is a knowledge of the maximum concentration which produces no mortality or inhibition of reproduction over a much longer period of time. However, such information is much more difficult and expensive to obtain than the 96-hour TL_m, and consequently, is not readily available.

In order to utilize the 96-hour TL_m, biologists have applied safety or application factors to this value to permit estimation of tolerable or "safe" levels of dissolved toxicants. There is still considerable disagreement among biologists as to what constitutes an appropriate application factor. In fact, application factors may vary from one toxicant to another and may be species specific. While recognizing these limitations, the National Technical Advisory Subcommittee (1968) has recommended that the following general application factors be adopted until further data are available: 1) for nonpersistent or noncumulative materials, having less than a 96-hour half life, the concentration should not exceed 1/10 (0.1) of the 96-hour TL_m at any time after mixing, nor should the 24-hour average exceed 1/20 (0.05) of the 96-hour TL_m at any time after mixing and, 2) for persistent toxicants, the same values should be 1/20 (0.05) and 1/100 (0.01) of the 96-hour TL_m.

With this background let's compare the concentrations of the Trojan waste chemicals in the Columbia River after mixing to some representative TL_m values (Resources Agency of California, 1963).

Sodium, sulfate and phosphates fall into the nontoxic category and may be eliminated from further consideration. Likewise boron as borate or boric acid and lithium salts are toxic to fish only at fairly high concentrations exceeding 100 parts per million. However, lithium chloride immobilizes *Daphnia magna*, a water flea, at only 7.2 parts per million. The toxicity of a series of 34 amines to creek chub in 24 hours ranged from about 5 parts per million up to 16,000 parts per million. The concentrations of all of these in the Columbia River after mixing would be many times less than toxic levels. The remaining three chemicals, free chlorine, chromate and zinc, are somewhat more toxic and may be present in high enough concentrations to exert some effect.

Free chlorine is reportedly toxic to fish at concentrations from 30 parts per billion to 3,000 parts per billion. Assuming that no free chlorine was present in the river before mixing, the residual concentration after mixing would be only 0.15 parts per billion, less than 1/100 of the lowest reported toxic level. This dilution would seem to be safe using the 1/100 application factor guideline of the National Technical Advisory Subcommittee.

Extreme variations in the toxicity of zinc to fish have been reported, ranging from a low of only 10 parts per billion to a high of 200,000 parts per billion. The mean concentration of zinc in the Columbia River at McNary Dam has been reported to be 21 parts per billion (Kopp and Kroner, 1967). After mixing with the Trojan waste effluent the level would rise only to about 21.2 parts per billion. Thus, a chemical may already be reaching critical levels, but the addition is quite small.

River chromium exists primarily in the hexavalent form as dichromate or chromate anions. The toxicity of these forms to fish ranges from 5 parts per million to 520 parts per million (Resources Agency of California, 1963). However, the application factor may be very large for some species such as salmon and trout (National Technical Advisory Committee, 1968). Work at Hanford has suggested that the safe level for these species may be as low as 10 to 15 parts per billion. Toxicities of hexavalent chromium towards other organisms, both invertebrates and algae, range from 16 parts per billion to 148,000 parts per billion. The mean concentration of

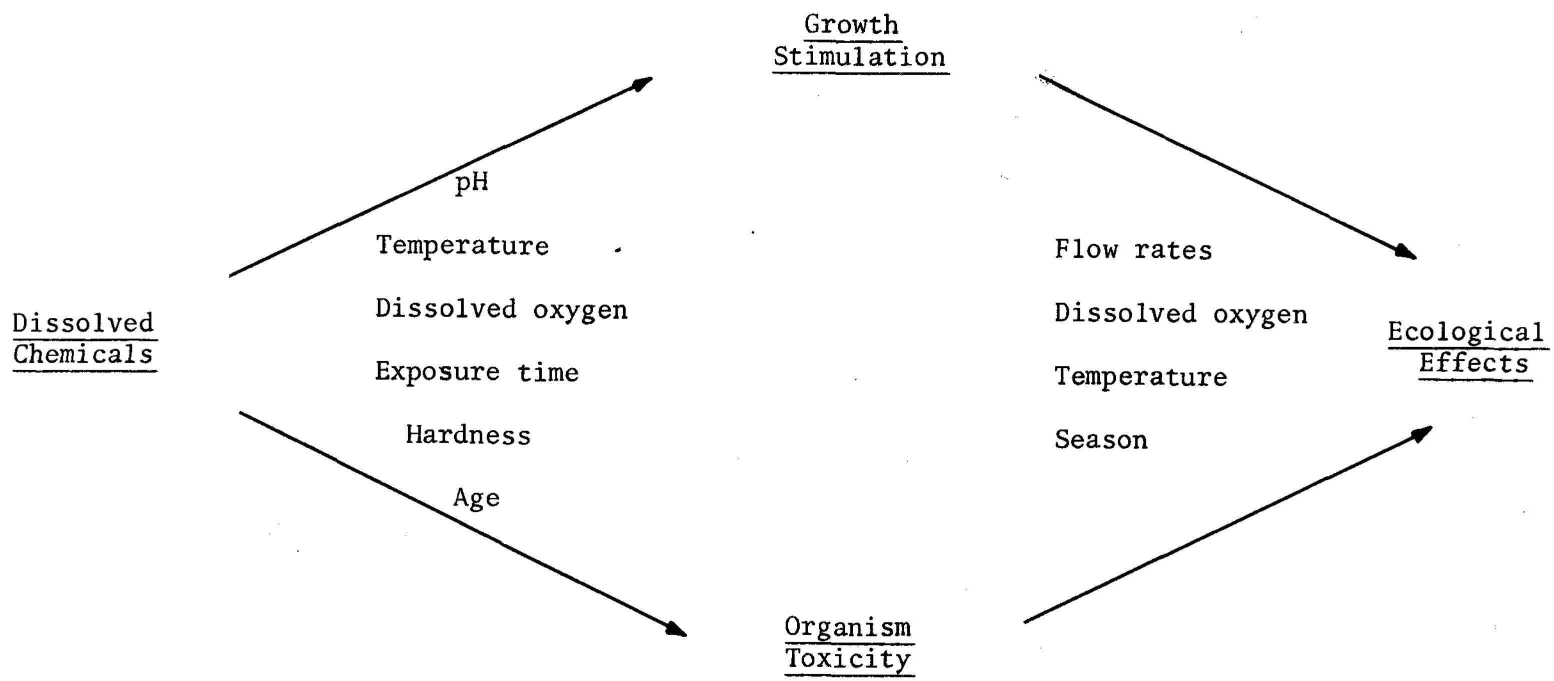
Growth
Stimulation
Dissolved
Chemicals
pH
Temperature
Dissolved oxygen
Exposure time
Hardness
Age
Flow rates
Dissolved oxygen
Temperature
Season
Ecological
Effects
Organism
Toxicity

Figure 1

chromium in the Columbia River is reported to be 6 parts per billion with a range of from 1 to 22 parts per billion (Kopp and Kroner, 1967). These levels suggest that the threshold of chromium toxicity for some species may already have been reached. Chromium waste from another nuclear plant similar to Trojan would increase these values by about 1.4 parts per billion at the maximum.

To summarize these data, some caution seems indicated with respect to the toxicants chromium and zinc and the plant nutrient phosphate.

Figure 1 summarizes some important concepts in an oversimplified diagram. Dissolved chemicals may be toxic to plants and animals with resultant ecological change. Alternatively they may stimulate growth which again leads to ecological change. I have indicated in the diagram only a few of the physical and biological factors which influence these effects to emphasize the extreme complexity of predicting the ecological changes from a knowledge of the chemical additives. While there seems to be little reason to anticipate biological damage in the Columbia River from the chemicals of a nuclear plant waste discharge similar to that of the Trojan plant, there are so many unknowns and assumptions that we must continue to recognize the possibility of unforeseen damage.

DISCUSSION

Q: Please clarify the figures given in parts per million and parts per billion.

A: These are weight relationships. One part per billion is equivalent to 1/1000 of a part per million.

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DISPOSAL OF RADIOACTIVE WASTES FROM NUCLEAR POWER PLANTS

Marshall W. Parrott with the
technical assistance of Gary Boothe

Essentially, there are two levels of waste from a nuclear power plant. Low-level wastes are produced by neutrons from the core impinging upon various nonradioactive elements. High-level wastes are comprised of the fuel rods from the core.

Low-level wastes may be derived from ion exchange resins used to clean the products of a neutron activation cooling system. Other waste may result from small bits of rag used to wipe up a minor spill or from the isotope retention units that prevent the release of radioactive materials to the environment. When properly handled, this material is not hazardous. Its transport in steel barrels to a burial site does not create significant problems. Using cobalt-60 as the unit of measure, the resins are rarely over 100 curies and comprise about 55 cubic feet total per year. The half-lives of low-level wastes range from 5 to 10 years.

The high-level wastes from fuel rods are a serious hazard. The fuel rods are not considered a radiation hazard when they are first shipped to a plant and may be handled quite casually, with little or no shielding. After approximately one year of operation, between 25 and 33 percent of the fuel rods are removed from the reactor due to efficiency loss caused by xenon poisoning. Because they contain great quantities of short half-life radioactivity, they are placed in a tank of water to cool for a period of approximately three months, before being removed and transported from the reactor to one of the three fuel reprocessing plants in the United States. No reprocessing takes place within Oregon, thus safe transportation of nuclear fuel rods has been the major concern. These rods are very radioactive and must be handled with great care to avoid contamination or loss in transit.

Primary reliance for safety is placed on the container in which the rods are shipped. The characteristics of the container and its contents have been clearly defined. For example, in a normal, undamaged container, radiation and heat from the contents might be a hazard; container design must protect against these hazards by shielding and cooling. Packages must be built and tested to standards that would prevent release of the contents under "hypothetical accident" conditions. The containers must be designed, constructed and tested to prevent release of the contents and loss of shielding beyond specified limits under three conditions: if the package were to drop 30 feet in its most vulnerable position onto a hard, flat surface; if it were to drop 40 inches onto a 6-inch diameter steel spike; if a fire were to occur at 1,475°F for 30 minutes followed by total immersion of the package in water. In the transportation of all types of radioactive materials, there is a vast difference between potential hazard and realized damage. The safety design of the container has primary importance in preventing the potential danger from becoming a reality.

The shipment that arrives at the reprocessing plant undergoes a series of steps as shown in Figure 1. The low-level waste generated by the operation of these plants may be stored on the site for decay, concentrated and sent to permanent burial sites, or discharged to the environment. High-level waste may be stored for decay for an interim period but eventually must be converted into solid form and transported to designated permanent retention sites for storage. The recovered uranium and plutonium must also be transported to manufacturing plants for refabrication into ^{238}U slightly enriched with 2 or 3 percent ^{235}U. Only about 2 percent of the rod is actually utilized in the fission process thus recovery of the remaining 98 percent is both feasible and essential.

A major problem is the disposal of the high-level waste generated from these reprocessing plants. Currently, the Atomic Energy Commission is investigating the possibility of the use of salt mines in Lyons, Kansas for permanent storage of this material, with the possibility of future utilization. The fission product buildup during the irradiation within the core of the power reactor is quite rapid and reaches an equilibrium at approximately 500 days, thus the decay and the production of the radioactive material are about equal. The amounts of material in beta and gamma curies, the initial half-times and fractional fission product activity remaining as waste are shown in Table 1.

Table 1

FUEL CORE FISSION PRODUCT ACTIVITY
OF AN 1,100 MEGAWATT NUCLEAR POWER REACTOR

Total Beta and Gamma Curies produced after 500 days of operation equals 1.57×10^9 Ci.

Total Beta and Gamma Curies produced after 50 years of operation equals 1.76×10^9 Ci (1 day after shutdown).

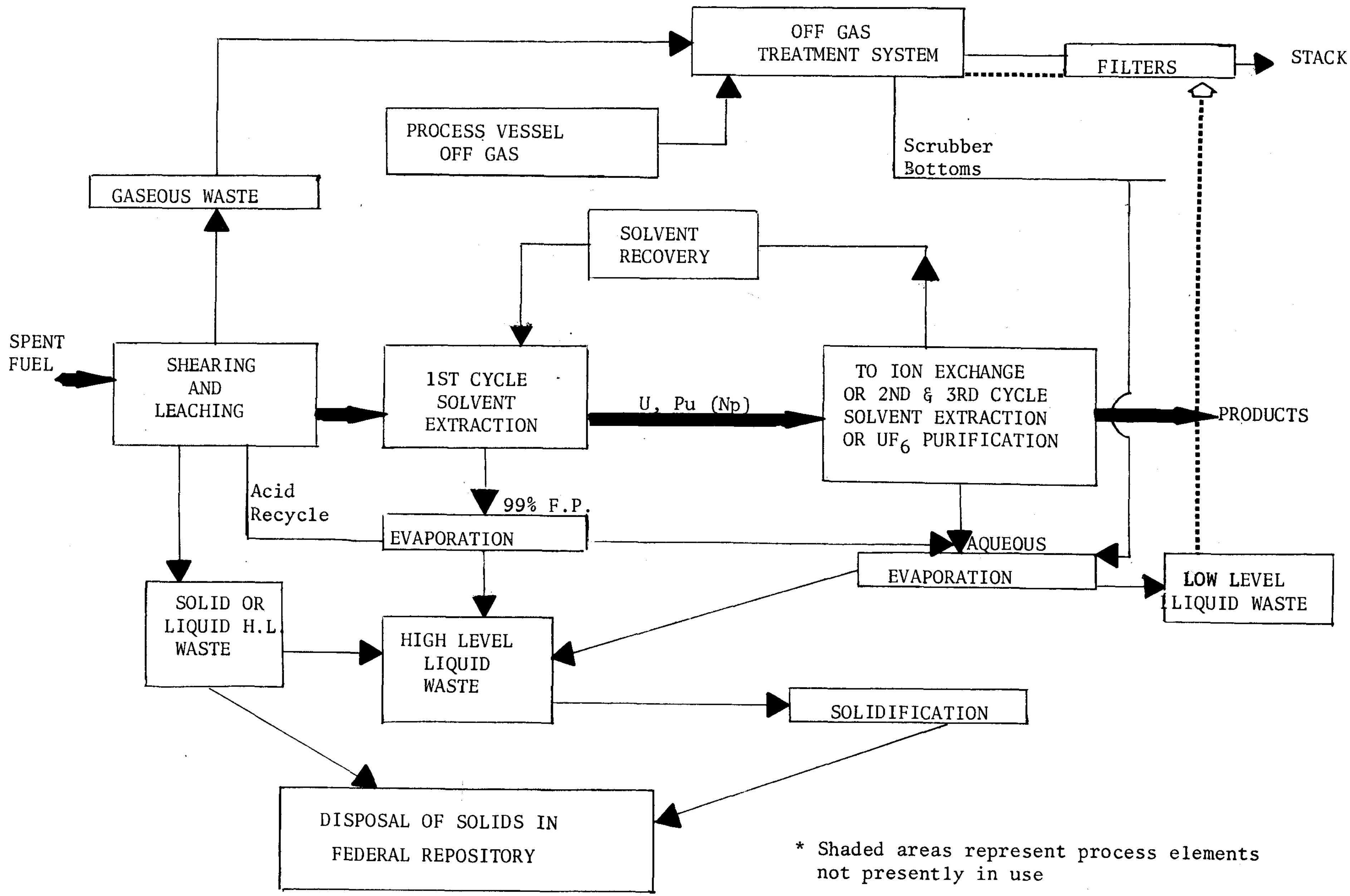
Half-life at time specified after shutdown:

	T 1/2
100 seconds	0.81 days
1 year	0.73 years

Time After Shutdown in Years	Fraction of Initial Fission Product Activity Remaining
0	1.00
1	0.06
2	0.02
3	0.01
4	0.009
5	0.008

This high-level solid waste represents approximately 40 cubic feet per year from a reactor of 1,100 megawatts. Table 2 shows the amount of material in the fuel which will require disposal or be used for medical purposes.

GENERALIZED REPROCESSING PLANT FLOW SHEET



* Shaded areas represent process elements not presently in use

Figure 1

Table 2.

ACTIVITY IN FUEL ONE YEAR OF OPERATION OF
1,100 MEGAWATT PLANT, ONE DAY DECAY

Isotope	T 1/2	Amount (megacuries)
Sr^{89}	50.5 days	140.00
Sr^{90}	28.9 years	4.30
Y^{90}	64.8 hours	3.22
Y^{91}	57.5 days	188.00
Mo^{99}	67.0 hours	143.00
I^{131}	8.1 days	82.50
Cs^{134}	2.3 years	0.108
Te^{132}	78.0 hours	108.00
I^{133}	20.5 hours	93.00
Cs^{136}	13.0 days	0.537
Cs^{137}	27.0 years	4.65
Ba^{140}	12.8 days	172.00
La^{140}	40.5 hours	129.00
Ce^{144}	290.0 days	107.00

Since approximately 2 percent of the uranium is utilized each year before a fuel exchange is made, technically after 50 years of operation only one core equivalent would have been used. An 1,100-MW pressurized water reactor requires approximately 140 tons of fuel for its first loading. One cubic foot of uranium has the same energy content as 1.7 million tons of coal, 7.2 million barrels of oil, or 32 billion cubic feet of natural gas. Fission of one gram of ^{235}U will produce about 1000 kilowatts of electricity over a period of 24 hours, and a pound will produce a quantity of heat equivalent to that from 1,480 tons of coal. Therefore, 140 tons in one reactor operating continuously for 50 years could produce the heat equivalent of 414,400,000 tons of coal.

IRRIGATION AND NUCLEAR POWER THERMAL PLANTS

John F. Mangan

Irrigation with warmed water is not entirely new here in the Northwest--there have been several opportunities for individuals to irrigate small tracts with naturally warmed water from thermal springs. In the Boise area there has been a most successful greenhouse operation using hot water to warm the soils. However, there has not been a great deal of information published on the use of warm water for irrigation until recent years. One of the outstanding demonstrations of the successful use of warm water is taking place right here in Oregon in a cooperative demonstration by the Eugene Water and Electric Board, the Federal Water Quality Administration, Weyerhaeuser Company, Vitro Corporation, and seven local farmers in the vicinity of Springfield, Oregon. This demonstration is showing that water at a temperature of 120°F can be successfully distributed to growing plants by overhead sprinkler irrigation.

In the demonstration project, the heated water leaves the Weyerhaeuser plant at 120°F, is carried to the 170-acre field through underground pipelines, and is then released to the crops through overhead sprinklers. The water traveling through the pipelines cools only about 10 degrees before it leaves the overhead sprinkler. Tests have shown, however, that when it reaches the crops after being sprayed into the air, it is close to wet bulb temperature. By comparison, water from a cool source pumped through the overhead sprinklers warms to near wet bulb temperature by the time it reaches the crops. The wet bulb temperature is normally several degrees less than air temperature, depending largely upon the relative humidity. If air temperature is 75°F and the relative humidity is 40 percent, the wet bulb temperature would be about 60°F. For the same 75°F air temperature but with 80 percent relative humidity, the wet bulb temperature would be about 71°F. The Springfield demonstration is confirming that when the warmed water is applied by sprinkler, it is very little different from the conventional overhead sprinkler irrigation that we know today. Figure 1 illustrates this point.

Within the past season, Oregon State University has conducted tests showing that when soil is heated by underground piping there is increased growth in several varieties of plants from the effects of higher soil temperature. Conversely, it has been demonstrated very dramatically that plants cannot resist high temperature water such as occurs when underground piping leaks and releases water upwards at 100°F directly to plants and trees. In this situation pole beans die quickly in puddled hot water and orchard trees are severely damaged or killed.

Knowing that warm water can be handled successfully through sprinkler application, we can now investigate the possibility of practical application on a large-scale development utilizing the large volumes of coolant water from a nuclear power plant. We have set up hypothetical situations based on broad assumptions to emphasize some of the considerations that are involved in a large-scale multipurpose nuclear-powered thermal plant and a related irrigation development.

Let us assume a nuclear power plant accessible to the Columbia River and in the vicinity of large tracts of potentially irrigable land. We have these two physical factors available to us here in northern Umatilla, Morrow, and Gilliam Counties.

The power plant people tell us that for once-through cooling of a 1,000-MW nuclear plant the required water supply would vary, depending on the allowable rise in temperature. A 20-degree rise in temperature would require about 1,600 second-feet. If a 40-degree rise were allowed, the flow of water would be much smaller, approximately 800 second-feet.

Using the warm water for irrigation during the growing season would dispose of the once-through flow of cooling water during the summer for a nuclear plant located on a river where the return of the warm water to the source would cause thermal pollution problems. This does not solve the problem during the nonirrigation season unless a sizable storage reservoir is available (Figure 2).

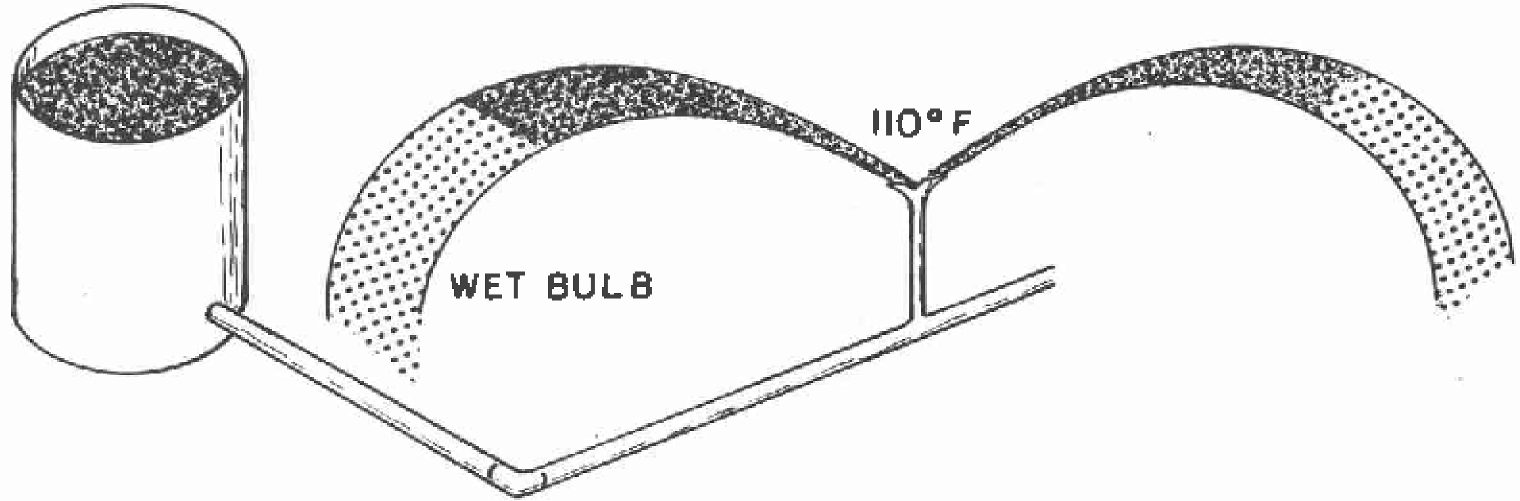
Assuming a 40-degree rise in water temperature on once-through cooling of a 1,000-MW power plant, the flow of water required for continuous operation would be 800 second-feet. We assume further that the nuclear plant would operate 90 percent of the time. Since the irrigation season is only about 8 months long, extending generally from March through October, it does not coincide with the continuous or near-continuous operation of the base load power plant. Therefore, storage is required to capture the outflow from the power plant and to reregulate it for irrigation use. On the basis of the assumptions we have made, this storage reservoir would need to be about 235,000 to 250,000 acre-feet in capacity. This water supply, however, and the 250,000 acre-foot reservoir, would be adequate to irrigate about 100,000 acres.

As illustrated in Figure 2, all of these lands would not necessarily need to depend on outflow from the reservoir. On the basis of the tests conducted at Springfield, if the water was applied to the crops by sprinkler, a substantial area of land could be irrigated directly from the discharge line depending on the physical conditions in the area, the length of the discharge line, and the suitability of the land for irrigation. Other lands could be served by a distribution system leading directly from the storage reservoir.

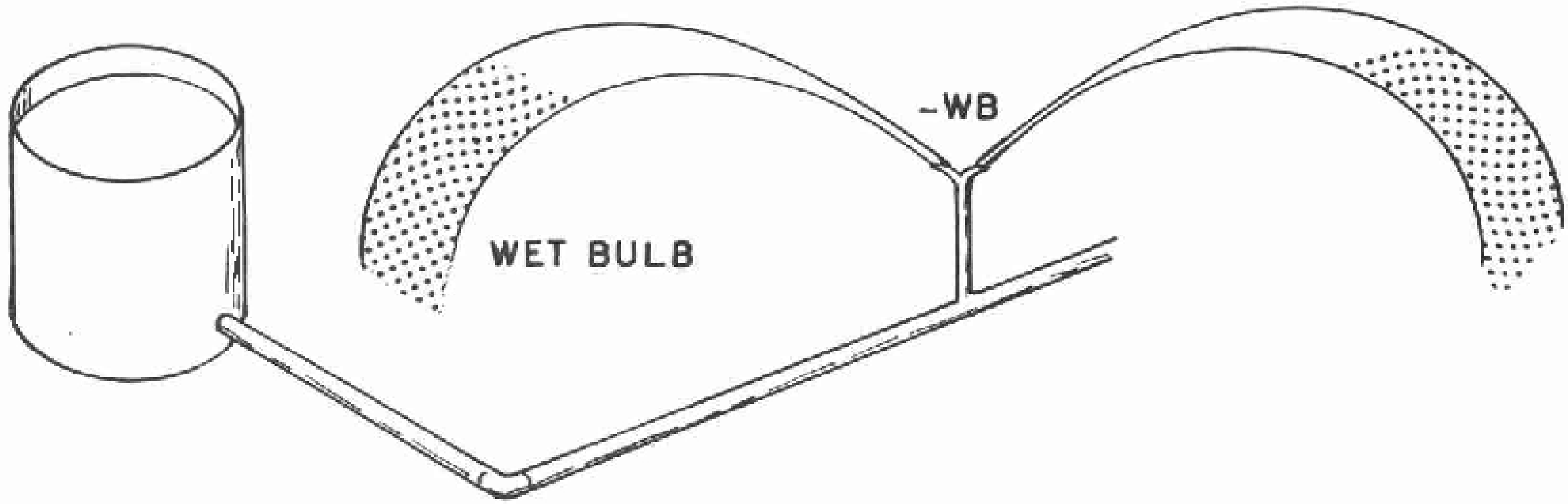
The project would benefit economically if the design of the power plant were closely coordinated with the design and layout of the irrigation system. The actual rise in temperature of the coolant water would determine the amount of regulating storage required and would affect the sizing of the discharge line. The topography of the area would determine the length of the discharge line, and the physical dimensions of the reservoir would be dependent on the topographic considerations of the surrounding terrain.

The irrigation system then would not be dependent on continuous operation of

Figure 1



Irrigation from warm water source



Irrigation from cold water source

Figure 2. Schematic layout with regulating reservoir
Power plant capacity 1,000 MW
Discharge line capacity 770 CFS
Discharge line diameter 120"
Regulating reservoir capacity 250,000 A.F.

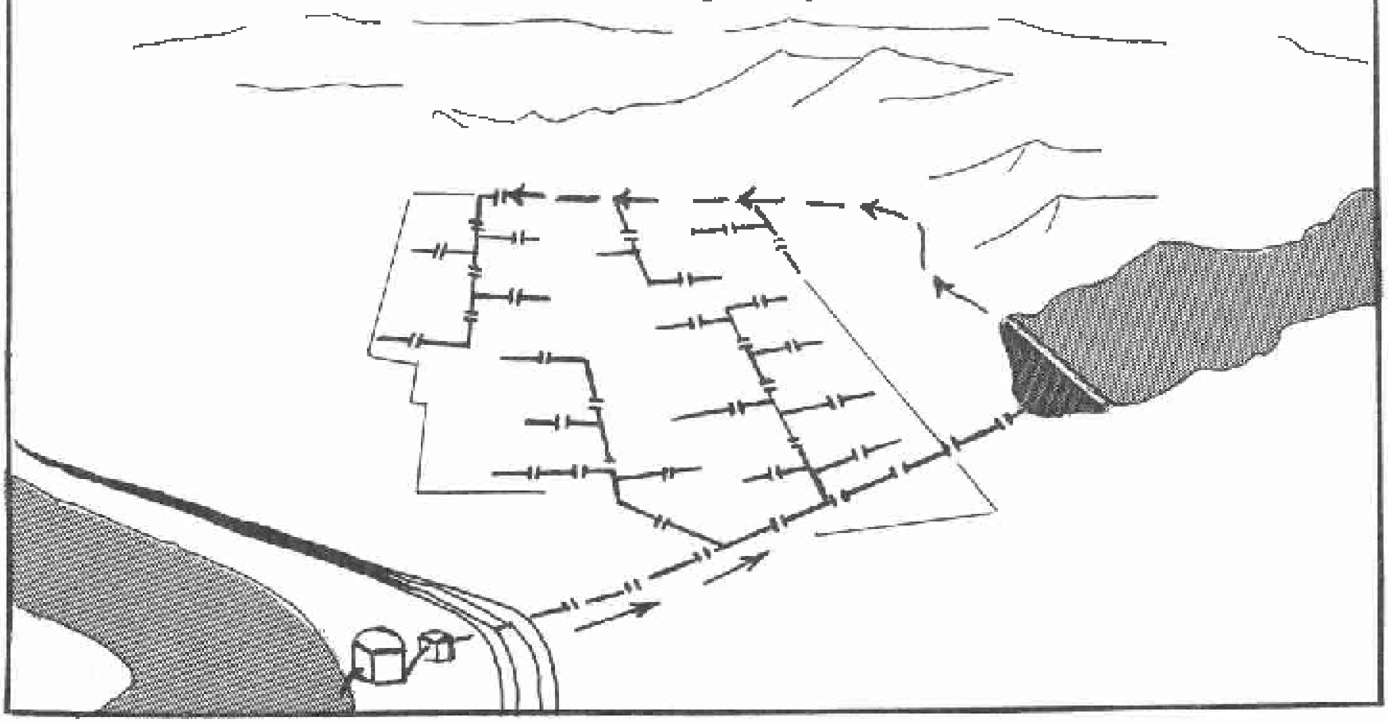
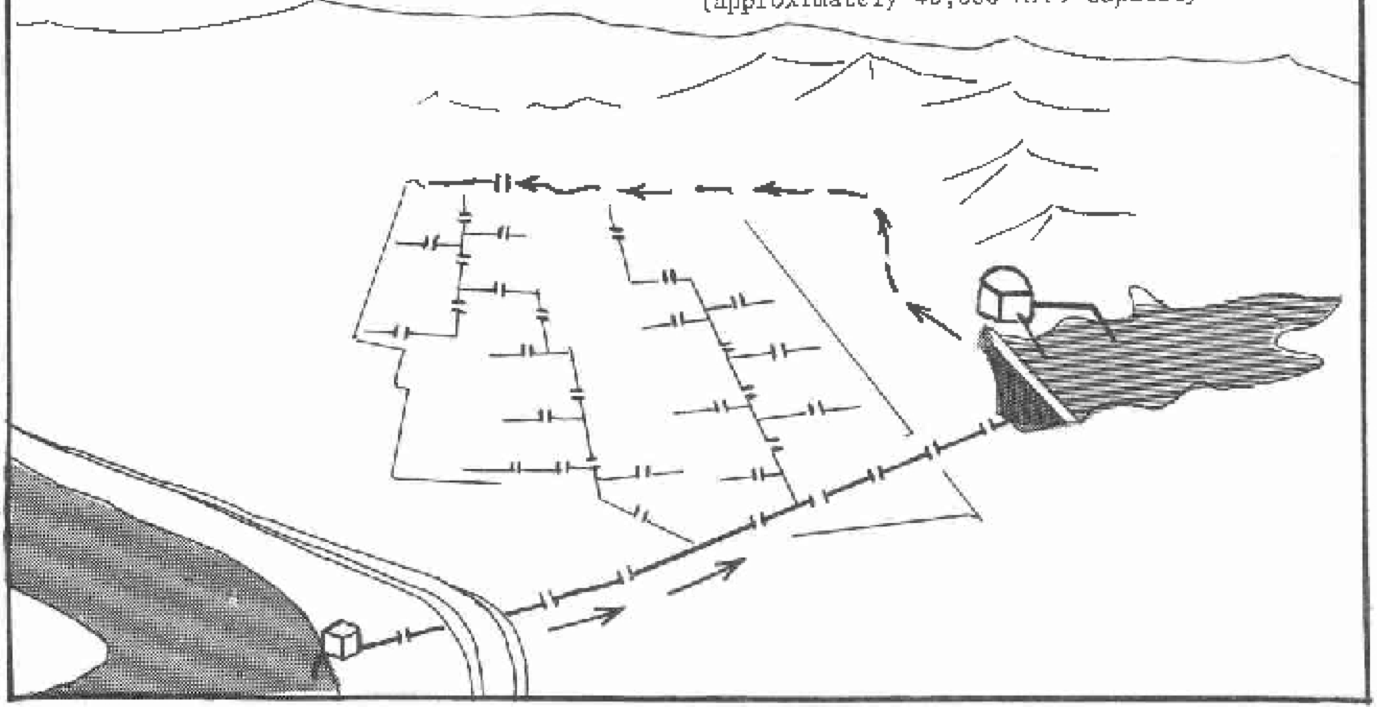


Figure 4. Schematic layout with cooling pond.
Power plant capacity 1,000 MW
Discharge line capacity 1,700 CFS
Discharge line decimeter 2 each - 120"
Cooling pond area 2,000 AC
(approximately 40,000 A.F. Capacity



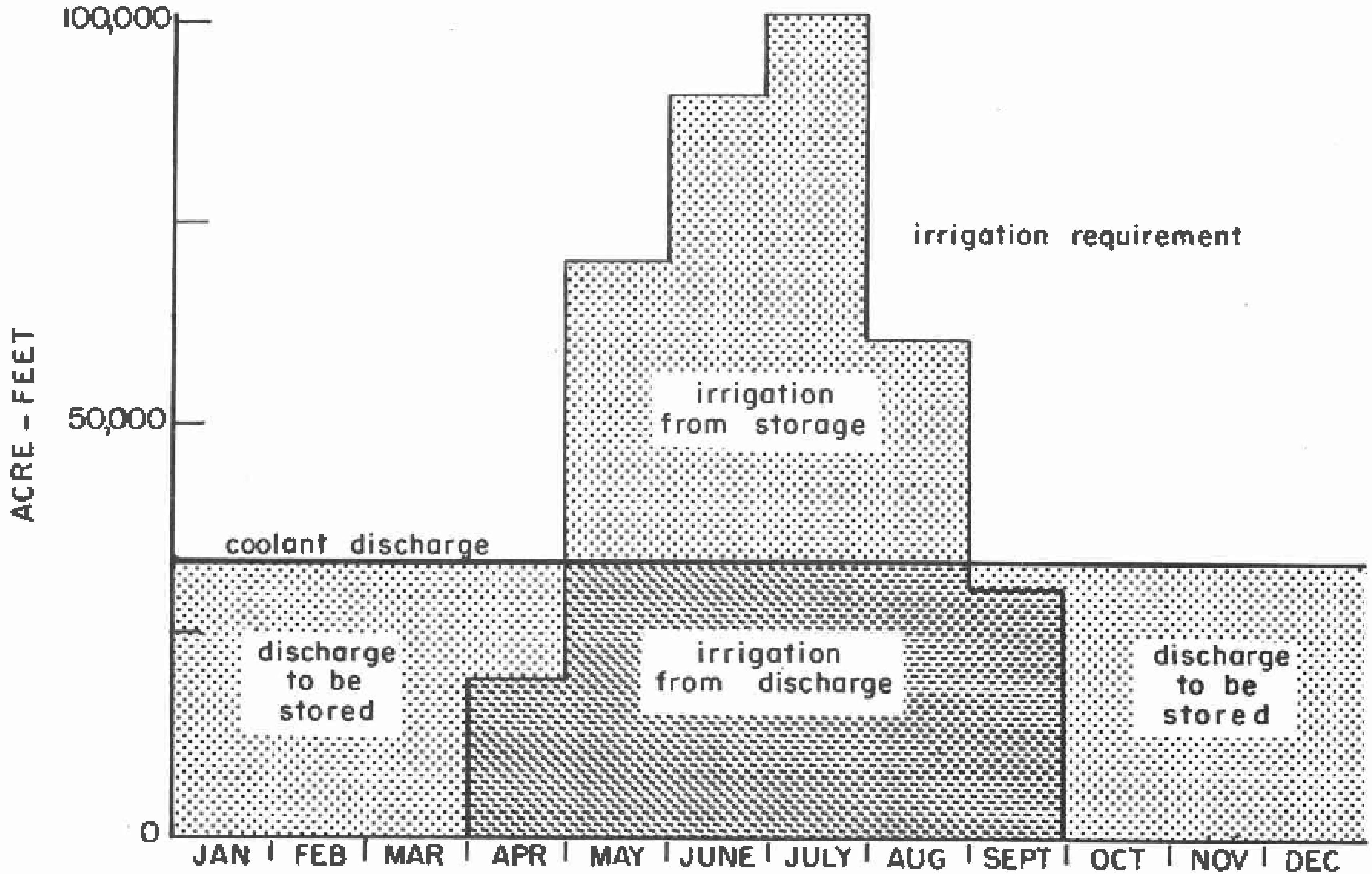
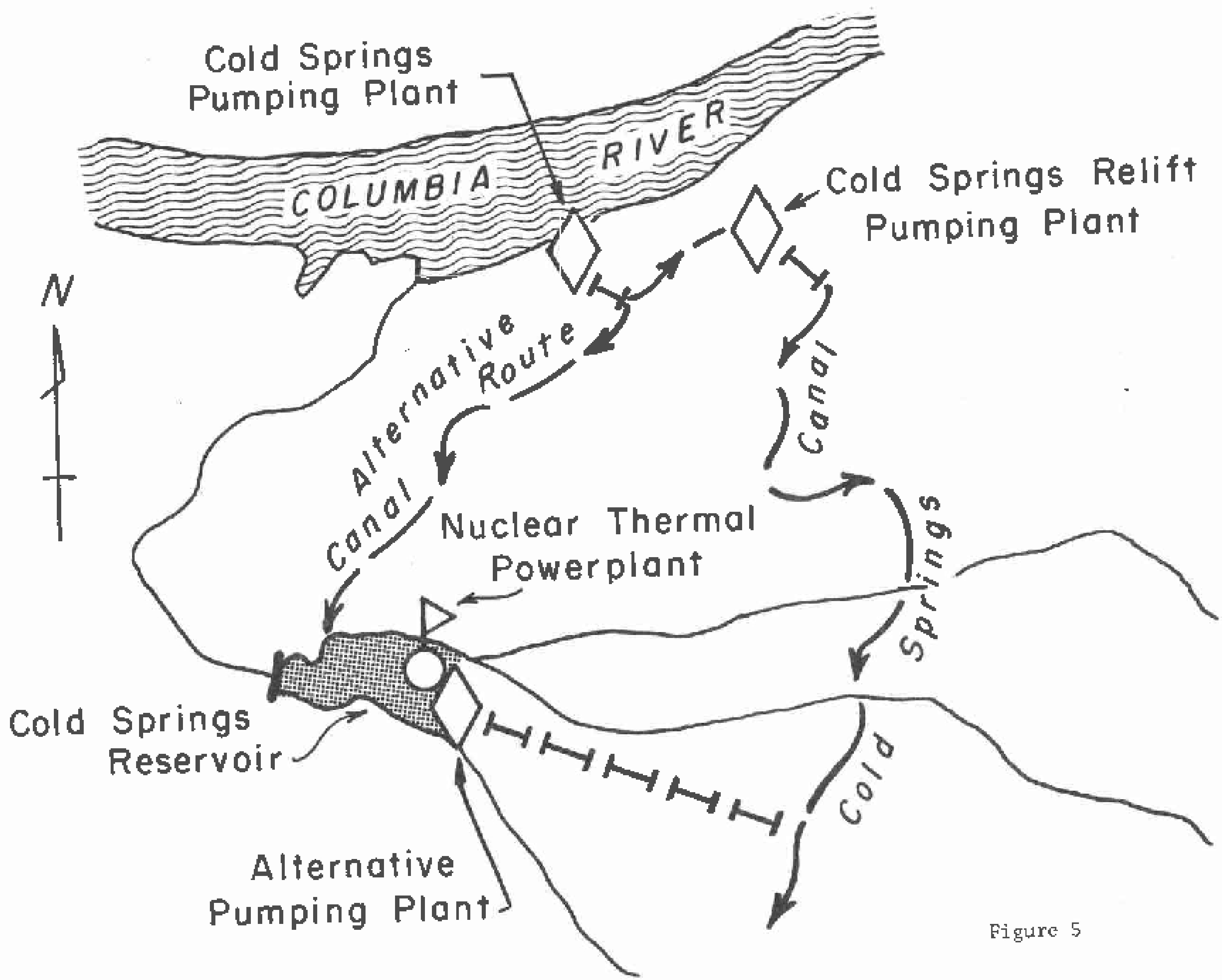


Figure 3. Reactor coolant discharge related to irrigation requirements.
Power plant capacity = 1,000 MW.
Irrigable area = 100,000 acres.



Cold Springs
Pumping Plant
COLUMBIA RIVER
Cold Springs Relift
Pumping Plant
N
Alternative Route
Canal
Canal
Cold Springs Canal
Nuclear Thermal
Powerplant
Cold Springs
Reservoir
Alternative
Pumping Plant

Figure 5

the power plant during the irrigation season; rather, an equalizing reservoir would capture the output of heated water and reregulate it for irrigation. During the nonirrigation season the reservoir would be on a filling schedule; during the irrigation season the water would be drawn from the reservoir and from the discharge line. If the power plant were shut down for servicing during the irrigation season, surplus water in the reservoir could be fed back through the discharge line to the lower-lying sprinkler-irrigated lands. The system would be designed to allow direct pumping for irrigation only during the irrigation season if the nuclear power plant were down for an extended period. The relationship between coolant water requirements and irrigation usage is shown in Figure .

An alternative plan would utilize a smaller equalizing reservoir with the power plant located on the shore of the reservoir (Figure 4). This scheme requires a substantially larger discharge line, but a much smaller equalizing reservoir. Under the cooling pond concept, it is estimated that a pond or reservoir surface area of 2 acres averaging 20 to 30 feet in depth would be required for 1 MW of thermal power. Thus our hypothetical plant would require a pond of about 2,000 surface acres with an average depth of 20 feet or more. It would act as a cooling pond during the nonirrigation season or at other times when the irrigation pumping plant is not in service.

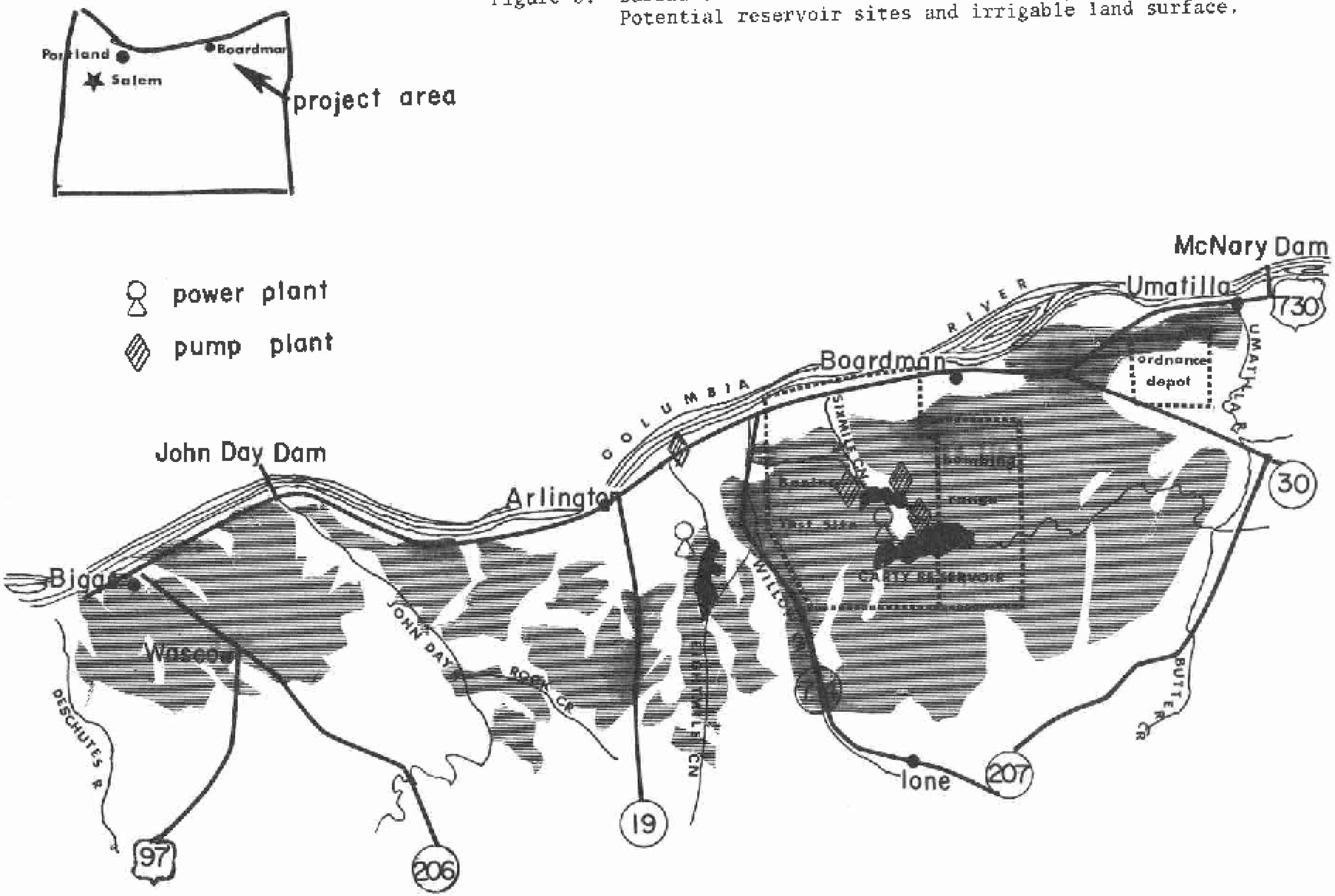
The principle difference between these schemes is that most of the lands lying along the discharge line would be irrigated with cold water in the conventional manner and a lesser amount of land would be dependent on the equalizing reservoir. Under the second scheme the amount of land served could be varied to meet the local conditions. For the same area, the pumping plant for the second plan would be larger (1,700 cu. ft. per sec.). There are a great many variations that could be made on either of these plans. These would be dependent on the relative location of the nuclear power plant, the irrigation project, and the water source.

If once-through cooling of the effluent is the adopted plan, a rather substantial storage reservoir would be required to provide for adequate reregulation of the outflow and to capture the outflow during the nonirrigation season. This permits some economies in the size of the discharge line and pumping plant as compared to the alternate situation where a smaller reservoir is used basically as a cooling pond. However, the second plan would permit a variation in the size of irrigation system compatible with the availability of suitable lands.

The existing Cold Springs Reservoir of the Umatilla Project, with a surface area of about 1,500 acres and a volume of about 40,000 acre-feet, might be adapted to a nuclear power plant as shown in Figure 5. This illustrates how a nuclear power plant could be added to the project plan recently published in the Bureau of Reclamation's Umatilla Basin Project Report. The lands to be irrigated would lie south and west of the reservoir.

Figure 6 shows the Bureau of Reclamation's Columbia South Side Project area presently under reconnaissance-level investigation. There are approximately 500,000 acres in this study area with about 400,000 acres considered arable. Two possibilities for combining irrigation with nuclear power generation are illustrated. We have superimposed potential reservoir sites on the irrigable

Figure 6. Bureau of Reclamation's Columbia South Side Project - Oregon. Potential reservoir sites and irrigable land surface.



area of the Columbia South Side Project. The Carty reservoir, with a surface area of approximately 5080 acres and a capacity of about 110,000 acre-feet at the 675-foot contour could serve both as a cooling pond and a source of irrigation water. The Sixmile Canyon reservoir would have a surface area of 760 acres and a capacity of 18,000 acre-feet at the 550-foot contour. There could be several variations on this plan, depending on the source of water.

Figure 6 also illustrates a scheme for utilizing a storage site on Eightmile Creek in Gilliam County. This reservoir would have surface area of 1,400 acres and a volume of about 78,000 acre-feet at the 600-foot contour. The irrigable area here lies east of Eightmile Creek.

These are not plans, but schemes--possible plans that require a great deal of study before a feasible plan would evolve--and there are many unanswered questions in these schemes, not the least of which is the water-holding ability of the potential reservoir sites. Some questions are environmental, concerned with problems that might be encountered in the storage reservoirs due to warmer-than-normal stored water. The use of engineering economics is necessary to determine the most feasible arrangement of facilities considering the siting requirements of the nuclear plant and the topographic conditions relative to the irrigation function. The proximity of the reservoir to the source of water is of considerable concern, as is the proximity of suitable irrigable lands.

Further study is needed to determine the length of time water must be held in the larger reservoir before it would have cooled sufficiently to be released to a natural stream. There is some information in the literature on temperature stratification in on-stream reservoirs, but work would need to be done on the natural cooling that might take place in off-stream reservoirs such as we have described here. Perhaps with some study we would find that under certain circumstances it would not be necessary to construct a reservoir sufficiently large to retain the full output of the power plant in the nonirrigation season.

One of the most interesting facets in need of thorough study is the potential for a recreation and fishing complex on the warm water pond. There might be some very interesting developments that could evolve here--far different than anything presently on the drawing boards. We can look to some existing power developments in Texas where the cooling pond idea is actually in use. The recreation and fishing on these warm water ponds is far different than we normally think of in the Pacific Northwest. We do have an opportunity here--but it will require a great deal of study and cooperative effort.

DISCUSSION

Q: Can you consider direct return of the Columbia River, instead of storing part of the year?

A: We wouldn't consider that in this scheme. As I listened to some of the talks this morning, I got the feeling that the temperature of the Columbia River was probably about as high as they wanted to get it now.

Q: Do you have any estimates of what this water would cost?

A: No, we haven't gone that far. I do have some estimates of what the pumping power lift would be. On the Cold Springs site, we're lifting water 283 feet static head, and with some friction, we would estimate that the pumping plant would require about 38,000 horsepower, or about 3 percent of the power generated by the plant. At the Carty Reservoir site, we're pumping about 490 feet a head and that's about 59,000 horsepower, or about 4 1/2 percent of the output of the plant. However, we haven't made any attempt to price this out.

Q: Will this plan stabilize the water levels?

A: Yes, I think they'd be more stable than they are now. They pump for irrigation and for the cooling pond approach.

Q: What fluctuation in levels would you need to have in the design of your power plant?

A: I don't believe you would want very much. You have to stabilize it to pretty near normal pool.

Q: What is the value of water for irrigation in a reservoir of this type?

A: It varies from project to project depending on the crops.

SOCIO-ECONOMIC EFFECTS OF CONSTRUCTION AND OPERATION OF NUCLEAR POWER PLANTS

Herbert H. Stoevener

In the eastern part of our state we have a very intensive interest in economic development and in associated population increases. This area is not dissimilar to many parts of rural America. People want to have access to jobs. Those living in an area generally prefer to stay where they are and they find it to their advantage to increase their range of economic opportunity. In addition to an active job market, these opportunities include access to a consumer goods market which is large enough so that it can offer a wide range of products and services at competitive prices. Eastern Oregon generally lacks a population density great enough and a level of economic activity high enough to let many people fulfill their desires for improved employment and other economic opportunities.

When development is projected for a rural area the economic impact upon the affected communities becomes an issue. Mr. Day has already discussed certain economic impacts. There is often much confusion about certain kinds of secondary effects which result from a development project. The basic concept here is that of the "multiplier". It is to reflect the total effect upon the economic activity in an area which results from some initial increase in the area's income, such as the sale of electric energy from a new power plant. Let us look at this concept in a little more detail.

The multiplier can be presented by the simple equation

$$M = \frac{1}{a}$$

In this simple equation the multiplier is seen to be a function of "a". This variable represents individual savings or other so-called "leakages" in the economy. How do they affect the multiplier?

In order for this expansion effect of a production change in a particular area to go beyond the level of the original change, some of the generated income must be respent in the area. If those who receive the initial flow income do not respend but save the income received, this secondary beneficial effect cannot occur. Similarly, if the people who receive the original flow of income spend this income somewhere else than in the local area, the respending effect will again be zero from the viewpoint of the local area. Examples would be the importation of goods by a local business or expenditures made by a local resident while vacationing outside the area under consideration. Thus it can be seen that peoples' spending patterns both with respect to how much they spend rather than save and with respect to the location of their expenditures are very important in determining the effect on the overall level of economic activity resulting from some initial change in income.

The above equation summarizes these considerations. As we have seen the "a" represents that portion of an initially generated flow of income which is not re-spent locally. If this number is large, i.e. nearly all of the income is either saved or spent outside of the area, the multiplier effect is small. In the extreme case where the portion of income saved and the portion spent for goods and services outside of the community add up to one, there would be no multiplier effect at all. The one dollar of initial income generated would have no greater effect than just the one dollar.

What determines the size of "a" in this problem? Let us first turn to the consumer's saving. Generally, savings and investment patterns vary over time according to the conditions of the national economy. They also vary among individuals depending upon their levels of personal income. Generally those with high incomes spend a smaller portion and save a greater portion of their incomes than do the people with lower incomes. Anticipation of future income changes is also important in the allocation of income between savings and consumption. This explains why many young families appear to be living beyond their means from the viewpoint of an older observer. These younger consumers are really making their expenditures on the basis of their anticipated higher future incomes.

The other component of the variable "a" in our equation is what we call "leakage" or spending outside of the community. The size of this component depends largely upon the characteristics of the local economy, particularly its complexity and population size. In a small and simple economy it is frequently impossible to obtain certain goods and services which can readily be obtained in a more complex economy. Let us take a look at the most extreme case, a community consisting of only two farms which produce an identical product. Nothing could be gained from trade between the two farmers. All of their trade would have to be with partners outside the community under consideration. On the other hand, consider the entire U.S. economy as the "local area". Here we have a large market area of a very complex economy. Practically everything can be bought and sold within the economy. Only 6.5 percent of the Gross National Product was exported during 1970.(U.S. Govt., 1971). Hence the multiplier for the U.S. is very high

What might the size of a multiplier be for a rural area such as the one we are concerned with here? We have made several studies in various parts of the state but unfortunately none in this particular area. Of the economies we have studied, Klamath County may be most nearly representative of these local conditions. In Klamath County we classified the various types of businesses (manufacturing, agriculture, barber shops, local government, etc.) into 17 different sectors. Then we interviewed a sample of about 450 of these businesses in an effort to determine the trade patterns existing within this economy and between it and the rest of the world. Specifically, we need to find out how people traded with each other in the area and what types of businesses were largely responsible for imports and exports, also to what extent these businesses made payments for wages and taxes.

Through some mathematical manipulation with the collected data it was then possible for us to estimate the multiplier for each type of business. As can be seen in Table 1 the output multiplier for agriculture in Klamath County was about 1.8. This means that an increase in output of the agriculture sector of one dollar will lead to an additional increase in output of $0.82 in the rest of the economy. Some other multipliers for Klamath County are shown in Table 1. For example, for the construction sector the multiplier is 1.39 and for thd automotive sector it is 1.13. These individual output multipliers can be used to calculate an estimate of the overall economic effect upon the economy resulting from an output change in one of the area's sectors.

Table 1. Output Multipliers and Income-Output Coefficients for Selected Economic Sectors, Klamath County, Oregon (Reiling, 1970)

Sector	Output Multiplier	Income-Output Coefficient
Agriculture	1.82	0.55
Lumber	1.43	0.41
Cafes and Taverns	1.70	0.50
Automotive	1.13	0.20
Construction	1.39	0.35

What do these multipliers mean to the people living in the county? I presume that most businessmen are quite interested in the effect on their businesses resulting from economic changes in their local area. However, even those who may be operating and owning business firms are less concerned with the total volume of business they may be conducting than they are with the net income which is derived from the operation of their firms. The net income reflects the return for the input of labor and management services which are consumed by a business as well as the return on the capital invested in the business. The column labeled "income-output coefficient" in Table 1 gives us some indication of these types of net income changes associated with a $1.00 output change in a certain sector. For example, if output increases by $1.00 in the agriculture sector the effect upon net incomes in that sector is $0.55. As one might expect, the agriculture sector has a reasonably high income-output coefficient. This is so because agriculture is relatively labor intensive. Some of the manufacturing nuclear power plant gets into operation its labor requirements are low. It is estimated that the Trojan facility will require 60 employees for its operation.

In addition to the concern over access to the market for employment and consumer goods and services, there is another important issue in the development program of a rural area. This relates to the availability and the quality of certain public services in an area. For certain kinds of public services it is necessary again to have a sufficiently large population concentration before it becomes feasible to make them available. To be specific some public services enjoy what economists call "economies of scale". Their unit costs decline as a larger quantity of them are produced. A very small quantity of them can usually only be produced at very high costs, and generally low population communities decide not to produce them at all. It is for this reason that many small communities are found lacking in certain qualities of health, educational and other cultural services. We have very little data available on the basis of which we could make some definitive statement about the size of the community which would gain the benefits of most of these economies of scale. There seems to be some agreement among various authorities that for some of the most frequently used public services the optimum size of a conmunity is somewhere in the 50,000 to 250,000 population range.

The above range in population is wide, and its estimate is not very reliable. But it is also apparent that communities such as those here in Umatilla County are small enough so that it is likely that a rise in population from current levels will make possible the provision of certain public services. not now available or a less costly provision of some others. It is the possibility of deriving these benefits which make some people willing to give up some of the disadvantages of economic development which previous speakers discussed.

An aspect of nuclear power development in this area which must be very exciting to many individuals is the prospect of a substantial addition to the local tax rolls. Again, for the Trojan facility a capital addition of about $250,000 has been predicted. The tax revenue which would be generated would greatly strengthen the financial support for various public services. It could also reduce the tax burden which would otherwise have to be born by other economic sectors. One can expect that economic development of the kind discussed here will be associated with a considerable struggle by various interest groups in the community to shift the incidence of the benefits from the development toward them and the burden of the costs toward others. Much of the development controversy can be understood by the study of this phenomenon. It is a real challenge for local government to provide for an institutional framework within which the various affected segments of the community can share equitably in the advantages and disadvantages associated with economic development.

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