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USE OF ENVIRONMENTAL DATA FOR DETERMINING CONDENSER WATER SYSTEM ALTERNATIVES

L.P. Beer
Roy F. Weston, Inc.
West Chester, Pennsylvania U.S.A.

ABSTRACT

Environmental data can and should be used for determining condenser water system alternatives to effect the protection of the use of the receiving water body. A well-designed thermal effects study program will include physical, chemical, and biological data. The type and amount of data must be considered in the experimental design of the study plan so that the data will be useful in providing engineering design criteria to minimize environmental degradation. These data will be used for such condenser water system alternatives as once-through cooling with no special intake or discharge structures, modifications to intake and discharge design, use of extended discharge canals, diffuser pipes, cooling canals (both with and without spray modules), cooling ponds, and mechanical and natural draft cooling towers.

INTRODUCTION

Environmental data can be used for the design of condenser water system alternatives to effect the protection of the use of the receiving water body. A well-designed thermal effects study program would include physical, chemical and/or biological data collection. The type and amount of data to be collected must be considered when developing the experimental design of the study plan so that the data will be useful to provide engineering design criteria to minimize environmental degradation. It is essential that data be collected in a well-integrated and organized manner so that manipulation of these data will result in conclusions that are useful in deciding on alternative designs. Collection of data "just for the sake of collection" has no value except to confuse the issue and actually hamper the development of the resulting conclusions and recommendations.

This paper will address the collection of physical, chemical and biological data as part of an experimental design to evaluate alternative condenser water systems including once-through cooling, modified intake and discharge structures, intake and discharge canals, cooling canals, cooling ponds, cooling canals and ponds with spray modules, and both mechanical and natural draft cooling towers. This paper is the result of study programs conducted by the author at the site of power stations on the Ohio, Illinois, Mississippi and St. Johns rivers, as well as smaller rivers, Lake Michigan and the Florida coast.

Physical Data

The collection of physical data will include temperature, current movement, bathymetry, sediment transport, meteorological measurements, thermal transfer, a combination of field and analytical techniques for ambient and plume observations, and predictive modeling procedures. Thermal plume and ambient observations probably represent the most difficult aspects of a physical data collection program associated with a power station. This is particularly true in the case of estuaries and other tidally-influenced systems. In the case where the aquatic system is tidally-influenced and, therefore, ambient thermal conditions vary during a tidal cycle, it is essential to conduct the field measurement program within a very short period of time (approximately one to two hours) during each of the four tidal cycles. In the case of a tidally-influenced system, plume observations and ambient conditions have to be evaluated within the period not to exceed one to two hours, otherwise the plume and ambient conditions represent a combination of two or more tidal cycles and, therefore, two or more thermal conditions. In the case of a lake-river discharge, it is essential to conduct a field survey when the power plant has been discharging condenser waters at a constant rate for at least 12 to 24 hours prior to the time of measurement, and the system has reached equilibrium. Typical plume isothermal sections are shown in Figures 1 and 2.

Computer and physical models can be used to predict plume dispersion as well as ambient thermal conditions in aquatic environments. Comparison of plume and ambient predictions with actual field conditions is needed to verify or modify model assumptions. Figures 3, 4 and 5 are examples of graphical representations of plume predictions using computer modeling techniques.

If, for example, physical measurements are needed to help design spray modules for use in an intake or discharge canal, then such data as thermal profiles, current velocities (both horizontally and vertically), thermal transfer (solar radiation, etc.), and meteorological (wind speed and direction, lapse rates, etc.) will be required. Tank studies to determine spray modules efficiency both with and without induced air movement by use of fans, will be required under controlled conditions. Temperature measurement in the water entering the center of the spray module as well as in the spray periphery of discharge from the module, determinations of amounts of water being withdrawn from the tank, effects of interference between and among spray modules, as well as drift conditions will need to be evaluated. Use of computer modeling techniques will be required to determine suitable spacing and configuration of spray modules to minimize "shading" effects and drift loss.

Chemical Data

Chemical data for input to the engineering design of condenser water systems principally relate to dissolved oxygen (DO) and nutrients. Although DO is typically considered a physical measurement, for purposes of this discussion, it is considered part of chemical data analysis. Dissolved oxygen measurements, on the intake and discharge canals and in the area of the discharge plume are needed in cases where the same water bodies have DO levels approaching upper lethal limits for most fishes. In the case of lakes, such as Lake Michigan, measurements of oxygen and nitrogen to determine supersaturation values that might affect and cause "gas bubble disease" may be needed. Nutrient information is required in order to evaluate synergistic effects of nutrients presence and elevated water temperatures in order to decide upon points of withdrawal and discharge of intake and discharge systems. Based on dissolved oxygen, nutrients, and in some instances nitrogen data, the intake and the discharge structures can be designed to make adequate use of the existing environment: for example, withdrawal of near-shore waters in areas that are thermally mixed with placement of the discharge into the hypolimnion of deeper waters where, in general, low dissolved oxygen levels are prevalent.

Biological Data

Biological information includes benthic invertebrates, zooplankton and phytoplankton, periphyton, icthyoplankton, and fish. Of particular interest and need are the types and numbers of organisms as well as their location and habitat preference. Data such as pollution/thermal tolerance and migrational behavior are needed. The use of tag and recapture methods as well as selective fish sampling methods (including electro-shocking) is also useful. Statistical techniques and initial experimental biological design projects can be used to determine the numbers of samples required as well as the frequency of sampling. For example, it is desirable to run a short-term benthic invertebrate sampling program in areas where biological productivity is pronounced. Evaluations of "representativeness" on samples collected using various types of dredges including Ponar, Ekman, Peterson and others can be determined by comparing the composition of biological samples from replicate samples using these techniques.

CONDENSER WATER SYSTEM ALTERNATIVES

Examples of the use of physical, chemical and biological environmental data in the design of condenser water system alternatives to effect the efficient utilization of water bodies and the protection of the receiving water body or its enhancement are indicated in Table 1.

CONCLUSIONS

Physical, chemical and biological data from studies in the vicinity of power stations can be of considerable value when designing alternate condenser water systems to effect the most efficient use of the receiving water body and prevent degradation of waters. The state-of-the-art of collecting environmental data, experimental design of study programs, and design of condenser water system alternatives is advanced to the point that a minimal amount of environmental data can be developed, analyzed and interpreted for the sole purpose of providing design criteria for thermal discharges to protect the aquatic environment.

Table 1

Type of Structure/ Design	Figure No./ Schematic	Data Required		
		Physical	Chemical	Biological
Inlet pipe structure	Figures 6,7	current velocity, dissolved oxygen, water temperature	nutrients	fish and zooplankton presence, thermal tolerance, temperature and swim speed relationship.
Intake structures: traveling screens, skimmer walls, trash racks.	Figure 8	current velocity		swim speed preference of fishes, fish eating habits (bottom feeders, plankton feeders, carnivores, etc.).
Condenser tubes (velocity & pressure) chlorination versus mechanical cleansers		current velocity, pressure	chlorine	zooplankton, ichthyoplankton, temperature and pressure tolerance, size and types of organism as affecting by mechanical, chemical and thermal damage to eggs, larvae fry, zooplankton.
Discharge pipe structure	Figures 1-5, 9, 10.	current, velocity, water temperature, dissolved oxygen, turbidity, modeling (computer & physical)	nutrient analysis	fish, migratory habits, habitat preference, thermal and dissolved oxygen preferences, feeding habits, swim speed preference.

Table 1
(continued)

Type of Structure/ Design	Figure No./ Schematic	Data Required		
		Physical	Chemical	Biological
Discharge water structures: cooling towers, submerged or surface jet spray canals, diffuser pipe, cooling pond or once-through system	Figures 11, 12, 13, 14, 15	dissolved oxygen, temperature turbidity, meteorological conditions, current velocity and direction, thermal transfer	dissolved oxygen, nutrient levels, total organic carbon, trace metals	zooplankton, phytoplankton, periphyton, ichthyoplankton
Pond for biological replacement 1/	Figure 15	water temperature, current velocity, turbidity, dissolved oxygen	nutrient data, trace metals.	entrainment, impingement data, zooplankton, ichthyoplankton, habitat preference, temperature tolerance, physical/chemical/biological relationships
Mariculture/aquaculture facilities; marinas & other recreational structures; artificial heating of homes; agricultural designs. 2/		complete	complete	complete

1/ A holding pond can be used to raise organisms which would then be discharged into the discharge canal or directly into the receiving water body to replace entrained organisms that were killed during the passage through the condenser water system; still in experimental stage of development and evaluation.

2/ The beneficial uses of heated waters can be categorized into the following major divisions: mariculture and aquaculture, heated waters to keep marinas and other recreational structures free from ice, artificial heating of homes, agricultural uses; in addition, use of waste steam for beneficial industrial purposes is feasible.

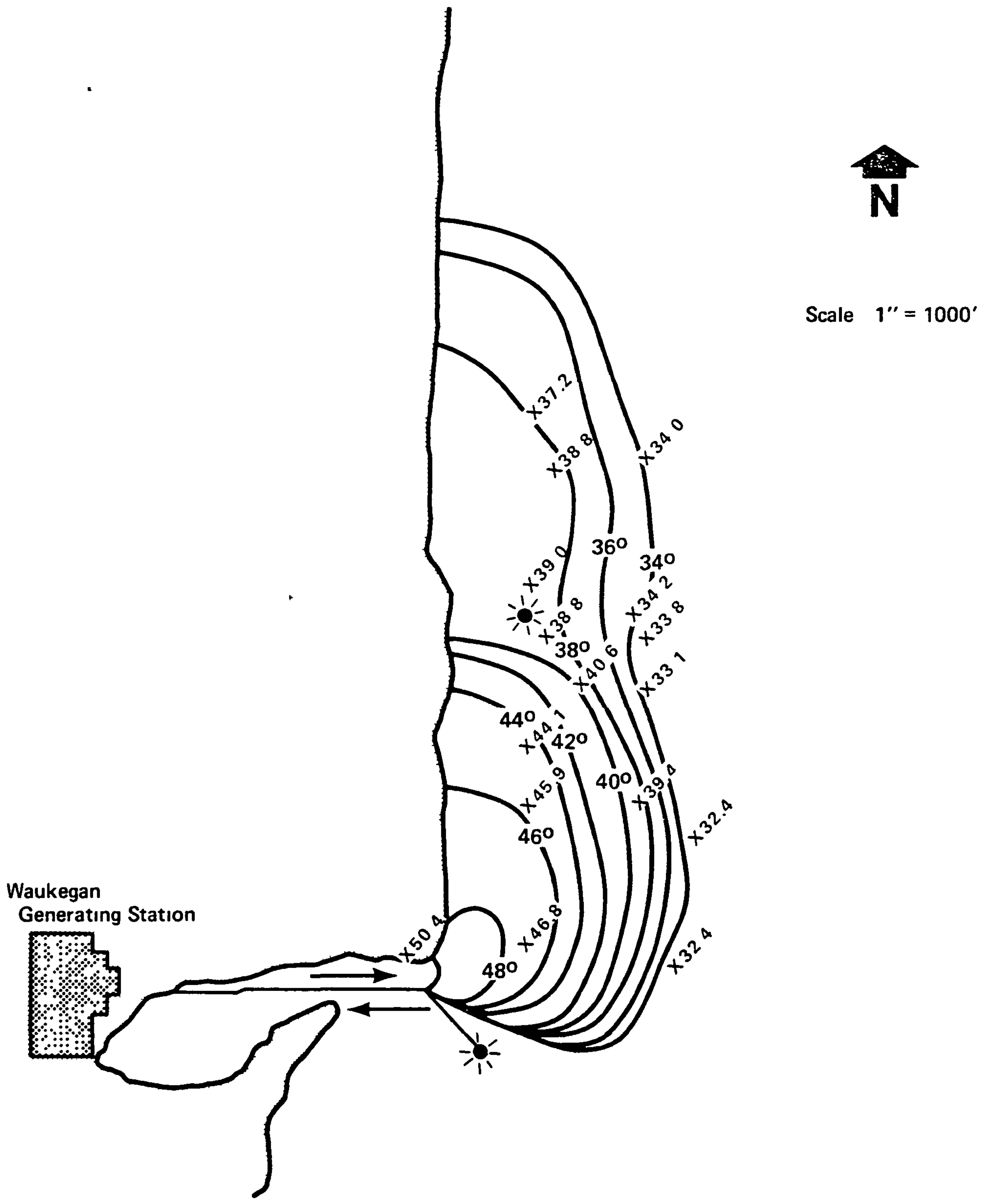

Figure 1. Surface Water Temperatures on Feb. 21, 1970

Reference Pipes, W O , D W Pritchard and L P Beer
"Condenser Water Discharge Plumes from Waukegan Generating Station
under Winter Condition "Commonwealth Edison Company
Chicago, Illinois (January, 1973)

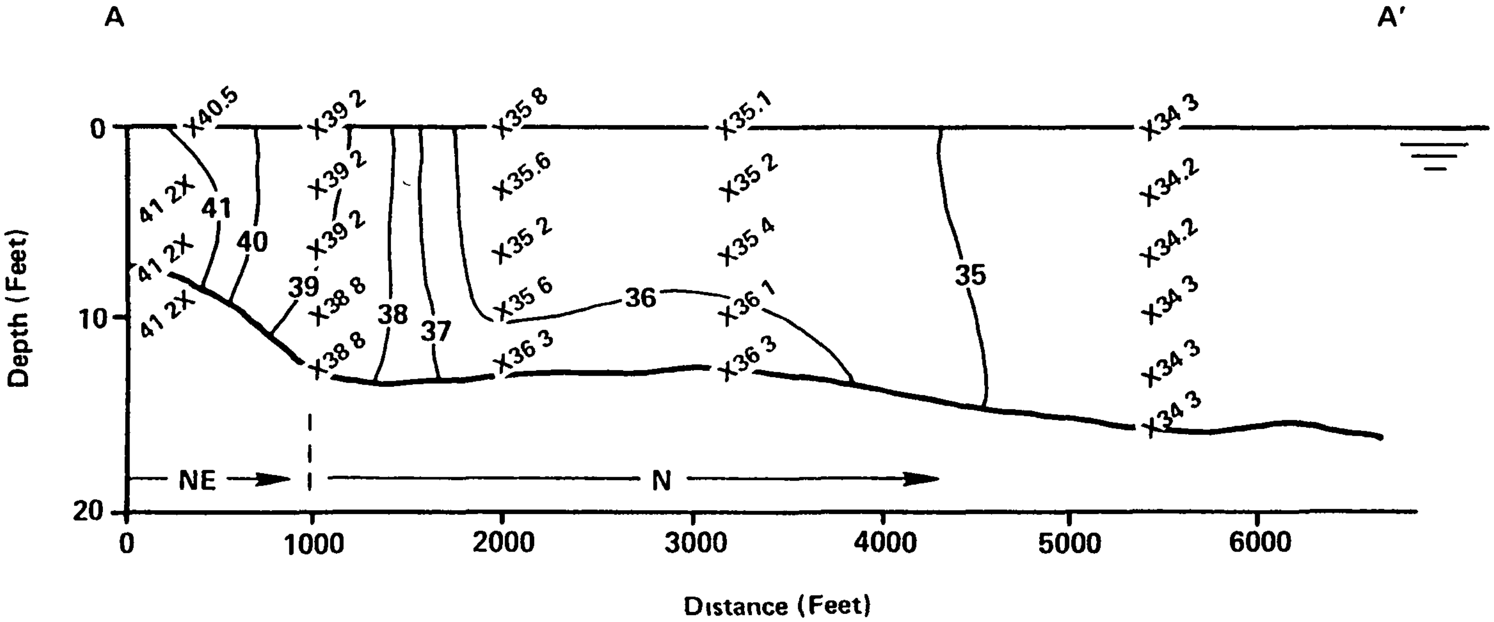

Figure 2: Vertical Section Showing Temperatures along Centerline of Discharge Plume on Feb. 16, 1971

Reference Pipes, W O , D W Pritchard and L P Beer
"Condenser Water Discharge Plumes from Waukegan Generating Station under Winter Condition "Commonwealth Edison Company
Chicago, Illinois (January, 1973)

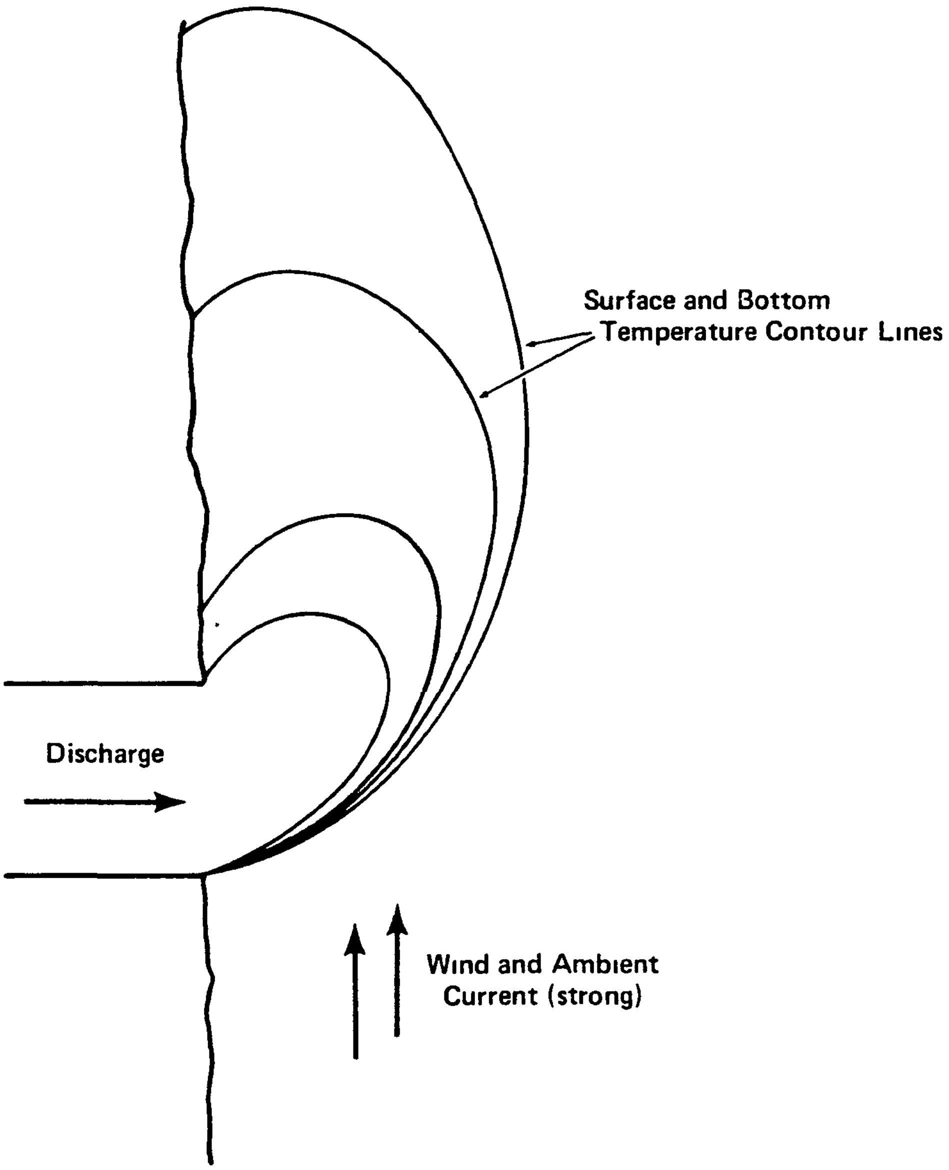

Figure 3. Hypothetical Case 1. Winter Discharge Plume for Shoreline Discharge

Reference Pipes, W O , D W Pritchard and L P Beer
"Condenser Water Discharge Plumes from Waukegan Generating Station
under Winter Condition "Commonwealth Edison Company
Chicago, Illinois (January, 1973)

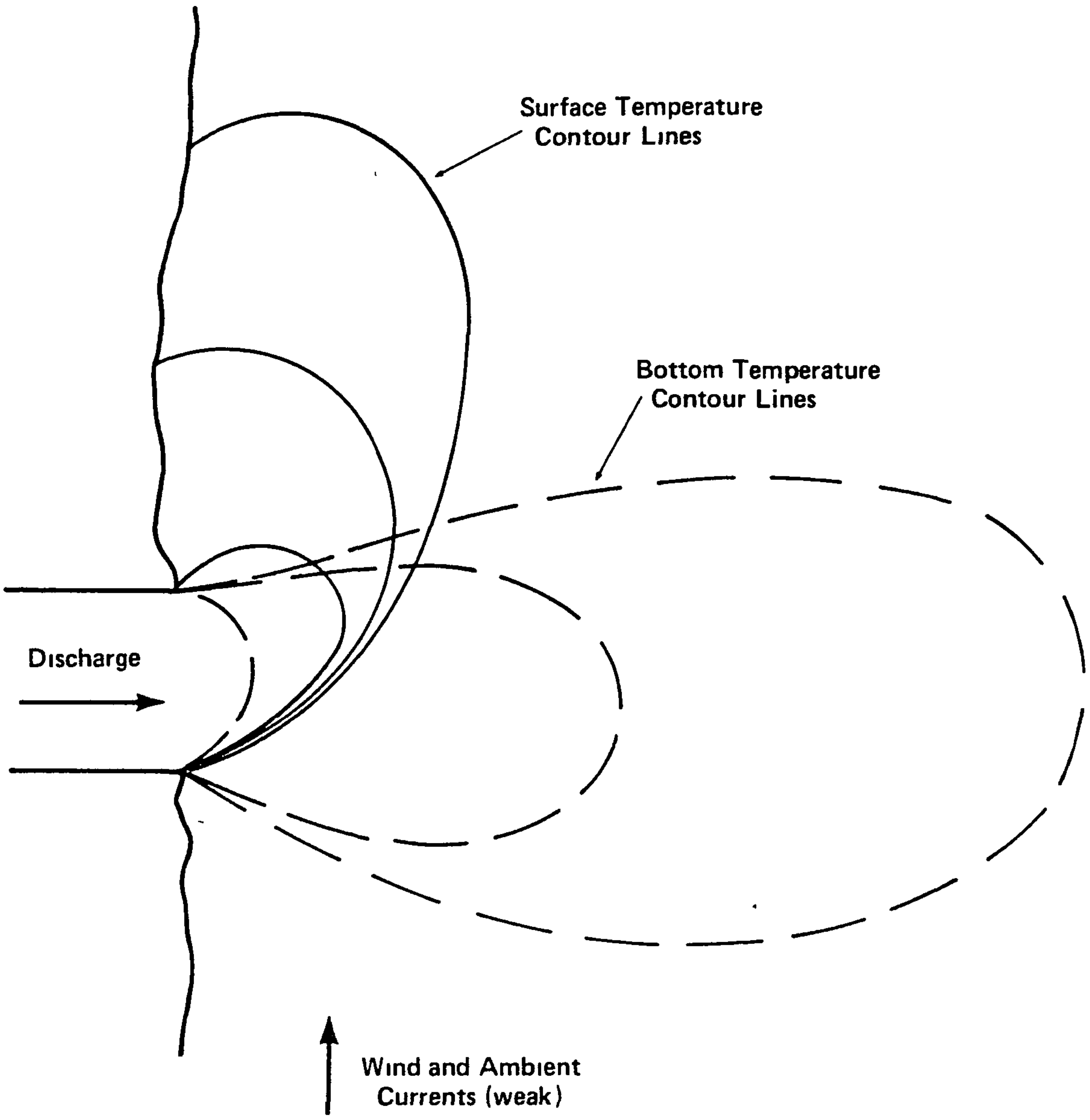

Figure 4. Hypothetical Case 2. Winter Discharge Plume for Shoreline Discharge

Reference Pipes, W O , D W Pritchard and L P Beer
"Condenser Water Discharge Plumes from Waukegan Generating Station
under Winter Condition "Commonwealth Edison Company
Chicago, Illinois (January, 1973)

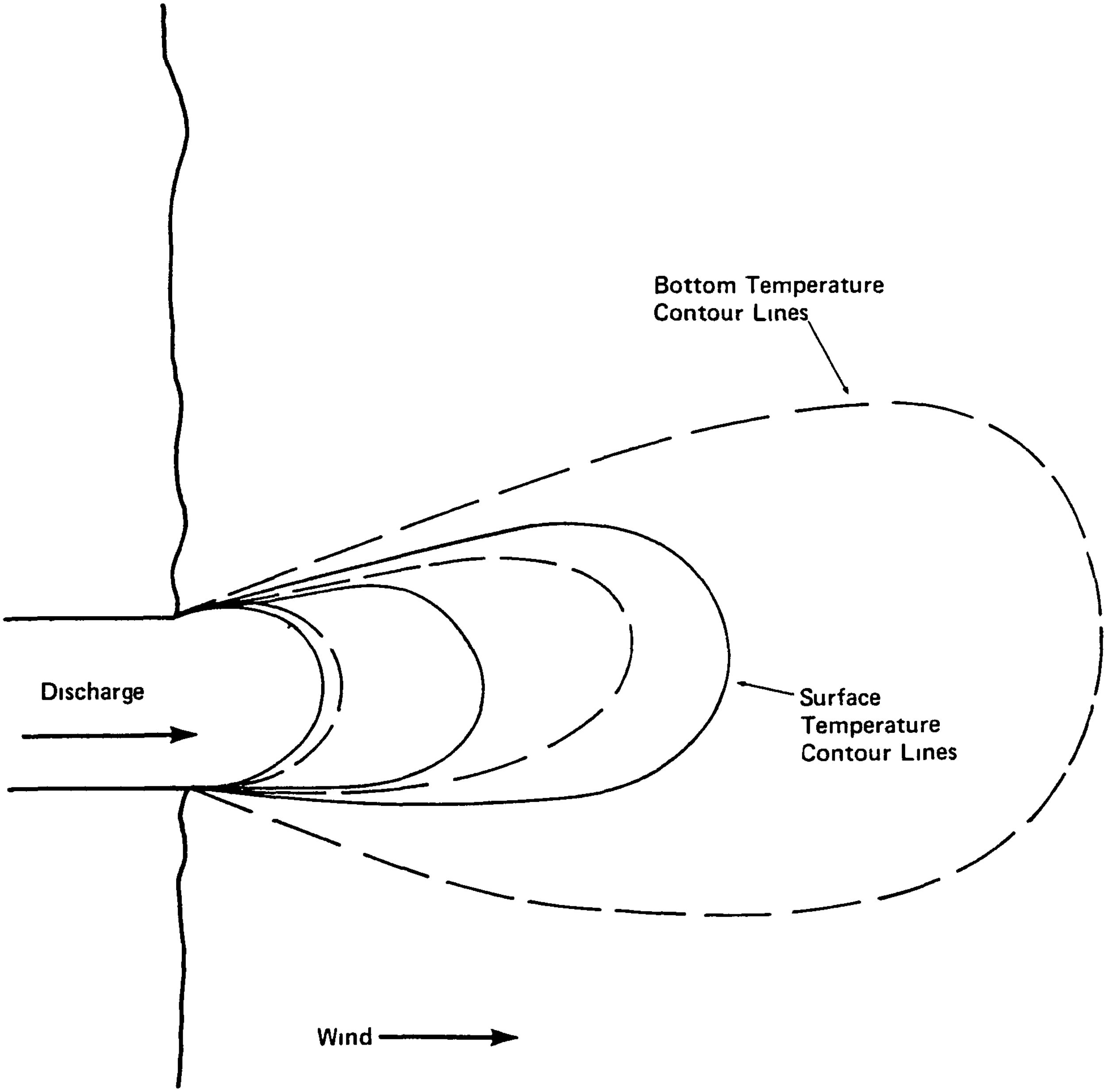

Figure 5. Hypothetical Case 3. Winter Discharge Plume for Shoreline Discharge

Reference Pipes, W O , D W Pritchard and L P Beer
"Condenser Water Discharge Plumes from Waukegan Generating Station under Winter Condition "Commonwealth Edison Company
Chicago, Illinois (January, 1973)

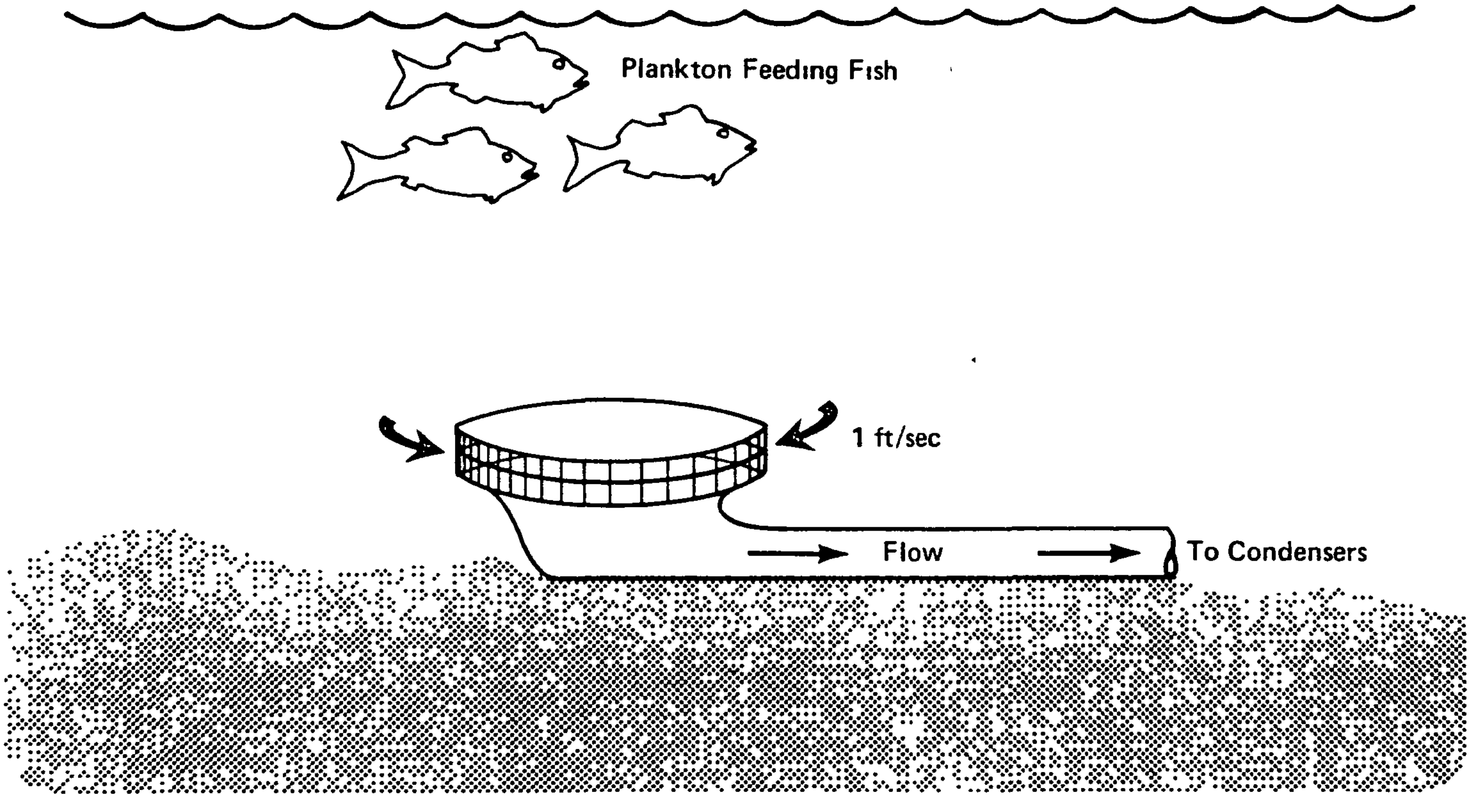

Figure 6. Schematic Diagrams of Intake Structures to Minimize Adverse Biological Impact (continued)

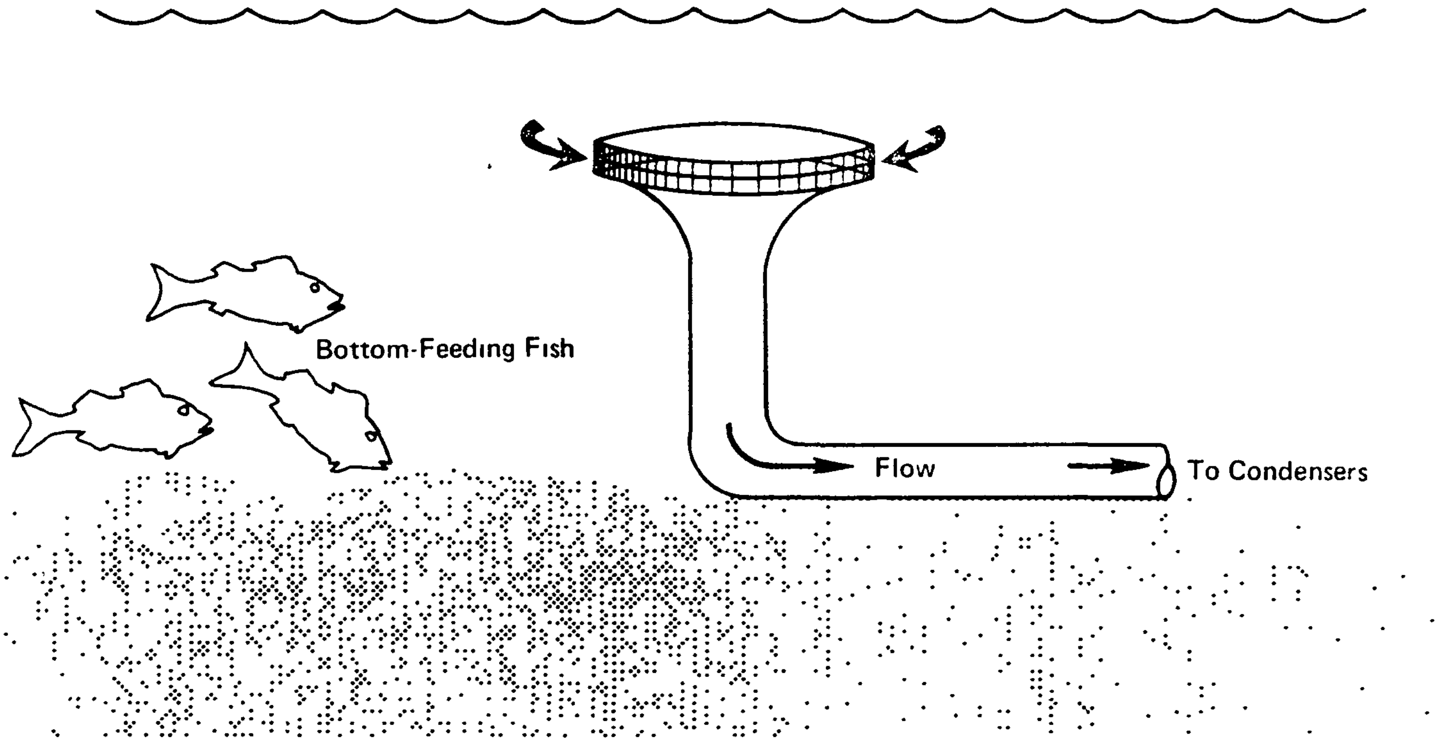

Figure 7 Schematic Diagrams of Intake Structures to Minimize Adverse Biological Impact (continued)

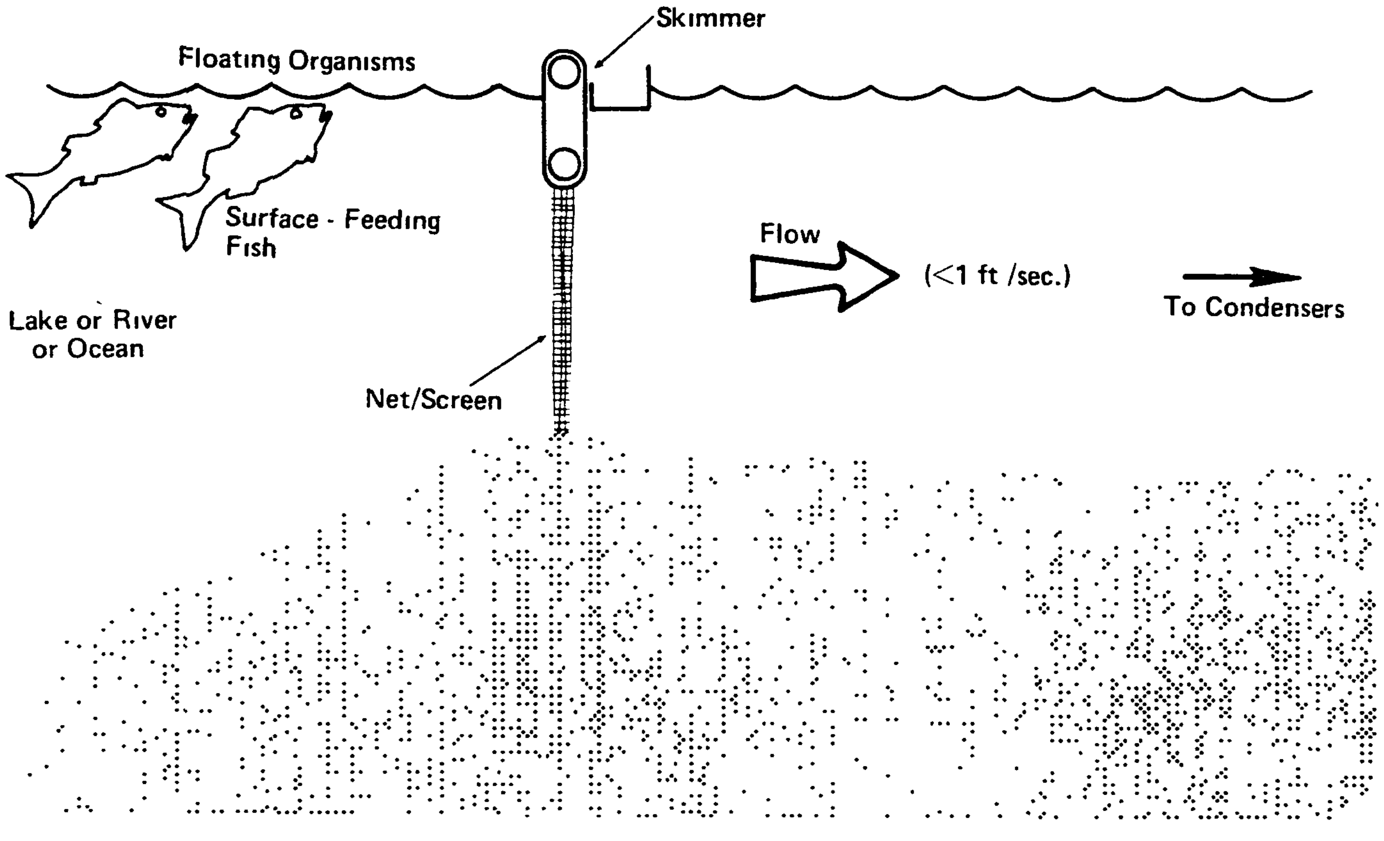

Figure 8. Schematic Diagrams of Intake Structures to Minimize Adverse Biological Impact

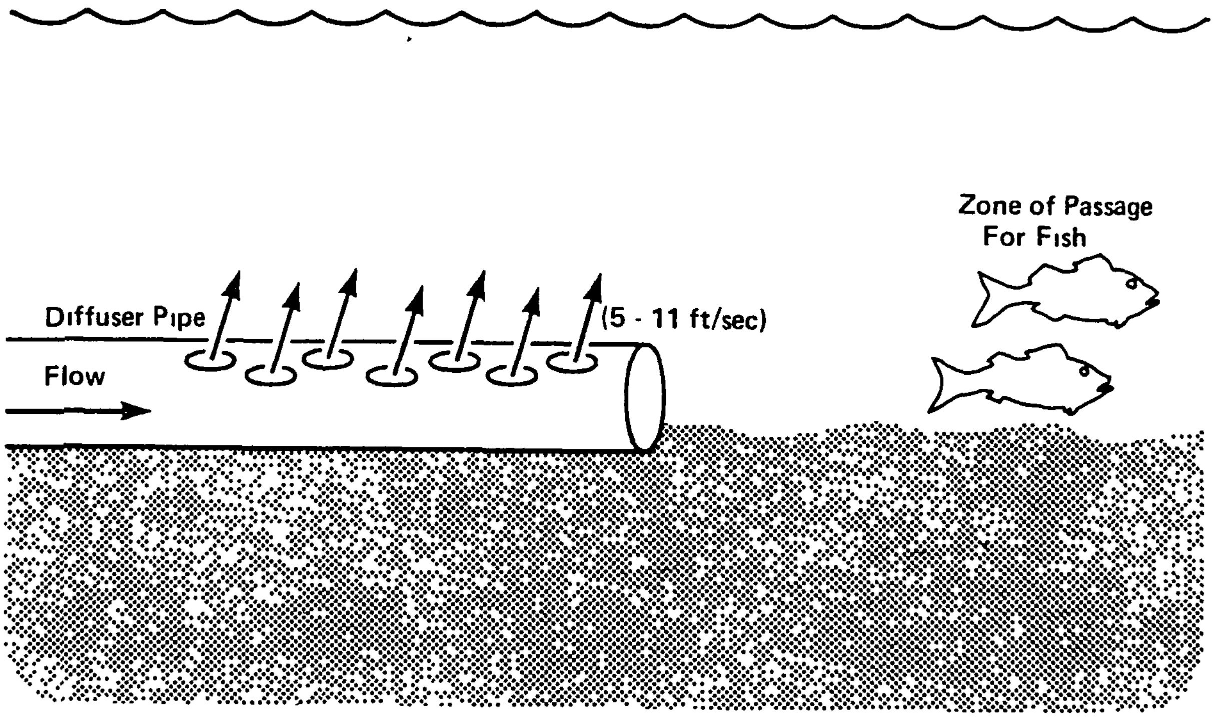

Figure 9 Schematic Diagrams of Discharge Structures to Minimize Adverse Biological Impact

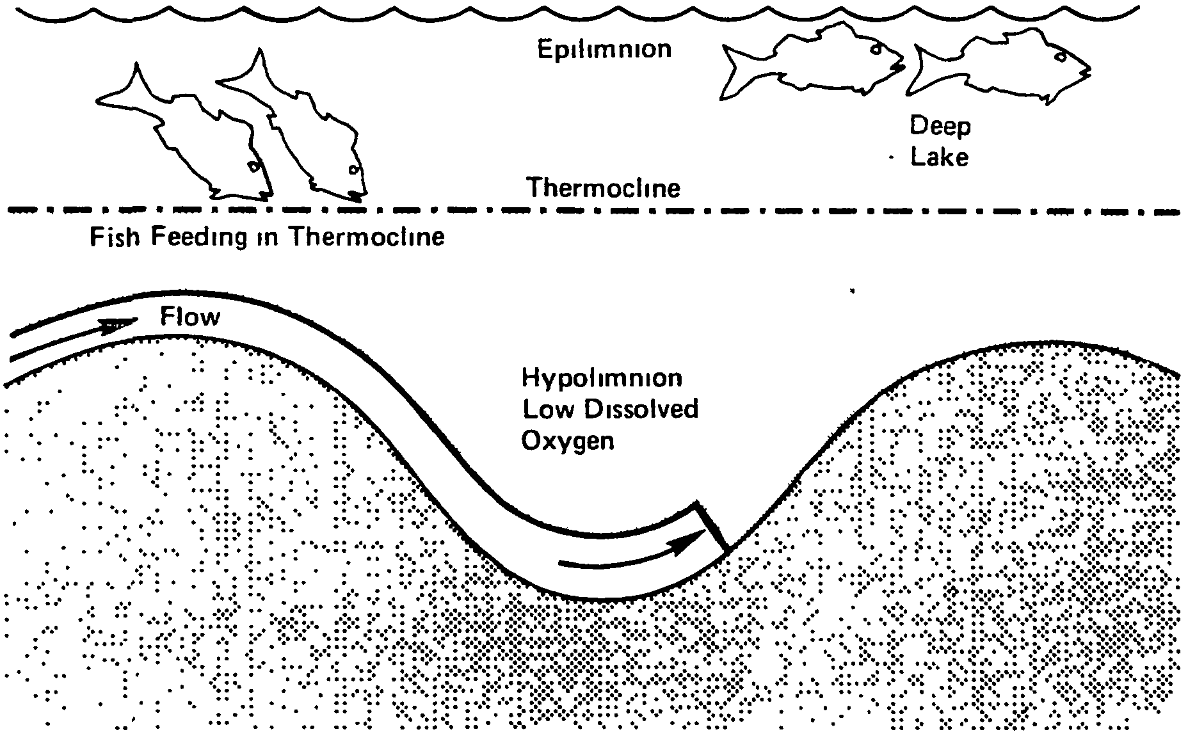

Figure 10. Schematic Diagrams of Discharge Structures to Minimize Adverse Biological Impact (continued)

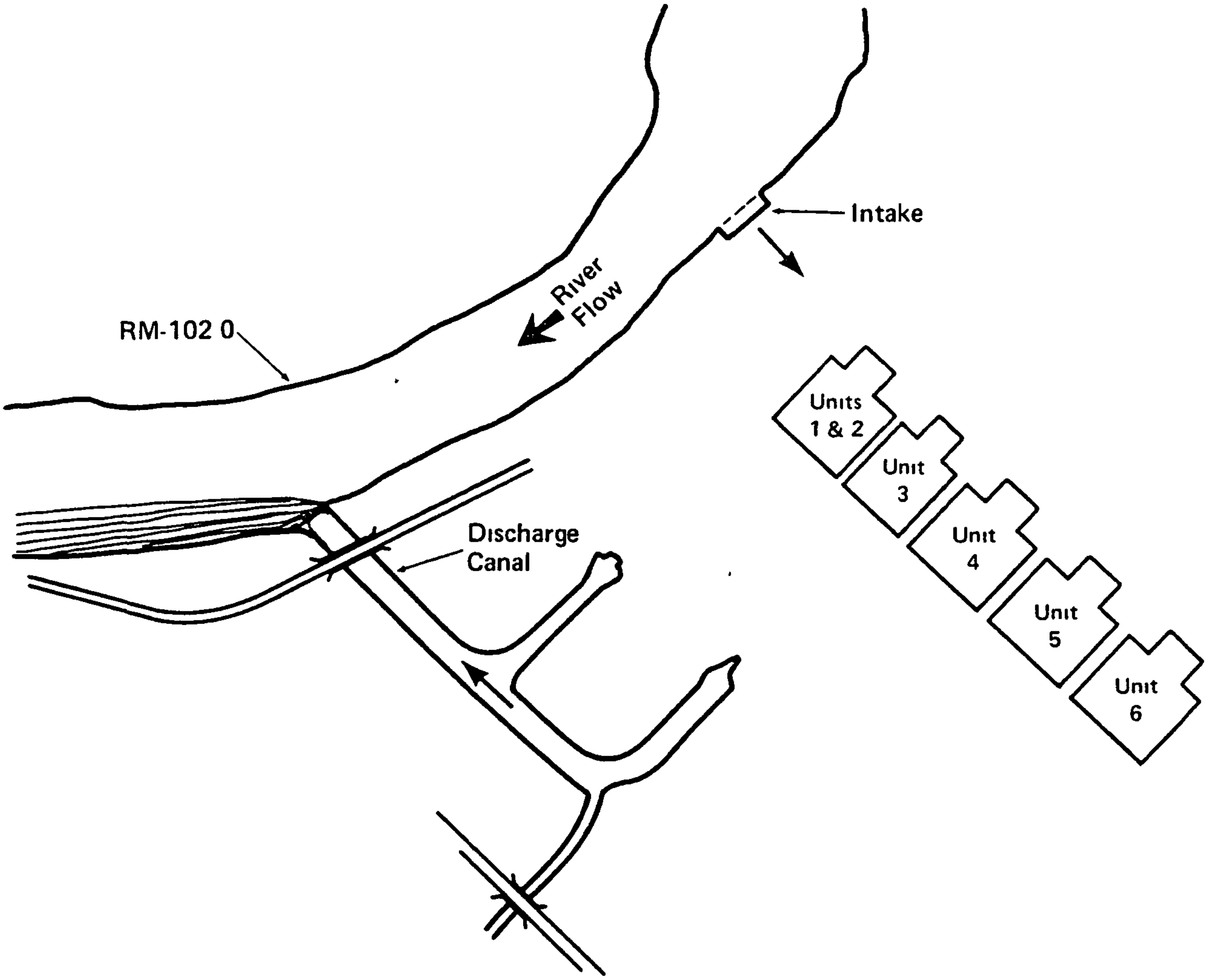

Figure 11. Discharge Structures/Condenser Water Alternatives

Plan View Once-Through System

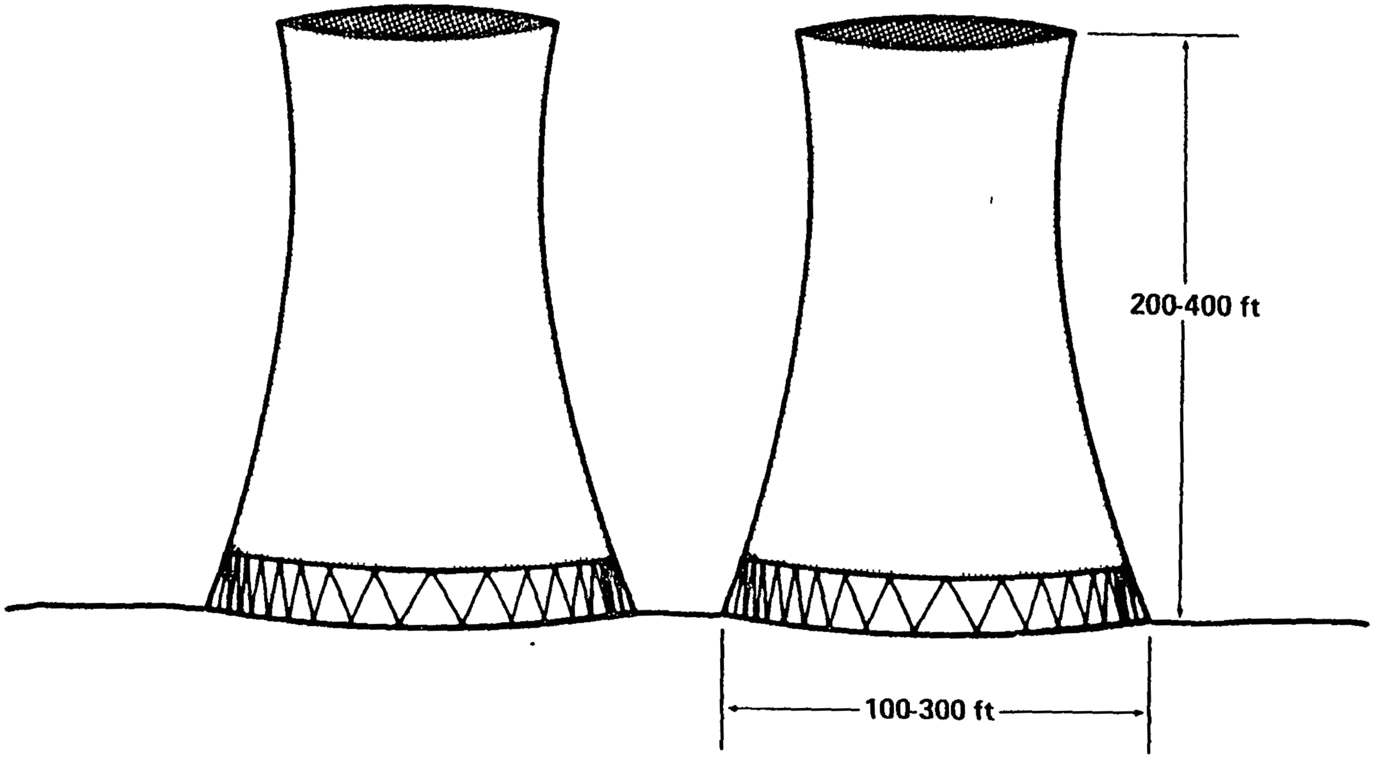

Figure 12. Discharge Structures/Condenser Water Alternatives (continued)

Cooling Towers

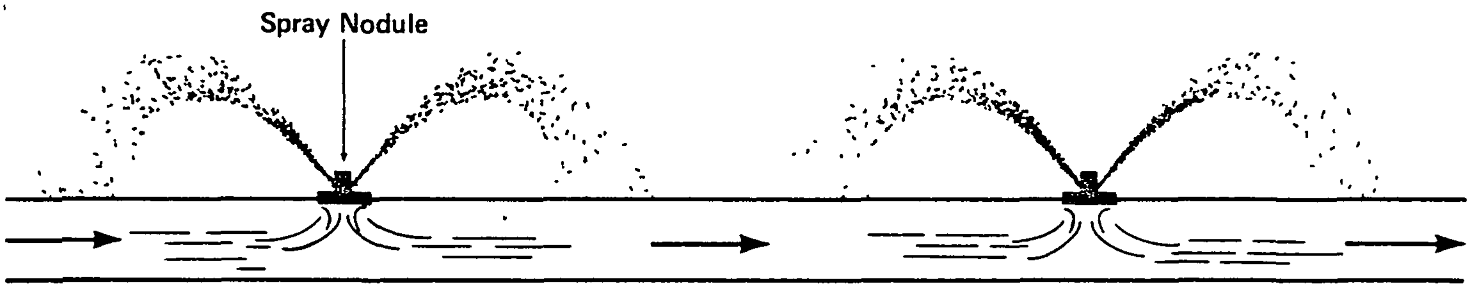

Figure 13. Discharge Structures/Condenser Water Alternatives (continued)

Spray Canals

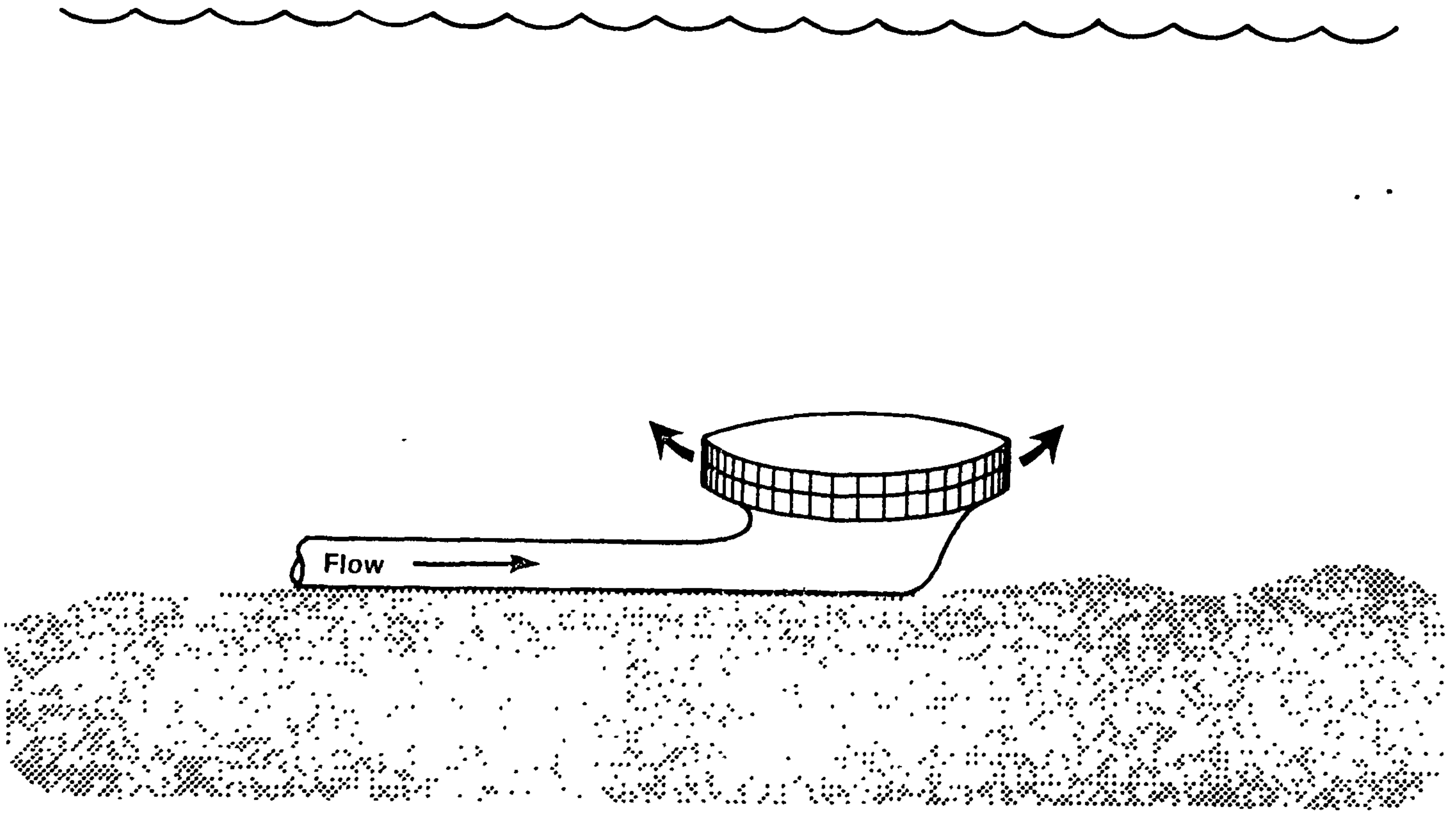

Figure 14 Discharge Structures/Condenser Water Alternatives (continued)

Submerged Discharge

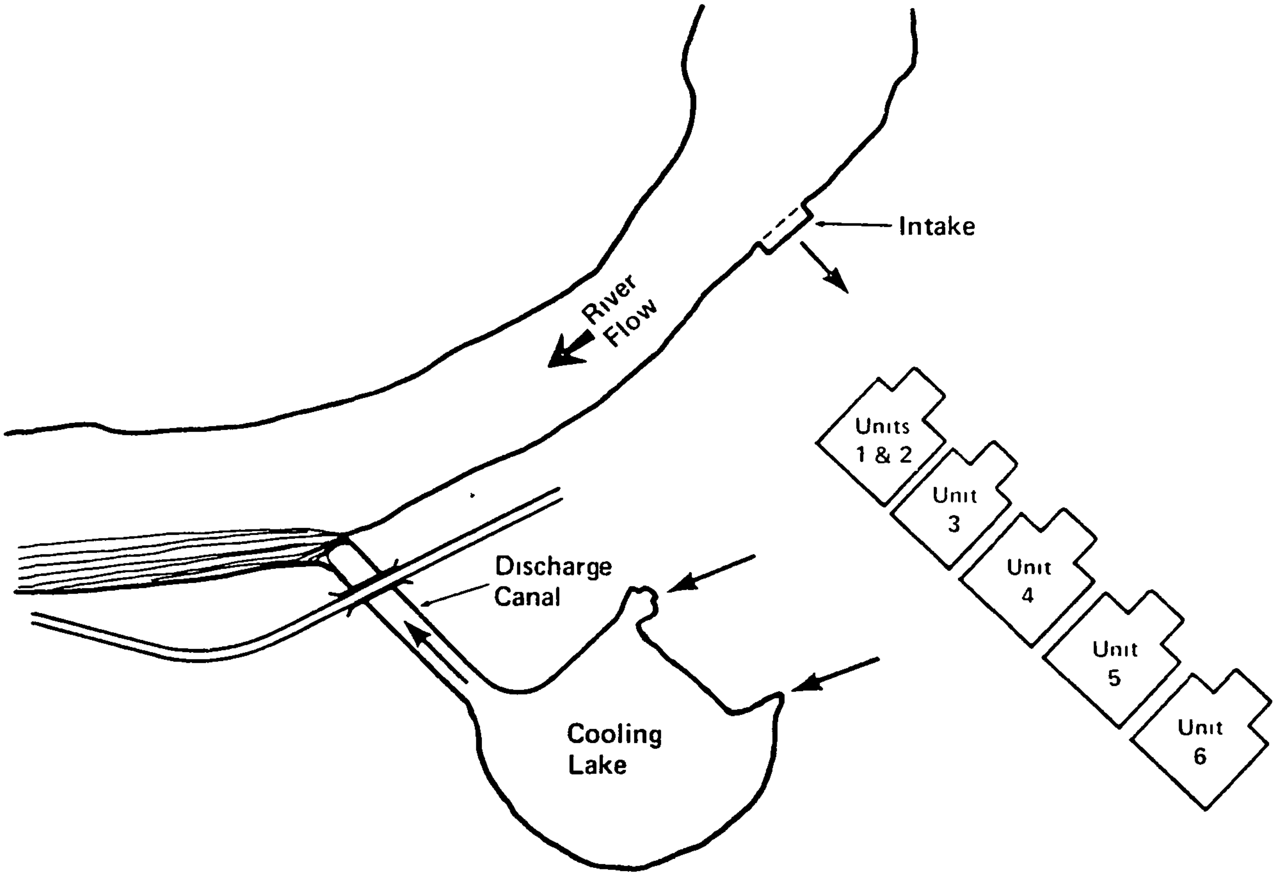

Figure 15. Discharge Structures/Condenser Water Alternatives (Continued)

Plan View D - Cooling Lake