FINAL

ENVIRONMENTAL STATEMENT

ADDITION OF UNIT NO. 2
CANAL PLANT

CANAL ELECTRIC COMPANY

MONTAUP ELECTRIC COMPANY

PREPARED BY

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND

WALTHAM, MASSACHUSETTS

DECEMBER, 1973

ADDITION OF UNIT NO. 2

CANAL PLANT
Canal Electric Company
Montaup Electric Company

Sandwich, Massachusetts

( )Draft (x) Final Environmental Statement
Responsible Office: U.S. Army Engineer Division, New England, Waltham, Mass.

1. Name of Action (x) Administrative ( ) Legislative

2. Description of Action

The addition of a 560 MW electric generating unit, equal in capacity to existing 560 MW Unit No. 1, including some modifications to Unit No. 1 to enable common use of a single 500 foot stack and removal of the existing 300 foot stack, and modification to enable use of a common cooling water discharge system.

3a. Environmental Impacts

Generation of 560 MW of electric energy.

Dredging and disposal on land of about 15,000 cubic yards of material from the Canal.

Use of 426 cubic feet per second of Cape Cod Canal seawater for cooling purposes in addition to the 372 cubic feet per second now used, for a total of about 800 cubic feet per second, or about one percent of the Canal tidal flow. The discharge temperature will be 28 F above the ambient temperature of the Canal, similar to the heat increase of Unit No. 1. The total volume of heated water from the two units will be about double that from Unit No. 1.

Cooling of discharge waters will improve because of improved discharge methods. The current effect of the discharge will also be improved. Maximum water temperature of 86 F will be maintained in the upper 15 foot strata of the Canal, as compared to 90 F now from Unit No. 1, and discharge velocities of 1.6 feet per second at the Canal surface. These velocities will not affect recreational boating in the Canal.

Concentrations of stack emission fallout will be decreased primarily due to the higher stack and wider dispersal of stack emissions, despite the fact that total emissions to the world's atmosphere will be increased.

Entrapment of planktonic organisms.

Entrapment of larger finfish. A fish sill will be constructed at Unit No. 2 and if proven successful will be added to Unit No. 1. Entrapped fish will be sluiced directly into Canal waters at ambient temperatures.

Added receipt and storage of fuel oil (about double present volumes).

3b. Adverse Environmental Impacts

Thermal loading of Canal water.

Passage of cooling water through plant.

Entrainment of marine life.

Entrapment of marine life.

Chemical wastes.

Added emissions to air of region.

4. Alternatives

Do nothing.

Purchase power from another source.

Alternative means of electric generation, such as nuclear, coal, and hydro.

Use of different site.

Alternative cooling methods.

5. Comments Requested

Advisory Council on Historic Preservation
U.S. Environmental Protection Agency
U.S. Coast Guard
U.S. Dept. of Commerce
U.S. Dept. of the Interior
U.S. Dept. of Housing and Urban Development
U.S. Dept. of Health, Education and Welfare
Federal Power Commission
New England River Basins Commission

Mass. Secretary of Environmental Affairs
Mass. Dept. of Commerce and Development
Mass. Dept. of Community Affairs
Mass. Dept. of Natural Resources
Mass. Public Works Dept.
Mass. Dept. of Public Health
Mass. Exec. Office of Administration and Finance
Office of Planning and Programming Coordination
Marine Resources Council
Sierra Club
Natural Resources Defense Council
Mass. Audubon Society
National Foundation for Environmental Control
Environmental Information Center
Mass. Wildlife Federation, Inc.
Mass. Association of Conservation Commissions
New England Natural Resources Center
Board of Selectmen, Sandwich, Mass.
Public Library, Sandwich, Mass.
Cape Cod Chamber of Commerce
Canal Electric Company
Montaup Electric Company
Economic Development Administration

6. Draft Statement sent to CEQ September 4, 1973
Final Statement sent to CEQ _____

PREFACE

The responsibility of issuance of discharge permits was transferred from the U.S. Army Corps of Engineers to the Environmental Protection Agency on October 18, 1972, by passage of the 1972 Federal Water Pollution Control Act. This Act contained sections which replaced the 1899 Refuse Act permit program.

The responsibility for the issuance of permits for construction within the navigable waters of the United States remains with the Corps of Engineers.

Both discharge and structural considerations are included in this one Environmental Statement.

Much of the information used in the preparation of this Environmental Statement was supplied by the Canal Electric Company and Montaup Electric Company by means of a report prepared by Stone & Webster Engineering Corporation. Prior to the preparation of this Environmental Statement, the Canal Electric Company and the Montaup Electric Company received permits and certificates of approval for various aspects of the project from state and local agencies. The Corps of Engineers notes that certain conditions have been stipulated by the state agencies of the Commonwealth of Massachusetts in connection with the certificates and permits issued by these agencies. If the Corps of Engineers were to issue a permit, it would not eliminate or overrule any conditions imposed by the state or municipality under existing state or local law. To assist in understanding restrictions which will modify environmental impact, these conditions are summarized below:

<u>Massachusetts Division of Water Pollution Control</u>

1. Residual chlorine shall not exceed 0.1 mg/l at any time.

2. The discharge temperature within 15 feet of the surface directly above the diffusers shall not exceed 86 F at any time.

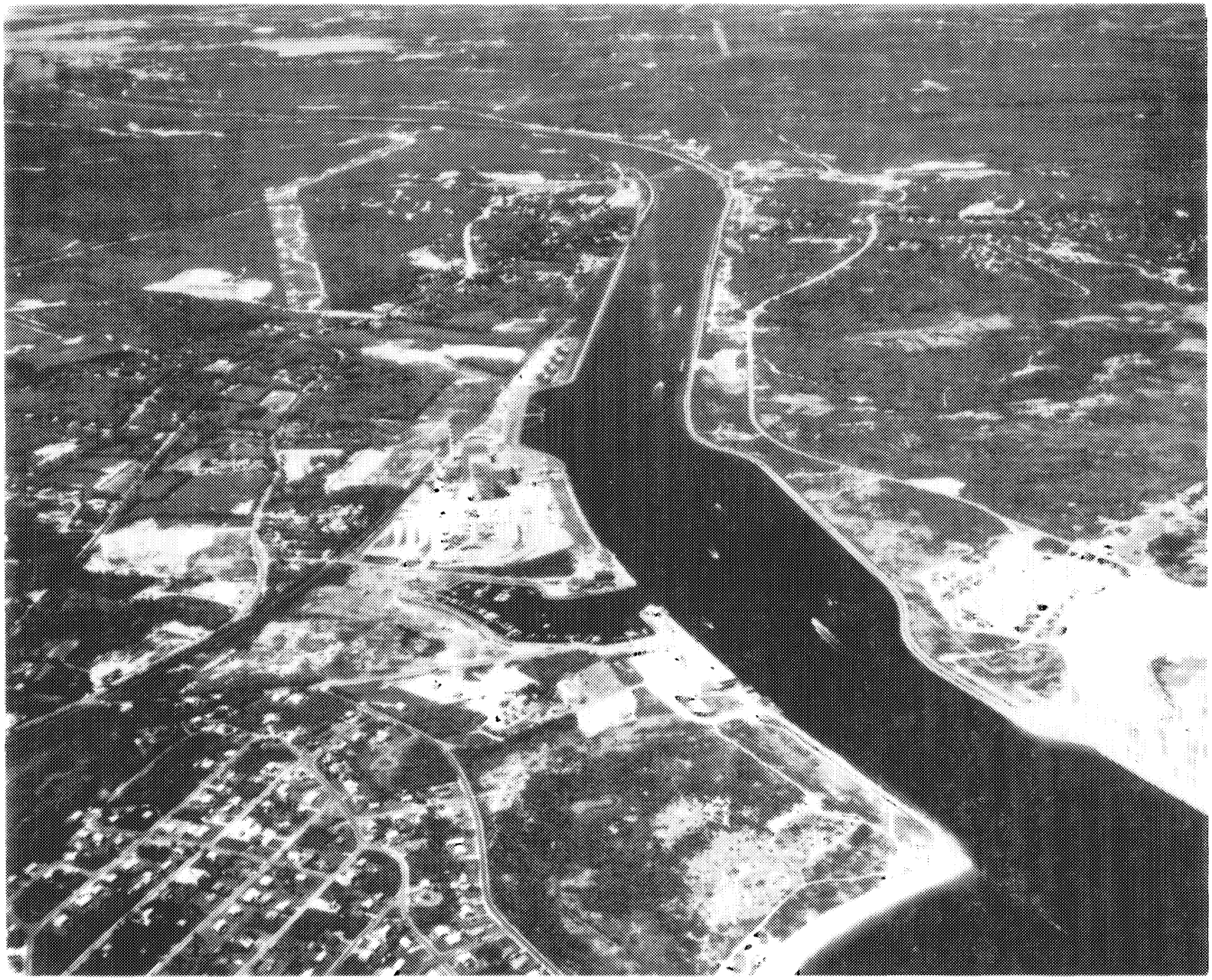
3. A continuous recorder of the discharge temperature shall be installed.

4. Records from monitors and waste treatment systems shall be made available to the Division upon request.

5. A postoperational hydrothermal study of discharge plume shall be conducted.

6. Additional hydrothermal ecological and/or waste treatment studies shall be conducted if the need arises.

AERIAL VIEW OF CANAL PLANT - LOOKING EAST



AERIAL VIEW OF CANAL PLANT - LOOKING WEST

7. Should any pollution arise through or because of the construction of the proposed facility or through failure to comply with the Massachusetts Water Quality Standards, the Division will direct that the condition be corrected. Noncompliance on the part of the licensee will be cause for the Division to recommend the revocation of the license issued therefore or to take such other action as is authorized by the general Laws of the Commonwealth.

Massachusetts Division of Marine Fisheries

A. Recommendations with Regard to Unit No. 1

1. That residual chlorine levels in discharge water be maintained at or below 0.1 ppm during the seven minute treatment cycle. This value may be subject to adjustment following completion of other laboratory studies of temperature-chlorine tolerances of selected fishes.

2. That a residual chlorine recorder be installed to facilitate prompt detection of changing chlorine demand and appropriate adjustment of treatment levels.

3. That the Canal Electric Company implement a means of maintaining water temperatures at the mouth of the existing discharge flume below 90 F.

4. That the screen wash sluiceway be rerouted to discharge into the Cape Cod Canal rather than into the discharge flume as is presently the case. Viable fishes entrapped on screens will be returned to water of ambient temperature and not abruptly subjected to elevated discharge temperatures.

(Note: Items 1,3,and 4 above would no longer be pertinent in view of the proposed modifications to the cooling water system of Unit No. 1 in connection with construction of Unit No. 2. If, however, Unit No. 2 is not built, these requirements would still be pertinent.)

B. Recommendations with Regard to Unit No. 2

1. That sodium hypochlorite dispensing apparatus be designed and placed to permit treatment of each half of each condenser alternately. Chlorine concentration may then be increased if necessary, due to the two-fold dilution afforded by mixing of treated and untreated water on the exhaust side of the condensers.

2. That the common discharge flume recommended by Stone and Webster Engineering Corporation (1965) be installed with

construction of a second generating unit. This will eliminate any possibility of coolant water recirculation and provide a capability of diluting chlorine concentrations still further by treating each unit separately.

3. That the design of future units (i.e. Unit No. 2) be such that coolant water temperatures at the point of discharge into the Canal proper not exceed 86 F. If this is accomplished through increased pumping rates and the subsequent dissipation of waste heat in larger volumes of coolant water, intake flumes must be enlarged to maintain intake velocities at or below 1.5 feet per second.

4. That the lower edge of the opening in the seaward end of intake flumes be no less than nine feet above the Canal substrata. It is felt that this provision will discourage bottom dwelling fishes, particularly winter flounder, from entering intake flumes where they are subject to impingement on screens. If, during a trial period, this measure effectively reduces or eliminates flounder losses, the opening in the existing intake flume should be raised in a like manner.

5. That the Administrative Technical Advisory Committee formed to supervise these investigations remain intact for the purpose of aiding Canal Electric Company with implementation of the aforementioned recommendations.

C. Special Conditions Imposed by Permit Dated 30 November 1972

1. All spoil must be suitably confined on the upland.

2. All construction must conform in every respect with the plan submitted, entitled "Plan Accompanying the Petition of Canal Electric Company, Montaup Electric Company, for Construction of Intake and Discharge Structures in Cape Cod Canal, Sandwich, Massachusetts," dated May 1972, Sheets 1 through 3 of 3.

U.S. Dept of the Interior

The Department of the Interior, Northeast Region, recommends that:

1. The applicant be required to perform adequate environmental monitoring which would indicate whether the operation of Units No. 1 and No. 2 is having significant adverse effects on local or transient marine organisms and take corrective action as required.

2. The applicant continue coordination with the Mass. Division of Marine Fisheries Service, the Bureau of Sport Fisheries and Wildlife, and other members of the "Canal Plant Advisory Committee" during the pre- and postoperational periods of Unit No. 2.

Massachusetts Department of Public Utilities

The Department's permit granting exemption from operation of the zoning by law of the Town of Sandwich was approved subject, however, to the following conditions:

1. That the site of the generating unit and related facilities to be constructed, be landscaped in a manner acceptable to the Department.

2. That prior public notice of the blowing of steam lines during construction be given by publication once in a newspaper of general circulation in the Sandwich area at least 24 hours in advance of the commencement of such blowing. The notice shall state that such blowing will produce loud noise and also state the intended dates, approximate times and duration of such blowing. Mufflers to reduce the sound intensity shall be used if feasible and practical. Blowing shall be limited to the period between 9:00 AM and 5:00 PM, shall not be continuous for a period greater than 1 hour, and shall have quiet periods of at least 1 hour between blowing periods. No blowings shall be made on Sundays. A recording sound level meter shall be kept in operation during all blowing periods at a location to be determined by the Department.

3. That special measures, such as wetting down roadways and covering truck loadings, be taken to prevent dust nuisances during construction. Company-owned roadways are to be used insofar as practicable during construction in order to reduce traffic noise and dust nuisances.

4. That petitioners periodically investigate and report to the Department on the effect of their use of well and town water on the quantity and quality of the water supply of the Town of Sandwich.

5. That the petitioners, upon completion of Unit No. 2, periodically investigate and report to the Department on the effect of electromagnetic radiation from the plant site on radio and television reception.

6. That petitioners submit a monthly report on or about the fifth day of each month beginning with the date of this order and continuing for a period of 6 months after the

date of commercial operation of Unit No. 2. The report shall include:

a) detailed case histories of all complaints received and action taken, relating to activities at the Canal Electric Company site in Sandwich.

b) brief summary of all significant contacts with other state and federal regulatory agencies relating to the operation or proposed operation of the Canal Electric Company plant in Sandwich.

c) Brief summary of unusual operating conditions.

d) Summary of water use and results of investigation of effect on the Town of Sandwich water supply.

e) Summary of investigations relating to electromagnetic radiation effect on radio and television reception.

f) Such other information as the Department may request.

7. That the petitioners obtain all necessary permits, licenses and approvals from other Commonwealth of Massachusetts and federal agencies that are necessary for the construction, maintenance and operation of Unit No. 2 and related facilities.

8. That sound levels dB(A) caused by normal operations at the Canal Electric Company plant shall not exceed the values given below when measured at the property lines designated. The Department reserves the right to change these values on a reasonable basis after notice to petitioners and an opportunity for petitioners to be heard.

Property lines	dB(A)
Northerly property lines of parcels #1 and #2	70
Northerly property line of parcel #3	not specified at this time

Those portions of the southerly property lines of parcels #1 and #2 (total length approximately 2995 ft.) which are situated directly opposite the northerly property line of property line of parcel #3	not specified at this time
All other property lines	49

9. That petitioners inform the Department, on request, of their progress in developing or otherwise obtaining a suitable sound muffling device for use during blowing of steam lines.

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SECTION I

PROJECT DESCRIPTION

SECTION I

PROJECT DESCRIPTION

1.1 PROPOSED ACTION

In response to increased power demand in the New England area, Canal Electric Company (CEC) and Montaup Electric Company (MEC) plan to jointly construct an additional generating unit at the existing Canal Plant located on Cape Cod Canal within the corporate limits of the Town of Sandwich, Massachusetts.

The proposed 560 MW oil-fired steam electric generating unit, to be called Canal Plant - Unit No.2, is scheduled for completion in 1975. The combined total plant generating capability after construction of Unit No. 2 will be 1,120 MW. The new generating unit will be constructed directly adjacent to the present facility.

Units No. 1 and No. 2 will use certain common systems. Among these are a common stack and a common circulating water discharge system.

In environmental terms, this proposed action by CEC and MEC involves the following:

1. Further use of land presently committed to electric power generation purposes. Aproximately 17 percent of previously unused land at the site will be used for Unit No. 2.

2. Easement by the U.S. Corps of Engineers for specific parcels of shoreline along Cape Cod Canal for the intake and discharge structures.

3. Commitment of 800 cubic feet per second of Cape Cod Canal water for use in Canal Plant condensers and heat exchangers. This water will be used in "once-through" processes and returned to the Canal essentially unaltered, except for increased temperature.

4. Increased stack emissions from a new common stack of the combined Canal Plant – Units No. 1 and No. 2, but reduced ground level concentrations due to better dispersal from higher stack.

5. Increased fuel oil storage in the area presently committed for this purpose.

6. Use of groundwater (100 gallons per minute) for boiler feedwater makeup.

The Canal Plant - Unit No. 2 will be equipped with carefully selected systems for pollution control. These systems in combination with controlled operating techniques will minimize the impact of the Canal Plant on the environment.

1.2 PLANT DESCRIPTION

1.2.1 Site

The Canal Plant is located in the town of Sandwich, Massachusetts, on the south bank of the Cape Cod Canal, about one mile from the east entrance to the Canal from Cape Cod Bay (See Figure 1.2-1). The Cape Cod Canal is a sea-level canal of trapezoidal cross-section connecting Cape Cod Bay with Buzzards Bay and is about 7 miles long and 480 feet wide at the canal prism line. Typical channel depths in the site vicinity are about 35 to 40 feet below mean low water.

The plant is on level ground with general yard grade at approximately 16.4 feet Mean Low Water (MLW) datum. The ground floor of the plant is at El. 16.9 feet. Foundations for equipment and buildings are spread footings, designed for a normal maximum load of 8,000 pounds per square foot (psf).

Bituminous paved roads and railroad spurs from the Penn Central Railroad line at the east property line provide access for men and material.

The plant is easily seen from the Sagamore Bridge over the Cape Cod Canal which bears a heavy summer tourist traffic load. Because the town of Sandwich has historic interest, especially as the site of a famous early American glass works, aesthetic values are considered important.

All land required for this installation is owned by Canal Electric Company. Easements are already in effect from the U.S. Government to permit access to the plant and to accommodate present circulating water structures. These will be altered as required to reflect present design arrangement, as described in Section 1.2.3.3. See Figure 1.2-2 for a map of the site area.

1.2.2 Buildings and Architecture

The administration building, built along the west wall of Unit No. 1, is of steel frame construction with concrete floors, exterior walls of 12-inch concrete block, and steel roof deck covered with insulation and built-up roofing.

The station enclosure for Unit No. 1 consists of 19-foot high concrete block masonry walls with uninsulated corrugated asbestos siding on steel girts for the remainder. Aesthetic treatment consists of painted exposed steel, green and fawn-colored siding, and plastic panels in a vertical pattern at the boiler room corners and in a horizontal pattern at the turbine room roof elevation. The main powerhouse roof is constructed of steel decking covered with insulation and built-up roofing. Unit No. 2 will be east of, and adjacent to, Unit No. 1, with similar architectural features.

Like that of Unit No. 1, the screenwell house for Unit No. 2 will be a single-story concrete block building supported on a concrete screenwell deck at the downstream end of the unit intake flume. Roof construction will be of steel decking, insulation, and built-up roofing, with equipment removal hatches in the roof above the circulating water pumps and traveling water screens.

Other small, permanent, auxiliary buildings of similar construction, erected for Unit No. 1, but in some instances extended or supplemented for Unit No. 2, are:

Main gate guard house

Construction gate guard house

Switchyard relay house

Maintenance building in switchyard

Fuel oil drain pump house

Low pressure fuel oil transfer house

High pressure fuel oil transfer and fire pump house

Fuel oil terminal office

In addition to the normal effort to produce functional buildings with clean lines compatible with their surroundings, suitable landscaping is planned.

1.2.3 Plant Systems

1.2.3.1 Generating and Draft System

Canal Plant Unit No. 1 has been in commercial operation since early 1968 and consists of a double reheat turbine directly coupled to a hydrogen-cooled generator rated at 632,000 kVA. The rated maximum station sendout is 560,000 kW under optimum operating conditions. Steam is delivered to the turbine throttle from an oil-fired, super-critical, steam generator rated at 3,720,000 pounds of steam per hour. Unit No. 1 was designed for base load operation (full time).

Unit No. 2 is being designed for cyclic operation (only 50 percent capacity nights and weekends) with a July 1975 scheduled commercial operating date. The turbine generator is a tandem-compound, single reheat, four-flow turbine unit, directly coupled to a hydrogen-cooled generator rated at 610,000 kVA. Turbine operating conditions will be 2,400 psig, 1,000 F with one reheat cycle of 1,000 F and 2 inches of mercury backpressure. As with Unit No. 1, its maximum rated sendout will be 560,000 kW.

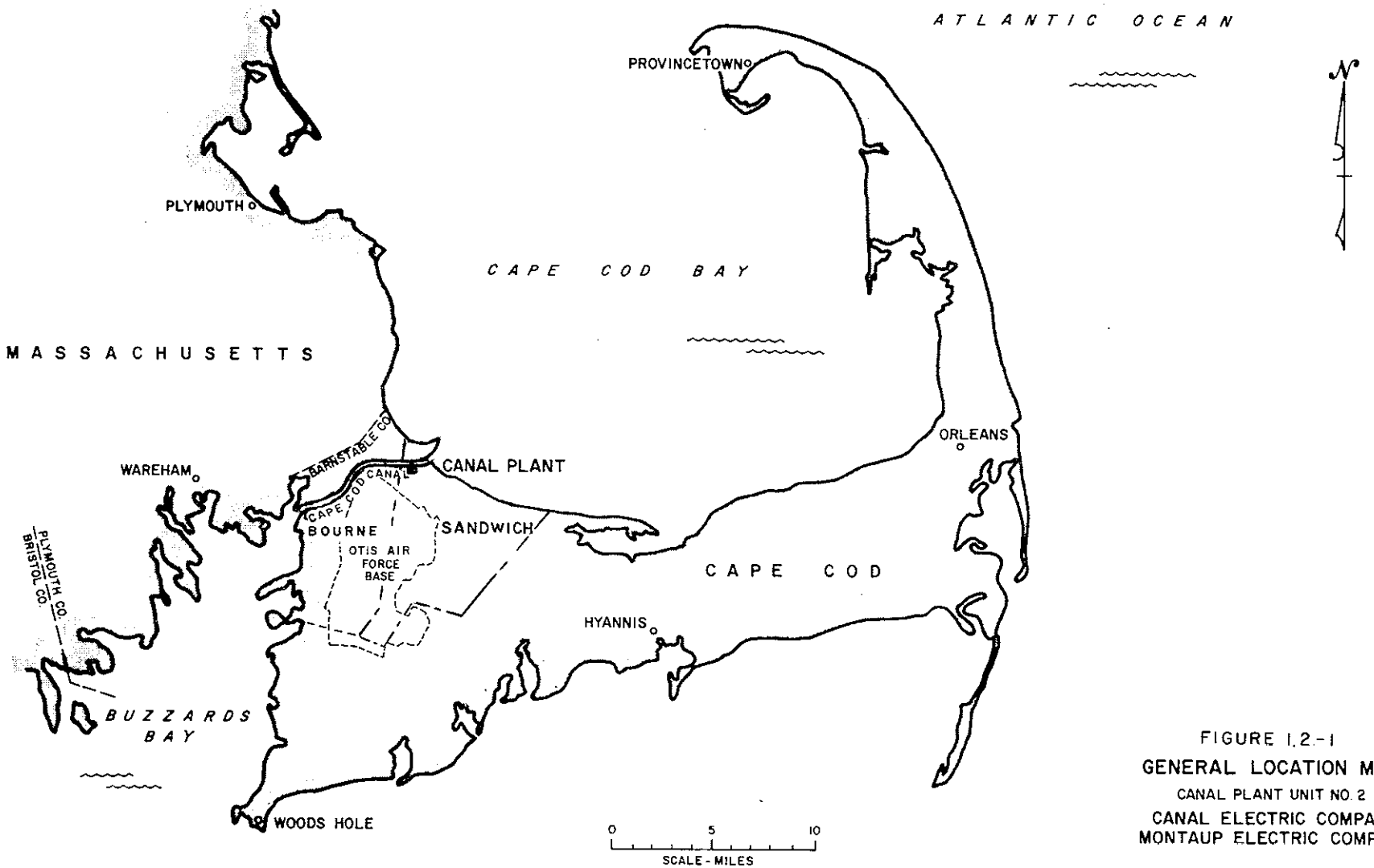


FIGURE 1.2-1
GENERAL LOCATION MAP
CANAL PLANT UNIT NO. 2
CANAL ELECTRIC COMPANY
MONTAUP ELECTRIC COMPANY

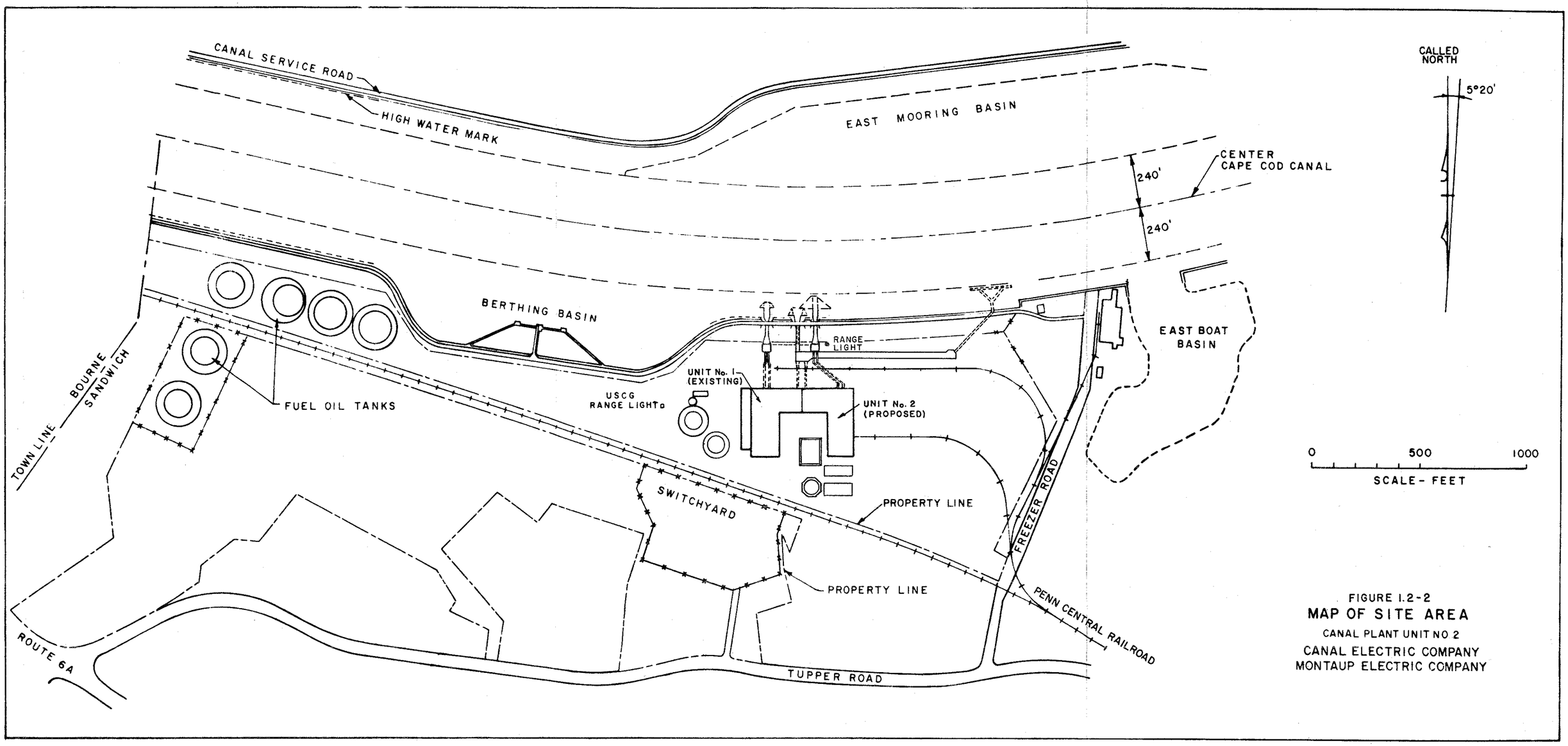


FIGURE 1.2-2
MAP OF SITE AREA
CANAL PLANT UNIT NO 2
CANAL ELECTRIC COMPANY
MONTAUP ELECTRIC COMPANY

Once-through cooling is used in Unit No. 1, with the turbines exhausting to a 190,000 square foot condenser; a similar system with a 182,000 square foot condenser is planned for Unit No. 2.

Steam for the turbine will be provided by an oil-fired steam generator, rated at 4,000,000 pounds of steam per hour at a superheater outlet pressure of 2,500 psig. The boiler will be designed for quick start and cycling service. The furnace will be a balanced draft type, arranged so that exit flue gases pass through an electrostatic precipitator located at grade behind the boiler. The temperature of the flue gas leaving the air heater (flue gas) at the boiler's maximum continuous rating will be in excess of 300 F.

The boiler will be designed with specific goals that affect environmental considerations, namely:

Minimum formation of particulate matter (see Section 3.1)

Excess air at the economizer outlet of 5 percent or less at full load

Nitrogen oxides at the economizer outlet of 200 parts per million (ppm) maximum at full load.

The boiler will be designed for oil firing only, with circular register burners and steam atomizers for normal load operation and for cold startups.

Recirculation of flue gas from the economizer outlet to the burners will reduce flame temperature and minimize formation of nitrogen oxides. This recirculated gas is also used for reheat steam temperature control, being admitted through the furnace bottom when more recirculation is required than can be admitted through the burners.

Automatically controlled soot blowers using steam as the cleaning medium will be provided for cleaning superheater, reheater, boiler walls and air heater (fireside surfaces).

Excess air control will be based on flue gas-oxygen measurement and automatic comparison of the difference from the oxygen set point with the firing rate demand, finally changing the operation of the forced draft fans as required.

Two forced draft fans will be provided; each fan will be located in an enclosed plenum fan room and will take suction from the room, which will have glycol air preheaters to raise inlet air temperatures and noise attenuators at the outside air intake openings. The fans will discharge through combustion air heaters to regenerative air heaters, thence to the boiler. Each forced draft fan is specified to have a capacity of 624,000 cfm at 100 F

and produce a static pressure of 25 inches of water across the fan.

Two induced draft fans will also be provided, located in an enclosed room designed for noise suppression, taking suction in parallel from an electrostatic precipitator and discharging through suitable breeching to the stack. Each induced draft fan is specified to have a capacity of 1,000,000 cfm of flue gas at 394 F, with a differential of 27.75 inches of water across the fan.

An electrostatic precipitator receives the flue gases after the gases leave the regenerative air preheater. This equipment is specified to have a capacity of 2,000,000 cfm of flue gas at an inlet temperature of 300 to 373 F, a normal operating draft of 18 inches of water at the inlet and an inlet grain loading of 0.10 grain per actual cubic foot (gr/acf). The precipitator will be designed to operate with acceptable additives mixed with the fuel oil prior to entering the boiler burners. The performance guarantee of the precipitator will be based on an outlet concentration of particulates not to exceed 0.010 gr/acf at a temperature of 300 F to 373 F.

1.2.3.2 Stack and Flue Gas

Flue gases from the steam generator of Unit No. 1 are presently discharged through two regenerative air preheaters in parallel flow and then joined in a single vertical steel stack erected above the plant roof on boiler supporting steel. The existing Unit No. 1 stack extends 298 feet above ground level.

Unit No. 1 has been modified by the installation of an electrostatic precipitator and interconnecting steel ductwork between the air preheaters and the stack. The precipitator is located directly south of the boiler enclosure and supported on a separate foundation.

A new reinforced concrete chimney shell will be erected south of the station on a separate reinforced concrete foundation mat. White strobe lights and red warning lights will be used as aircraft obstruction warning devices. No special exterior coloring will be used to modify the natural grey color of the concrete. The chimney will extend 483 feet above ground level and the two steel liners will project 15 feet above the rain hood making an overall height of 498 feet.

The Unit No. 2 steam generator will discharge gases through its own air preheaters, electrostatic precipitator, and induced draft fans via steel ductwork to the new concrete chimney.

The ductwork from both units to the chimney will be rectangular in cross-section, insulated and lagged, and supported on structural steel columns of lengths up to 40 feet. The breeching

for Unit No. 1 will enter the chimney on the west side at an angle of 45 degrees to the horizontal in the vertical plane. The breeching for Unit No. 2 will enter the chimney diametrically opposite the Unit No. 1 breeching, and also at 45 degrees to the horizontal.

The gases from each unit will discharge into separate vertical steel liners within the concrete shell. The liners will be insulated for their full height and be supported on a structural steel framework just above the breeching. This steel framework in turn is supported on the concrete shell. Mild carbon steel, unpainted, will be used for the liners, except for the upper 35 feet which will be stainless steel.

Flue gas temperatures in ducts and stack are expected to vary between 300 and 350 F. Temperature readings (average of four thermocouples in each duct) are printed hourly in the station data system.

Smoke monitoring equipment, sampling ports for particulate measurement and for sulfur dioxide and nitrogen oxides concentration monitoring will be provided at suitable locations in the flue gas ductwork. Smoke monitoring will be continuous and particulate sampling will be performed as requested.

Platforms will be installed at various levels within the chimney to provide access to the aircraft obstruction warning lights, the inspection panels and sampling ports on the liners, supporting steel, and ash hopper outlets at the bottom of the liners.

1.2.3.3 Circulating Water Facilities

An overall plan of the Canal Plant circulating water system is shown in Figure 1.2-3. Circulating water for cooling purposes will be obtained from Cape Cod Canal and will be returned undiminished in quantity to the same body of water. The circulating water system for the proposed Unit No. 2 is similar to the existing Unit No. 1 except for the discharge portion.

The existing Unit No. 1 discharge flume will be blocked off and the circulating water from both units will be collected in a common discharge flume and then released to Cape Cod Canal through an outfall structure at the far northeastern corner of the Canal Plant site.

The Canal Plant Unit No. 2 will require about 191,000 gpm or 426 cfs of Cape Cod Canal water for cooling purposes. The condenser circulating water accounts for about 181,000 gpm; the remaining 10,000 gpm are used for miscellaneous station heat exchangers. The Unit No. 2 circulating water flow is therefore slightly higher than the present Unit No. 1 flow of 167,000 gpm or 372 cfs. The combined flow of Units No. 1 and No. 2 of

approximately 800 cfs amounts to about one percent of the mean tidal flow in Cape Cod Canal.

When either or both units of the station are operating at full load, the temperature of the circulating water at the condenser outlets will be about 28 F above ambient water temperature.

The Unit No. 2 intake is shown in Figure 1.2-4. Based on the recommendations of the Massachusetts Division of Marine Fisheries (Reference 1)*, a 9-foot high fish sill will be installed to discourage bottom-swimming fish from entering the intake.

The intake flume will be about 154 feet long and varies in width from 26 feet at the canal to 20 feet at the center portion and to about 31 feet at the screenwell. It will be formed by two rows of steel sheet piling and is rip-rapped at the bottom. Intake velocity for all water levels in Cape Cod Canal will be 1.02 fps at the entrance. A maximum flume velocity of 2.10 fps at the center portion of the intake flume and 0.74 fps in front of the traveling screens would occur at mean low water. The velocities expected to occur at the traveling screens range as follows:

Water Level	Velocity (fps)
Extreme low water	0.94
Mean sea level	0.59
Extreme high water	0.43

The screenwell structure will be located at the downstream end of the intake flume. It will be a two-celled structure, about 47 feet long and 31 feet wide with a concrete floor at El. 19.1 feet MLW datum and steel sheet pile walls. Each of the two cells will be provided with trash racks, a vertical traveling 3/8-inch screen, and a vertical mixed flow circulating water pump rated at 95,500 gpm with a total dynamic head of 23.5 feet. Circulating water pumps, pump-motors, and motors for the traveling screens will be supported on the service deck at El. 16.9 feet. The screen washings will be conveyed in a sluiceway to a point near the north end of the Unit No. 1 discharge canal (Figure 1.2-3). Since this flume will no longer be part of the circulating water system, water in the flume will be at ambient temperature.

The two 95,500 gpm circulating water pumps will deliver the water to the condenser through two 66-inch diameter pipes. Beyond the outlet of the condenser, the two 66-inch diameter pipes will join to form one 90-inch diameter pipe which will return circulating water to the common discharge flume.

*References are given at the end of this report.

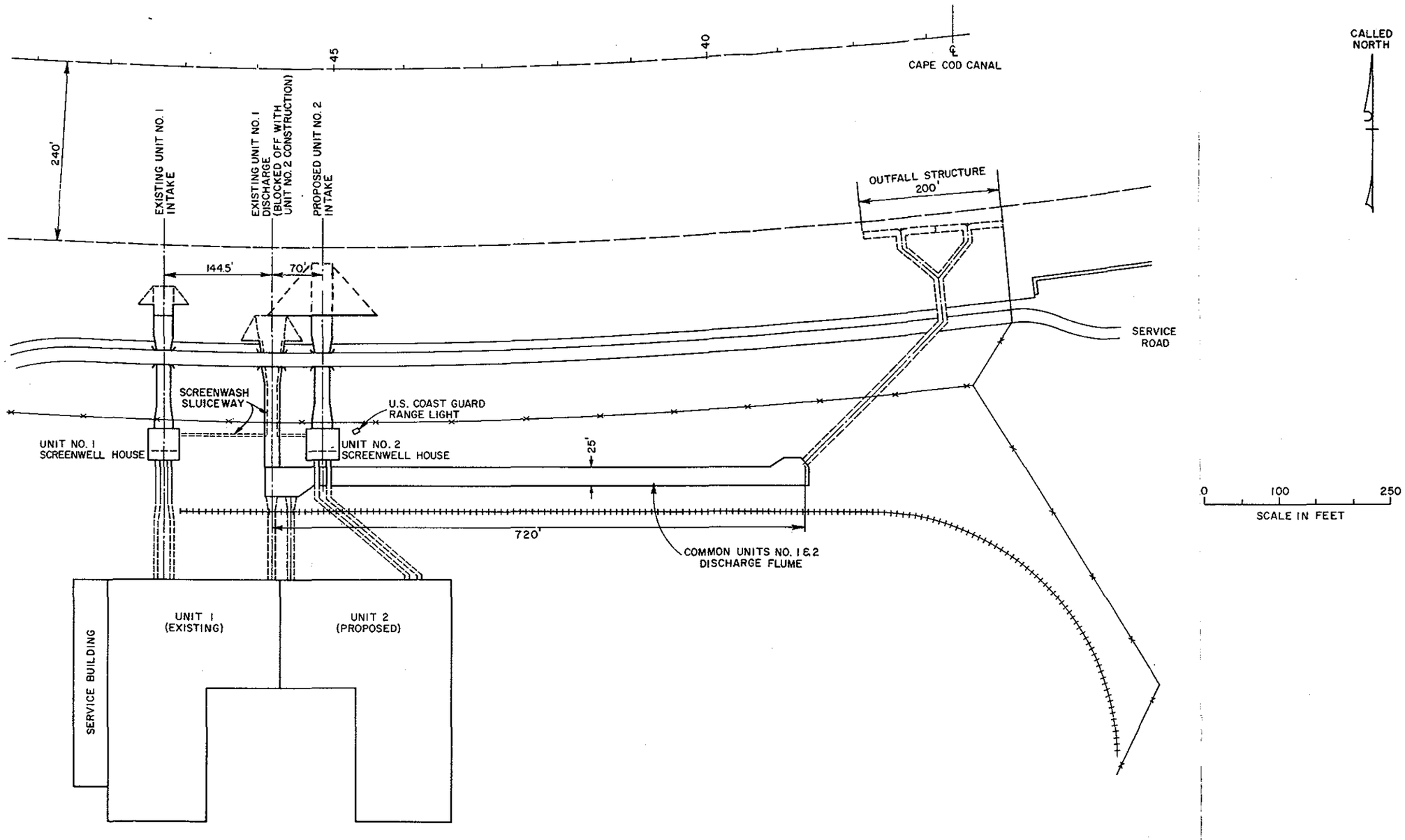
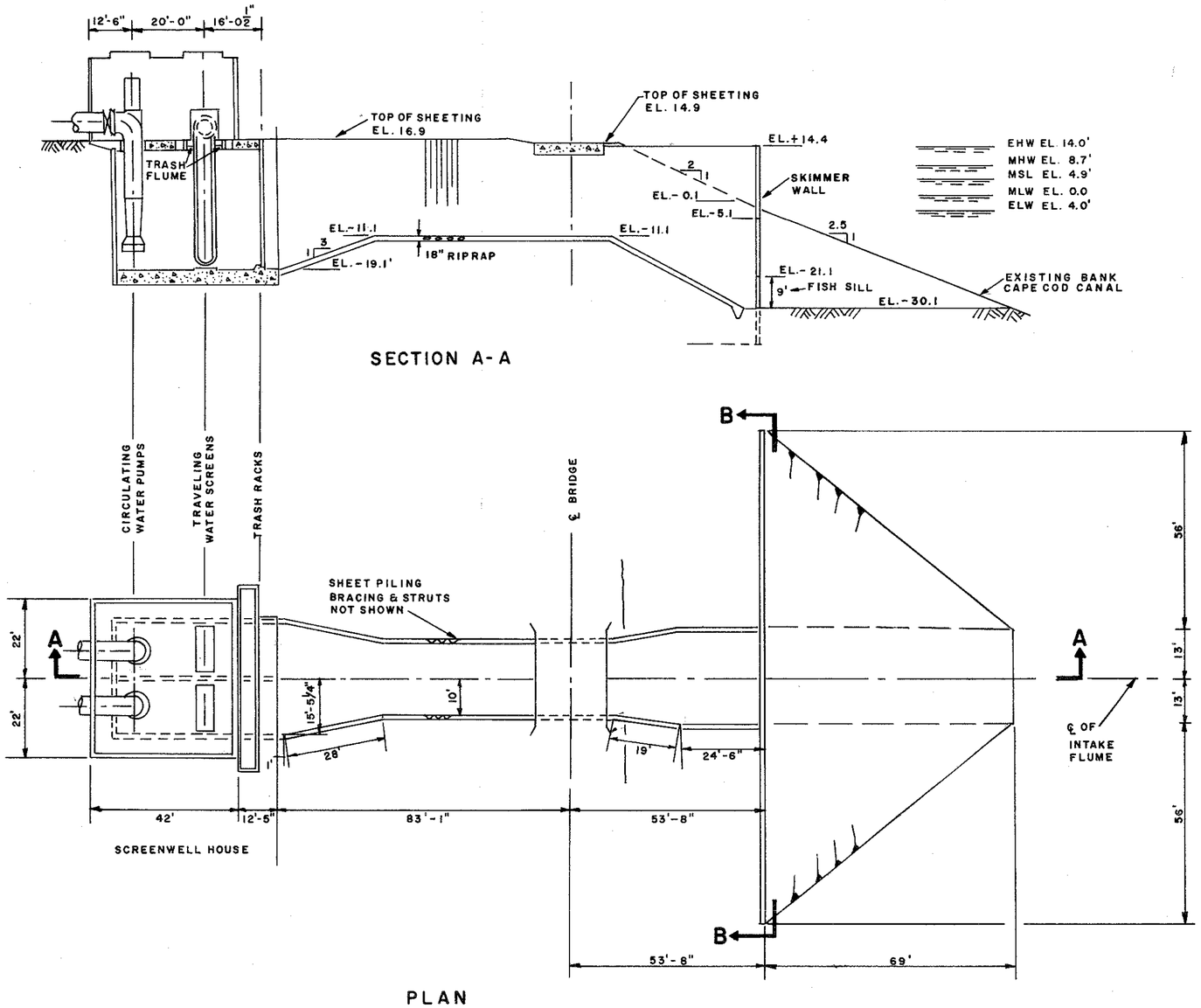
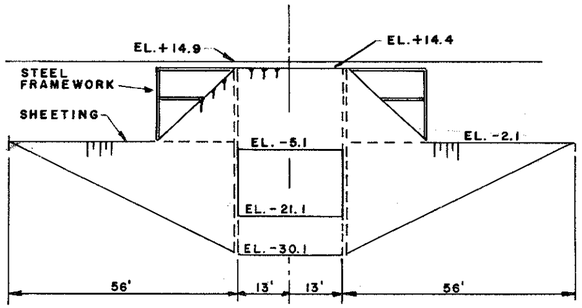
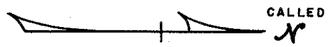


FIGURE 1.2-3
PLAN OF CIRCULATING WATER SYSTEM
UNITS NO. 1 & 2
CANAL PLANT UNIT NO. 2
CANAL ELECTRIC COMPANY
MONTAUP ELECTRIC COMPANY







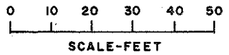


FIGURE 1.2-4

CIRCULATING WATER INTAKE

UNIT No. 2

CANAL PLANT UNIT No. 2

CANAL ELECTRIC COMPANY

MONTAUP ELECTRIC COMPANY

The single-pass condenser contains approximately 14,000 1-inch O.D. tubes through which the circulating water passes. Exhaust steam leaving the turbine will flow over and around the outside of these tubes and, in so doing, condense to water and drop to the bottom of the condenser shell where the condensate will be collected for reuse in the cycle. This process will transfer the latent heat of condensation of the steam to the circulating water which will undergo a temperature rise of about 28 F at full load.

The circulating water discharge facilities shown in Figure 1.2-3 consist of an open discharge flume about 720 feet long terminating near the eastern boundary of the Canal Plant site. The discharge flume will convey the circulating water flow to a buried discharge conduit which terminates in a submerged outfall structure.

The major features of the discharge flume are shown in Figure 1.2-5. The flume is 25 feet wide and formed by two parallel rows of sheet piling. The bottom of the flume will be concrete and varies in elevation from -13.1 feet MLW datum at the junction with the condenser discharge conduits to -11.1 feet along the rest of the flume. The water level in the flume will fluctuate according to the tide stage in Cape Cod Canal. Velocities are expected to vary between 1.4 fps at mean high water and 2.0 fps at mean low water.

The station cooling water outfall system as shown in Figure 1.2-6 is carefully designed to control temperature rises and velocity patterns to within the limits recommended by the Massachusetts Department of Natural Resources, Division of Marine Fisheries, and by the U.S. Army Corps of Engineers. This will be accomplished by discharging the cooling water in vertical direction through a series of 1.5-foot wide slots. The proposed outfall system consists of a 10-foot diameter conduit which splits into two 8-foot diameter conduits leading to separate 100-foot long discharge pipes located parallel to the bank. Each of the 8-foot diameter discharge pipes is provided with 1.5-foot wide by about 5-foot long slots which extend for 80 feet along the top of the structure. The centerline elevation of the slot is located at -27.1 feet MLW, which results in a submergence of 24.1 feet at low slack water and 29.1 feet at high slack water. Discharge velocities average about 3.5 fps through the slots for the maximum circulating water flow of 800 cfs. Velocities at the surface are less than 1.6 fps.

The engineering and hydraulic model studies which formed the basis of the design for the circulating water outfall structure are discussed in Section 3.2.1.

Certain modifications reflecting suggestions by the Massachusetts Division of Marine Fisheries will be made to the existing Unit No. 1 circulating water facilities during Unit No. 2

construction. Recommendations made by the Division of Marine Fisheries are enumerated in Appendix No. 1.

If the installation of a fish sill in the Unit No. 2 intake (Figure 1.2-4) proves successful in discouraging bottom dwelling fishes from entering the intake, a similar sill will be constructed at Unit No. 1.

The present Unit No. 1 discharge flume is located parallel to the proposed Unit No. 2 intake at a distance of 70 feet to the west. With the addition of the Unit No. 2 common discharge flume, the existing Unit No. 1 discharge flume will be blocked off (Figure 1.2-3). The Unit No. 1 discharge will be used as an emergency spillway during abnormal tide levels in Cape Cod Canal. However, the spillway crest is set high enough (at 14.9 feet above mean low water) so that there will be no spilling of circulating water under normal tide conditions. Abnormally high tides must exceed 11.2 feet above MLW before any spillage will occur (spring high tide is 10.1 feet). This would mean that storms of tropical hurricane strength are needed before any spill over the emergency weir would happen. The probability of a tropical storm with hurricane intensity at Cape Cod is approximately 24 percent per year. Actual tide records for the past 17 years indicate that the tide exceeds 11.2 feet by a few tenths of a foot about three times a year, and exceeds it by 0.5 foot up to 2.0 feet about once every two years.

1.2.3.4 Fuel Oil Unloading and Storage

The present fuel receiving facilities adjacent to the Canal Plant include a ship's berthing basin at the easterly end of the Cape Cod Canal; the basin can accommodate a medium-sized tanker (500-800 feet in length). The outboard side of the tanker at its berth is approximately 100 feet outside of or clear of the navigable portion of the Canal itself. Average interval between present fuel oil unloadings is 11 days and will be about 6 days when Unit No. 2 becomes operational.

Fuel is pumped from the tanker into four steel storage tanks with a total capacity of 747,000 barrels. The unloading lines are constructed so that they may be drained and pumped forward into the storage or day tanks. All unloading lines are heat traced and a compressed air supply system is available at the dock to force the oil on through the lines and hoses, thus avoiding spillage when the hoses are disconnected. Each oil storage tank is surrounded by a steel dike which has 110 percent capacity of the oil tank it protects in case of leakage.

This fuel oil unloading and storage facility was constructed after obtaining approval from the U.S. Army Corps of Engineers, the Massachusetts Department of Natural Resources, and the Massachusetts Department of Public Safety. All facilities were

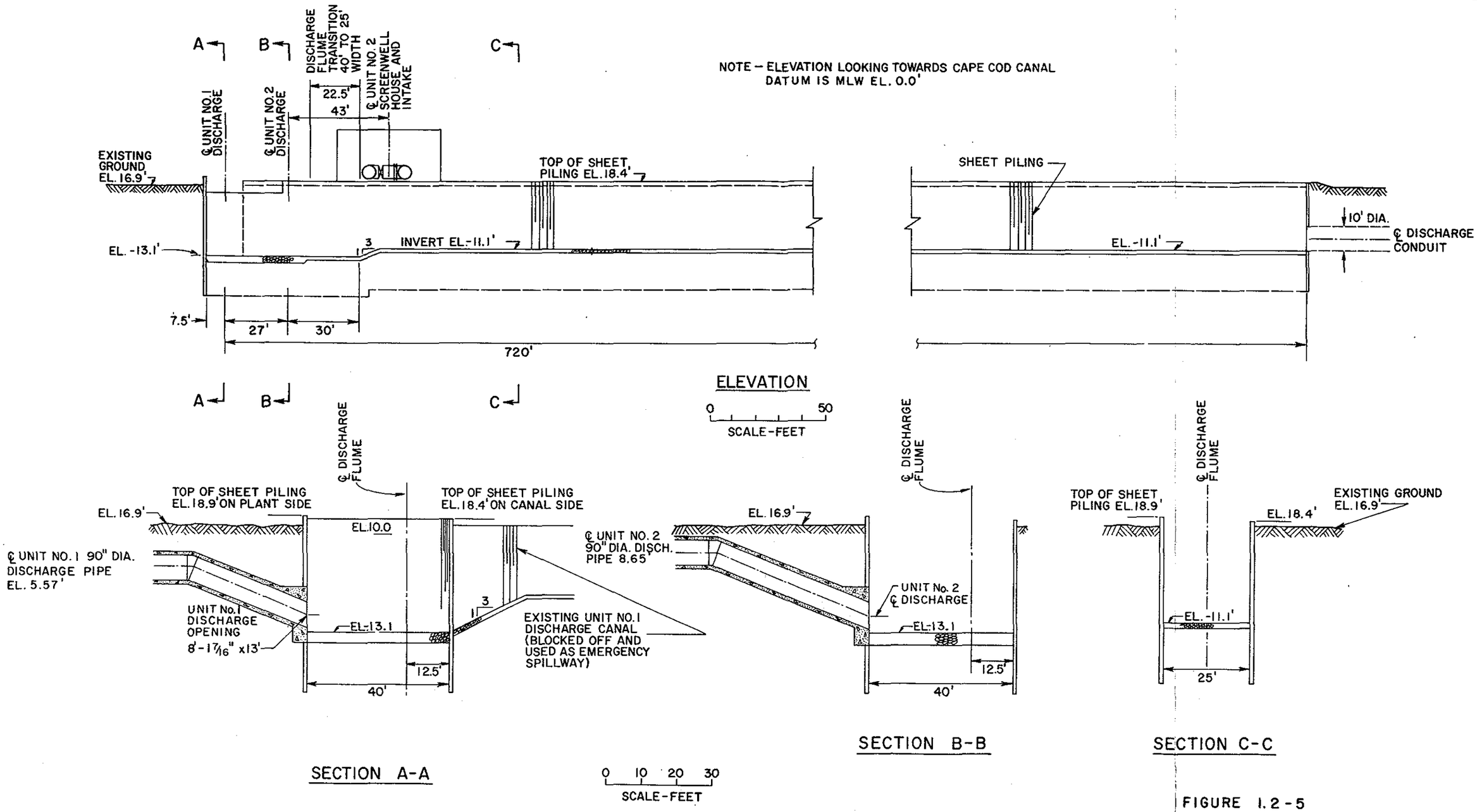


FIGURE 1.2-5

DISCHARGE FLUME
UNITS NO. 1 & 2

CANAL PLANT UNIT NO. 2

CANAL ELECTRIC COMPANY
MONTAUP ELECTRIC COMPANY

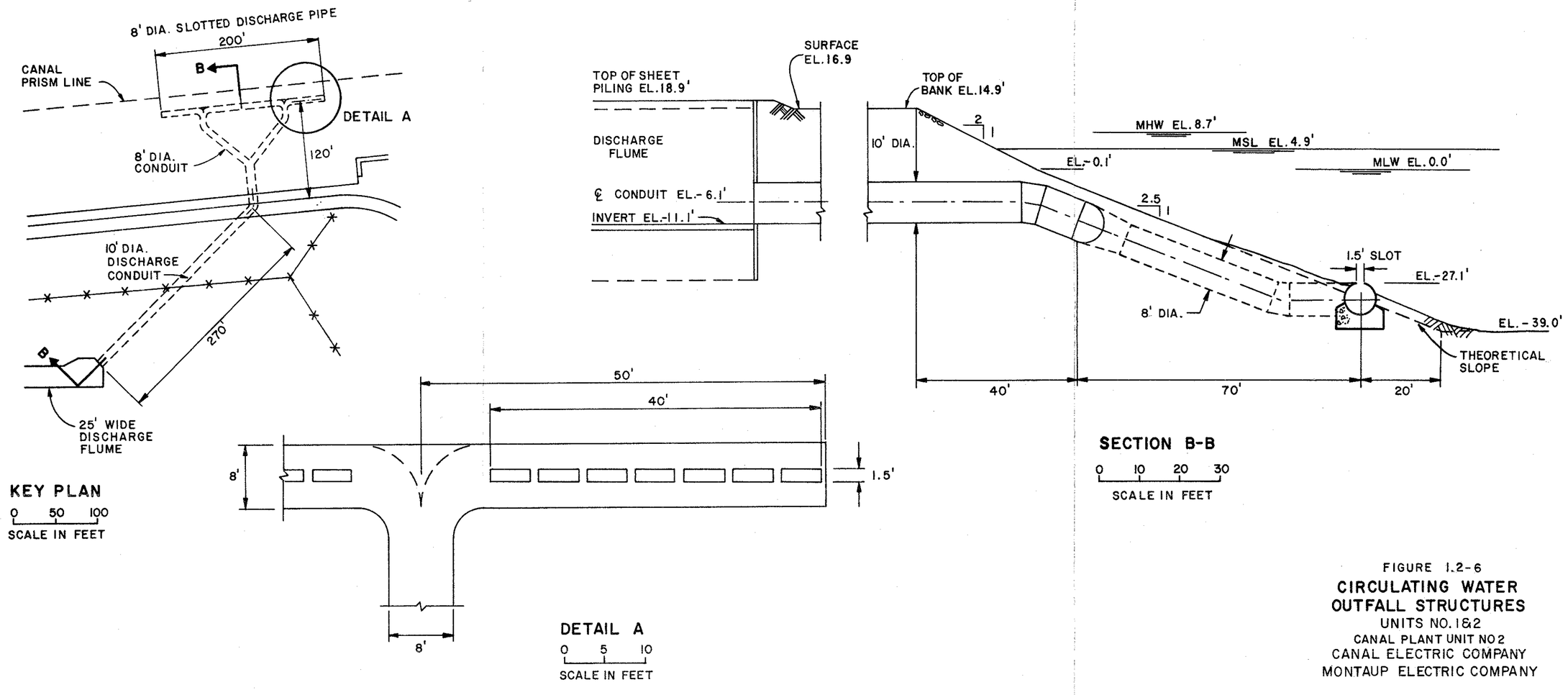


FIGURE 1.2-6

CIRCULATING WATER OUTFALL STRUCTURES

UNITS NO. 1&2

CANAL PLANT UNIT NO 2

CANAL ELECTRIC COMPANY

MONTAUP ELECTRIC COMPANY

inspected by these agencies during and after construction and pronounced safe and adequate.

The total fuel unloading, storage, and transfer system is owned by NEPCO Terminal, Inc. with Division offices at 1330 Boylston Street, Chestnut Hill, Massachusetts 02167. In July 1969 NEPCO was notified by the Commonwealth of Massachusetts, Water Resources Commission, that they would be required to become licensed on an annual basis in accordance with the Rules for Prevention and Control of Oil Pollution in the Waters of the Commonwealth. The current license, permit No. 73-42, is for the period July 1, 1973, through June 30, 1974. These rules prescribe the care and preventative measures that must be observed by the terminal and provide for an inspection report as well as notification of any instances in which fuel oil has been spilled into the waters off the coast of Massachusetts. NEPCO has also posted a $25,000 bond as required by Massachusetts law which would be forfeited upon failure to provide adequate cleanup of a spillage incident.

In compliance with these rules, NEPCO presently has 400 feet of Pirelli 36-inch oil boom stored at the site, together with 500 feet of 36-inch type "T-T" oil boom, owned by East Coast Services but stored at this terminal.

NEPCO has an agreement with East Coast Services so that in case of any mishap, they will respond immediately to provide orderly containment of any spillage and adequate cleanup.

Two additional oil storage tanks will be installed with Unit No. 2. These tanks will each contain approximately 183,500 barrels and will be located to the south of the railroad tracks as shown on Figure 1.2-2. The tanks will be filled from the existing unloading facilities and will be interconnected with the four existing tanks so that oil may be pumped from any one of these to serve Units No. 1 or No. 2. All fuel transfer lines will be stream-traced and recirculation with external heating will also be available.

Unit No. 1 is presently served by a 43,000-barrel day tank which is located reasonably close to the station and adjacent to the high pressure fuel oil pump house. Fuel oil is received at the pipeline inlet to this day tank from NEPCO Terminal, Inc., which controls transfer of the oil.

Oil is drawn from the day tank into high pressure fuel oil supply pumps and forwarded into the station and to the boilers. Recirculation , as required, is back to the day tank. A suitable steel dike surrounds the day tank; within the dike is a 20,000-gallon No. 2 ignition oil storage tank which is used in the boiler to light the main oil burners. A 1,300-barrel standby oil tank is located next to the day tank in the same area.

Unit No. 2 will have essentially the same type of facilities with its own day tank and high pressure pumps. NEPCO will deliver oil by transfer pumps to the day tanks as required and will control operation of these pumps. The day tanks are also designed so that oil within each tank may be drawn out, heated and recirculated if a unit is down for scheduled maintenance during cold weather. Temperature can thus be properly maintained in the tanks.

The temperature of the fuel at the burners is controlled by a bank of fuel oil heaters inside the station and the temperature to which the oil is heated is dependent upon the viscosity of the fuel oil supplied by NEPCO.

As listed in the Region I Multiagency Oil and Hazardous Material Pollution Contingency Plan of the U.S. Coast Guard, the following floating booms for containment of oil spills are available in the area: 800 feet of Johns-Manville boom with the New England Petroleum Corporation, Sandwich, and 328 feet of type "T-T" boom with the Woods Hole, Martha's Vineyard and Nantucket Steamship Authority, Woods Hole.

If an oil spill occurs, the predesignated subregional responsibility center is the U.S. Coast Guard Group Office, Woods Hole, Massachusetts.

1.2.3.5 Chemical and Solid Waste Handling

Present Unit No. 1 liquid waste facilities will be modified and expanded in conjunction with Unit No. 2 construction. Liquid wastes resulting from Unit No. 1 operation, namely those from the makeup and condensate polisher demineralizers, equipment cleaning, floor drains, as well as chlorination for biofouling control are presently treated in the same manner as described herein for Unit No. 2.

Chlorination of circulating water for Unit No. 2 condenser cooling is required during summer to maintain reliable unit operation by controlling biological growths in the circulating water system and on tube heat transfer surfaces. Since chlorination of existing Unit No. 1 circulating water has not been necessary from November through June, it is anticipated that chlorination of Unit No. 2 circulating water will also be unnecessary during this 8-month period. When chlorination of circulating water with sodium hypochlorite is used, it will occur only for short periods (5 to 10 minutes, twice daily). Residual chlorine in the circulating water while dosing will be maintained at levels less than 0.1 ppm at the discharge from the condenser. A residual chlorine monitor will be installed and used during the chlorination season. This residual will be diluted by a factor of two, since each condenser half will be alternately chlorinated.

Further dilution by a factor of two will occur in the Units No. 1 and No. 2 common discharge flume, since circulating water for each unit will be chlorinated during separate intervals. Residual chlorine levels in Cape Cod Canal at the point of discharge will be less than 0.025 ppm due to an overall dilution factor of four when all four circulating water pumps are operating.

Utilization of ferrous sulfate with concentrations of approximately 0.50 ppm in the condenser intake are presently being investigated for protection of condenser tube surfaces.

Collected ash from the electrostatic precipitator for Unit No. 1 will be hydraulically conveyed from the hoppers to the precipitator ash settling basin. Ash sluicing will be incorporated in a closed system which utilizes about 500 gpm of water to sluice ash from hoppers to a waste sump. Caustic will be added to the sump for pH control. Provisions will be made for the addition of a wetting agent and defoaming agent to promote more rapid settling of the fly ash and minimize foam formation, if necessary. Operation of the precipitator ash settling basin is shown schematically in Figure 1.2-7. This method is similar to the ash collection system provided for Unit No. 1.

The basins for Unit No. 2 will be constructed of reinforced concrete lined with coal tar epoxy in two sections, each 50 feet wide, 100 feet long, and 10 feet deep, with a total capacity of approximately 750,000 gallons. Each section can be utilized independently should it be necessary to clean one section of the basin while the other is in operation.

Basin characteristics at a flow rate of 500 gpm will consist of an overflow rate of 150 gallons per square foot per day and a retention time of approximately one day. These characteristics represent conservative sedimentation design parameters, and settling efficiencies are expected to be very high.

Effluent from the settling basin during normal operation will be recycled to the precipitator ash hoppers at 500 gpm and, therefore, no overflow effluent will be discharged from the precipitator ash settling basin to the circulating water system.

Evaporative makeup for the ash sluicing system will be supplied from the plant service water system. Floor and equipment drain waste water will be discharged to oil-water separators, and the treated effluent will also serve as makeup water for the ash sluicing system.

Settled ash will be removed from the precipitator ash settling basin and disposed of in an approved manner.

During equipment cleaning cycles, discussed in later sections, or upsets in normal operation, liquid wastes from the waste sump and

clean water sump will be conveyed to the existing waste retention basin for suspended solids removal prior to neutralization in the waste neutralization tank. If the discharge effluent is clear, it will be discharged directly to the waste neutralization tank. Effluent from the neutralization tank will be discharged by gravity to the circulating water discharge flume. The waste neutralization tank has a capacity of 50,000 gallons and is provided with a continuous pH monitor.

Under normal operation of Unit No. 2, boiler feedwater will be treated with ammonia to maintain a pH of 9 to 9.5, and with hydrazine to remove dissolved oxygen.

Boiler water will be blown down, as required, to maintain silica levels below 0.20 ppm and, under normal operation, will be conveyed to the condenser hot well prior to contaminant removal in the condensate polisher demineralizer, as shown in Figure 1.2-7. In this manner, treatment of fresh makeup water is minimized and the volume of water significantly reduced during normal operation of the Unit No. 2 boiler, since blowdown will be recovered and recycled in a closed system.

Unit No. 1 incorporates a universal pressure boiler. Blowdown of boiler water from this unit is not required.

Floor and equipment drains will collect water from Unit No. 2 plant floor areas and the water will be conveyed through underfloor piping to an oil-water separator. From the oil-water separator, clarified water will be pumped to the precipitator ash settling basin via a waste sump as shown in Figure 1.2-7.

Estimated average flow rates for floor and equipment drain wastes will be 10 to 20 gpm. This flow rate will serve as evaporative makeup water for the precipitator ash settling basin system.

Collected oil will be removed from the oil-water separators and stored in 55-gallon drums for offsite disposal.

The sanitary waste system will be similar to that for Unit No. 1. The sanitary waste system for the expanded plant will be composed of a septic tank and leaching field and will be designed for a waste flow of 35 gallons per person per day.

Roof, yard, and storm drains will be collected and discharged to Cape Cod Canal.

Accumulation of oil ash on equipment interior surfaces necessitates periodic cleaning of air heaters, economizer, boiler fireside, and electrostatic precipitator.

Air heaters will be washed with 800 gpm of service water. The economizer and boiler fireside will be washed with 275 gpm of service water. Each of the four precipitator sections will be

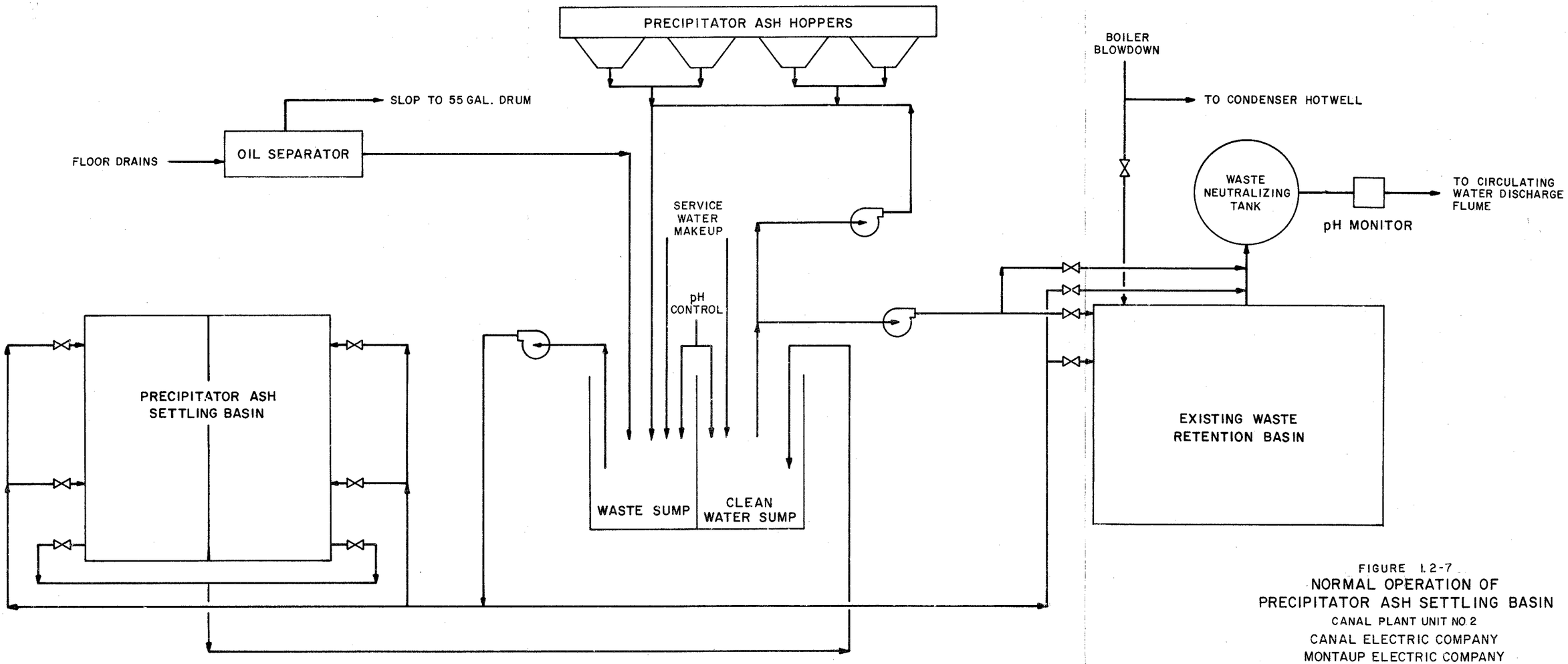


FIGURE 1.2-7
NORMAL OPERATION OF
PRECIPITATOR ASH SETTLING BASIN
CANAL PLANT UNIT NO. 2
CANAL ELECTRIC COMPANY
MONTAUP ELECTRIC COMPANY

washed with 130 gpm of service water. Each piece of equipment will be washed separately, usually two to four times a year. Duration of the wash cycle will vary, depending upon the degree of cleaning required. Washing cycles may continue for 5 to 10 hours.

Wash water from periodic equipment cleaning will be acidic and contain suspended solids. This wash water will be conveyed to a waste sump for pH control prior to discharge into the precipitator ash settling basin for removal of suspended solids.

Retention time in the ash settling basin during equipment cleaning is expected to provide a high solids removal efficiency. The precipitator ash settling basin overflow will be neutralized and discharged into the circulating water discharge flume.

In the event of an upset in operation of the precipitator ash settling basin during equipment cleaning, the overflow would be directed to the existing waste retention basin for further treatment. Capacity of the existing waste retention basin is approximately 400,000 gallons.

Chemical cleaning of the boiler prior to startup and as conditions require (experience indicates every three to five years), is necessary to provide clean, properly conditioned heat transfer surfaces to maximize unit capability. Briefly, chemical cleaning usually consists of:

1. Alkaline boilout of the boiler with a solution of trisodium phosphate (0.5 percent by weight), disodium phosphate (0.01 percent by weight), and sodium sulfite (0.02 percent by weight)

2. Acid cleaning cf the boiler, including economizer, with a solution of inhibited hydrochloric acid (5 percent by weight)

3. Neutralization of the boiler with a solution of soda ash (1.0 percent by weight) or ammonium hydroxide (1.0 percent by weight)

4. Boiler passivation with a solution of monosodium phosphate (0.25 percent by weight), disodium phosphate (0.25 percent by weight), and sodium nitrite (0.50 percent by weight).

During chemical cleaning of the boiler, the superheater is backflushed with demineralized water containing approximately 5 ppm of hydrazine and 0.25 ppm of ammonia. The boiler will be backflushed with water between each of the above four cleaning operations listed. After passivation, the boiler will be rinsed with demineralized water. The water and chemicals used to clean the boiler and superheaters are discharged into the ash settling

basin for neutralization before being discharged into the circulating water discharge flume for release to Cape Cod Canal.

Total boiler waterside volume, consisting of steam drum (flooded) waterwalls and economizer, is approximately 120,000 gallons. Total spent chemical solutions and rinse water is estimated to amount to approximately 1,000,000 gallons, and will be transported to the precipitator ash settling basin. After neutralization and removal of suspended solids, the treated effluent containing approximately 8,500 ppm of dissolved solids will be conveyed to the circulating water which naturally contains approximately 32,000 ppm of dissolved solids. The unit will not be operating during chemical cleaning; however, circulating water pumps will be placed in operation to maximize the dilution of the treated effluent prior to discharge into the Cape Cod Canal.

In general, sufficient time is available between chemical cleaning phases so that alkaline boilout and acid cleaning wastes could be treated separately. However, the precipitator ash settling basin and existing waste retention basin have ample capacity to retain the entire estimated volume of spent chemical solutions resulting from chemical cleaning operations.

Regeneration of the makeup demineralizer ion exchange system will be accomplished using dilute sodium hydroxide and sulfuric acid. Duration of the regeneration cycle is approximately 4 hours and occurs on the average of every 2 days.

The regeneration cycle consists of backwashing of the cation and anion resin beds, regeneration of the cation and anion resins with dilute sulfuric acid (3 percent by weight) and sodium hydroxide (3 percent by weight), respectively, and slow and fast rinse cycles. Figure 1.2-8 presents a schematic illustration of the makeup demineralizer regeneration cycle.

Each regeneration cycle of the makeup demineralizer will require approximately 560 pounds of 66 deg Bé sulfuric acid and 650 pounds of sodium hydroxide diluted to 3 percent solutions. Additional water for backwashing and rinsing will result in a total waste volume of 15,000 gallons.

Spent acid and caustic solutions will be conveyed to a waste neutralizing tank as shown in Figure 1.2-8.

After complete neutralization, the treated effluent will be discharged to the circulating water discharge flume via a pH monitoring system. This treated effluent will contain approximately 9,000 ppm of dissolved solids (sodium sulfate) prior to discharge in the circulating water which, as already mentioned, naturally contains approximately 32,000 ppm of dissolved solids. Resultant dissolved solids levels in the circulating water will be slightly less than 32,000 ppm due to

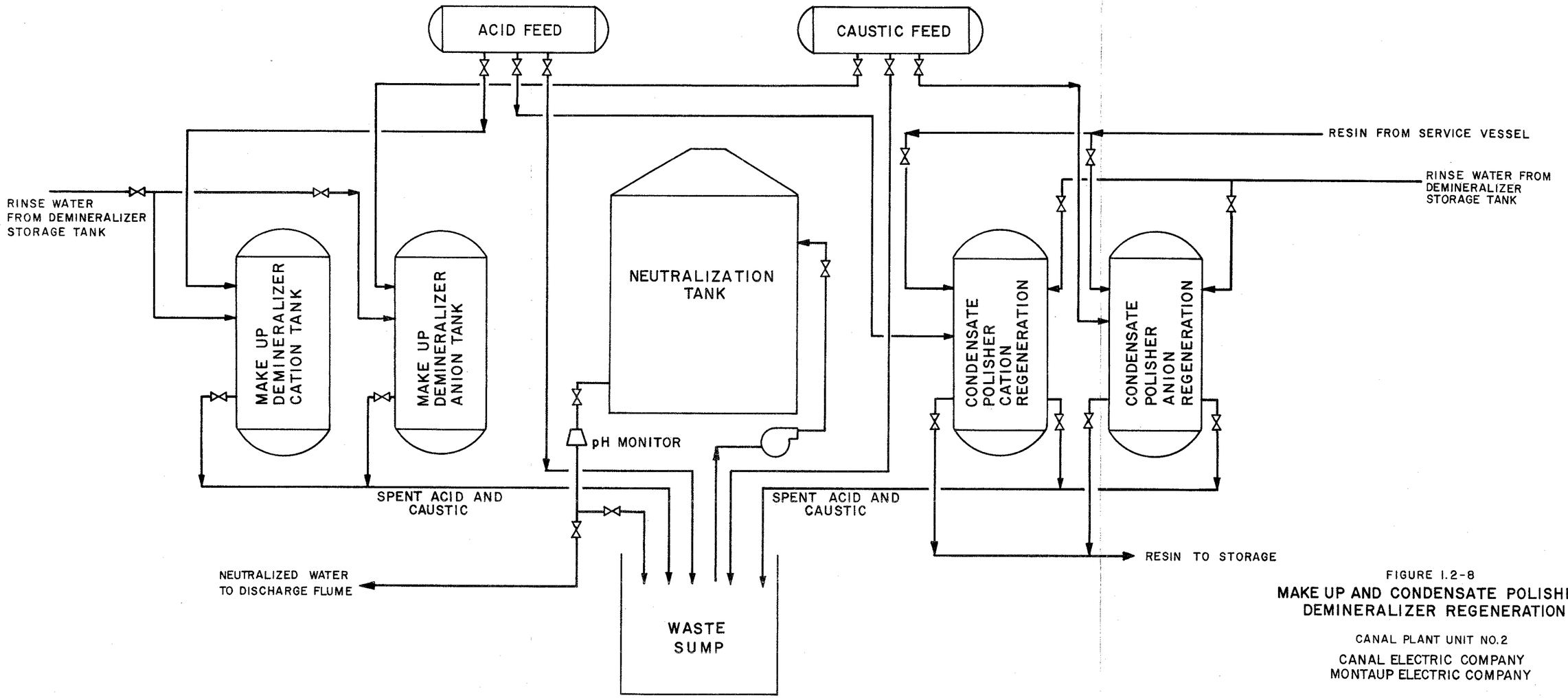


FIGURE 1.2-8

MAKE UP AND CONDENSATE POLISHER DEMINERALIZER REGENERATION

CANAL PLANT UNIT NO.2

CANAL ELECTRIC COMPANY
MONTAUP ELECTRIC COMPANY

overall dilution by a neutralized effluent having a lower dissolved solids concentration. (See Section 3.2.2.)

A similar system is provided for Unit No. 1.

Regeneration of the condensate polisher mixed bed ion exchange system will be accomplished using dilute sodium hydroxide and sulfuric acid. In general, regeneration occurs once daily for an approximate duration of four hours. The following sequence of events relates specifically to the regeneration cycle:

1. Mixed resin is backwashed in the service vessel

2. Mixed resin is hydraulically separated and transferred to anion and cation regeneration vessels

3. Regeneration of anion and cation resins with dilute solutions of sodium hydroxide (3 percent by weight) and sulfuric acid (8 percent by weight)

4. Slow and fast rinse cycles

5. Remixing of anion and cation resins

6. Storage of mixed resin.

Figure 1.2-8 presents a schematic illustration of the condensate polisher regeneration cycle.

Each regeneration of the condensate polisher will require approximately 1,450 lb of sulfuric acid and 400 lb of sodium hydroxide diluted to approximately 8 percent and 3 percent by weight solutions, respectively. Additional water for backwashing and rinsing will result in a total waste volume of 20,000 gallons.

Spent acid and caustic solutions will be conveyed to a waste neutralizing tank as shown in Figure 1.2-8.

After complete neutralization, the treated effluent will be automatically discharged to the circulating water discharge flume via a pH monitoring system. This treated effluent will contain approximately 12,500 ppm of dissolved solids (sodium sulfate) prior to discharge in the circulating water discharge flume containing approximately 32,000 ppm of dissolved solids. Resultant dissolved solids levels in the circulating water will be slightly less than 32,000 ppm due to overall dilution by a neutralized effluent having a lower dissolved solids concentration. A similar system is provided for Unit No. 1.

1.2.3.6 Switchyard and Transmission

The switchyard for Canal Plant is located south of the Penn Central Railroad tracks, about 200 feet southwest of the power plant proper. Power is received at 345 kV from the main transformer at the power station and transmitted at 345 kV and 115 kV. See Figure 1.2-9 for a schematic of the switchyard.

The existing 345-kV switchyard has four 345-kV sulfur hexafluoride (SF6) insulated circuit breakers. Two new air blast circuit breakers are to be added to form a six-breaker ring bus. There are two outgoing 345-kV lines, one incoming line from Unit No. 1 of the plant and one 400-MVA autotransformer feeding a 115-kV outgoing line. An additional incoming line from new Unit No. 2 and a second 400-MVA autotransformer feeding an outgoing 115-kV line are to be added.

Another source of plant start-up power at 22 kV from the second autotransformer tertiary windings will be provided.

A temporary 115-kV transmission line will go through the south side of the switchyard. There will be a 3-pole steel deadend angle structure and a 3-pole wood angle structure along with a 2-pole wood tangent structure before connecting to the existing steel getaway structure. Ultimately, the 115-kV line will be rerouted along the north side of the switchyard to be connected to a double circuit steel tower line.

A sound barrier wall has been constructed near the existing autotransformer to prevent noise from disturbing residents of the area. A U-shaped sound barrier wall has been erected around the new autotransformer. The wall is made from 8-inch concrete blocks with an innerlining of 8-inch Type A-1 "Soundblox." The design goal of 15 dB reduction was achieved in preliminary tests.

A prefabricated, heated, lighted, and insulated building housing relay panels and control boards associated with the switchyard for Unit No. 1 is being extended to provide for additional similar equipment required by the enlarged switchyard serving both units. Also, a new maintenance building is being constructed.

Corona-free connectors are used to reduce Radio Interference Voltage (RIV), and hot line equipment is provided to facilitate live line maintenance. Refer also to Section 3.4 - Electromagnetic Interference.

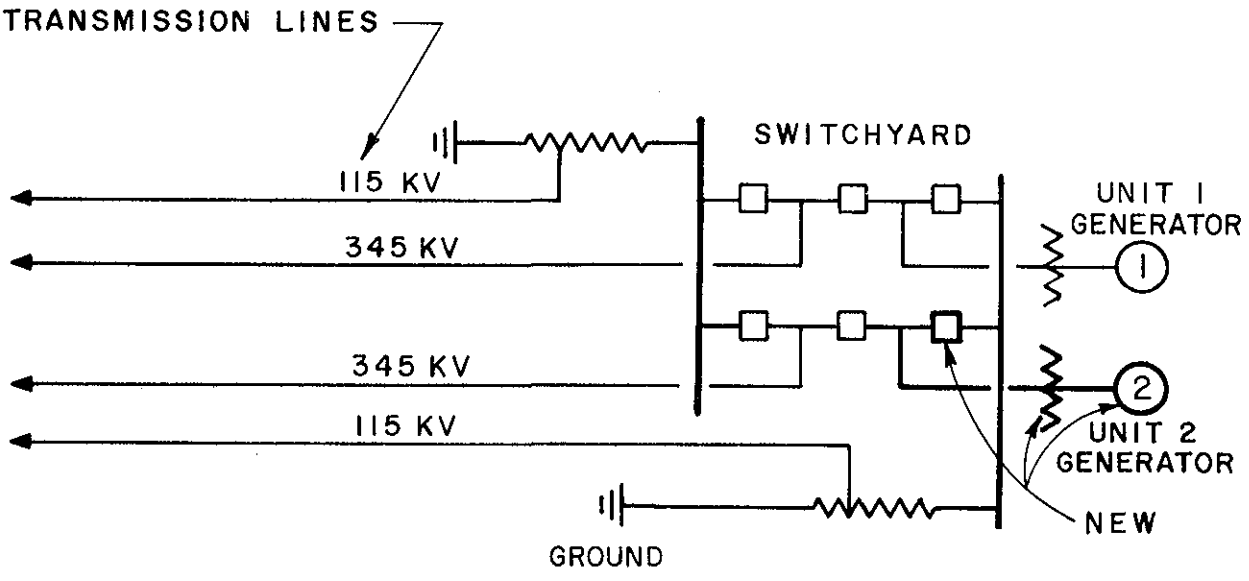


FIGURE 1.2-9
TRANSMISSION FACILITIES
CANAL PLANT SWITCHYARD
CANAL PLANT UNIT NO.2
CANAL ELECTRIC COMPANY
MONTAUP ELECTRIC COMPANY

SECTION II

ENVIRONMENTAL SETTING WITHOUT THE PROJECT

SECTION II

ENVIRONMENTAL SETTING WITHOUT THE PROJECT

2.1 CLIMATOLOGY AND METEOROLOGY

The climate in the vicinity of the Canal Plant is greatly influenced by the vast expanse of land to the west and the Atlantic Ocean to the east.

During winter, precipitation averages a little more than four inches per month. Most precipitation is a result of storms moving northward, roughly parallel to the Atlantic coast. These storms are intensified by the temperature contrast induced by the land-water boundary and many follow paths close enough to the Canal site to cause precipitation. Most storms result in rain or a combination of rain and snow. A snowstorm of at least eight inches occurs on an average of at least once each season. Average annual winter temperatures rarely fall below 0 F due to the moderating influence of the ocean. However, the exposure of the site and its proximity to the mean storm path result in frequent wind and cloudiness which make it seem colder than the thermometer would indicate.

The summer climate is generally pleasant considering that hot weather is rare; temperatures exceed 90 F an average of only four days each summer. The slowness of the Atlantic ocean to warm above its cold winter levels and frequent fog often results in delay of real summer type recreation weather until as late as July. Summer precipitation is slightly less than that of winter and the cool surrounding water limits thunderstorms to an average of only three or four a month.

2.1.1 Means and Extremes

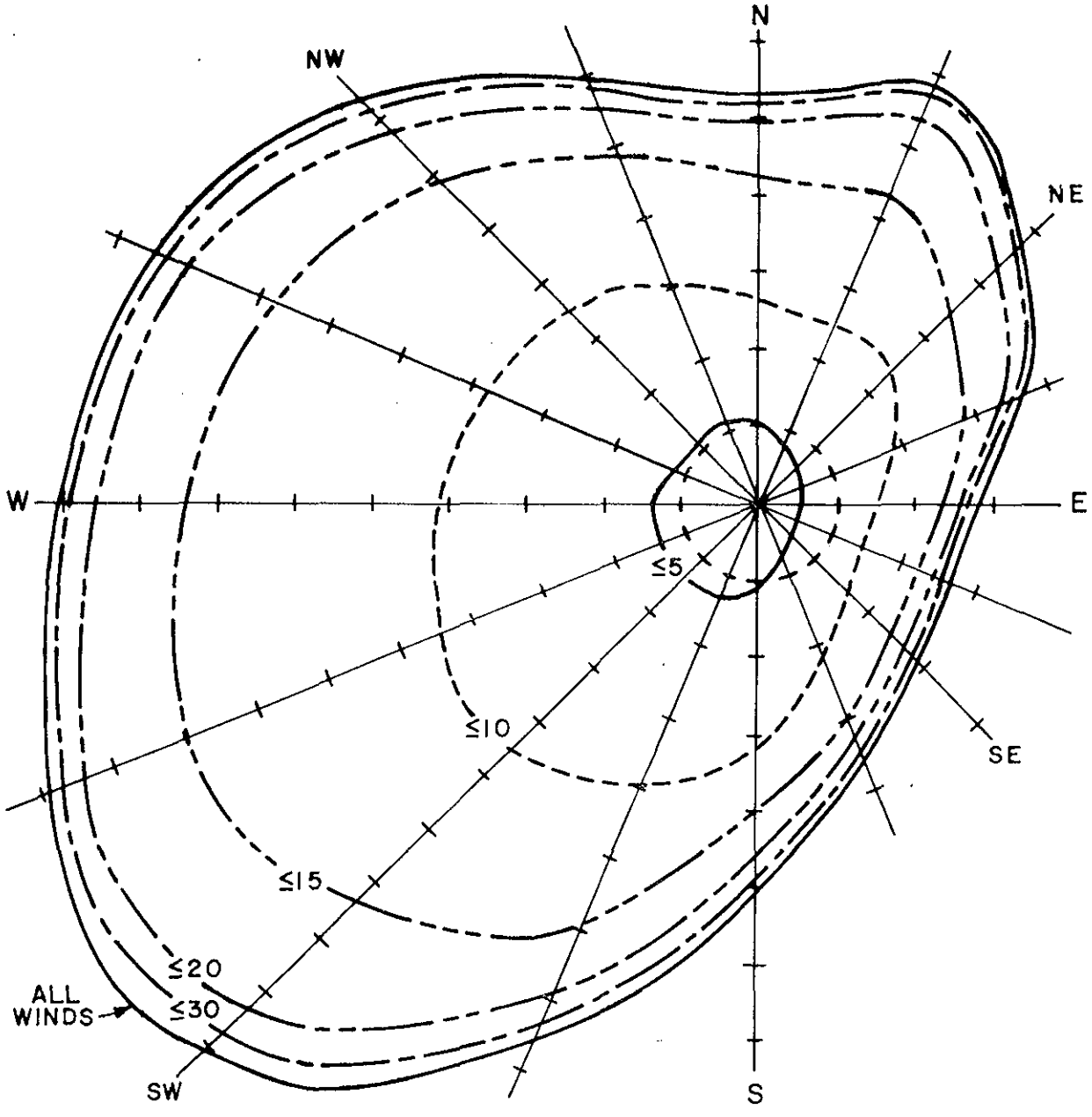
Mean and extreme temperatures, precipitation, and wind speeds for each month in the vicinity of the Canal Plant are shown in Table 2.1-1. The annual wind roses, including wind speed frequency, are shown in Figure 2.1-1. Wind roses for spring, summer, fall, and winter, and for day and night, are shown in Figures 2.1-2 through 2.1-7. The prevailing wind direction is southwest, except northwest in the winter, with a secondary peak from north to northeast during all seasons, that reflects, the passage of low pressure systems. Extreme sustained winds of 55 mph may be expected to occur once every two years and maximum winds of 100 mph may be expected to occur every 100 years.

Table 2.1-1

Climatological Means and Extremes
Temperature, Precipitation and Wind Speed
(Otis Air Force Base, 10 year Data)

Month	Average Temperature F	Extreme Temperature F		Average Precipitation Inches	Wind		
		Max	Min		Prevailing Direction	Average Speed, Mph	Greatest Speed, Mph(1)
Jan	29	72	-13	4.30	NW	15	52
Feb	29	68	-18	3.60	NW	15	45
Mar	36	86	-8	4.80	NW	15	52
Apr	46	91	11	4.3	WSW	17	46
May	56	97	31	3.5	SW	15	32
June	65	100	41	3.3	SW	11	32
July	71	104	50	2.9	SW	12	30
Aug	70	101	46	4.3	SW	11	32
Sep	63	102	34	3.8	SW	11	55
Oct	53	90	25	3.4	W	12	43
Nov	43	83	-2	4.6	WNW	13	40
Dec	32	68	-17	4.2	WNW	14	46
Year	49.3	104	-18	46.9	SW	13	

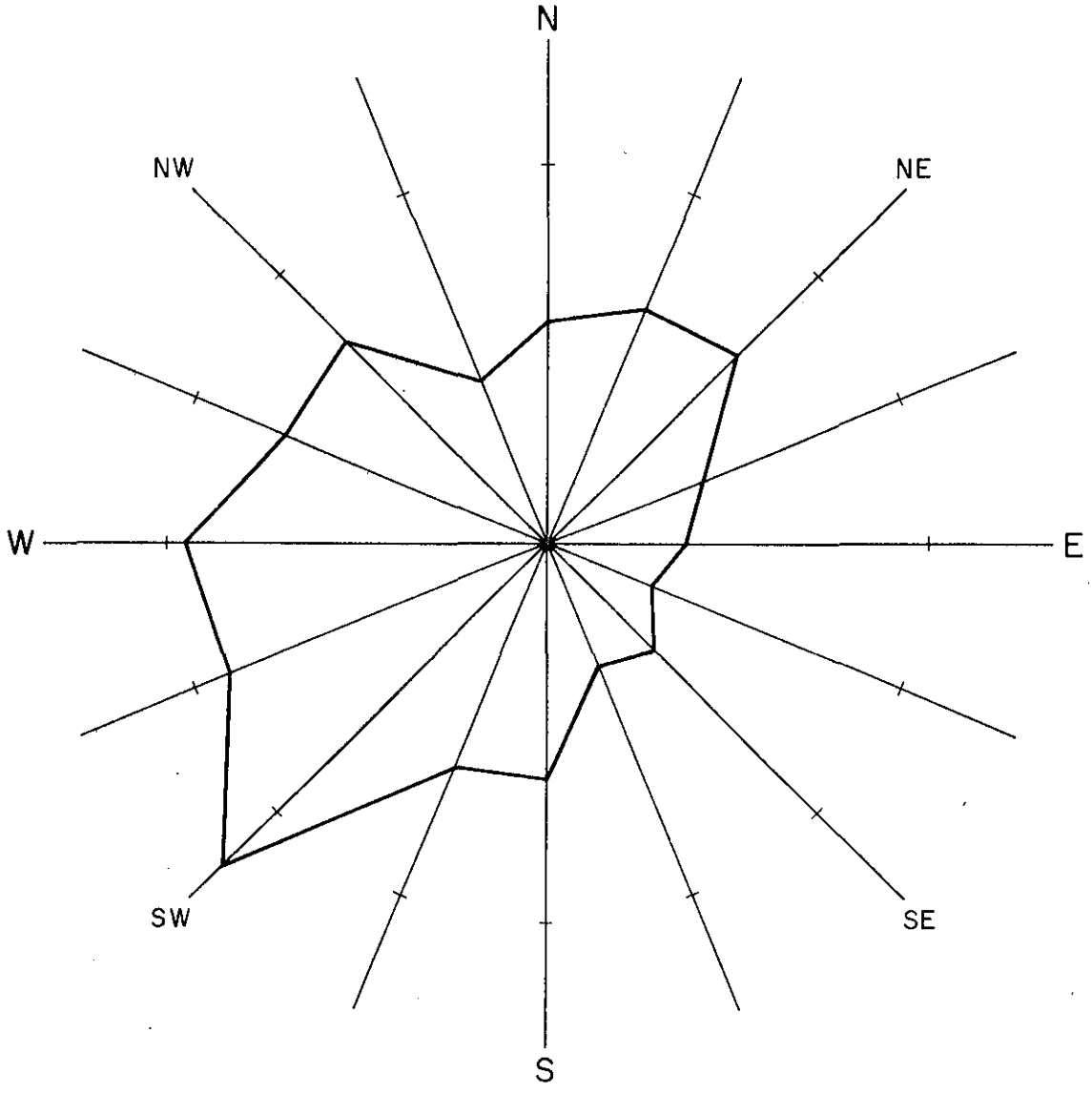
(1) It should be noted that these observations are made on the hour and are less than the "fastest mile," which are maximum speeds of 1-minute duration as measured by a continuously recording instrument.



0 1 2 3 4
SCALE-PERCENT
OF TOTAL OBSERVATIONS

NOTE
WIND SPEED IN KNOTS
BASED ON OTIS AFB 10 YEARS DATA

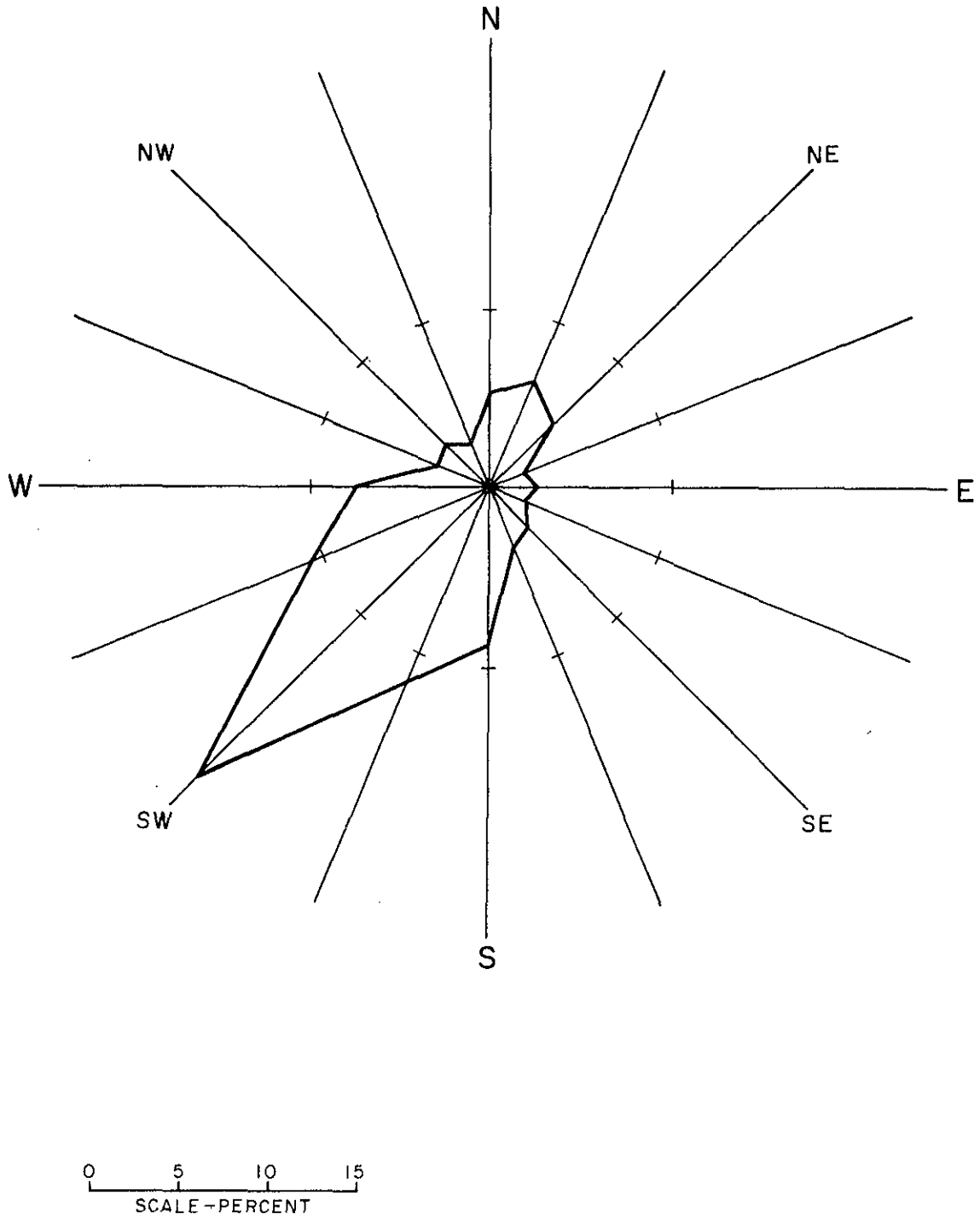
FIGURE 2.1-1
WIND VELOCITY ROSE
OTIS AIR FORCE BASE
CANAL PLANT UNIT NO. 2
CANAL ELECTRIC COMPANY
MONTAUP ELECTRIC COMPANY



0 5 10
SCALE – PERCENT

NOTE
PERIOD OF OBSERVATIONS —
SPRING 1955-1964

FIGURE 2.1-2
WIND DISTRIBUTION ROSE
PERCENT TOTAL OBSERVATIONS
CANAL PLANT UNIT No. 2
CANAL ELECTRIC COMPANY
MONTAUP ELECTRIC COMPANY



NOTE
PERIOD OF OBSERVATIONS —
SUMMER 1955-1964

FIGURE 2.1-3

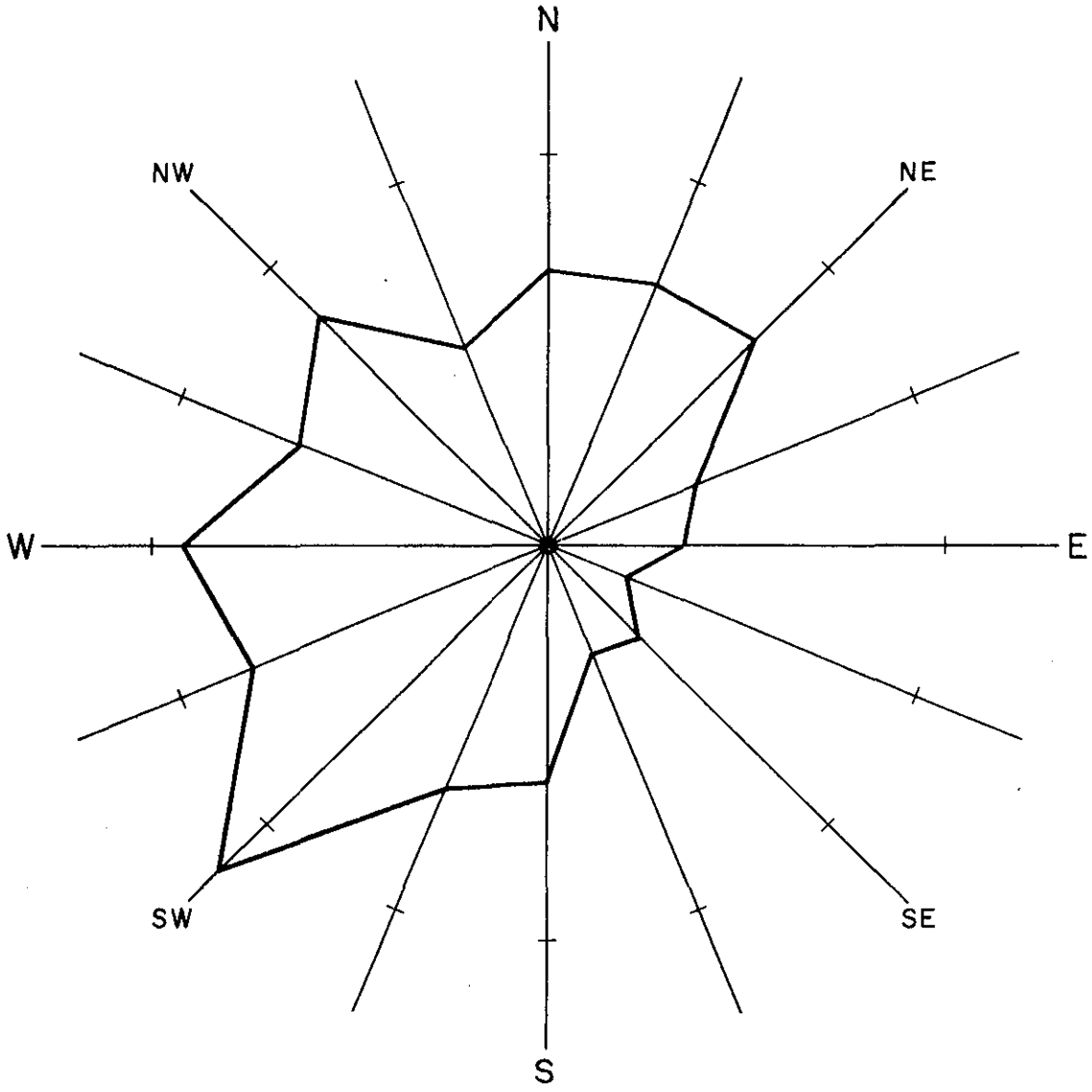
WIND DISTRIBUTION ROSE

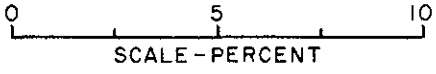
PERCENT TOTAL OBSERVATIONS

CANAL PLANT UNIT No. 2

CANAL ELECTRIC COMPANY

MONTAUP ELECTRIC COMPANY





NOTE
PERIOD OF OBSERVATIONS—
FALL 1955-1964

FIGURE 2.1-4

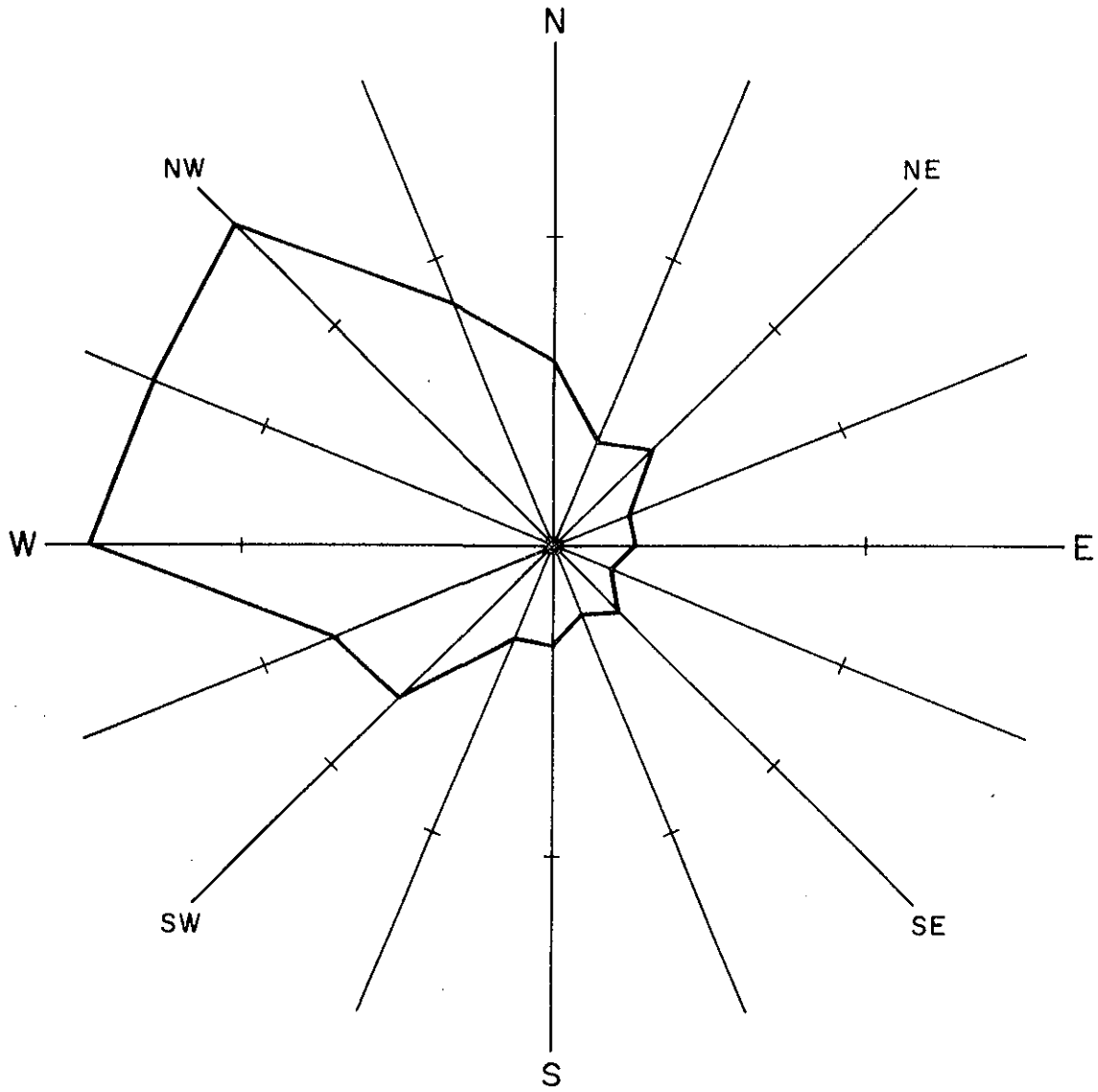
WIND DISTRIBUTION ROSE

PERCENT TOTAL OBSERVATIONS

CANAL PLANT UNIT No. 2

CANAL ELECTRIC COMPANY

MONTAUP ELECTRIC COMPANY



0 5 10
SCALE - PERCENT

NOTE
PERIOD OF OBSERVATIONS —
WINTER 1955-1964

FIGURE 2.1-5

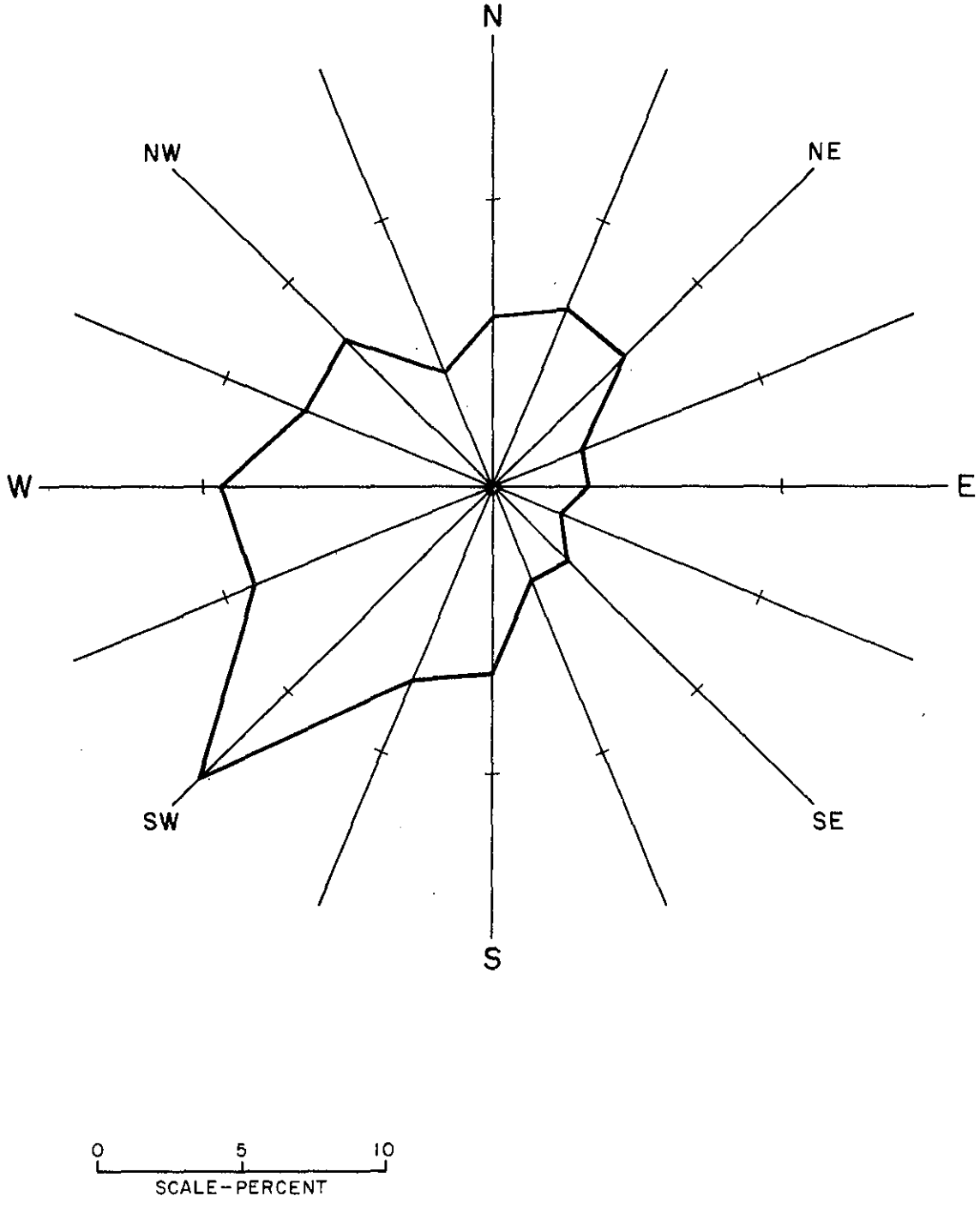
WIND DISTRIBUTION ROSE

PERCENT TOTAL OBSERVATIONS

CANAL PLANT UNIT No. 2

CANAL ELECTRIC COMPANY

MONTAUP ELECTRIC COMPANY



NOTE
PERIOD OF OBSERVATIONS —
ANNUAL, DAY 1955-1964

FIGURE 2.1-6

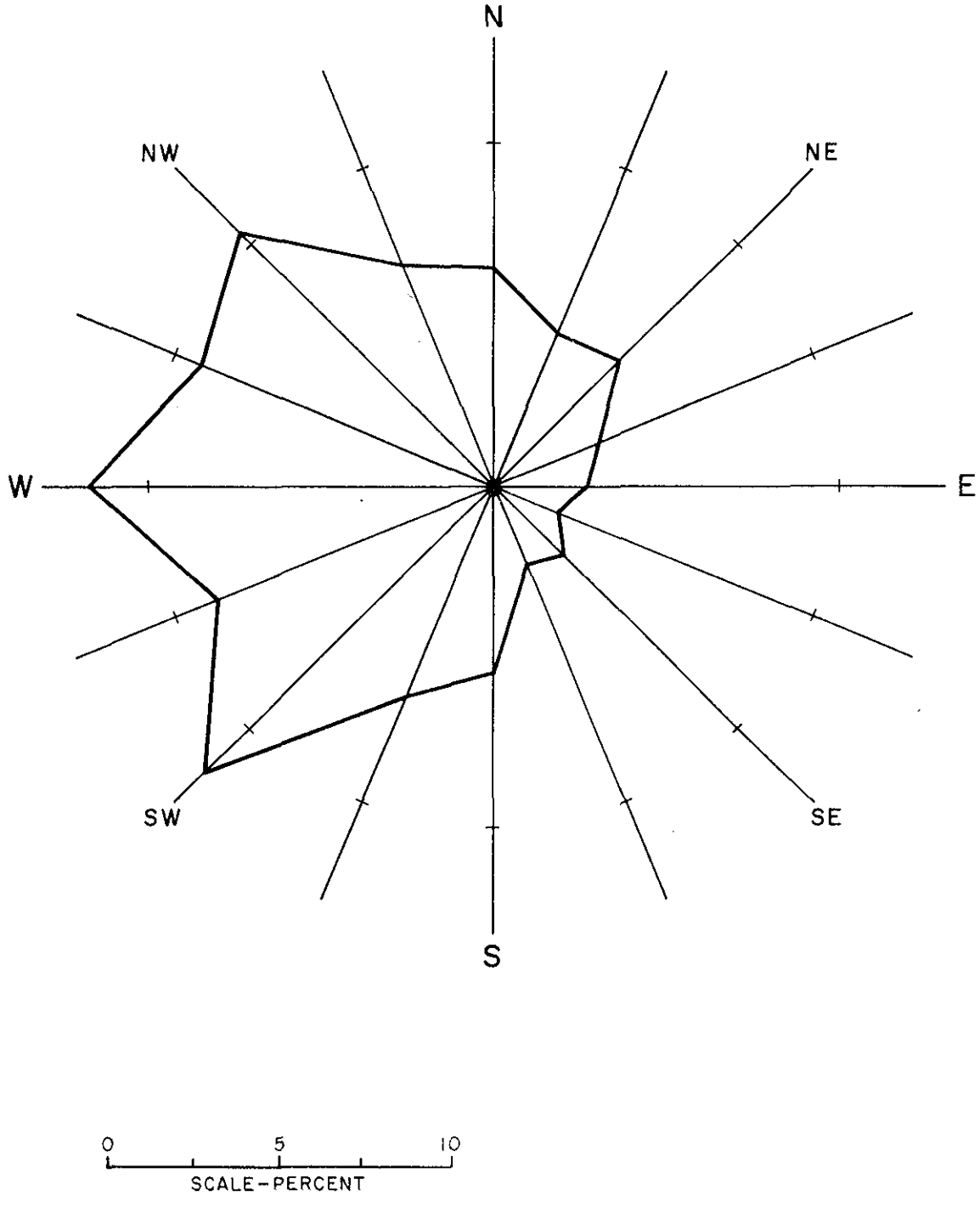
WIND DISTRIBUTION ROSE

PERCENT TOTAL OBSERVATIONS

CANAL PLANT UNIT No. 2

CANAL ELECTRIC COMPANY

MONTAUP ELECTRIC COMPANY



NOTE
PERIOD OF OBSERVATIONS—
ANNUAL, NIGHT 1955-1964

FIGURE 2.1-7

WIND DISTRIBUTION ROSE

PERCENT TOTAL OBSERVATIONS

CANAL PLANT UNIT No. 2

CANAL ELECTRIC COMPANY
MONTAUP ELECTRIC COMPANY

2.1.2 Atmospheric Stability

The rate of diffusion of stack effluents is a function of the amount of turbulence in the atmosphere. An unstable atmosphere produces rapid diffusion whereas in a stable atmosphere the rate of diffusion is slow. Table 2.1–2 shows annual stability frequency according to stability classes (A = very unstable; F = very stable) and direction from which the wind is blowing. Table 2.1–3 shows stability frequencies for the four seasons of the year. The referenced tables indicate stable atmospheric conditions in the region which tend to reduce dispersion of stack emissions.

2.1.3 Inversions

During periods of atmospheric stagnation, ground level concentrations of contaminants emitted by low level sources are often high. An analysis of inversion frequency was performed to ensure that the proposed stack height is sufficient to avoid these conditions. This analysis was based on vertical sounding data obtained at Nantucket by the National Weather Service.

Table 2.1-2

Annual Stability Frequency, Percent

Wind Direction	Stability Class A	B	C	D	E	F	
N	.03	.14	.47	4.05	.45	.98	
NNE	.02	.21	.53	4.47	.26	.37	
NE	.03	.20	.52	4.38	.28	.43	
ENE	.02	.10	.26	2.37	.19	.31	
E	.02	.12	.23	2.20	.17	.33	
ESE	.01	.06	.16	1.77	.11	.15	
SE	.02	.15	.33	2.26	.21	.33	
SSE	.01	.13	.41	2.00	.22	.35	
S	.02	.22	.59	3.83	.52	.93	
SSW	.03	.17	.52	4.70	.63	.94	
SW	.03	.27	1.06	9.15	1.25	1.53	
WSW	.02	.21	.73	5.70	.98	1.15	
W	.02	.34	.99	5.71	1.55	1.71	
WNW	.03	.17	.61	4.48	1.34	1.17	
NW	.01	.14	.56	4.73	1.49	1.55	
NNW	.01	.10	.35	3.02	.77	1.15	
All Directions	.33	2.73	8.32	64.82	10.42	13.38	100%

Table 2.1-3

Seasonal Stability Frequencies
Annual Hours and Percent

SEASON	STABILITY CLASS					
	A	B	C	D	E	F
Annual Hours	30	238	728	5,662	912	1,172
Percent	0.3	2.7	8.3	64.9	10.4	13.4
Spring Hours	8	62	181	1,485	208	260
Percent	0.4	2.8	8.2	67.3	9.4	11.8
Summer Hours	19	116	264	1,347	192	164
Percent	0.8	5.2	12.0	61.0	8.7	12.3
Fall Hours	3	26	172	1,347	251	374
Percent	0.1	1.2	8.0	62.0	11.6	19.9
Winter Hours	<1	17	111	1,503	260	274
Percent	0	0.8	5.1	69.4	12.0	12.6

The frequency of occurrence of ground-based and elevated inversions and their effect on the dispersion of sulfur dioxide emitted from Canal Electric Plant were investigated using 10 years of vertical sounding data collected by the National Weather Service on Nantucket Island. These data, which are the nearest available sounding data to the Canal location, were analyzed to determine inversion frequency relative to the height of the inversion base, the height of the inversion top, and the temperature gradient through the inversion layer. The method used to estimate inversion frequency as a percentage of total time from the two soundings taken each day at Nantucket was based on a procedure suggested by Hosler (Ref. 2). The resulting statistics for inversions based at heights of 600 meters are summarized in Table 2.1-4.

Table 2.1-4

Frequency of Occurrence of Inversions at Nantucket By Inversion Base Height, Height of Top, and Temperature Gradient

Height of inversion base, m	Frequency (% of total time) Night	Day	Height of inversion top, m	Relative frequency Night	Day	Temperature gradient, °C/100 m	Relative frequency, %
0-100	25.7	8.9	0-100	16.2	2.6	0-1.0	44.0
101-150	1.8	3.2	101-200	25.4	12.1	1.1-2.0	29.3
151-200	1.4	2.1	201-300	16.7	17.6	2.1-3.0	12.2
201-250	0.9	1.3	301-400	11.3	13.2	3.1-4.0	6.5
251-300	0.9	1.1	401-500	8.4	13.8	4.1-5.0	3.3
301-450	2.2	3.3	≥501	22.0	40.7	>5.0	4.7
451-600	1.7	1.4	--	--	--	--	--
Totals	34.6	21.3	--	100.0	100.0	--	100.0

2.2 HYDROLOGY

Cape Cod Canal is noted for its unusual flows and velocities resulting from the differences in tidal phase and amplitude between Cape Cod Bay at the Canal's eastern end and Buzzards Bay at the Canal's western end.

High tide in Buzzards Bay occurs about three hours earlier than in Cape Cod Bay, and the mean tidal ranges at the east and west canal entrances are 8.7 feet and 3.5 feet respectively (Tide Tables, United States Coast and Geodetic Survey, 1970). Consequently, the water surface at one end alternately rises above and falls below the level at the other end, creating a reversing current approximately every six hours. Tidal currents generally set to the east when flooding and to the west when ebbing.

Current velocities and discharge at the plant site are shown in Figure 2.2–1; tidal flows are summarized in Table 2.2–1.

The volume of water in the Cape Cod Canal for extreme low water, which is 4 feet below mean low water, is 570,000,000 cubic feet.

Water elevations are referenced from El. 0.0 which is local mean low water level. Mean high water at the site is El. +8.7 feet, mean sea level is +4.9 feet. Climatological effects superimposed on the most adverse astronomical tides have caused a maximum tide level of about +14.0 feet above mean low water, and a minimum level of about -4.0 feet below this datum. It should be noted that slack water periods are very short and do not coincide with high and low tide, but precede them by about 2 hours.

Table 2.2-1

Tidal Flow

	Flood (Eastward Flow)	Ebb (Westward Flow)
Velocity (fps)		
Mean	3.00	3.15
Maximum	4.25	4.45
Discharge (cfs)		
Mean	74,000	90,000
Maximum	102,000	128,000
Duration (hour)	6.35	5.95

Hydrographic studies of the Cape Cod Canal (Ref. 4, 5) show that the Canal is completely flushed out during each tidal cycle.

Drift bottle investigations indicate a net movement of water through the Canal in the westerly direction.

Natural water temperature at the east entrance to the Canal, based on 12 years of records from 1955 to 1966 (Ref. 6), are shown in Table 2.2-2.

Table 2.2-2

Natural Water Temperature, F
East Entrance Cape Cod Canal

	Jan	Feb	Mar	Apr	May	June
Mean	34.3	32.9	35.6	41.4	48.9	55.0
Mean Max	38.1	35.4	38.7	46.2	55.9	61.9
Mean Min	30.9	30.6	33.1	37.8	44.2	47.6

	July	Aug	Sept	Oct	Nov	Dec	Year
Mean	58.6	60.8	60.3	55.4	48.7	40.3	47.6
Mean Max	67.8	68.7	66.6	60.3	52.9	45.1	
Mean Min	50.4	52.2	55.0	51.1	44.2	34.3	

Because of the strong currents and the extreme turbulence in Cape Cod Canal, there is no thermal stratification. However, during most of the year there are considerable water temperature differences between Buzzards Bay and Cape Cod Bay. Buzzards Bay waters are warmer during spring, summer, and fall, but cooler in winter. During mid-summer, Buzzards Bay waters are typically 15 F to 20 F warmer than Cape Cod Bay waters.

From continuous water temperature measurements recorded at various stations along the Canal by the Massachusetts Department of Natural Resources, Division of Marine Fisheries, in connection with their 1966 to 1969 ecological studies of Cape Cod Canal (Ref. 1), it was found that during the mid-summer months colder Cape Cod Bay water enters the Canal from the east about 1 hour after high slack tide and that temperatures drop abruptly. About 2 1/2 hours later, the cold water reaches the west end of the Canal and continues to flow out into Buzzards Bay for another 2 1/2 hours, at which time low slack water occurs. Low temperatures persist at the west entrance for approximately 1 hour following low water and then gradually increase at the rate of 4 to 5 F per hour for 3 hours and 1 to 2 F for 2 hours. Two hours after the onset of increasing temperatures at the west end, warmer water reaches the east end and temperatures increase at the rate of 4 to 5 F per hour for 3 hours, or until high slack tide occurs again.

A slight decrease in salinity and the gradual increase in water temperature recorded at the west entrance on the eastbound tide

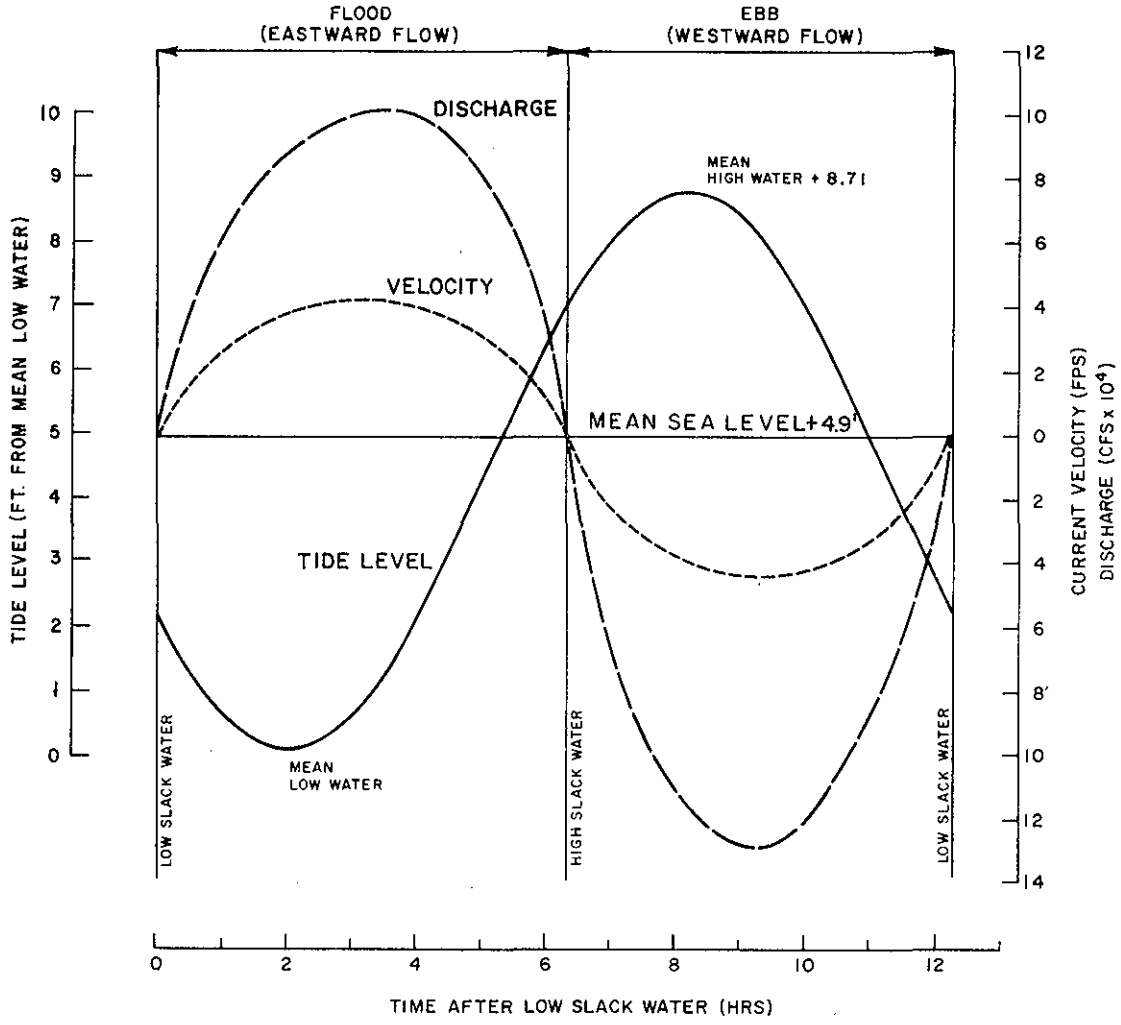


FIGURE 2.2-1

TYPICAL TIDE LEVEL, CURRENT VELOCITY AND DISCHARGE CURVES

EAST ENTRANCE CAPE COD CANAL

CANAL PLANT UNIT NO. 2

CANAL ELECTRIC COMPANY
MONTAUP ELECTRIC COMPANY

suggest that the water entering the Canal from Buzzards Bay initially consists of Cape Cod Bay water, Buzzards Bay water, and fresh water that have mixed in the upper reaches of Buzzards Bay.

Conversely, cooler Cape Cod Bay water enters the eastern entrance of the Canal in undiluted form as indicated by a rapid temperature reduction during the summer months. The warmer Buzzards Bay water that flows out the east end of the Canal during the latter stages of the eastbound tide does not return when the tide turns. Consequently, Cape Cod Bay water persists in the vicinity of the circulating water intake for 8 hours out of each 12 1/2-hour tidal cycle. The relationship between water temperature and tide stage is shown in Figure 2.2-2 for a typical tide cycle in July, when maximum temperature differentials occur.

Monthly averages of surface salinities at the east entrance to the Canal are quite uniform over the year, ranging from 31.2 to 31.6 parts per thousand and averaging 31.5 parts per thousand. In general, Buzzards Bay water is slightly less saline, presumably due to an influx of fresh water from several streams and rivers that drain into the upper reaches of the Bay.

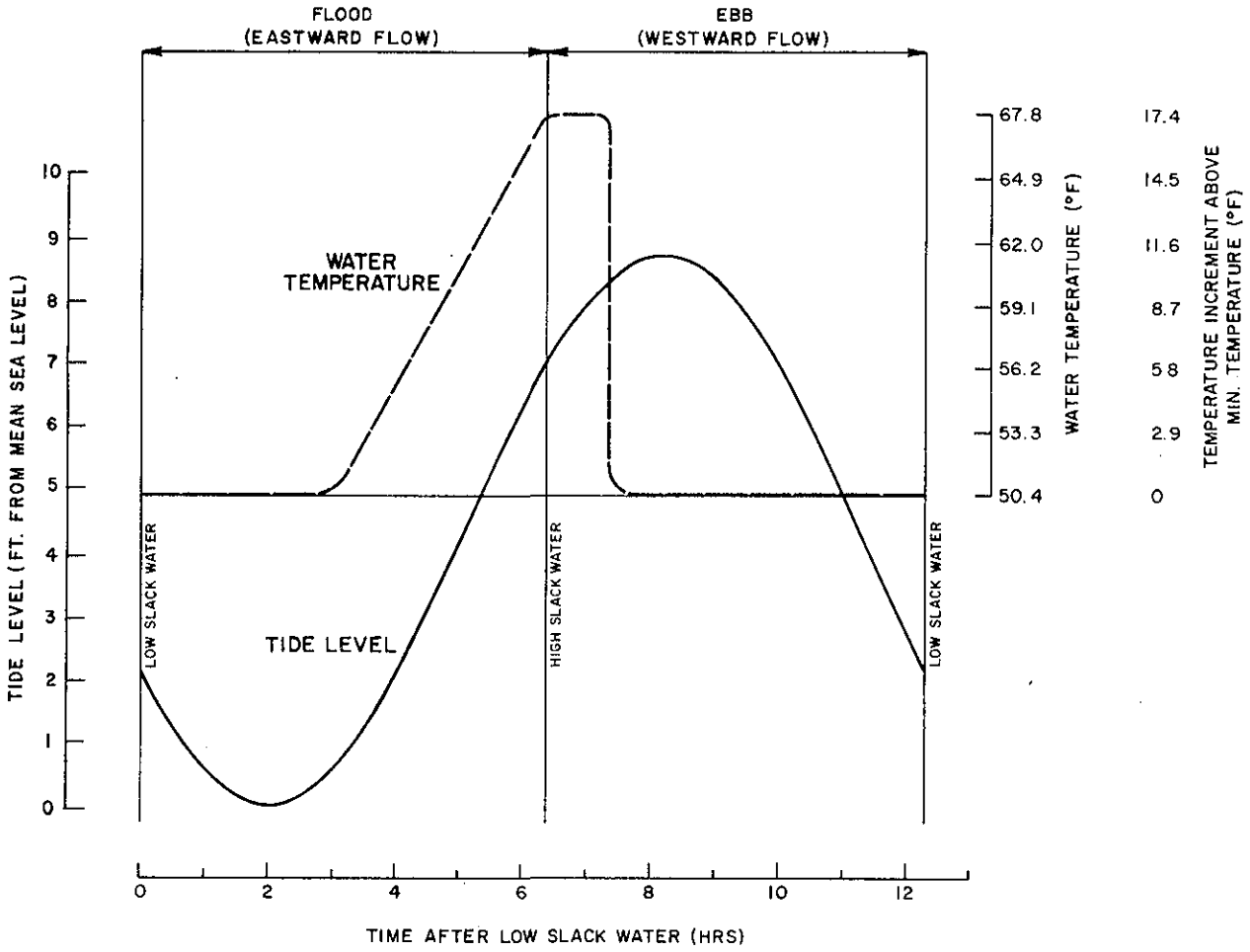


FIGURE 2.2-2

TYPICAL TIDE LEVEL AND WATER TEMPERATURE CURVES FOR JULY

EAST ENTRANCE CAPE COD CANAL

CANAL PLANT UNIT NO. 2

CANAL ELECTRIC COMPANY
MONTAUP ELECTRIC COMPANY

2.3 GEOSCIENCE

2.3.1 Geology and Topography

The Canal Plant is located as shown in Figures 1.2-1 and 1.2-2 on the south side of Cape Cod Canal in Sandwich, Massachusetts, about one mile from the east entrance from Cape Cod Bay. The site property is nearly level, about 17 feet above mean low water level and bounded by the Cape Cod Canal to the north; the railroad tracks of the Penn Central Transportation Company to the south, except for a portion north of Tupper Road including the switchyard and two oil tanks; the Sandwich town line to the west, and Freezer Road to the east. A ship's berthing basin was dredged along the Canal on the westerly part of the property to accommodate fuel oil tankers. The immediate site area and the main features of existing Unit No. 1 and the proposed Unit No. 2 are shown in Figure 1.2-2.

Cape Cod Canal to the north of the site connects Cape Cod Bay with the northeasterly end of Buzzards Bay (Figure 1.2-1). The Canal, which is about seven miles long and 480 feet wide at the bottom, was constructed in 1914 and enlarged to its present size in 1940. Its steeply sloped banks of loose sand and gravel are riprapped in the intertidal zone. Channel depths at the south prism line along the site vary between 35 and 40 feet at mean low water level (El. 0.0 feet).

Geologically, Cape Cod is a terminal moraine formed at the conclusion of the ice age. The presence of glacial material at the site was confirmed by test borings and excavation during construction of Unit No. 1. Under the top covering of sand were layers of peat; there was no bedrock as far as 100 feet down. To make a suitable foundation for the plant, all surface material will be excavated, removed and replaced by compacted sand and gravel.

2.3.2 Seismic Activity

The earthquake history of eastern Massachusetts extends back to the time when people who could read and write first settled the area about 350 years ago. It is likely that any significant earthquake which occurred since the early 1600's has been noted and recorded. In addition, seismographic records and epicenter locations have been available since 1933, when Boston College Seismological Observatory at Weston, Massachusetts, was established. While the listing of earthquakes for the area shows a relatively large number of entries compared to other parts of the country, in large measure this is probably due to the long period of recorded history.

Eastern Massachusetts is an area of minor seismic activity. The Newburyport area, historically, has been the most active region. Extrapolation of existing epicentral data suggests that the

epicentral area of the concentration of earthquakes is some 50 miles offshore of the Newburyport-Cape Ann region. In general, the remainder of eastern Massachusetts is characterized by scattered, relatively minor earthquakes not as associated with any concentration or with any known faults. Table 2.3-1 is a listing of all earthquakes in eastern Massachusetts since the mid-17th century that have an intensity V or larger on the Modified Mercalli scale. It will be noted that no earthquake having an intensity exceeding VI has been recorded in this area since 1755. The 1755 earthquake occurred offshore, northeast of Newburyport and Cape Ann. Epicentral intensity is estimated to have been Modified Mercalli VIII. This earthquake caused damage in Boston and Cambridge where it destroyed a large number of chimneys and the gable ends of a number of brick structures. The intensity of ground motion in Boston from this earthquake was substantially greater than that which has been observed from any other earthquake in the area. In evaluating damage reports of colonial times, it must be kept in mind that construction quality of most structures was very poor; for example, many chimneys were laid up with mud rather than mortar.

There are no known active faults in the area. The last period of intense tectonic activity was in the late Triassic Period of Mesozoic time when large-scale block faulting was accompanied by volcanic activity with intrusion of dikes and sills in the eastern and central Massachusetts areas. Since this period, approximately 180 million years ago, the area has been essentially stable with only long continued erosion. Many geologists believe that the scattered seismic activity which does occur results primarily from rebound of the earth's crust since removal of the ice load with the retreat of the glaciers of Pleistocene time.

The nearest area of the significant tectonic activity is the St. Lawrence River region in the vicinity of Montreal and Three Rivers. Earthquakes of intensity IX to X have occurred in this region which is about 350 miles north of the site. Based on observed attenuation of earthquakes in the Northeastern U.S., an intensity X earthquake in the nearest approach of the St. Lawrence active zone would result in an intensity of approximately IV to V at the site.

Generally, eastern Massachusetts, except for the offshore area north and east of Newburyport, is seismically quiet with only occasional scattered earthquakes. However, it has experienced significant ground motion from distant earthquakes, especially the 1755 earthquake offshore of the Newburyport area. Because of attenuation of high frequencies with distance, and the tendency for deep, soft soil to amplify the remaining long wave periods, damage in such distant earthquakes has largely been confined to areas underlain by deep soft clays. It may be anticipated that the conditions that have persisted over the past 300 years will continue in the reasonably foreseeable future.

Table 2.3-1

Earthquakes of Eastern Massachusetts
Modified Mercalli Scale Intensity V or Larger
(References 7, 8, and 9)

	Date	Epicentral Location	Epicentral Intensity
1643	6/11	Newbury (probably offshore)	V
1658	4/14	New England	VII
1662	2 on 1/26 1 on 11/6	New England	VII
1727	11/9	Newbury	VIII
1728		Brigham (Ref. 9) lists a number of aftershocks, some fairly strong	
1737	2/17	Eastern Massachusetts	IV - V
1741	6/24	Eastern Massachusetts	IV - V
1744	6/14	Eastern Massachusetts	IV - V
1755	11/18	East of Cape Ann	VIII
1761	3/12	Northeast of Boston	V
	11/1	Northeast of Boston	
1766	2/2	Offshore	IV - V
1800	12/25	North of Boston	IV - V
1810	11/9	Offshore - North of Cape Ann	VI
1817	10/5	Woburn	VI
1846	5/30	Offshore - Cape Ann	VI - V
1847	8/8	Southeast Massachusetts	IV - V
1852	11/27	Northeast Massachusetts (probably offshore)	V
1854	12/10	Northeast Massachusetts (probably offshore)	V
1876	9/21	Southeast Massachusetts	V
1880	5/12	Northeast Massachusetts	IV - V
1903	1/21	Southeast Massachusetts	V
	4/24	Northeast Massachusetts	V
1907	10/15	Northeast Massachusetts	V
1925	1/7	Near Cape Ann	V
	4/24	Southeast Massachusetts	V
1940	1/28	Near Buzzards Bay	V
1954	7/29	Offshore of Cape Ann	V
1963	10/16	Near Coast of Massachusetts	VI
	10/30	Near Ipswich, Massachusetts	VI

The soils underlying the Canal Plant are compact fills and dense sands. Considering the distance from the offshore area northeast of Newburyport, a repetition of the 1755 earthquake could be expected to cause an intensity at the site of high V to low VI intensity. The damage which would be anticipated from such an intensity earthquake is characterized by the Modified Mercalli scale as follows:

Intensity VI - Felt by all, many frightened and run outdoors; some heavy furniture moved; a few instances of fallen plaster or damaged chimneys; damage slight.

It would be anticipated that a well-built modern power station designed for heavy wind loads due to hurricane would suffer no damage from an earthquake of this intensity.

The following, more detailed description of relative effects from earthquakes of varying intensities may assist in evaluating the judgment as to the adequacy of the proposed power plant design in respect to possible earthquake shock.

Intensity is a rather subjective measure of the surface shaking (vibratory motion) of an earthquake at a specific location from the effects on people, structures, or other objects. Usually the greatest intensity will be felt in the immediate region of the epicenter and intensity will decrease with distance from th epicenter. Thus each earthquake has associated with it a range of intensities, the largest usually being in the epicentral region and lesser intensities in elliptical zones surrounding the epicenter. In lists of earthquakes only the epicenter intensity is usually given. The intensity scale used in the United States is the Modified Mercalli scale, adapted from a scale published in Italy by Harry O. Wood and Frank Neumann in 1931.

Magnitude was first defined by C. F. Richter in 1938, based on the amplitude of the trace from a standard seismograph corrected to a standard distance. Approximate empirical relations between magnitude and total energy release during an earthquake have been developed.

There is not necessarily a direct relationship between intensity, even in the epicentral region, and magnitude. Hypofocal depth, that is, the depth of initiation of fault breakage, may vary from a few kilometers to more than 600 kilometers. A very shallow earthquake of intermediate magnitude may cause very intense shaking and thus high intensities in a limited area, for example the San Fernando earthquake of 1971, whereas a deep focus earthquake of larger magnitude might result in modest vibratory motion at the surface in the epicentral region and be felt for large distances.

MODIFIED MERCALLI INTENSITY SCALE OF 1931
by Harry O. Wood and Frank Neumann

Adapted from Sieberg's Mercalli-Cancani scale, modified and condensed.

I. Not felt--or except rarely under especially favorable circumstances.

Under certain conditions, at and outside the boundary of the area in which a great shock is felt: sometimes birds, animals, reported uneasy or disturbed; sometimes dizziness or nausea experienced; sometimes trees, structures, liquids, bodies of water may sway, doors may swing, very slowly.

II. Felt indoors by few, especially on upper floors, or by sensitive, or nervous persons.

Also, as in Grade 1, but often more noticeably: sometimes hanging objects may swing, especially when delicately suspended; sometimes trees, structures, liquids, bodies of water may sway, doors may swing, very slowly; sometimes birds, animals, reported uneasy or disturbed; sometimes dizziness or nausea experienced.

III. Feld indoors by several, motion usually rapid vibration.

Sometimes not recognized to be an earthquake at first. Duration estimated in some cases. Vibration like that due to passing of light or lightly loaded trucks, or heavy trucks some distance away. Hanging objects may swing slightly. Movement may be appreciable on upper levels of tall structures. Rocked standing motor cars slightly.

IV. Felt indoors by many, outdoors by few.

Awakened few, especially light sleepers. Frightened no one, unless apprehensive from previous experience. Vibration like that due to passing of heavy or heavily loaded trucks. Sensation like heavy body striking building, or falling of heavy objects inside. Rattling of dishes, windows, doors; glassware and crockery clink and clash. Creaking of walls, frame, especially in upper range of this grade. Hanging objects swung, in numerous instances. Disturbed liquids in open vessels slightly. Rocked standing motor cars noticeably.

V. Felt indoors by practically all, outdoors by many or most; outdoors direction estimated.

Awakened many, or most. Frightened few--slight excitement, a few ran outdoors. Buildings trembled throughout. Broke dishes, glassware, to some extent. Cracked windows--in some cases, but not generally. Overturned vases, small or unstable objects, in may instances, with occasional fall. Hanging objects, doors, swing generally or considerably. Knocked pictures against walls, or swung them out of place. Opened or closed doors, shutters, abruptly. Pendulum clocks stopped, started, or ran fast or slow. Moved

small objects, furnishings, the latter to slight extent. Spilled liquids in small amount from well-filled open containers. Trees, bushes, shaken slightly.

VI. Felt by all, indoors and outdoors.

Frightened many, excitement general, some alarm, many ran outdoors. Awakened all. Persons made to move unsteadily. Trees, bushes, shaken slightly to moderately. Liquid set in strong motion. Small bells rang--church, chapel, school, etc. Damage slight in poorly built buildings. Fall of plaster in small amount. Cracked plaster somewhat, especially fine cracks in chimneys in some instances. Broke dishes, glassware, in considerable quantity, also some windows. Fall of knick-knacks, books, pictures. Overturned furniture in many instances. Moved furnishings of moderately heavy kind.

VII. Frightened all--general alarm, all ran outdoors.

Some, or many, found it difficult to stand. Noticed by persons driving motor cars. Trees and bushes shaken moderately to strongly. Waves on ponds, lakes, and running water. Water turbid from mud stirred up. Incaving to some extent of sand or gravel steam banks. Rang large church bells, etc. Suspended objects made to quiver.

Damage negligible in buildings of good design and construction, slight to moderate in well-built ordinary buildings, considerable in poorly built or badly designed buildings, adobe houses, old walls (especially where laid up without mortar), spires, etc.

Cracked chimneys to considerable extent, walls to some extent. Fall of plaster in considerable to large amount, also some stucco. Broke numerous windows, furniture to some extent. Shook down loosened brickwork and tiles. Broke weak chimneys at the roof-line (sometimes damaging roofs). Fall of cornices from towers and high buildings. Dislodged bricks and stones. Overturned heavy furniture, with damage from breaking. Damage considerable to concrete irrigation ditches.

VIII. Fright general--alarm approaches panic.

Disturbed persons driving motor cars. Trees shaken strongly--branches, trunks, broken off, especially palm trees. Ejected sand and mud in small amounts. Changes: temporary, permanent; in flow of springs and wells; dry wells renewed flow; in temperature of spring and well waters.

Damage slight in structures (brick) built especially to withstand earthquakes.

Considerable in ordinary substantial buildings, partial collapse: racked, tumbled down, wooden houses in some cases; threw out panel walls in frame structures, broke off decayed piling. Fall of walls. Cracked, broke, solid stone walls seriously. Wet ground to some extent, also ground on steep slopes. Twisting, fall, of chimneys, columns, monuments, also factory stacks, towers. Moved conspicuously, overturned, very heavy furniture.

IX. Panic general.

Cracked ground conspicuously. Damage considerable in (masonry) structures built especially to withstand earthquakes: threw out of plumb some wood-frame houses built especially to withstand earthquakes; great in substantial (masonry) buildings, some collapse in large part; or wholly shifted frame buildings off foundation, racked frames; serious to reservoirs; underground pipes sometimes broken.

X. Cracked ground, especially when loose and wet, up to widths of several inches; fissures up to a yard in width ran parallel to canal and stream banks.

Landslides considerable from river banks and steep coasts. Shifted sand and mud horizontally on beaches and flat land. Changed level of water in wells. Threw water on banks of canals, lakes, rivers, etc. Damage serious to dams, dikes, embankments. Severe to well-built wooden structures and bridges, some destroyed. Developed dangerous cracks in excellent brick walls. Destroyed most masonry and frame structures, also their foundations. Bent railroad rails slightly. Tore apart, or crushed endwise, pipe lines buried in earth. Open cracks and broad wavy folds in cement pavement and asphalt road surfaces.

XI. Disturbances in ground many and widespread, varying with ground material.

Broad fissures, earth slumps, and land slips in soft, wet ground. Ejected water in large amount charged with sand and mud. Caused sea-waves ("tidal" waves) in significant magnitude. Damage severe to wood-frame structures, especially near shock centers. Great to dams, dikes, embankments, often for long distances. Few, if any (masonry), structures remained standing. Destroyed large well-built bridges by the wrecking of supporting piers or pillars. Affected yielding wooden

bridges less. Bent railroad rails greatly and thrust them endwise. Put pipe lines buried in each completely out of service.

XII. Damage total--practically all works of construction damaged greatly or destroyed..

Disturbances in ground great and varied, numerous shearing cracks. Landslides, falls of rock of significant character, slumping of river banks, etc., numerous and extensive. Wrenched loose, tore off, large rock masses. Fault slips in firm rock, with notable horizontal and vertical offset displacements. Water channels, surface and underground, disturbed and modified greatly. Dammed lakes, produced waterfalls, deflected rivers, etc. Waves seen on ground surfaces (actually seen, probably, in some cases). Distorted lines of sight and level. Threw objects upward into the air.

2.4 AMBIENT AIR QUALITY

A local survey of present air quality in the vicinity of Canal Plant has been in progress since July 1970 under contract between the GCA Technology Division, Bedford, Mass. and the Canal Electric Company. In addition to overall direction of the program, GCA has provided field support, laboratory analysis, instrument calibration, data analysis and interpretation.

As part of the contract effort, GCA developed a computer program package to process the plant, meteorological, and sulfur dioxide concentration data and present the results in a format that permits comparison of ambient concentrations with existing or proposed regulatory air quality standards and facilitates the analysis and interpretation of the data. During the contract period, data have been regularly processed in monthly data blocks by NEGEA's IBM 370 computer.

Observations by the monitoring network define ambient levels resulting from all sources contributing to the concentration at the monitor sites. The contribution of the Canal Plant itself to these ambient levels can be estimated by examining the records for the individual sites as a function of wind direction.

The objective in designing the monitoring network was to select sites where the maximum concentrations of plant effluents occur, paying particular attention to areas of high population density. To meet this objective, it was necessary to predict both the distance and direction from the plant at which these maximums would be expected. Calculations based on diffusion models and results of measurements made near other power plants showed that the maximum concentration would usually be found at distances of one to three miles from the plant, depending on meteorological conditions. Climatological data for the area showed that the prevailing winds during the period from November through March are northwesterly, while the prevailing winds during the remainder of the year are southwesterly. Since the only land area over which the plume passes before reaching Cape Cod Bay during southwesterly winds is sparsely populated or open beach and generally less than one mile from the plant, it was decided that the area of most concern lay to the southeast of the plant. Accordingly, two of the automatic sulfur dioxide sampling stations are located in this quadrant, one at a distance of 1.7 miles and the other at a distance of 3.2 miles from the plant.

Although seasonal and annual concentration patterns are closely associated with the frequency distribution of wind direction during the period, relatively high concentrations may be experienced over short time periods at any bearing from the plant. To cover two of the remaining quadrants, one automatic

analyzer is located northwest of the plant and the remaining automatic analyzer is located southwest of the plant. Because of the difficulties of operating an automatic station along the shore northeast of Canal Plant, this quadrant is monitored only by Huey sulfation plates. With the distribution of automatic stations described above there is usually at least one instrument upwind of the plant that may be used to define the background sulfur dioxide concentration as air enters the Sandwich area from peripheral regions. The basic network of four automatic stations is supplemented with sulfation candles and Huey plates.

The locations of the various sampling stations are given in Table 2.4–1 and shown on a map in Figure 2.4–1.

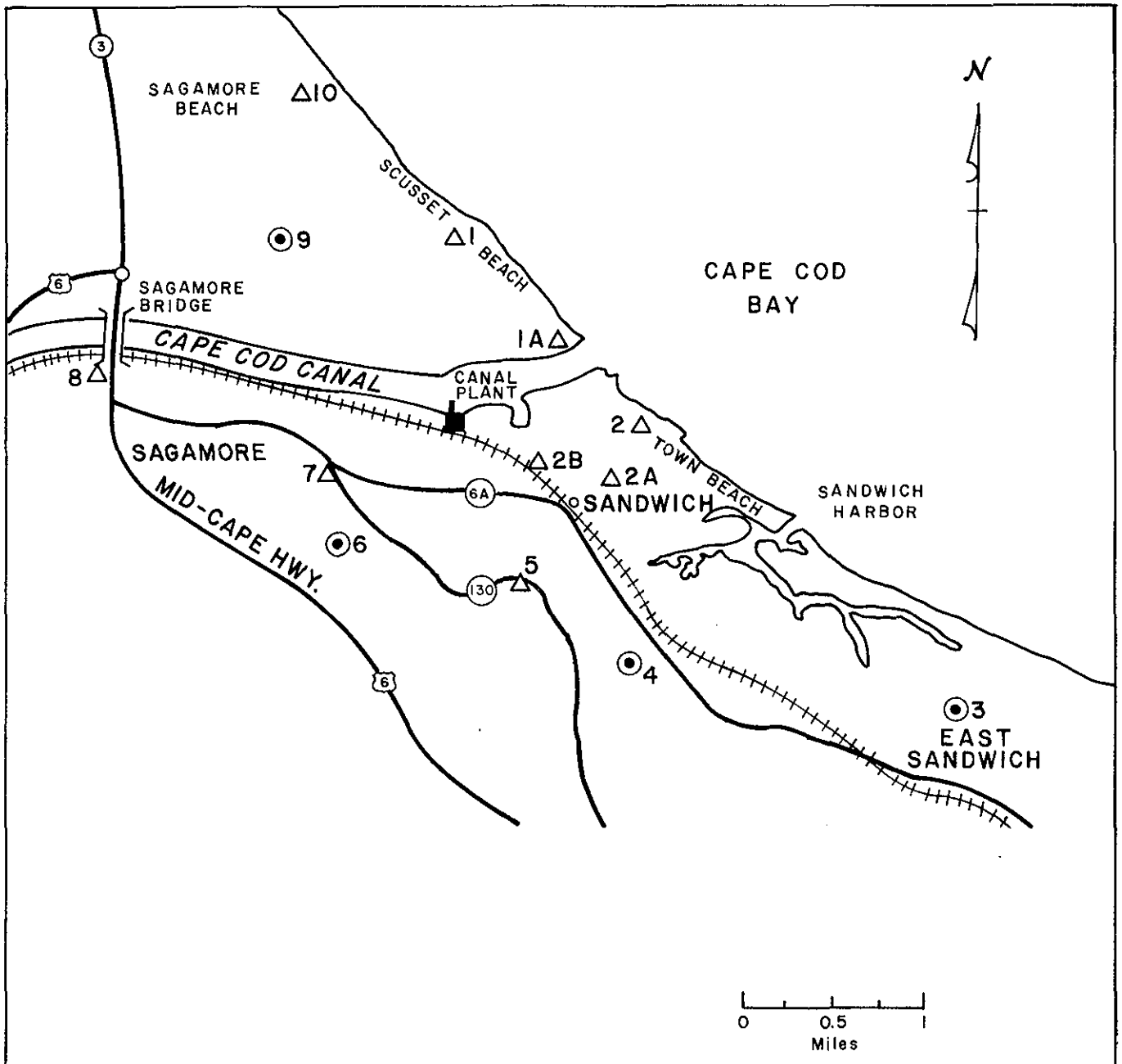
Table 2.4-1
Location of Sampling Stations for Air Quality Survey

Station Number	Bearing (Deg)	Range (mi)	Instrumentation
1	000	1.0	H
1a	005	0.7	H
2	090	1.0	H
2a	109	0.9	HC*
2b	112	0.5	H
3	120	3.2	HLCV
4	145	1.7	HLCV
5	160	1.0	H
6	224	0.9	HLCV
7	245	0.8	H
8	277	2.0	H
9	315	1.4	HLCV
10	335	2.0	H

Notes:

H = Huey sulfation plate L = Lead peroxide candle
C = Continuous sulfur dioxide monitor
V = Hi-Vol sampler
C* = Temporary location of fifth continuous sulfur dioxide monitor

Study of the sulfur dioxide measurements made by the continuous automatic analyzers of Station numbers 3, 4, 6, and 9 during the 1-year period from August 1, 1970, to July 31, 1971, showed only three occasions when hourly concentrations exceeded the Massachusetts standard of 0.28 ppm; no 3–hour averages exceeded the Federal Air Quality Standards for sulfur dioxide. The three occasions that exceeded Massachusetts standards all occurred at Station 9 on three consecutive hours of October 23, 1970, during a period of light rain and steady east-southeasterly wind of about 22 miles per hour. Concentrations approximately equal to the Massachusetts standard were observed on two other occasions. On December 17, 1970, the hourly concentration at Station No. 4 reached a value of 0.279 ppm during northwesterly winds of about 36 miles per hour and on January 1, 1971, the hourly



LEGEND

⊙ AUTOMATIC SO_2 STATION, HI VOL SAMPLER HUEY PLATE AND SULFATION CANDLE.

△ HUEY PLATE ONLY.

FIGURE 2.4-1

AIR SAMPLING NETWORK

CANAL PLANT UNIT No. 2

CANAL ELECTRIC COMPANY

MONTAUP ELECTRIC COMPANY

concentration reached a maximum value of 0.282 ppm at Station No. 6 during northeasterly winds of about 36 miles per hour.

The maximum 24-hour average concentration measured during the year was 0.093 ppm on October 23, 1970, at Station No. 9. This value is below the Massachusetts standard of 0.105 ppm and also below the Federal secondary standard of 0.10 ppm.

The Canal Plant appears to be the predominant source for those few periods during the year when either high 1-hour or high 24-hour concentrations are detected. At present Massachusetts limits sulfur emissions from plants of this size to less than half the levels that were allowable when these peaks were observed. This reduction in plant emissions is expected to preclude future concentrations in excess of the Massachusetts or Federal air quality standards.

The effects of the Canal Plant in long-term average concentrations in the area appears to be largely masked by concentrations from other sources currently unidentified. Averaged over a 6-month period predicted plant contributions accounted for less than 40 percent of the observed concentrations at the maximum and less than 10 percent at the minimum.

In summary, during this 1-year period with field measurements, annual mean concentrations at all four stations were far below both State and Federal standards, and 24-hour concentrations never exceeded either the Massachusetts standard or the Federal secondary standard. The hourly concentration did exceed the Massachusetts standard three times during the year, but this occurred only at one station and on consecutive hours.

With regard to particulate matter, the annual geometric means of 30.7, 24.9, 24.4, and 24.5 ug/m^3 measured at the four locations may be compared with the Massachusetts annual standard of 75 ug/m^3, and with the Federal primary and secondary annual standards of 75 ug/m^3 and 60 ug/m^3, respectively. The highest 24-hour concentration observed during the year was 105.8 ug/m^3, measured at Station No. 6 on March 4, 1971. This concentration is well below both the maximum 24-hour Massachusetts standard of 180 ug/m^3 and the maximum 24-hour secondary Federal standard of 150 ug/m^3. The seasonal variations observed are fairly typical of non-urban locations where contributions from both manmade and natural sources increase during the summer months.

2.5 AMBIENT SOUND LEVELS

The Canal Plant is bounded on the north, east, and west by relatively large, open land areas and by water, but there is a small residential area and motel south of the plant. The current sound level in this residential area and the sound sources are discussed in this section.

Several sound level surveys were conducted in the vicinity of the Canal plant to define the natural ambient sound level, as well as the contribution of the present plant to the ambient sound levels in the area of the plant. The location of these measurement positions is shown in Figure 2.5–1. Octave band sound pressure level measurements, as well as A-scale measurements (dBA), were taken at each of the sites. An example of octave band data is given in Figure 2.5–2, but for ease of comparison, most of the data are presented in dBA in Table 2.5–1. In general, the sound levels at the west, south, and eastern property lines, and across the canal are 50 dBA or less. These values may be compared with the ambient measurement taken at Site 6 of 39 dBA in an area unaffected by plant sound. As a point of reference, 50 dBA is approximately equivalent to the sound of a bedroom air conditioner measured at a typical distance from the noise source.

Table 2.5-1

Sound Level Measurements
Decibels, A Scale, RE 0.0002 Microbars

Date	Site Number 1	2	3	4	5	6
2-12-71, Day	49	74	-	53	-	-
2-12-71, Night	51	72	-	50	-	39
6-1-71, Day	46	70	51	47	42	-
6-1-71, Night	52	70	49	45	50	-

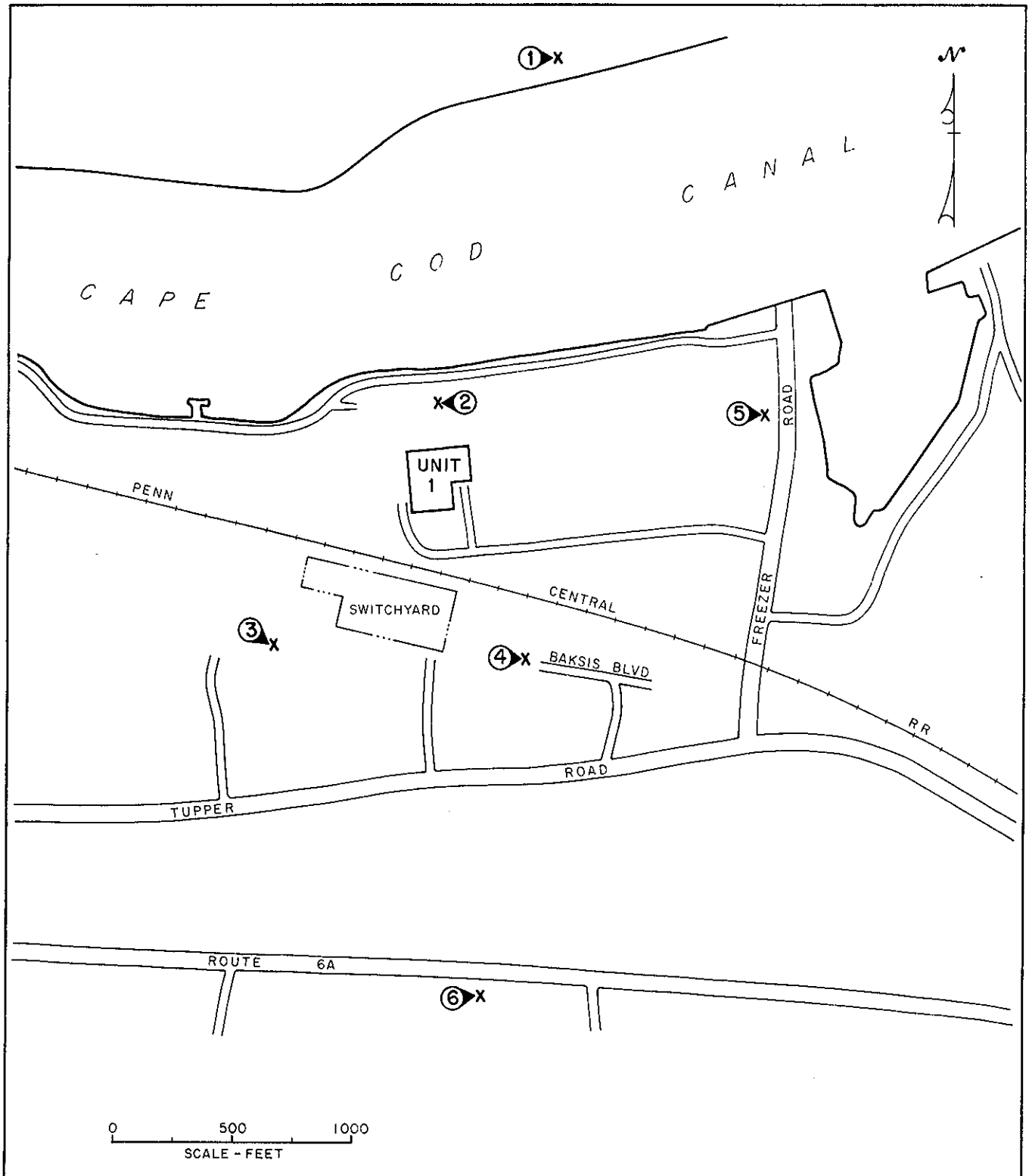


FIGURE 2.5-1
SOUND LEVEL MEASUREMENT LOCATIONS
CANAL PLANT UNIT No. 1
CANAL ELECTRIC COMPANY
MONTAUP ELECTRIC COMPANY

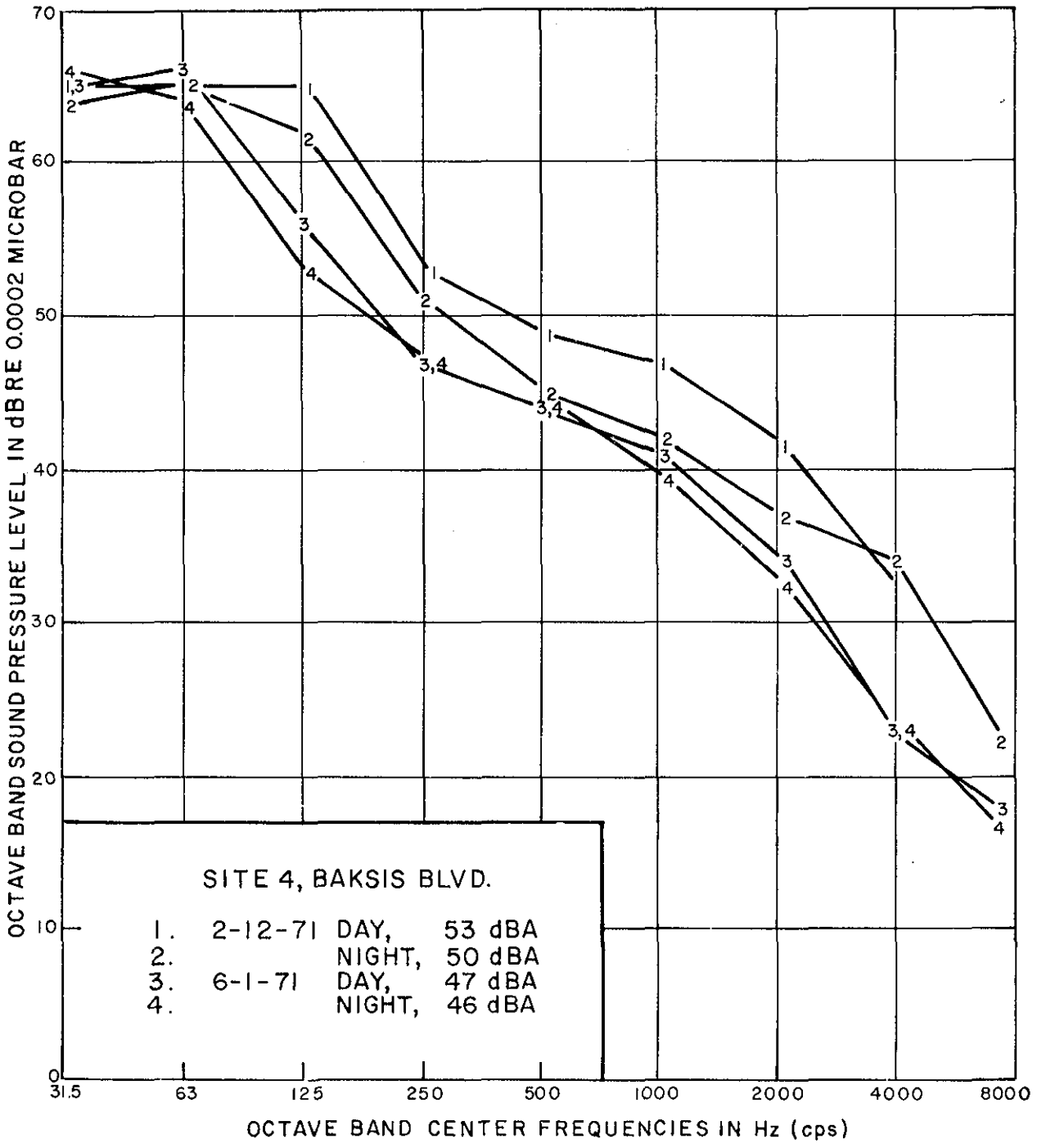


FIGURE 2.5-2

TYPICAL OCTAVE BAND DATA

CANAL PLANT UNIT No. 2

CANAL ELECTRIC COMPANY

MONTAUP ELECTRIC COMPANY

2.6 LAND USE

For purposes of site consideration an area of 10-mile radius was selected for examination. Consideration of some activities, however, cannot be conducted without considering Cape Cod as a whole.

2.6.1 Population

The population within a 10-mile radius of the Canal Plant in 1970 was about 30,000. This number amounts to 0.15 persons per acre, and it is likely that it will double by 1990 giving 0.3 persons per acre. This increase is partly due to low property taxes in Sandwich which help to attract new residents. The most populated area is the section from the southwest to the northwest containing the town of Bourne and the southern portions of the town of Plymouth. About two-thirds of the population within 10 miles of the Canal Plant live in this area. The overall population of the area has fluctuated greatly since 1955 because of Otis Air Force Base which is located 10 miles south of the Canal Plant. From 1958 to 1972, the military and civilian personnel at Otis AFB have ranged from a low of about 1,000 to a high cf about 8,000 people, all of whom are included in the population count. At present, about 5,500 people work at Otis AFB and live in the area.

A large portion of the present population commutes to work outside of the Cape Cod area to such places as Boston and the suburban Boston business and industrial complexes. This portion is expected to increase in the future as is the portion of the population represented by retired people.

2.6.2 Industry

There is little industry within a 10-mile radius of the Canal Plant. The two largest industries are the Canal Electric Company generating station and a soft drink bottling plant located along the Canal area in Sagamore. A major source of income to the area is the construction of vacation and retirement homes. There are several construction companies in the Sandwich area which specialize in this type of work. A principal source of income, although only seasonal, comes from the tourist business from June through September. There are more than 600 resort facilities located throughout the Cape. Of lesser importance are bottled gas facilities and home heating fuel facilities located in the Sandwich area. These facilities are supplied by truck and occasionally by tank car. Fuel is stored in small storage facilities. The Commonwealth of Massachusetts maintains a fish hatchery and a game farm on Route 6A in East Sandwich.

2.6.3 Agriculture

The only major agricultural activity carried on in the area is cranberry farming. About three-fourths of the world's cranberry supply is grown on Cape Cod and in neighboring Plymouth County. There are also some cultivated blueberry fields in the area.

There are a few small farms in Sandwich. Small amounts of vegetable crops are grown and the remaining farm area is used to cultivate flowers.

2.6.4 Recreation

Cape Cod has a variety of land-related recreational facilities, most of which are used seasonally from May to September. During these months there is horseback riding, bicycling, tennis, golf, picnicking and camping. There are several parks in the area with picnic tables and fireplaces. Camping facilities are also available in the nearby area. Hunting is carried on through most of the Cape area from October through February. Hunting is limited to small game, such as pheasants, grouse, rabbit, deer, and waterfowl.

2.6.5 Historic and Scenic Sites

The area within the 10-mile radius of the Canal Plant has many historic and scenic sites. After the Pilgrims settled in Plymouth, they soon migrated to the lower Cape area. In 1627, Pilgrims from the Plymouth Colony, along with Dutch traders from New Amsterdam, built the Aptuxcet trading post. Today a replica of the trading post stands on the original site. There are many 17th-century homes still standing as well as 18th-century churches. This same area is also noted for the beautifully colored Sandwich glass produced from 1825 to 1888. A list of some of the historic and scenic sites in the vicinity of Sandwich is given in Table 2.6-1. Other historic sites, such as a stone marking the site of the original Tupper House, also can be found near the Canal Plant. The National Register of Historic Places, National Registry of Natural Landmarks, and state, local and reqional publications were checked and no other sites were listed.

2.6.6 Archaeological Sites

Although Cape Cod was one of the first settled areas of the new world and is probably rich in undiscovered artifacts, there are no known archaeological sites listed by the Cape Cod Chamber of Commerce.

Table 2.6-1

Historic and Scenic Sites

Site Name	Distance from the Plant	Description
Aptucxet Trading Post	4 miles West on Route 6 in Bourne	A replica of 1627 Pilgrim-Dutch trading post, probably first commercial establishment in America.
Hoxie House	1 1/2 miles South	Originally built in 1637, restored and refurnished.
Thomas Dexter's Grist Mill	1 1/2 miles South	Built 1654. The mill has been restored and operates from June to October.
Saddle and Pillion Rocks	2 miles East	These rocks mark the graves of two of the early settlers of Sandwich, Edmund and Elizabeth Freeman.
Dillingham three-quarter house	2 1/4 miles South	Built in 1650; fine example of 3/4 Cape Cod house.
Ellis House	2 1/4 miles South	Built in 1638.
West Parish Meeting House	9 1/2 miles South-east	Recently restored; built in 1717.
First Church of Christ	1 1/2 miles South-east on Route 6A	Built in 1848; spire designed by Christopher Wren, famed English architect.
First Parish Meeting House	2 miles South-east	Church established in 1638, houses bell and town clock donated by a freed slave, Titus Winchester, in 1749.
Yesteryears Miniature and Doll Museum	2 miles South-east	Housed in the First Parish Meeting House (1638). Old dolls and miniature shops.

Table 2.6-1 (Cont'd.)

Site Name	Distance from the Plant	Description
Old Quaker Meeting House	6 miles South-east	Typical example of Quaker meetinghouse.
Heritage Plantation	2 miles South on Route 130	Autos from 1899-1930's. Lilly Collection of miniature soldiers and antique firearms.
Sandwich Historical Society and Sandwich Glass Museum	2 3/4 miles South	Famous collection of Sandwich glass and other artifacts.
State Game Farm	5 miles South-east on Route 6A	
State Fish Hatchery	5 1/2 miles South-east on Route 6A	
Pairpoint Glassworks	1/2 mile West	Lead crystal and blown glassware are manufactured in the 18th-century traditions.
Lowell-Holly Reservation	7 1/2 miles South	130-acre public park containing 500 holly trees, herbs, heath, heather, and rhododendrons.
Gray Gables	7 miles West	President Grover Cleveland's summer home in Bourne, now a summer hotel.
Massachusetts Maritime Academy	7 miles West on Buzzards Bay	
Bourne Scenic Park	6 miles West	A small picnic area which overlooks the Cape Cod Canal.

2.7 WATER USE

2.7.1 Industry

Industry is rather sparse along the Cape Cod Canal. Otis Air Force Base utilizes facilities at the East Boat Basin in Sandwich for unloading and pumping aviation fuel to the air field. Home fuel oil storage and unloading facilities are also located at this site. There are also several small fish processing plants in the East Boat Basin and a marina which services small pleasure craft. There are several other marinas at the west end of the canal for servicing small pleasure craft. In 1970 over 12 million tons of commercial shipping and over 21,000 pleasure craft passed through the Cape Cod Canal. Table 2.7-1 shows the amount of ship and boat traffic through the Canal from 1965 through 1970.

Table 2.7-1

Ship and Boat Traffic in Cape Cod Canal

Year	Commercial No. Vessels (Gross Tonnage)	Recreational No. Boats
1965	4,906 (10,661,500)	12,650
1966	6,608 (10,694,700)	12,507
1967	7,105 (11,660,700)	12,526
1968	4,816 (13,029,400)	18,922
1969	4,632 (12,348,700)	19,932
1970	6,846 (12,342,700)	21,242

2.7.2 Recreation

The water-related recreational facilities on Cape Cod are used mostly in the months of May through September. Swimming is the major recreational sport during these months, but boating, water-skiing, skindiving, and fishing all lend to the sporting activities carried on during summer. Most of the ponds and lakes on Cape Cod are stocked by the Commonwealth of Massachusetts with various types of gamefish. Salt water gamefish can be found along the salt water beaches, both on the north and south shores of Cape Cod. Boating facilities are located in several areas along the shore.

2.8 TERRESTRIAL ECOLOGY

A qualitative ecological survey designed to describe the principal plant and animal species present on the site and its immediate environs was carried out. The following description is based on the results of that survey.

The power plant is situated at the easterly end of the Cape Cod Canal in the Town of Sandwich. The topography of the area is low, irregular hills interspersed with depressions that are usually occupied by ponds or marshes. The soil in the vicinity of the site, as on most of the Cape, is glacial till. This sandy substrate, together with the wind and salt, are the natural factors that play a major role in determining the types and extent of vegetation that has developed in the region. The area surrounding the station has been developed for various human activities. Several private homes are located south of the plant property along Tupper Road. A motel and small farm are also in this vicinity. A marina on the east side of the property harbors pleasure boats and small commercial vessels. The land across the Canal is owned by the state and has been developed for recreation. It includes a fishing pier and beach.

On the plant site itself three different areas can be differentiated: cleared land, powerline right of way, and forested areas. These areas show differences in vegetation due primarily to the extent the natural plant cover has been altered by man. A full listing of plant and animal species observed in the area is given in Table 2.8–1.

2.8.1 Cleared Land

The area around the Canal Plant proper and tank farm has been cleared and altered for installation of the power plant facilities. This cleared area covers almost the entire northern section of the property. Some native vegetation has grown back and interspersed with it are many weed species that normally invade land after it has been cleared. The vegetation is very low, rarely reaching more than three feet in height. The tallest and densest vegetation on this section of land occurs in the northeast corner of the property.

Some of the plants identified include several species of cord grass (*Spartina* sp.), reed grass (*Phragmites communis*), soft rush (*Juncus effusus*), and little bluestem grass (*Andropogon scoparius*). Woody species reinvading the area include red cedar

(*Juniperus virginiana*), bayberry (*Myrica pennsylvanica*), and staghorn sumac (*Rhus typhina*). Some of the weedy species that invade cleared land include goldenrod (*Solidago* sp.), chicory (*Cichorium intybus*), common evening primrose (*Oenothera biennis*) and Queen Anne's lace (*Daucus carota*).

Table 2.8-1

List of Plant and Animal Species
Reported from the Canal Plant
Site and Surrounding Area

Cleared Land

Reed grass	(*Phragmites communis*)
Cord grass	(*Spartina* sp.)
Soft rush	(*Juncus effusus*)
Little bluestem grass	(*Andropogon scoparius*)
Red cedar	(*Juniperus virginiana*)
Bayberry	(*Myrica pensylvanica*)
Staghorn sumac	(*Rhus typhina*)
Goldenrod	(*Solidago* sp.)
Chicory	(*Cichorium intybus*)
Common evening primrose	(*Genothern biennis*)
Queen Anne's lace	(*Daucus carota*)
Rose	(*Rosa* sp.)
Willow	(*Salix* sp.)

Powerline Right of Way

Red oak	(*Quercus rubra*)
Red maple	(*Acer rubrum*)
Sassafras	(*Sassafras albidum*)
Sweet pepperbush	(*Clethra alnifolia*)
Meadowsweet	(*Spiraea latifolia*)
Greenbrier	(*Smilax* sp.)
Alder	(*Alnus* sp.)
Thistle	(*Circium* sp.)
Blackberry	(*Rubus allegheniensis*)
Milkweed	(*Asclepias* sp.)
Skunk cabbage	(*Symlocarpus foetidus*)
Reed grass	(*Phragmites communis*)
Soft rush	(*Juncus effusus*)
Cattail	(*Typha latifolia*)
Duckweed	(*Lemna minor*)
Pitch pine	(*Pinus rigida*)
Willow	(*Salix* sp.)
Dodder	(*Cuscuta gronovii*)

Forest Area

White oak	(*Quercus alba*)
Gray birch	(*Betula populifolia*)
Black cherry	(*Prunus serotina*)
Black oak	(*Quercus velutina*)
Pitch pine	(*Pinus rigida*)
Red oak	(*Quercus rubra*)
Cottonwood	(*Populus deltoides*)
Wild grape	(*Vitis* sp.)

Table 2.8-1 (Cont'd)

Highbush blueberry	(*Vaccinium corymbosum*)
Meadowsweet	(*Spiraea latifolia*)
Black locust	(*Robinia pseudoacacia*)
Greenbrier	(*Smilax* sp.)
Multiflora rose	(*Rosa multiflora*)
Staghorn sumac	(*Rhus typhina*)
Sensitive fern	(*Onoclea sensibilis*)
Poverty grass	(*Danthonia spicata*)

Plants Outside of Plant Proper

Scrub oak	(*Quercus ilicifolia*)
Red oak	(*Quercus rubra*)
Scarlet oak	(*Quercus coccinea*)
White oak	(*Quercus alba*)
Sheep laurel	(*Kalmia angustifolia*)
Beach plum	(*Prunus maritima*)
Pitch pine	(*Pinus rigida*)
Highbush blueberry	(*Vaccinium corymbosum*)
Trailing arbutus	(*Epigaea repens*)
Bayberry	(*Myrica pennsylvanica*)
Bracken fern	(*Pteridium equilinium*)
Black cherry	(*Prunus serotina*)
Red cedar	(*Juniperus virginianus*)
Beach heath	(*Hudsonia tomentosa*)
Gray birch	(*Betula populifolia*)
Red maple	(*Acer rubrum*)
Raspberry	(*Rubus* sp.)
Arrowwood	(*Viburnum dentatum*)
Blackberry	(*Rubus allegheniensis*)
Willow	(*Salix* sp.)

Plants Outside of Plant Proper (cont'd)

Reed grass	(*Phragmites communis*)
Cranberry	(*Vaccinium oxycoccus*)
Alder	(*Alnus* sp.)
Apple	(*Pyrus malus*)
Earth-star	(*Gester hygrometrious*)
Pokeweed	(*Phytolacca americana*)

Animals in the Area

Mammals

White tailed deer	(*Odocoileus virginiana*)
Cottontail rabbit	(*Sylvilagus floridonus*)
Red squirrel	(*Tamiasciurus hudsonicus*)
Gray squirrel	(*Sciurus carolinensis*)

Table 2.8-1 (Cont'd)

Birds

Herring gull	(Larus argentatus)
Great black-backed gull	(Larus marinus)
Black duck	(Anas rubripes)
American goldeneye	(Bucephala clangula)
Ring-necked pheasant	(Phasianus colchicus)
Bobwhite quail	(Colinus virginianus)
Mourning dove	(Zenaidura macroura)
Canada goose	(Branta canadensis)

2.8.2 Powerline Right of Way

A 400-foot wide right-of-way has been cleared on the site for transmission powerlines. This strip runs southwest from the switchyard. The powerline right-of-way is an area of low bushy vegetation; the plants are maintained periodically to avoid interference with the powerlines. Much of this area was once forested and many tree species are sprouting up from old stumps. Red oak (Quercus rubra), red maple (Acer rubrum), and sassafras (Sassafras albidum) are three tree species still living on this cleared area. Some smaller shrubs growing in the area are greenbrier (Smilax sp.), alder (Alnus sp.), thistle (Circium sp.), blackberry (Rubus allegheniensis) and milkweed (Asclepias sp.). Some wet areas on the powerline support more water-loving plants. Skunk cabbage (Symplocarpus foetidus), reed grass, soft rush, cattail (Typha latifolia), and duckweed (Lemna minor) can be found in these depressions.

2.8.3 Forest Area

There are three small areas of forest on the plant site which come closest to representing natural cover that would develop in this area if it had not been altered by man. The trees are generally smaller than their counterparts on inland areas. The forest has a stunted appearance due to the sandy soils and effects of the sea. The three areas are basically the same in species composition, but certain species predominate in each area. The first forest area is at the west end of the site, south of the tank farm and north of the powerlines. Dominant tree species in this area include white oak (Quercus alba), red maple, pitch pine, gray birch (Betula populifolia), and black cherry (Prunus serotina). The understory contains greenbrier, wild grape (Vitis sp.), highbush blueberry (Vaccinium corymbosium), and several species of ferns.

There is a small marshy area in this forest just south of the tank farm. Cattail is the dominant species here, with some grasses and meadowsweet (Spiraea latifolia) on the edges.

The second forested area on the plant site is near the southwest boundary of the site, south of the powerlines. The area is similar to the first area described. The black locust (Robinia pseudoacacia) is the only major species present in this area in larger numbers than on the other side of the powerlines.

The third forest area on the site is on the south edge of the site, east of the motel. Pitch pine is more abundant at this location compared to the other forested areas.

2.8.4 Areas Surrounding the Site

Since the plant site is only about 110 acres, the surrounding terrain was examined to see if the vegetation was similar to that on the site. The vegetation was recorded from several places on the Shawme-Crowell State Forest located south and west of the plant property. Fire has burned part of this area and pitch pine and several species of oak have become dominant. Scrub oak, a bushy oak, is also common here. Sheep laurel (Kalmia angustifolia), beach plum (Prunus maritima), and blueberry are common shrub species on this site. Bracken fern (Pteridium equilinium), an indicator of poor soil conditions, also was present on the forest lands.

East of the plant site there is a low area of heavy brush six to eight feet high. The vegetation here is very dense, including arrowwood (Viburnum dentatum), shodbush (Amelanchier arborea), red cedar, gray birch, and red maple being the tallest members of the community. Pokeweed (Phytolacca americana), raspberry (Rubus sp.), and several species of fern and grasses also occur here.

Further east of the plant site and east of the marina is a dry flat sandy area. Pitch pine is dominant here with bayberry (Myrica pennsylvanica), red cedar, blueberry, and black cherry also occurring.

The vegetation was also surveyed on the opposite shore of Cape Cod Canal from the power plant site. Since the Canal is a man-made waterway, the entire shore shows signs of alteration. The vegetation is patchy with no mature forest present. The area is composed of grasses and shrubs with young tree species colonizing many areas. Pitch pine, red oak, red maple, and black cherry are some of the trees present. Other common species include gray birch, scrub oak, red cedar, and bayberry. There are also some areas where the dominant plant is beach heath (Hudsonia tomentosa). Where it occurs, it completely dominates areas of ten or more square feet excluding most other vegetation. Also, the fungus earth-star (Gester hygrometrious) is abundant on barren areas of exposed sand. In low depressions, cranberry plants (Vaccinium oxycoccus) were growing in moderate numbers.

2.8.5 Animals of the Area

The area appears to be good habitat for white-tailed deer (Odocoileus virginiana), and cottontail rabbit (Sylvilagus floridanus); tree nests of red squirrel (Tamiasciurus hudsonicus), and gray squirrel (Sciurus carolinensis) were also observed.

Since the site is near the ocean, many sea birds are in the area. Numerous herring gulls (Larus argentatus) and great black-backed gulls (Larus marinus) were observed on Cape Cod Canal. Also ducks including black duck (Anas rubripes), and American goldeneye (Bucephala clangula) were in the vicinity. Geese (Branta canadensis) have been occasionally seen in the area.

Upland game birds on the area included ring-necked pheasants (Phasianus colchicus), bobwhite quail (Colinus virginianus), and mourning doves (Zenaidura macroura).

2.9 MARINE ECOLOGY

The following description of the marine ecology in the area of the Canal Plant site is primarily derived from the results of an ecology survey conducted over a four-year period, beginning in 1966, by the Massachusetts Department of Natural Resources, Division of Marine Fisheries. A complete description and detailed results of this field survey along with its Appendix is included as an Appendix to this report. In addition to these field studies, a 2-year laboratory study was also conducted by the United States Fish and Wildlife Service, Bureau of Sport Fisheries and Wildlife, to determine the temperature tolerances of selected aquatic species in Cape Cod Canal.

The Cape Cod Canal represents an unusual marine habitat in that it connects Cape Cod Bay with Buzzards Bay and thereby artifically joins two distinct biogeographic regions. Cape Cod is the boundary between the American Atlantic Boreal Region to the north and the American Atlantic Temperate Region to the south. The coastal waters of these two regions have markedly different temperature regimes and therefore support different assemblages of species. The organisms of the boreal region are primarily cold-water species that are adapted to the low-temperature waters that have their origins in the chill currents that flow southward into the region from more northern climes.

The organisms of the temperate region inhabit waters that are significantly warmer, being under the primary influence of currents originating from areas to the south. This means that the flora and fauna that occur in the Canal are a mix of species from both regions. The descriptions given below bear this out.

The biological portion of the field studies conducted by the state consisted of monitoring the extent of the sport fishery, the distribution and species composition of the adult and larval fishes, the benthic algae and the invertebrates in Cape Cod Canal.

2.9.1 Adult Fishes

Creel census information during 1967, 1968, and 1969 indicate that the Canal supports a valuable sportfishery. Striped bass (*Morone saxatilis*) were not included in the census due to the erratic nature of the fishery. The Canal, however, does support a fairly sizable striper fishery, especially during May and June. During the three years of study a total of 3,797 anglers were interviewed who fished a total of 6,369 hours and caught 6,321 desirable fish. Approximately 90 percent of the catch comprised Atlantic cod (*Gadus morhua*), Atlantic mackerel (*Scomber scombrus*), winter flounder (*Pseudopleuronectes americanus*) pollock (*Pollachius virens*) and tautog (*Tautoga onitis*). The remaining species in the catch were bluefish (*Pomatomus saltatrix*), rainbow smelt (*Osmerus mordax*), chub mackerel

(Scomber colias), hardtail (Caranx crypos), tomcod (Microgadus tomcod), squirrel hake (Urophycis chuss) and American eel (Anquilla rostrata).

A list of the fishes observed and recorded in the area of Unit No. 1 and the proposed station is given in Table 2.9-1. Forty-four different species are represented including the species of the sportfishery as well as species that are not exploited by the angler.

Most abundant among those species with little or no sport value in the area are the cunner (Tautogolabrus adspersus), Atlantic silverside (Menidia menidia), rock gunnel (Pholis gunnelus), grubby (Myoxocephalus aenaeus) and longhorn sculpin (Myoxocephalus octodecemspinosus). Alewives (Alosa pseudoharengus) and blueback herring (Alosa aestivalis) congregate during April, May, and June at the Bournedale Herring Run located west of the plant site on the opposite side of the canal. Schools of juvenile clupeid fishes, including Atlantic herring (Clupea harengus) and Atlantic menhaden (Brevoortia tyrannus), occurred during late summer and early fall. The Atlantic silverside (Menidia menidia) was encountered regularly and in substantial numbers.

Table 2.9-1

List of Fishes Recorded in Cape Cod Canal
May 1966 - November 1969

Spiny dogfish	Squalus acanthus
Atlantic torpedo	Torpedo nobiliana
Barndoor skate	Raja laevis
Winter skate	Raja ocellata
American eel	Anquilla rostrata
Blueback herring	Alosa aestivalis
Alewife	Alosa pseudoharengus
Atlantic menhaden	Brevoortia tyrannus
Atlantic herring	Clupea harengus
Rainbow smelt	Osmerus mordax
Goosefish	Lophius americanus
Fourbeard rockling	Enchelyopus cimbrius
Atlantic cod	Gadus morhua
Altantic tomcod	Microgadus tomcod
Pollock	Pollachius virens
Red hake	Vrophycis chuss
Mummichog	Fundulus heteroclitus
Atlantic silverside	Menidia menidia
Northern pipefish	Syngnathus fuscus
Striped bass	Morone saxatilis
Bluefish	Pomatomus saltatrix
Blue runner	Caranx crysos
Banded rudderfish	Seriola zonata
Scup	Stenotomus chrysops

Tautog	Tautoga onitis
Cunner	Tautogolabrus adspersus
Radiated shanny	Ulvaria subbifurcata
Rock gunnel	Pholis gunnellus
Northern sand lance	Ammodytes dubius
Atlantic mackerel	Scomber scombrus
Chub mackerel	Scomber japonicus
Barrelfish	Hyperglyphe perciformis
Northern searobin	Prionotus carolinus
Sea raven	Hemitripterus americanus
Grubby	Myoxocephalus aenaeus
Longhorn sculpin	Myoxocepgalus octodecemspinosus
Shorthorn sculpin	Myoxocephalus scorpus
Lumpfish	Cyclopterus lumpus
Seasnail	Liparis atlanticus
Wrymouth	Cryptocanthodes maculatus
Windowpane flounder	Scophthalmus aquosus
Yellowtail flounder	Limanda ferruginea
Winter flounder	Pseudopleuronectes americanus
Northern puffer	Sphoeroides maculatus

2.9.2 Larval Fishes

Weekly plankton tows were conducted in the vicinity of the plant in 1967 to establish estimates of fish egg and larval abundance. A list of the fishes whose eggs and/or larvae have been reported from the Cape Cod Canal in the vicinity of the power plant is given in Table 2.9–2. Of the 24 species represented, 6 have demersal eggs, 17 have pelagic eggs and 1 species, the northern pipefish, is viviparous. Eight species - the Atlantic cod, tautog, cunner, winter flounder, Atlantic mackerel, red hake, fourbeard rockling and northern sand lance - comprised 96.8 percent of the larvae collected during the ecological survey.

Of these only the cod, tautog, mackerel, and flounder are of major sport or commercial significance in the area. Cunner-tautog eggs (the researchers were not able to readily distinguish the eggs of the two species) occurred in greatest abundance, while cod was present in the largest number of samples. There were some apparent differences in the occurrence and abundance of the various species according to tidal stage.

The periods of the occurrence of eggs in the area correlated well with the spawning periods described for the species represented. The adult forms of five species were recorded in the Canal in substantial numbers during their respective spawning periods. These were the cunner, tautog, winter flounder, mackerel, and longhorn sculpin.

Table 2.9-2

List of Fish Eggs and/or Larvae Collected in Cape Cod Canal

Atlantic cod	Gadus morhua
American plaice	Hippoglossoides platessoides
Northern sand lance	Ammodytes dubius
Rock gunnel	Pholis gunnellus
Snake blenny	Lumpenus lumpretaeformis
Longhorn sculpin	Myoxocephalus octodecemspinosus
Winter flounder	Pseudopleuronectes americanus
Fourbeard rockling	Enchelyopus cimbrius
Haddock	Melanogrammus aeglefinus
American eel	Anguilla rostrata
Fourspot flounder	Paralichthys oblongus
Cunner	Tautogolabrus adspersus
Tautog	Tautoga onitis
Atlantic mackerel	Scomber scombrus
Northern searobin	Prionotus carolinus
Witch flounder	Glyptocephalus cynoglossus
Silver hake	Merluccius bilinearis
Atlantic menhaden	Brevoortia tyrannus
Red hake	Urophycis chuss
Windowpane flounder	Scophthalmus aquosys
Butterfish	Poronotus triacanthus
Northern pipefish	Syngnathus fuscus
Pollock	Pollachius virens
Atlantic herring	Clupea harengus

2.9.3 Benthic Flora and Fauna

Approximately 100 species of invertebrates, 26 species of algae and 1 flowering macrophyte were recorded from the areas of the canal surveyed during the field studies. A list of these organisms is contained in the Appendix.

Variations in species abundance rather than species composition constituted the major differences between the locations sampled and these were clearly associated with the nature of the substrate. There was an increasingly more luxuriant biota present proceeding from east to west which corresponded to the transition to a more rocky substrate towards the Buzzards Bay end of the canal. Vertical zonation was apparent on the steeply sloping banks of the canal. Seasonal fluctuations in abundances of dominant flora and fauna were detectable but not conspicuous in most instances. Variations in species composition among the locations sampled were few.

In summary, the fauna and flora of Cape Cod Canal represent a variety of resident and transient species indicative of a transitional zone between two biogeographic regions. It is apparent that species composition is strongly influenced by the different characteristics of the two water masses which pass through the Canal with the changing tides.

SECTION III

ENVIRONMENTAL IMPACT OF PROPOSED PLANT

SECTION III

ENVIRONMENTAL IMPACT OF PROPOSED PLANT

3.1 AIR QUALITY

When the enlarged power plant begins operating in 1975, the ground level concentrations of sulfur dioxide, nitrogen oxides and particulates resulting from the plant are expected to be below Massachusetts air quality standards. Mathematical diffusion analyses of both the present single-unit plant and the proposed two-unit plant have been performed and are described in detail in a report prepared by Stone & Webster Engineering Corporation (Ref. 10). A discussion of the methods used in computing these projections is also described in Appendix No. 2.

3.1.1 Results of the Dispersion Analysis

3.1.1.1 Sulfur Dioxide

When the enlarged power plant begins operation in 1975, the ground level concentrations of sulfur dioxide resulting from the plant are predicted to be less than the Massachusetts air quality standards. A comparison of anticipated concentrations due to plant emissions with Federal and the Massachusetts annual, daily and hourly air quality standards is presented in Figure 3.1-1. The following sections discuss the effects of the proposed plant.

Ground level concentrations have also been compared to concentrations expected without construction of Unit No. 2. In the following sections references to Unit No. 1 only describe conditions resulting from emissions by the present plant from a 298-foot stack when burning 1 percent sulfur fuel and operating with an electrostatic precipitator. References to Units No. 1 and No. 2 together describe conditions resulting from two units operating with a 498-foot stack, 1 percent sulfur fuel, and electrostatic precipitators.

a. Annual Average Concentrations

Estimated annual average sulfur dioxide concentration contours appear in Figures 3.1-2 and 3.1-3. These figures represent the annual average distribution of sulfur dioxide concentrations from Unit No. 1 only, and from Units No. 1 and No. 2 combined. In Figure 3.1-2, isopleths indicate the predicted contribution of the existing plant to ground level concentrations, when burning fuel with a 1 percent sulfur content. In Figure 3.1-3, isopleths indicate the predicted combined effects of Units No. 1 and No. 2.

The maximum annual average ground level concentration of sulfur dioxide from Unit No. 1 was calculated to be 0.00076 ppm, and the maximum value from Units No. 1 and No. 2, to be 0.00038 ppm.

These values occur in the northeasterly direction from the power plant because of the influence of the prevailing southwest wind. From Figures 3.1–2 and 3.1–3, it may be observed that at all points where calculations were made, annual average sulfur dioxide concentrations will decrease after construction of the second unit. It is expected that at all other points where the effects of plant emissions can be observed, a reduction will be noticed.

b. Daily Concentrations

Isopleths of anticipated maximum 24-hour averages of sulfur dioxide concentration are shown in Figures 3.1–4 and 3.1–5. These curves have been drawn for calculated ground level concentrations resulting from sulfur dioxide emitted by the single–unit plant and the proposed two-unit plant. For the single–unit plant (seen in Figure 3.1–4), a maximum of 0.032 ppm occurs within the 0.03 ppm isopleth, about three miles south-southwest of the stack. For the proposed plant, (seen in Figure 3.1–5) a maximum of 0.020 ppm occurs within the blue 0.015 ppm isopleth, approximately two miles south of the stack. By comparing contours in Figures 3.1-4 and 3.1-5 it can be concluded that maximum 24–hour concentrations will be approximately the same or lower at all points after completion of the proposed construction.

c. Hourly Concentrations

Maximum hourly ground level sulfur dioxide concentrations expected from the operation of Unit No. 1 and the combined operation of Units No. 1 and No. 2 are presented in Table 3.1–1. The data include the historical frequency of occurrence of the specified meteorological conditions expressed as number of hours per year. Weekend and nighttime periods were differentiated from daytime periods since Unit No. 2 is expected to operate at reduced loads during these periods.

Table 3.1-1 indicates that the predicted maximum hourly ground level sulfur dioxide concentration will be 0.22 ppm for the proposed plant. This would occur with conditions of extreme atmospheric instability at very low wind speed. The average frequency of occurrence for this condition has been about 11 hours per year. Under identical conditions, the predicted maximum concentration for the single-unit plant would be 0.18 ppm.

The table also shows that all hourly average concentrations are below the Mass. Air Quality Standard of 0.28 ppm. For almost all meteorological conditions, the calculated peak ground level concentrations would be reduced after construction of Unit No. 2. The exceptions are hours of extreme atmospheric instability or hours when high wind speed and neutral atmospheric conditions occur while the plant is at reduced load.

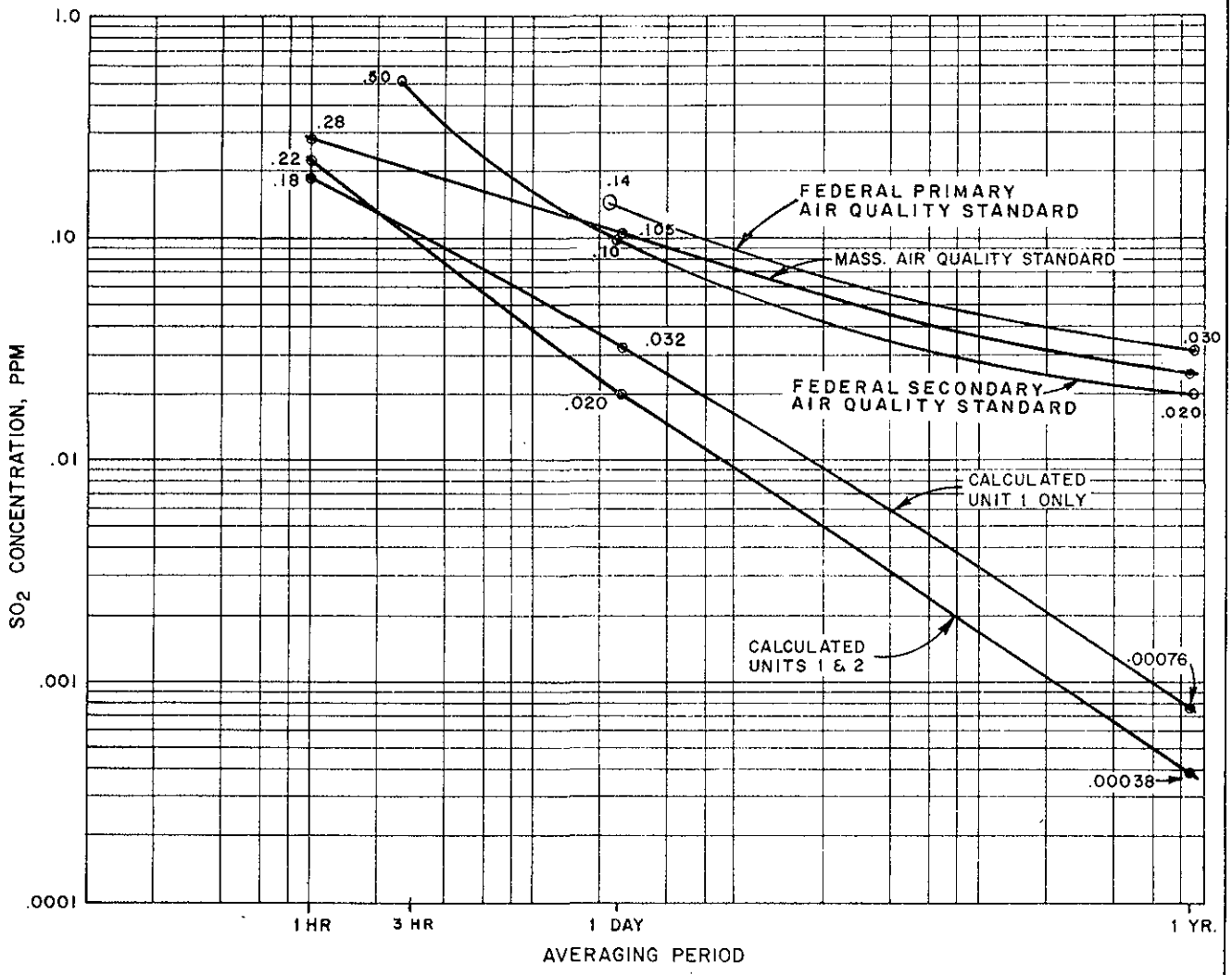


FIGURE 3.1-1

COMPARISON OF AIR QUALITY STANDARDS TO EXPECTED MAX. PLANT CONTRIBUTION

CANAL PLANT UNITS No. 1 & 2

CANAL ELECTRIC COMPANY

MONTAUP ELECTRIC COMPANY

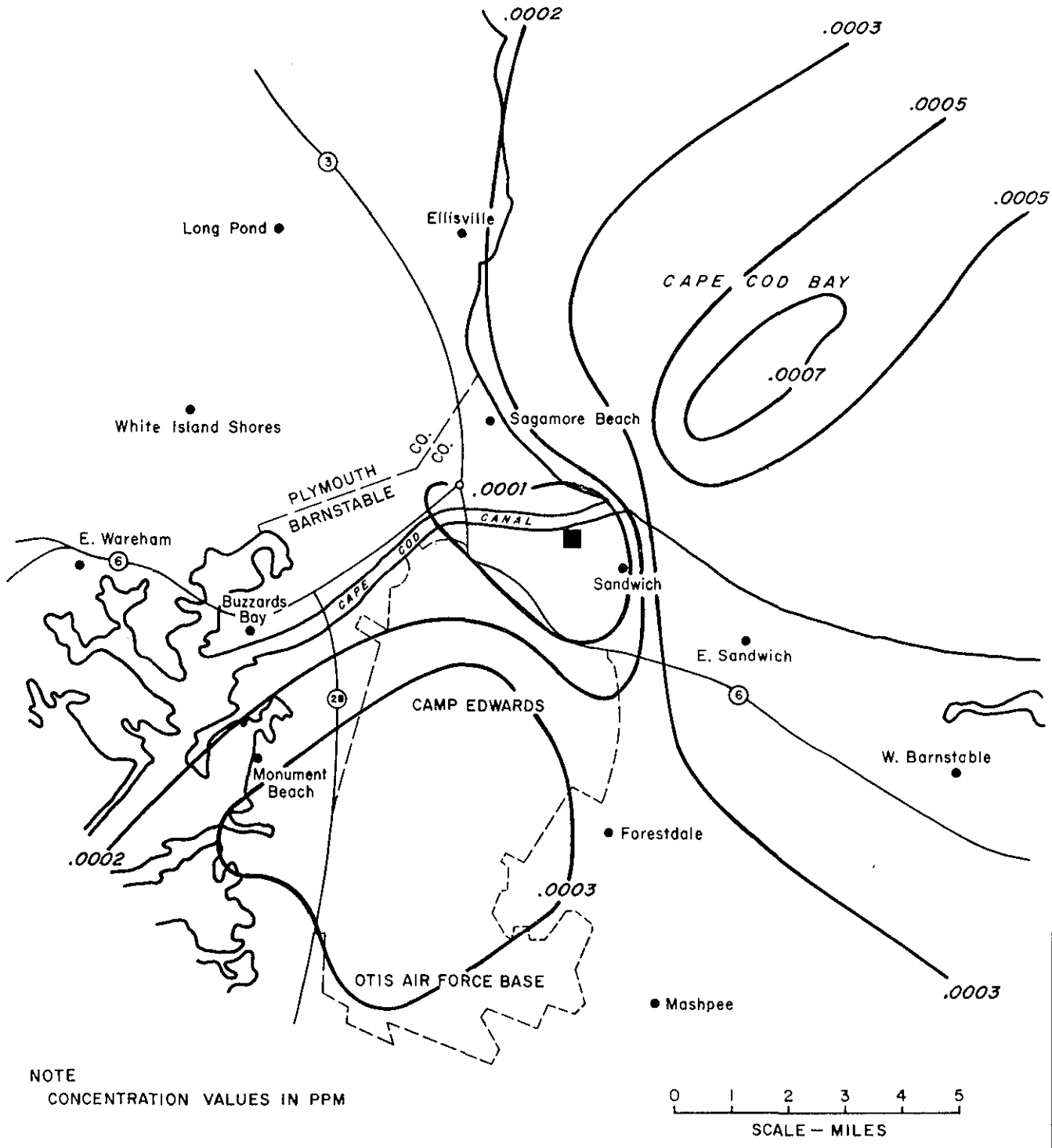


FIGURE 3.1-2
ANNUAL AVERAGE SULFUR DIOXIDE CONCENTRATIONS ISOPLETHS
UNIT NO. 1
CANAL ELECTRIC COMPANY
MONTAUP ELECTRIC COMPANY

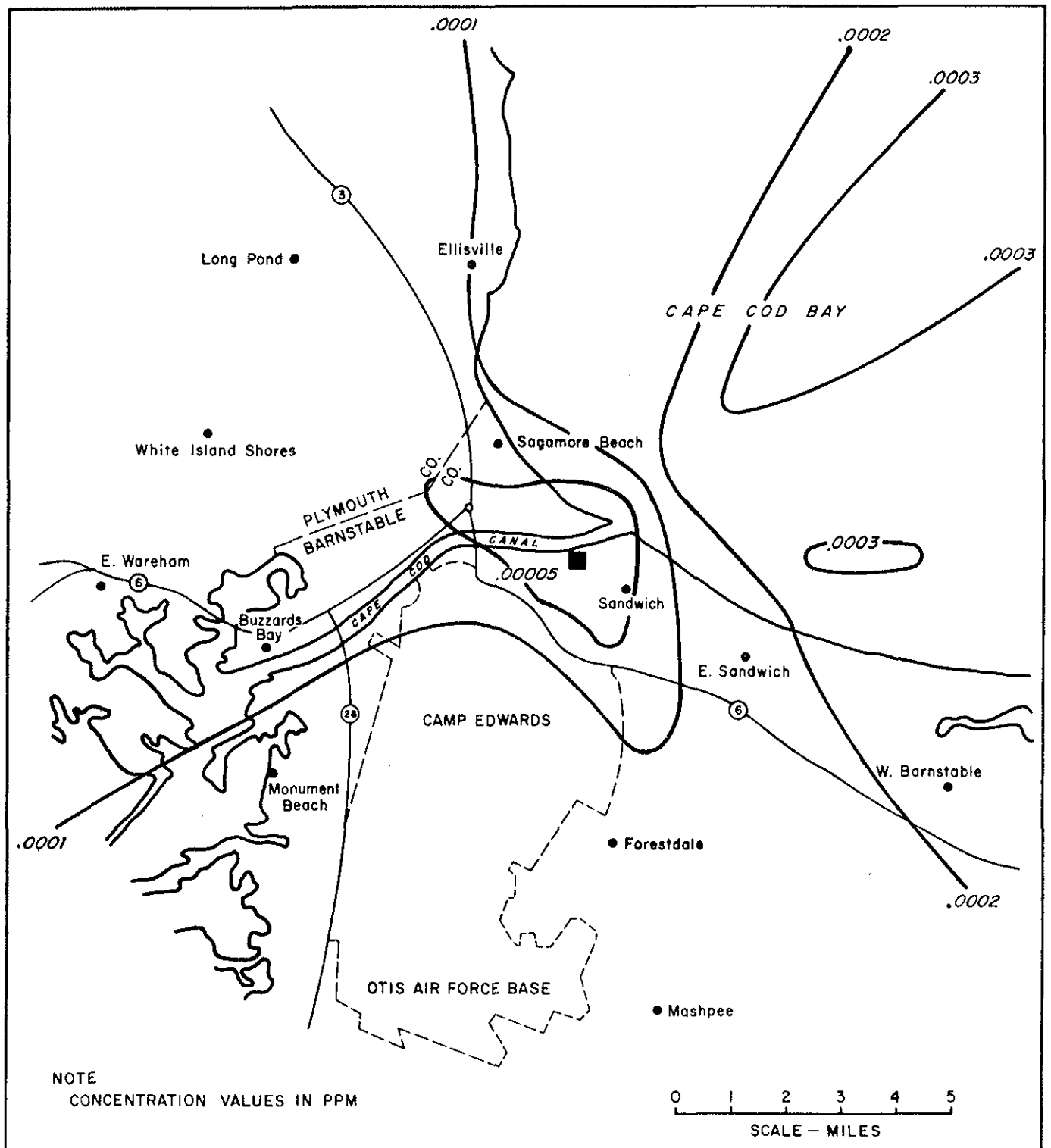


FIGURE 3.1-3
ANNUAL AVERAGE SULFUR DIOXIDE CONCENTRATIONS ISOPLETHS
UNITS NO. 1 & 2
CANAL ELECTRIC COMPANY
MONTAUP ELECTRIC COMPANY

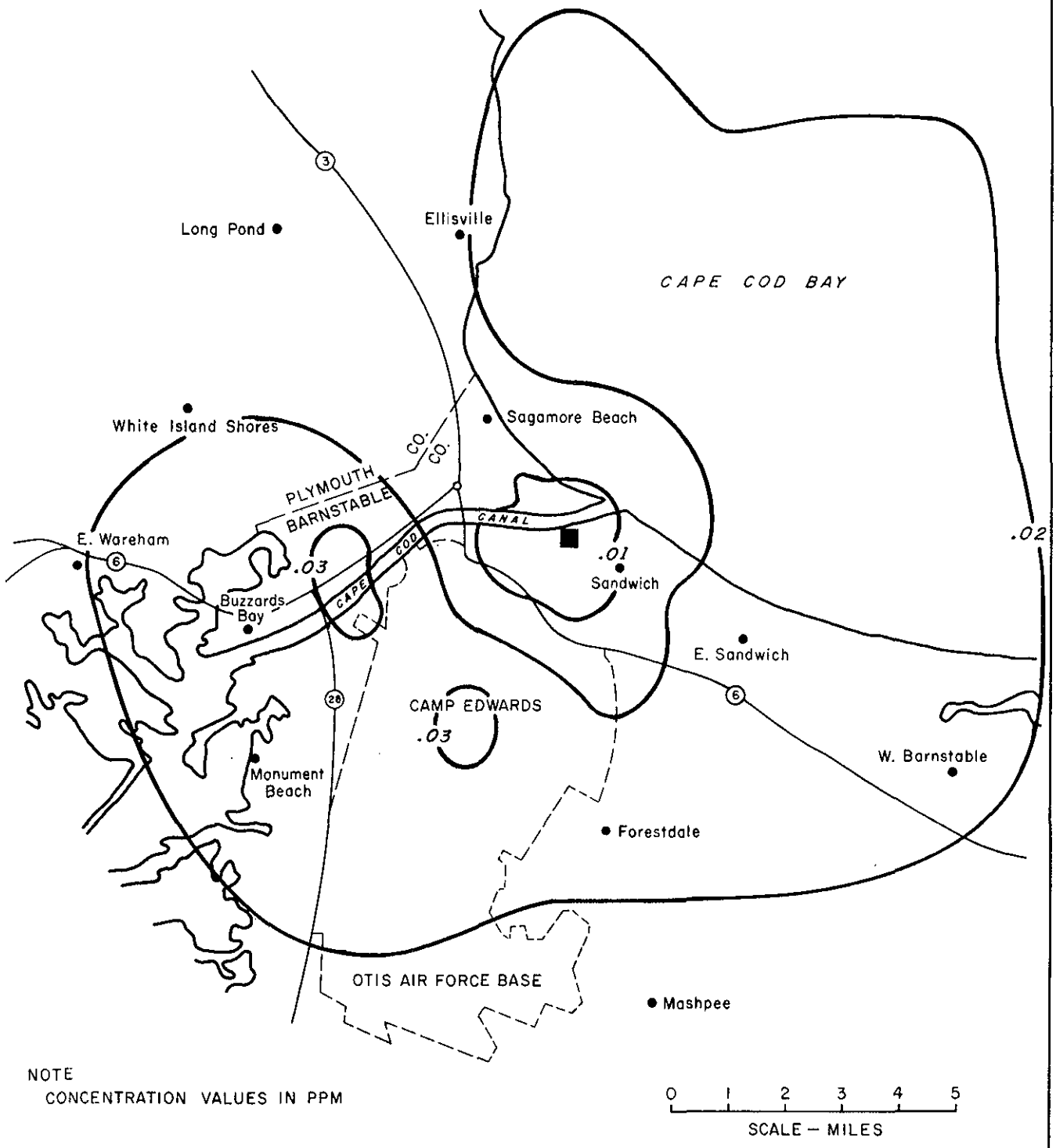


FIGURE 3.1-4
ISOPLETHS OF MAXIMUM 24 HOUR
SULFUR DIOXIDE CONCENTRATIONS
UNIT NO. 1
CANAL ELECTRIC COMPANY
MONTAUP ELECTRIC COMPANY

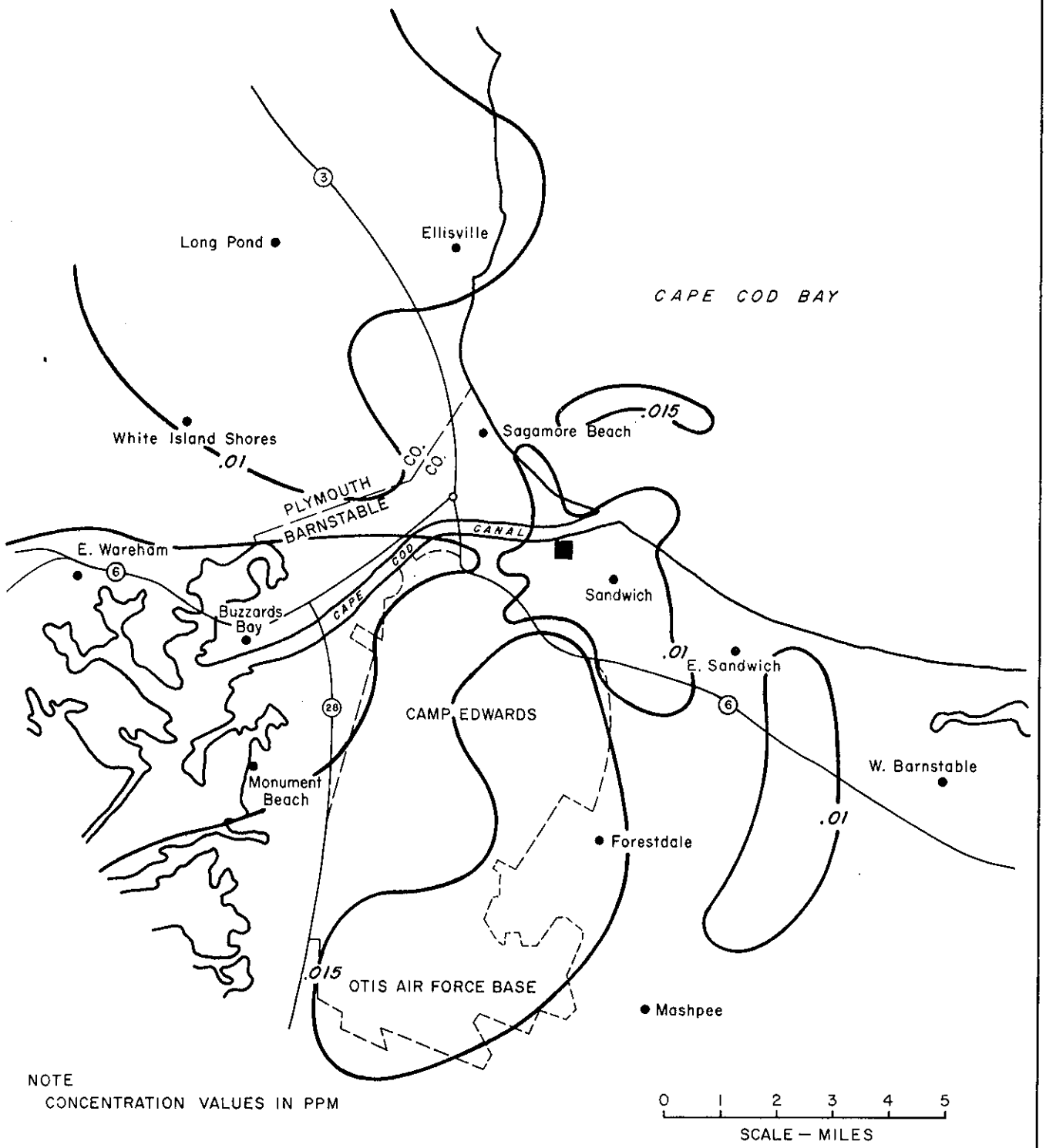


FIGURE 3.1-5
ISOPLETHS OF MAXIMUM 24 HOUR SULFUR DIOXIDE CONCENTRATIONS
UNITS NO. 1 & 2
CANAL ELECTRIC COMPANY
MONTAUP ELECTRIC COMPANY

Table 3.1-1
Calculated Maximum Hourly Sulfur Dioxide Concentration

Stability	Wind Speed, Mph	Daytime			Night and Weekend		
		Annual Hours	Conc. Unit 1, ppm	Conc. Units 1 and 2, ppm	Annual Hours	Conc. Unit 1, ppm	Conc. Units 1 and 2, ppm
A	0-1	11	.18	.22	7	.18	.19
	2-3	1	.17	.19	1	.17	.17
	4-5	7	.16	.18	3	.16	.16
B	0-1	26	.06	.05	10	.06	.05
	2-3	25	.06	.06	10	.06	.06
	4-5	30	.07	.07	15	.07	.06
	6	32	.07	.07	16	.07	.06
	7	35	.08	.07	16	.08	.07
	8-9	15	.08	.07	8	.08	.06
C	0-1	42	.02	.01	43	.02	.01
	2-3	24	.04	.04	16	.04	.04
	4-5	60	.05	.04	26	.05	.04
	6	48	.05	.05	19	.05	.04
	7	45	.05	.05	18	.05	.04
	8-9	179	.06	.05	74	.06	.04
	10	64	.06	.05	29	.06	.04
	11	27	.06	.05	14	.06	.04
D	0-1	64	.01	<.01	135	.01	<.01
	2-3	31	.01	<.01	56	.01	<.01
	4-5	202	.01	<.01	248	.01	<.01
	6	135	.01	<.01	150	.01	<.01
	7	136	.01	<.01	171	.01	<.01
	8-9	332	.02	.01	392	.02	.01
	10	315	.02	.01	300	.02	.01
	11	147	.02	.01	168	.02	.01
	12-14	700	.02	.01	655	.02	.01
	15-19	528	.03	.01	460	.03	.01
	20-29	168	.03	.02	167	.03	.01
	30-Up	12	.03	.02	15	.03	.09
E	4-5	44	<.01	<.01	105	<.01	<.01
	6	26	<.01	<.01	70	<.01	<.01
	7	37	<.01	<.01	124	<.01	<.01
	8-9	73	<.01	<.01	250	<.01	<.01
	10	38	<.01	<.01	144	<.01	<.01
F	0-1	106	<.01	<.01	394	<.01	<.01
	2-3	39	<.01	<.01	115	<.01	<.01
	4-5	67	<.01	<.01	255	<.01	<.01
	6	45	<.01	<.01	152	<.01	<.01

Hours of increased concentration due to instability are predicted to occur an average of about 26 hours per year. Under the most unfavorable condition, the calculated concentration from the proposed plant is 0.22 ppm as compared to 0.18 ppm from Unit No. 1.

Hours of increased concentration from Units No. 1 and No. 2 due to high wind speed are expected to occur about 15 hours per year. This increase in concentration would result from a reduced stack exit velocity which occurs when the expanded plant operates at reduced load at night and weekends. The calculated peak hourly concentration under these conditions is 0.09 ppm, and occurs approximately 3,500 meters from the stack. The maximum concentration predicted for the same conditions with a single unit is 0.03 ppm and occurs approximately 4,200 meters from the plant.

All other meteorological conditions which occur 99.5 percent of the time result in calculated peak ground level concentrations equal to or less than those which would occur with the current single-unit plant. All comparisons have been based on a fuel containing 1 percent sulfur.

3.1.1.2 Suspended Particulates

Ground level concentrations of suspended particulates due to plant operations are predicted to be extremely low. The combination of low emissions due to efficient dust collection and the dispersion capability of the 498-foot stack results in values well below air quality standards.

Maximum calculated concentrations for the single-unit plant and the proposed two-unit plant are given below, together with the applicable Massachusetts standard:

Averaging Period	Unit No. 1 Effects, ug/m^3	Units No. 1 and No. 2 Effects, ug/m^3	Standard, ug/m^3
Annual	0.047	0.024	75
Daily	2.0	1.2	180

These are at the same areas of maximum sulfur dioxide concentrations as shown on the preceding figures.

3.1.1.3 Nitrogen Oxides and Oxidants

Ground level concentrations of nitrogen oxides due to plant emissions will be well below the National Air Quality Standard. The maximum annual concentration, assuming no atmospheric reaction or decay, is calculated to be 0.00026 ppm. This is approximately half of 1 percent of the National Air Quality standard. Based on the same assumptions, the peak hourly value is expected to be less than 0.15 ppm.

Nitrogen oxides participate in photochemical reactions in the atmosphere which increase ambient concentrations of oxidants. These reactions are limited by the presence of other reactants, such as hydrocarbons, and by the amount of solar radiation. Exact procedures for calculating the effects of these reactions are not generally available.

Background concentrations of nitrogen oxides, hydrocarbons, and oxidants are assumed to be low in the Cape Cod area. This is due to the relatively low degree of industrialization and the low traffic densities in the predominantly residential and recreational area. When these facts are considered, together with the low concentration of nitrogen oxides caused by plant emissions, it may be concluded that no significant increase of oxidant level has resulted from operation of the existing plant. After construction of the second unit, ambient concentrations will be further reduced by the improved dispersion resulting from the 498-foot stack and the reduced emission rate from Unit No. 2.

3.1.2 Acidic Soot Fallout

Acidic soot fallout has been associated with operation of oil-fired utility plants. A few occurrences of fallout of this type have been noted at Canal Plant - Unit No. 1 in the past. These occurrences have been carefully reviewed and a plan for controlling this problem has been developed for Unit No. 2.

The majority of acidic soot fallout problems on Unit No. 1 were found to be related to upset conditions in the boiler and associated equipment, and to startups or shutdowns of the equipment. It has been concluded that condensation of sulfur trioxide on metal surfaces which are below the dew point of the flue gas initiates formation of acidic soot. Sulfur trioxide, which is formed by about 1 percent of the sulfur in the fuel (for a typical oil-fired boiler operating on low excess air), is highly acidic in the presence of moisture. Some of this acid is in turn absorbed by particulate matter adhering to metal surfaces. Upon upsets or sudden drastic changes in load, these acidic particles can be dislodged and carried out through the stack.

Since it is impossible to preclude upset conditions or extreme load changes due to equipment problems, it is difficult to

guarantee the ultimate effectiveness of any control system for acidic soot emissions. However, several equipment and operational methods have been found to reduce both the frequency and severity of these occurrences on Unit No. 1. These methods have been included in a plan for controlling the problem at the Canal Plant Unit No. 2. The plan is based on adherence to the following conditions: low excess air firing; high stack temperature resulting from insulated flues and stack liners; high efficiency particulate collection; use as necessary of a chemically basic fuel oil additive; and washing of air heaters, precipitators, and stack prior to cold startups.

3.1.3 Inversion Effects

In addition to the results seen in Table 2.1-4 it is necessary to obtain information on height of plume rise (for various atmospheric conditions) in order to identify situations where plume trapping by inversions may occur. Height of plume rise for this purpose was estimated for operating loads of 100 percent (daytime operations) and 75 percent (nighttime operations) for both ground-based and elevated inversions using formulations suggested by Briggs (Ref. 3).

Ground level concentrations were calculated using the inversion data described in Section 2.1, Climatology and Meteorology. The results of the plume rise calculations for ground-based inversions indicated that for the worst possible combination of atmospheric conditions an inversion having a top whose height is about 300 meters or higher is required in order to trap a significant fraction of the plume within the inversion layer. Maximum ground-level hourly average concentrations of sulfur dioxide for these conditions were estimated to be about 0.02 ppm.

For elevated inversions, the plume rise calculations indicated that the inversion layer for inversions based at heights of 200 meters or lower will be penetrated by the plume for all possible combinations of atmospheric conditions. In the absence of inversions at lower levels, plumes will generally level off at heights of about 300 meters for 12 meters-per-second winds, 400 meters for 6 meters-per-second winds and 600 meters for 3 meters-per-second winds. Hence, inversions based at heights of ≥300 meters will be required to cause significant plume trapping. Maximum ground level hourly average concentrations of sulfur dioxide for these conditions were estimated for various classes of stability beneath the inversion layer using a method suggested by Turner (Ref. 11). The results indicate a maximum value of 0.23 ppm, 0.13 ppm, 0.10 ppm, or 0.04 ppm, depending upon whether the layer beneath the inversion is very unstable, moderately unstable, slightly unstable, or neutral, respectively.

The degree of instability that may occur beneath elevated inversions was examined (on the basis of the Nantucket data)

using lapse rate categories of -1.6 to -2.5, -2.6 to -4.0, and less than -4.0 C/100m to define stability as slightly unstable, moderately unstable, and very unstable, respectively. The results showed that all three degrees of instability commonly occur, but only in coincidence with inversions based at heights of ≤100 meters and primarily during daytime hours of the spring and summer seasons. For inversions based at heights greater than 200 meters, the maximum degree of instability that occurred was "slightly unstable." In addition, only one inversion (from the 7,049 soundings examined) based at a height greater than 300 meters was found having an unstable layer beneath it. For this inversion, the maximum hourly average ground level concentration of sulfur dioxide was determined to be about 0.06 ppm. As indicated earlier, the lowest height at which an inversion may occur and cause significant plume trapping is about 300 meters. The maximum sulfur dioxide concentration that could result due to plant operation in this case is estimated to be 0.09 ppm, a value significantly lower than the 0.28 ppm set as a limiting value by the State of Massachusetts. The frequency of occurrence of "slightly unstable" conditions beneath inversions based at about 300 meters (and hence hourly average ground level concentrations of sulfur dioxide of 0.09 ppm) is estimated to be about 0.7 percent of the time or six hours a year.

Inversions with bases at an elevation greater than 600 meters will not cause significant plume trapping effects for this plant.

3.1.4 Fog

During winter, fog may form over the circulating water discharge flume during periods of extreme meteorological conditions. These periods are not expected to exceed a total of 40 to 50 hours for any year. During these periods of high fog producing conditions, the following factors must be coincidental: high relative humidity, low air temperature and high wind speed. If wind speed is moderate to high, some drift of the fog produced by the discharge flume can be expected. The winds during the winter months are predominantly from the northwest. Based on computer simulations, with a moderate to high northwest wind, the fog produced by the discharge water in the flume will dissipate in the plant yard within 500 feet of the flume. The expected height of this fog will not exceed 10 feet in any event. This maximum height may be reached during periods of moderate wind. The fog should not present any hazard to navigation in the Canal nor to traffic on adjacent roadways. If the wind is from the south, some fog will be carried towards the Canal but is expected to dissipate well before reaching the canal prism line. The basis of these predictions is a computer simulation of fog production by cooling ponds (Ref. 12).

3.1.5 Odor

No significant impact is expected due to odors from the proposed construction. The only foreseeable odor is the possibility of the odor of fuel oil being noticeable during times of unloading tankers at the station.

Since the size of the station is being doubled, this may be expected to occur twice as often as in the past. This is considered only a minor undesirable impact.

3.1.6 Total Stack Emissions

The addition of Unit No. 2 would double the capacity of the present power plant. As Unit No. 2 would be operated at only 50 percent capacity nights and weekends, the total fuel use is less than double the present volumes. Total stack emissions, compared to the present volumes are listed in Table 3.1-2.

It must be stressed that the air quality standards and the effect on the regional air quality is measured by the concentrations of emissions at ground level, as described in Sections 3.1 through 3.1.3. The total emissions shown in Table 3.1-2 represents the total increased discharge into the earth's atmosphere, despite the decrease in concentrations affecting man's environment in the region.

Table 3.1-2

Stack Emissions

	Estimated Total Daily Emissions	
	Existing Unit No. 1 298-Ft. Stack (1% S) lb/day*	Proposed Units No. 1 and No. 2 498-Ft. Stack (1% S) lb/day*
SO2	122,000	219,500
Maximum Average Particulate Emissions**		
Inorganic Ash	550	990
Organic Carryover	550	990
MgO	1,050	1,900
MgSO	630	1,140
Total	2,780	5,020

Load Factors

	Unit No. 1	Unit No. 2
Days	100	100
Nights	100	50
Weekend	100	50

Acidic Soot ***

*Average Daily Emissions (yearly basis) using above load factors. Emissions in day-to-day operation may vary.

**90 percent efficient precipitators on both units.

***Impossible to estimate, but measures have been taken to minimize both occurrence and quantity.

3.2 WATER QUALITY

3.2.1 Circulating Water Discharge Studies

Extensive engineering studies were conducted to yield information for the design of a circulating water discharge system that will be compatible with the Cape Cod Canal environment, particularly with respect to temperature and velocity effects. Results of these studies are described in Stone & Webster Engineering Corporation "Report on Circulating Water Discharge System, Canal Plant - Unit No. 2 Canal Electric Company, Montaup Electric Company," December 7, 1971 (Ref. 13). Hydraulic and hydrothermal analysis performed by Stone & Webster Engineering Corporation formed the basis for the selection of a concept employing a submerged circulating water discharge. Hydraulic model studies were conducted at the Ralph M. Parsons Laboratory for Water Resources and Hydrodynamics of the Massachusetts Institute of Technology to test various submerged discharge arrangements and develop a feasible design described in Reference 14, which is reproduced as Appendix No. 3.

Meetings were held at different stages of the project with various State and Federal agencies, specifically, the Massachusetts Department of Natural Resources, the U.S. Army Corps of Engineers, and the Environmental Protection Agency. The proposed design of the circulating water discharge facilities were presented to these agencies together with a demonstration of the hydraulic model.

It was determined that an improved plant discharge system would be required with the additon of Canal Plant Unit No. 2 to limit temperatures to acceptable levels near the discharge. Preliminary design and hydrothermal analysis of improved discharge systems were discussed with the regulatory agencies and resulted in the establishment of the following design criteria:

a. Temperature Criteria

Water temperatures in the top 15-foot layer should be kept below 86 F to prevent harmful effects on fish. These criteria were suggested by the Massachusetts Division of Marine Fisheries and are based on a survey described in Reference 1 and also in Appendix No. 1, which indicated that the heaviest concentration of pelagic fish in the Canal was generally found in the top 15-foot layer, and on thermal tolerance studies (Ref. 1) which showed that temperatures below 86 F would not be harmful to these species.

Continuous water temperature measurements at the east entrance of Cape Cod Canal during 1967, 1968, and 1969 (Ref. 1) showed the following natural water surface temperatures for the critical months of July and August when maximum temperatures occur. These are shown in Table 3.2-1.

Table 3.2-1

Surface Water Temperature, East Entrance, Cape Cod Canal

	Maximum Temperature (F)	Mean Maximum (F) Based on 12-Year Data For Comparison
1967	67.5 (July and August)	
1968	68.0 (July)	68.7 (August)
1969	71.5 (August)	

Based on the above data, a maximum ambient water temperature of 72 F was selected as a design basis. Therefore, with a design temperature rise across the condenser of 28 F and a maximum allowable water temperature of 86 F, it is necessary to dilute the circulating water flow with ambient water by a factor of 2.0, thus reducing the temperature rise above ambient to 14 F, before it reaches the top 15-foot layer. Figure 2.2-2 shows that highest natural water temperatures occur during the 1-hour period following high slack water. The critical time for temperature control occurs at high slack water when maximum ambient water temperatures are combined with the lowest water level for that period (El. 6.9 feet MLW Datum) and consequently lowest submergence of the outfall structure. Therefore, the discharge structure is designed to produce a minimum dilution of 2.0 at an elevation of -8.1 feet MLW Datum at high slack water. Consequently, water temperatures will meet the design criteria.

b. Velocity Criteria

Discussions with the Corps of Engineers indicated that it is considered desirable to limit cross currents induced by the subsurface discharge to values similar to the present Unit No. 1 discharge velocities in order to prevent any hazard to shipping or small craft navigating through the Canal. Consequently, a survey was conducted to determine the circulating water discharge plume velocities of Unit No. 1 (Ref. 15). Velocities were measured at high and low slack water since cross currents due to the circulating water discharge are highest at slack water when tidal currents in the Canal approach zero. The survey showed that plume velocities at low slack water range from 2.3 fps at the point of discharge to about 1.0 fps in the navigation channel and average about 1.6 fps. Accordingly, a maximum cross current velocity at slack water of about 1.6 fps in the top 5-foot layer was adopted as the appropriate surface velocity criteria.

Various discharge arrangements were investigated for suitability for discharging the circulating water into Cape Cod Canal in accordance with the design criteria listed above.

These arrangements were analyzed theoretically to obtain predictions of temperatures and velocities induced in the Canal

from the combined Units No. 1 and No. 2 circulating water discharge.

Based on these studies it was concluded that the arrangement most suitable for satisfying the requirements of the design criteria would employ a discharge flume extending toward the eastern boundary of the Canal Plant site and terminating in a submerged outfall structure. This design promotes rapid dilution at the point of discharge and minimizes recirculation to the intake.

The behavior of submerged buoyant jets has been extensively studied by various researchers (Refs. 16, 17, 18). Dilution of the condenser cooling water flow is accomplished by jet action of the discharge, which through turbulent mixing entrains substantial quantities of the surrounding ambient water and thereby achieves a rapid temperature drop within a short distance. The discharge jets are carried toward the surface by their initial momentum and their relative buoyancy and flow away horizontally from the intersection with the water surface (Figure 3.2-1). The direction, rate of spreading and additional dilution of the surface flow layer depends primarily on the relative buoyancy of the surface layer, the remaining discharge momentum and induced or natural currents of the receiving waters.

Based on theoretical analysis it is expected that the diluted cooling water will form a stable surface layer due to the still considerable density differences between the warm water layer and cooler ambient Canal water. Its initial thickness depends on the length of the path of the plume centerline and decreases with distance from the point of discharge due to dispersion and additional interfacial mixing.

The parameters used to describe the jet behavior are the dimensionless densimetric Froude number and the ratio of depth of submergence Y to characteristic jet width B.

The densimetric Froude number is defined for a slot jet as:

$$\mathbb{F} = \frac{U}{\sqrt{g' B}}$$

Where: U_0 = initial velocity at point of discharge in fps
g' = densimetric acceleration of gravity in ft/sec²

$$g' = \frac{\sigma \rho}{\rho} g$$

σ_ρ = difference in density between warm water and ambient water
ρ = density of warm water
g = acceleration of gravity
B = width of slot in feet

The characteristics of a buoyant jet may be determined analytically based upon considerations of energy, momentum and turbulence. Using available theories and empirical data, diffuser designs were developed to satisfy the criteria which has been established. It was found that dilution requirements could be met without much difficulty. However, in order to keep surface velocities within the limits of the design criteria, it is necessary to spread the heated effluent over a wide area by using a large number of openings or slots.

To verify the analytical models for temperature and velocity predictions it was deemed necessary to construct a hydraulic scale model. These studies were conducted at the Ralph M. Parsons Laboratory for Water Resources and Hydrodynamics, a division of the Department of Civil Engineering at M.I.T. (Ref. 14). The following is a summary of the basic objectives and results of the model studies.

The objectives of the hydraulic model studies were threefold:

a. Test various outlet designs with respect to temperature rise.

b. Test same outlet designs with respect to surface velocities.

c. Determine the amount of recirculation to the intakes during ebb tide (westward flow).

Initial tests were conducted with no tidal current to assess the effect of the design parameters on dilution and surface velocities. The parameters tested for a prototype flow of 800 cfs were:

Exit velocity, U_o
Submergence, Y
Slot width, B
Angle of discharge, α

Based on these studies, the optimum discharge arrangement was selected and tested for various steady state tidal current velocities to evaluate the diffuser performance under cross currents and to determine recirculation to the intakes.

It was recognized that a transient test simulating tidal reversal was required to assess the effect of direct recirculation to the point of discharge after change of current direction. This was

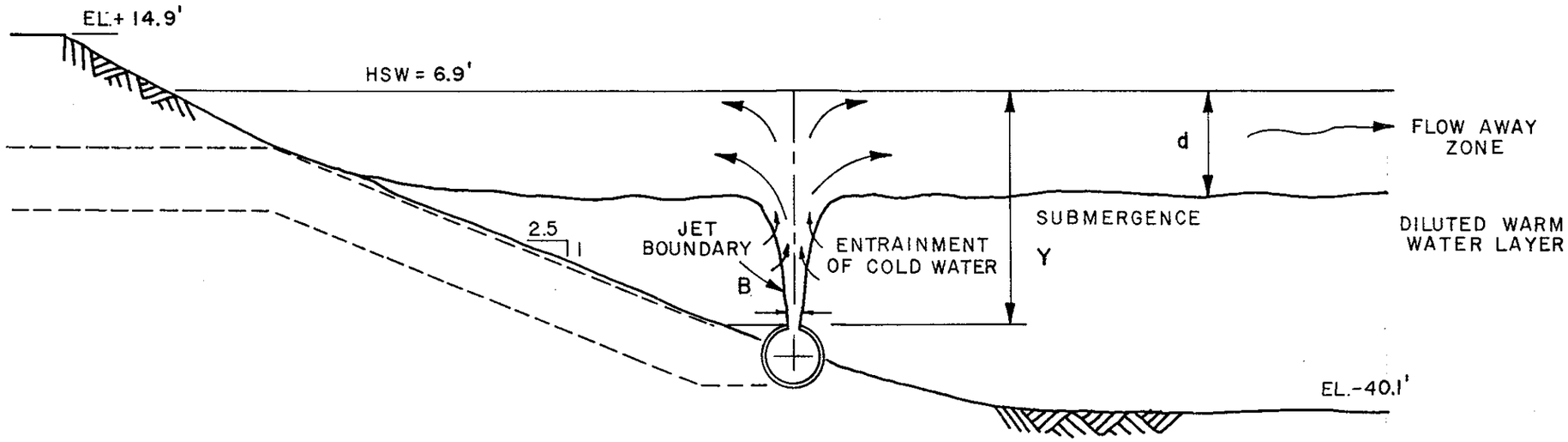


FIGURE 3.2-1

BUOYANT JET BEHAVIOR

CANAL PLANT UNIT NO. 2

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accomplished by establishing an initial cross flow, simulating the corresponding steady state condition, and then changing tidal velocity and direction according to the current velocity curve as shown on Figure 2.2-1 (Section 2.2).

The results of the slack water tests are presented in Figure 2.2-1 and show that a vertical discharge is most favorable with respect to surface velocities and still satisfies the temperature criteria. It should be noted that variation of the relative submergence Y/B does not noticeably affect the surface velocities within the range tested but has a major effect on dilution. High jet discharge velocities are desired because of the resulting reduction in length of the discharge structure and the more uniform flow distribution along the slot. Therefore, the maximum exit velocity which results in acceptable surface velocities may be selected from Figure 3.2-2. The corresponding Y/B which satisfies the dilution requirement may then be determined from the same slot. For a given submergence Y, the maximum possible slot width B is easily found and the required length of the discharge structure for a total flow of 800 cfs may be determined. Based on the slack water test results, a 160-foot long and 1.5-foot wide slotted vertical discharge was selected for further model investigation under tidal currents.

Tests with steady state cross-current velocities showed that dilution is lowest at low tidal velocities comparable to the velocities induced by the density current in the warm water layer. However, dilutions for the selected discharge arrangement were still higher than 2.0 at the 15-foot layer. Dilution capability of the diffuser improved considerably at high tidal velocities due to the large flushing. Recirculation to the intakes was deemed to be negligible since it never exceeded 1.0 F.

The results of the transient test simulating tidal reversal are shown in Figure 3.2-3. Lowest dilutions of 2.03 occur after current reversal when previously released heated water is recirculated and re-entrained into the discharge plume. This test is believed to yield conservative results since it was based on a steady state condition with low initial current velocities and consequently low initial dilution. In addition, the initial thickness of the warm water layer is greater than in the prototype, thus providing more recirculating to the discharge plume.

Careful hydraulic analysis was required to check the uniformity of the flow distribution along the discharge pipe. The method used was similar to that described by Rawn, Bowerman and Brooks (Ref. 19) for sewage diffusers. The procedure was to start at the end outlet with an assumed discharge or exit velocity and work back along the discharge line, calculating the discharge from each outlet. The analysis was conducted for various pipe sizes until the flow distribution was deemed to be acceptable.

It should be noted that the design of the circulating water discharge system is conservative for the requirements of the design criteria. For most of the time, waste heat discharged into the canal is rapidly dissipated by the large volumes of water flowing past the station. Temperatures approaching 86 F in the top 15-foot layer are expected only during a short period at and after high slack water on those days in July or August when exceptionally high water temperatures occur in Buzzards Bay and this water then is flushed past the site. Cross-current velocities induced by the circulating water discharge approach 1.6 fps four times a day during a short time at slack water. This current will not affect recreational boating in the Canal.

3.2.2 Liquid Wastes Treatment

Treatment equipment, monitoring systems and controls for liquid wastes associated with normal operation of Units No. 1 and 2 have been designed to ensure no harmful environmental impact on Cape Cod Canal.

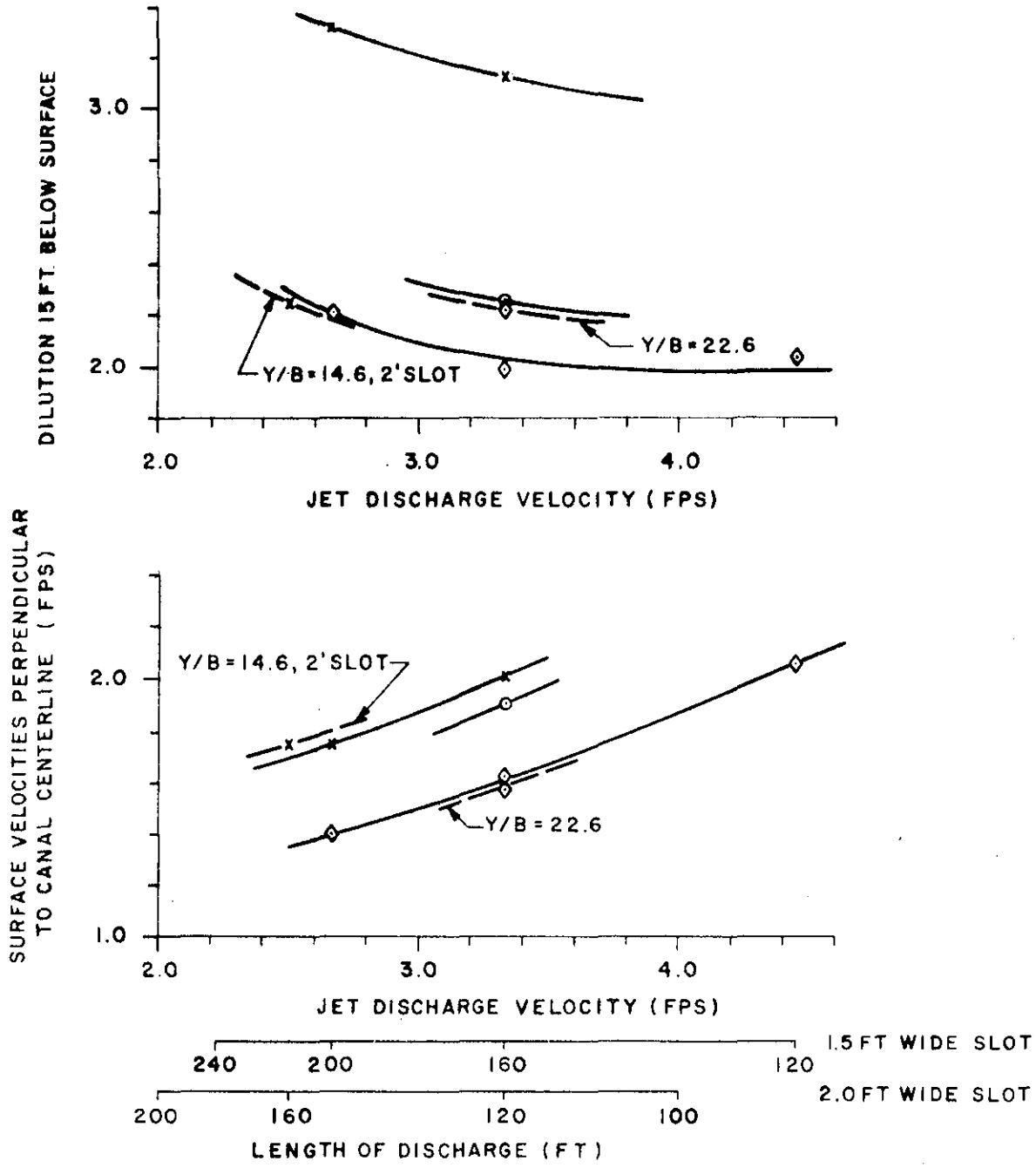
The most frequent discharges will consist of neutralized spent acid and caustic wastes resulting from intermittent regeneration of make-up and condensate polisher demineralizers. These wastes, after neutralization, will contain approximately 12,500 ppm of dissolved solids, mainly sodium sulfate, and will be mixed with circulating water from the Cape Cod Canal, containing approximately 32,000 ppm of dissolved solids. Neutralized effluents resulting from demineralizer regeneration processes will slightly decrease dissolved solids levels in the circulating water and will have no harmful effect on the Cape Cod Canal.

Comparisons of natural seawater concentrations of sodium and sulfate ions with the plant effluent are as follows:

	Sea Water ppm	Effluent ppm
Sodium	11,000	2,500
Sulfate	2,500	5,000

It should be borne in mind that the discharge volume of Units 1 and 2 combined equals about one percent of the tidal flow.

Liquid waste streams resulting from (1) equipment cleaning operations every three to four months, and (2) chemical cleaning performed once prior to start-up and occasionally as conditions require, will be treated for removal of suspended solids and neutralized prior to discharge to the Cape Cod Canal via the circulating water discharge flume. These effluents will contain only small quantities of dissolved solids, mainly sodium sulfate, and will have no harmful effect on the Cape Cod Canal.



NOTES: 1 ANGLE OF DISCHARGE α:
x α = 0° (HORIZONTAL)
⊙ 45°
◇ 90° (VERTICAL)

2. CHARACTERISTIC SUBMERGENCE Y/B = 19.5 EXCEPT WHERE NOTED
3. TESTS CONDUCTED WITH 1.5 FT. WIDE SLOT EXCEPT WHERE NOTED
4. DATA SHOWN FROM MODEL TESTS CONDUCTED AT MIT (REFERENCE 13)

FIGURE 3.2-2

MODEL TEST RESULTS FOR STAGNANT CONDITIONS

CANAL PLANT UNIT NO. 2

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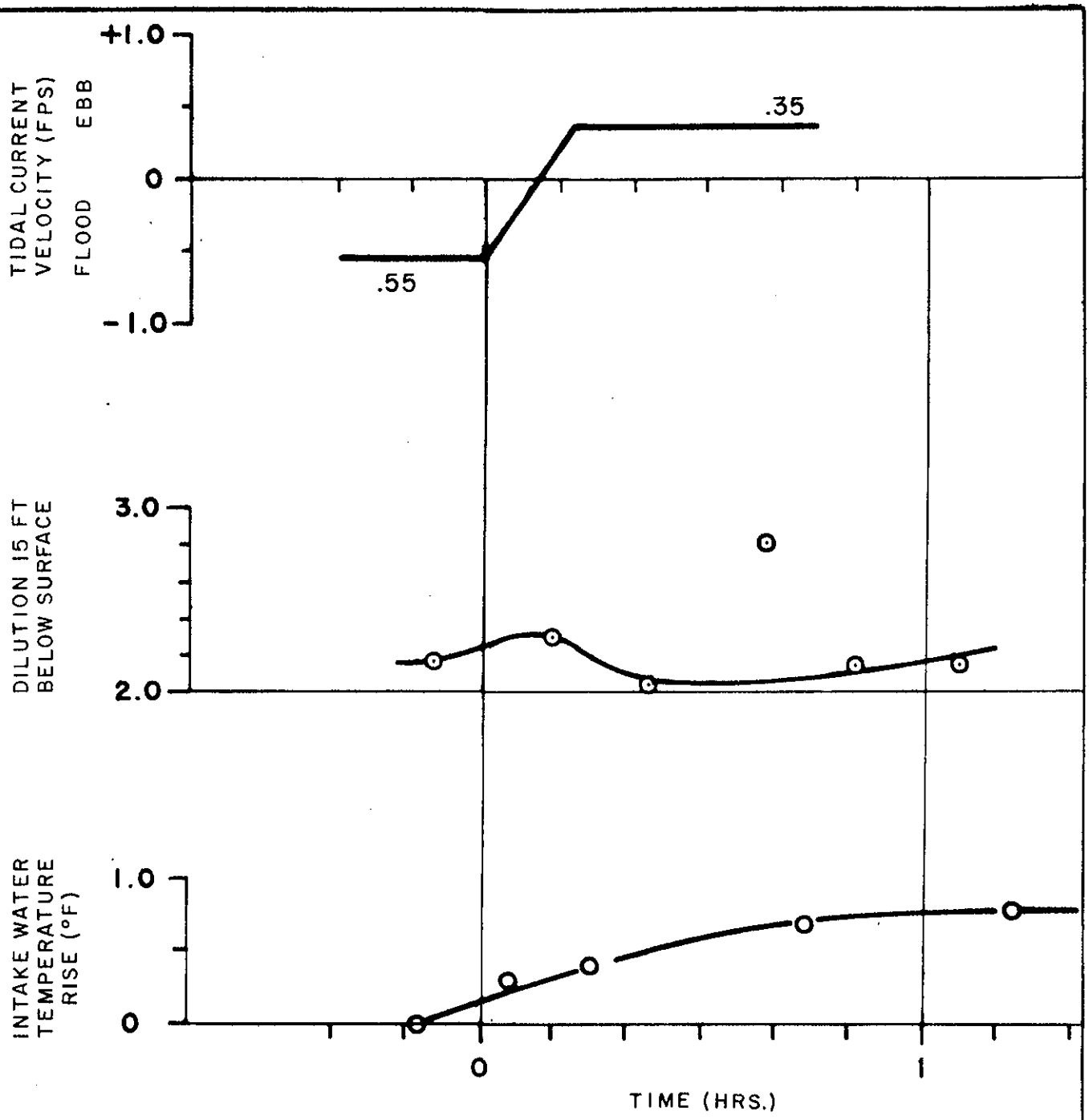

NOTES:

1. JET DISCHARGING VERTICALLY THROUGH 160' X 1.5' SLOT
2. SUBMERGENCE = 34.0 FT.
3. DATA SHOWN FROM MODEL TESTS CONDUCTED AT MIT (REFERENCE 13)

FIGURE 3.2-3

MODEL TEST RESULTS

FOR TRANSIENT TEST
SIMULATING CURRENT REVERSAL
CANAL PLANT UNIT No. 2

CANAL ELECTRIC COMPANY
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Other continuous and intermittent liquid wastes associated with normal operation of Units No. 1 and 2 will be treated and recycled in closed systems. No treated effluents other than those from demineralizer regeneration cycles and equipment cleaning described above, will be discharged to the Cape Cod Canal.

Table 3.2-2 summarizes all chemical and solid waste handling and treatment methods.

3.2.3 Water Well Effects

The Canal Plant - Unit No. 1 requires an average consumptive use of about 100 gpm of well water for boiler feedwater makeup and other normal operational purposes. Station potable water and sanitary water is provided by the Town of Sandwich. Well water requirements for Unit No. 2 will be slightly greater than for Unit No. 1.

There are presently one operating and one inoperable well at the Canal Plant. A new well, to be designated Well No. 3, is planned to supply additional water needed for Unit No. 2. The capacity of the well will be 200 gpm.

Based upon the pumping tests made during the construction of Well No. 2, it is anticipated that the construction of Well No. 3 will have no adverse effect in the aquifer beyond the station boundary. Additional pumping tests and water table level monitoring are planned during the construction of Well No. 3 to ensure that the new well will be located at the proper depth to prevent any detrimental effects to adjacent water supplies.

Station Water Requirements

Canal Plant - Unit No. 1 requires an average consumptive use of about 100 gpm of well water for boiler feed water makeup and other normal operational purposes. Station potable and sanitary water is obtained from the Town of Sandwich. The well water requirement for Unit No. 2 will be greater than that for Unit No. 1. The new water well is expected to provide approximately 300 gpm to supply the increased water needs of Unit No. 2.

Existing Well

Construction of the well presently in use to supply fresh water for the Canal Plant Unit No. 1 was begun in the summer of 1966 by E. H. Hartley of Turners Falls, Massachusetts. The well is situated just south of the Penn Central Railroad right-of-way in the plant switchyard, and is designated as Well No. 2. It was drilled to a final depth of 117-feet, with a 20-foot well screen located at the bottom. Installation of a 200-gpm capacity pump took place in the summer of 1967.

Table 3.2-2

Summary of Chemical and Solid Waste Handling

Type of Maintenance	Frequency of Maintenance	Cathartic Agent and Conc. Added	Treatment Before Discharge to Environment	Conc. of Chemical or Dissolved Solids at Discharge
Chlorination of circ. water	Summer months 5-10 min., twice daily	NaOCl	Water dilution at discharge	<0.025 ppm of residual chlorine at cooling water discharge.
Ash sluicing	Continuous	250 gpm of service water; closed sys.	Settleable solids contained in settling basin.	Periodic blowdown conveyed to waste treatment basin for heavy metal removal and final neutralization.
Boiler blowdown	Intermittent	Water resued in ash sluice system or neutralized and discharged	Settleable solids contained in settling basin.	No discharge of water.
Floor drains	Intermittent		10-20 gpm of residual water to oil-water separator. Water conserved in closed sys. for make-up service water; oil collected into 55 gal. drums.	
Periodic surface cleaning of air heaters, economizers, boiler, fireside.	2-4 time/yr, 5-10 hrs.	800 gpm of service water for air heaters, 275 gpm for economizer and fireside, 130 gpm for each of 4 precip. sec tions.	Wash water will be acidic and contained dissolved solids. After chemical treatment with NaOH, settleable and precipitated solids will be contained in settling basin. Wash water neutralized.	1,205 gpm of neutralized wash water released into discharge flume.

Type of Maintenance	Frequency of Maintenance	Cathartic Agent and Conc. Added	Treatment Before Discharge to Environment	Conc. of Chemical or Dissolved Solids at Discharge
Chem. cleaning of boiler	Ev. 3-5 yrs.	Alkaline boilout Na_3PO_4 - 0.5% wt Na_2HPO_4 - 0.01% wt Na_2SO_3 - 0.02% wt Acid Cleaning - 5% wt HCl. Neutralization NH_4OH - 1% wt; Soda ash - 1% wt Boiler Passivation Na_3PO_4 - 0.25% Na_2HPO_4 - 0.25% NaN_2 - 0.50% 5 ppm Hydrazine 0.25 ppm NH Total spent chem. sol'n and rinse - 10^6 gal.	Wash water chemically treated with NaOH, and settleable and precipitated solids contained in settling basin.	8,500 ppm of dissolved solids released into discharge flume.
Regeneration of makeup demineralizer	Ev. 2 days for 4 hrs.	NaOH - 3% by wt H_2SO_4 - 3% by wt +15,000 gal. of service water	Spent acid and caustic sol'ns conveyed to neutralization tank and released into discharge flume.	9,000 ppm of dissolved solids (Na^+, SO_4^{-2}) at cooling water discharge.
Regeneration of polisher condensate	Once daily, 4 hrs.	NaOH - 3% H_2SO_4 - 8% + 20,000 gal. of service water.	Water neutralized and released into discharge flume	12,500 ppm dissolved solids (Na^+, SO_4^{-2})

Pumping Tests

Pumping tests were made by the well driller to determine the capacity and water quality of the well. Pumping from Well No. 2 began on August 31, 1966 and continued for 26 hours at a capacity of about 339 gpm. Drawdown was measured in this well and also in a 60-foot deep observation well about 100 feet to the west, designated as Well No. 1.

The pumping tests indicated that a large supply of good quality water was available at this location. After about three hours of pumping, the water level reached the equilibrium in Well No. 2 and remained at this level for the duration of the 26-hour test. After completion of pumping, this recovery was rapid, with the water level in the well returning to its original level within three hours. The water level in the observation well dropped less than 1 foot during the test, indicating that pumping produced only slight effect on the water table in the upper 60-foot stratum.

The static level in Well No. 2 was over 5 feet higher than Well No. 1 at the beginning of the pumping test, indicating the possibility that Well No. 2 was located in an artesian aquifer. This conclusion is supported by a marked difference in the water analysis for the two wells and by the well driller's log, which indicated sandy clay and hardpan in the bottom third of Well No. 1.

Water Quality - Well No. 2

Complete chemical and bacteriological analyses of the water from Well No. 2 were made in 1966 after the well was drilled. The analyses showed the water to be high quality, with a somewhat lower mineral content than the town water supply. Water with a low mineral content is desirable for economic boiler feed water makeup and treatment. Since the well went into operation, the Canal Electric Company has made a partial analysis of the water from time to time, and complete analyses were made in August 1968 and April 1971. These tests show that the initial high water quality has continued to the present time.

New Well

A new well, to be designated Well No. 3, is planned to supply the additional water needed for Unit No. 2. The capacity of the new well will be approximately 300 gpm. It is expected that water will be drawn from the same aquifer as Well No. 1, which is located at a depth of 100 feet or more below the surface.

Effect of Canal Plant Wells on Ground Water Levels

The pumping tests made during the construction of Well No. 2 were analyzed to estimate the drawdown effect on the water table in

the area. Based on measurements made in Well No. 1 during the pumping tests of Well No. 2, no significant effect is to be expected on the ground water level in the aquifer consisting of the top 60-feet below ground level. Based on the drawdown in Well No. 2 during the pumping tests, it is calculated that the distance to the point where no drawdown will occur as a result of average plant pumping will be about 500 feet. This indicated that there will be no significant effect beyond the station boundary in the aquifer which will be pumped.

3.3 NOISE

The noise criterion for the Canal Plant with Unit No. 2 added was selected to be that of nondegradation, that is, the total sound levels in the vicinity of the expanded plant will be no higher than, and perhaps lower than, the present sound levels shown in Table 2.5-1.

The sound control on Unit No. 1 consists of solid concrete block forced draft fan rooms and large inlet silencers. The autotransformer No. 1 to the south of the plant has a sound barrier wall shielding the nearby motel.

With the addition of Unit No. 2, nondegradation will be achieved by adding further noise control to both Units No. 1 and No. 2. Unit No. 1 will have an extension added to the sound barrier wall on autotransformer No. 1. Tests on the forced draft fan inlet of Unit No. 1 to determine the most effective way of further reducing this sound source resulted in construction of louvers that attained sound level reduction of 10 to 15 dB.

Unit No. 2 noise control will be achieved with several techniques. The main power transformer on the north side will be purchased with 5 to 10 dB noise reduction. The forced draft fans will again be put in concrete fan rooms, and the forced draft fan intakes will be attenuated with large silencers. The induced draft fans located outside of the main building on the south side of the station will be enclosed in sound attenuating rooms. Autotransformer No. 2 will have a 3-sided acoustic block barrier wall plus an additional 5-dB attenuation built in.

With the additional noise control engineering going into both Units No. 1 and No. 2, it is anticipated that there will be no increase in the sound levels for the station, and it is anticipated that there may be an actual decrease in the sound levels in the area.

3.4 ELECTROMAGNETIC INTERFERENCE

Since the Canal Plant began operations in 1968, periodic complaints have been made of television interference. These complaints have been and will continue to be investigated.

Causes of electromagnetic interference in radio and television reception include loose or broken leads from the homeowner's antenna, the receiver's amplifier system, and electric transmission and distribution line imperfections, such as cracked insulators and loose tie wires. The investigation of complaints has shown that Canal Plant's operation has been the cause of some interference; other complaints have been completely unrelated to plant operation.

The problems related to the Canal Plant fall into the broad categories of disruptive voltage gradients, which are commonly referred to as "corona discharge", and sparking due to unsatisfactory contact between metal parts of adjacent insulator units in suspension strings. To eliminate these problems, corona rings have been installed, the conductors have been polished with emery cloth to remove sharp points or burrs, and bonding straps between insulator units have been installed.

Sanders Associates, Inc. of Nashua, New Hampshire, was retained to perform field intensity measurements and sources of corona discharge in investigating complaints. A rebuilding of part of the 345-kV switchyard that had been causing some interference was completed July 1, 1972. It is believed that this work has corrected the situation since only one complaint of television interference was received from July 1972 to May 1973; the particular tv set was far from the transmission line and the interference was more probably caused by amateur radio operations.

3.5 EFFECTS OF PLANT OPERATION ON MARINE ECOLOGY OF CAPE COD CANAL

The information from the various ecological studies as described in Appendix No.1 was used to formulate conceptual plans for the modification of Canal Plant Unit No. 1 and the design of Unit No. 2 to minimize the effects of plant operation on the marine environment of Cape Cod Canal. This section discusses the ecological considerations related to the effects of the thermal and chemical effluents on the biota of the Canal and to the potential entrapment of fish in the circulating water system.

3.5.1 Effects of the Effluent on the Receiving Waters

The circulating water discharged to the Canal will carry the waste heat from the condensers as well as various chemicals from the operation of Units No. 1 and No. 2. The details of the circulating water system and liquid waste handling systems are discussed in Sections 1.2 and 3.2.

A submerged multiport discharge will be employed to dilute the condenser cooling water flow for both units in the Canal. The Massachusetts Division of Marine Fisheries field studies described in Appendix No.1 indicated that the heaviest concentrations of pelagic fishes (primarily clupeids and silversides) were generally found in the upper 15 feet of the water column and that thermal tolerance studies on these species suggest that exposure to temperatures above 86 F may be lethal. The discharge was, therefore, designed so that temperatures in the Canal will never exceed 86 F within the upper 15 feet of the water column. Temperatures approaching 86 F will only occur for brief periods in July or August, twice each day during high slack water. The temperatures at the surface will be lower than at the 15-foot depth contour and will generally average only a few degrees above ambient intake temperatures. Benthic species should not be affected, since the thermal plume will not be in contact with the bottom in the vicinity of the discharge.

The heated discharge is not expected to adversely affect the present sport fishery in the Canal. Creel census investigations conducted prior to and following the operation of Unit No. 1 indicated that the sport fishery was unaffected by station operation.

Utilizing catch per unit effort statistics as a basis for analysis, the availability of sport species to the angler was determined both prior to and following plant start-up. The availability of pollock and winter flounder remained the same throughout each year. The catches of cod decreased while the catches of tautog and mackerel increased markedly. The declining catches in cod were offset by the increased tautog exploitation, so that bottom fishing catch/effort remained the same throughout

the study. The increased catches of Atlantic mackerel are significant in that this species was not repelled by the elevated temperatures after plant start-up.

As discussed in Section 2.9 and in Appendix No.1, eight species of fish, namely the Atlantic cod, tautog, cunner, Atlantic mackerel, winter flounder, squirrel hake, fourbeard rockling, and sand lance, comprised the majority of eggs and larvae collected in the Canal. Only the cod, tautog, mackerel, and flounder are of direct sport or commercial significance. Considering the fecundity of these species and their widespread distribution in the area, the losses of eggs and larvae which may result from passage through each unit are deemed negligible (See Appendix No. 1).

It is recognized that sudden plant shutdowns during the colder months may stress fish which are acclimated to warmer temperatures (Ref. 20). As discussed in Section 2.2 and in Appendix No.1, water temperatures in the Canal fluctuate naturally as much as 20 F over a tidal cycle due to the differences in water temperature between Buzzards Bay and Cape Cod Bay. It should also be noted that due to the hydrodynamics of the Canal the thermal plume is continually shifting with the changing tides. For these reasons, it is believed that the aquatic biota are adapted to conditions of rapidly changing temperatures. The combined diffuser system for both units decreases the chance of subjecting fish to rapidly decreasing temperatures in that it would be very unusual for both units to be shut down simultaneously. If both units were to shut down simultaneously, it is probable that any fish acclimated to higher than ambient temperatures would follow the dissipating plume to minimize thermal stress.

When a scheduled plant shutdown occurs, thermal stresses are minimized by continuing the operation of the circulating water system. This allows a gradual reduction in the temperature of the discharge.

When Unit No. 2 is placed on-line in 1975, two generating units of equal size will be operational at Canal Plant. Depending upon New England Power Exchange requirements, each of these units will be taken off-line separately for four to six weeks once a year for maintenance and repair. When one unit is taken off-line, the other unit will remain in service. The unit is taken off-line according to the following schedule: First, the unit's load is reduced from 100 percent to 0 percent over a period of three hours. Second, the circulating water pumps are kept on-line for approximately 12 hours more to gradually cool equipment and avoid thermal stress on the machinery. The cooling period required to bring a unit off-line is approximately 15 hours. Meanwhile, the other unit remains on-line to further minimize thermal shock to fish resident in the plume. When one unit is fully off-line, the plume of the remaining unit is still present.

Of course, unexpected pump trip-outs caused by accident or equipment failure cannot be accounted for in engineering design for bringing units off-line. The possibility of all four circulating water pumps failing simultaneously is remote and would cause equipment problems as well as damage to biota resident in the thermal plume.

The benthic studies conducted prior to and following Unit No. 1 operation indicated that, except for the immediate vicinity of the discharge flume, only minor changes in the benthic biota could be attributed to increased water temperatures resulting from Unit No. 1 operation. These changes included the establishment of the green alga (Codium fragile) along the shallower regions in the vicinity of the plant. An increase in borer activity (Teredinedae) was also noted in the vicinity of the warmer discharge temperatures. Natural fluctuations in the abundance of the dominant benthic flora sea lettuce (Ulva lactuca) and kelp (Laminaria saccharina) and invertebrates, including blue mussel (Mytilus edulis) and hydroids (Tubularia crocea), were decidedly more apparent than were changes in the biota due to plant operation.

Following the addition of a common diffuser for both Units No. 1 and No. 2 there is expected to be no additional impact on the benthic communities of the Canal. The thermal plume is discharged in a vertical direction and will not come in direct contact with the bottom in the vicinity of the discharge. As a result of the diffuser design and rapid mixing conditions within the Canal, the temperature of the plume will be within a few degrees of ambient when in contact with the benthic communities along the sides of the Canal.

The maximum temperature rise of the plume will be approximately 6 to 8 F when it reaches the southern bank of the Canal. It consists of a warm surface layer 15 feet in depth. When this plume contacts the canal bank, the contact area which will exceed 6 F would be less than 1/6 acre. When the plume reaches the northern bank of the Canal, the temperature would be approximately 2 or 3 F above the natural ambient.

As previously discussed in Section 3.2.2, liquid wastes will be treated prior to release so as to conform to the standards proposed by the Massachusetts Division of Water Pollution Control for Class SA waters. As such, there is expected to be no adverse affect on the biota of the Canal from these releases.

During the initial stages of Unit No. 1 operation, the periodic treatment of the circulating water system with sodium hypochlorite to control biofouling appeared to cause some mortality of juvenile menhaden in the vicinity of the discharge flume during a few treatment cycles. Bioassays were conducted on juvenile menhaden at different chlorine residuals and confirmed the high toxicity of chlorine to this species. The State,

therefore, recommended that free residual chlorine at the point of discharge be maintained at levels below 0.1 ppm. Chlorination is not required during winter when water temperatures are low.

During late spring, summer, and early autumn, chlorination of the circulating water will occur for short periods only, five to ten minutes twice daily. The residual chlorine concentration at the discharge of the condenser will be maintained at levels below 0.1 ppm. However, considerable dilution will occur since each condenser half will be treated separately and chlorination of each unit will be conducted at different times so that the low residual from one unit will be diluted by the unchlorinated flow from the second unit. Consequently, residual chlorine levels at the point of discharge into Cape Cod Canal will be less than 0.025 ppm when all four circulating water pumps are operating. Based on these considerations, chlorination as a means of biofouling control is not expected to adversely affect the biota of Cape Cod Canal.

3.5.1.1 Effects of Entrainment of Plankton

It is anticipated that the entrainment of plankton through Units No. 1 and No. 2 will have no significant impact on the ecology of the area.

The two units combined will circulate about 800 cfs which is about 1.1 percent of the mean flow past the site at ebb tide (approximately 74,000 cfs) and 0.9 percent of the mean flood tide flow (approximately 90,000 cfs). Most of the phytoplankton and zooplankton present in these water masses are part of larger populations present in Cape Cod Bay and Buzzards Bay. No matter what percentage of the entrained organisms might be killed, they still represent only a minute fraction of the total populations of these organisms in the area. Furthermore, coastal species of phytoplankton found in the area have a rapid generation rate of about one division every two to three days. Any losses of these organisms due to entrainment could be partially or wholly restored in a relatively short time.

The fish eggs and larvae in the Canal subject to entrainment were studied by the Massachusetts Division of Marine Fisheries (see Environmental Report Appendix No.1). They collected 24 species in their field sampling. Eight of these species, Atlantic cod, tautog, cunner, Atlantic mackerel, winter flounder, squirrel hake, fourbeard rockling, and sand lance comprised 96.8 percent of the eggs and 85.7 percent of the larvae collected. Only the cod, tautog, mackerel, and winter flounder are of direct sport or commercial significance. The investigators calculated that the number of eggs and larvae circulated through the plant would approximate the egg production of less than 50 cod and winter flounder and less than 1,000 mackerel. They conclude: "Considering the fecundity and distribution of these fishes and the fact that all three are fished commercially on the spawning

ground, the comparatively small losses that may result from passage of eggs and larvae through the Canal generating station are deemed negligible." The addition of Unit No. 2 would double the above loss estimates.

3.5.1.2 The Effects of Chlorination

The effects of chlorination on certain marine biota of the Canal were studied by the Massachusetts Division of Marine Fisheries. As a result of these studies they recommended that residual chlorine levels in the discharge water be maintained at or below 0.1 ppm during the 7-minute treatment cycle.

The residual chlorine concentrations leaving the condenser will be regulated so that they do not exceed 0.1 ppm, as is presently being done for Unit No. 1. The effluent will be diluted with unchlorinated water, since only one half of each condenser will be treated at one time and chlorination of each unit will also be done at different times. Thus, the low initial residual from one condenser half will be diluted by chlorinated flow from the other three condenser halves. Consequently, residual chlorine levels at the point of discharge into Cape Cod Canal will be less than 0.025 ppm when all four circulating water pumps are operating. Considering the chlorine demand of the untreated water, the residuals at the point of discharge will be unmeasurable.

Based on these considerations, chlorination as a means of biofouling control is not expected to adversely affect the biota of the Canal.

Fish kills were recorded for August 9, 14, 22, 25, and 26, 1972. An estimated 50,000-100,000 were killed per incident, primarily young-of-the-year menhaden. All incidents occurred during a high-slack tide with a discharge temperature above 90 F. The distressed fish were completely taken up immediately by sea gulls. With the proposed limitation of maximum temperature of 86 F in the top 15 feet of the Canal water, there would be no such fish kills.

3.5.2 Entrapment of Fish in the Circulating Water System

Observations by State biologists during the ecological field surveys indicated flat fishes, primarily winter flounder, were becoming entrapped on the vertical traveling screens and eventually damaged when released to the warm water of the Unit No. 1 discharge canal.

Modifications will be incorporated into the construction of the Unit No. 2 intake for the protection of aquatic life. On the suggestion of State biologists, a 9-foot high bottom sill will be placed at the entrance of the intake flume to prevent access to the flume by benthic fishes(primarily flounder). In order to keep approach velocities low, the skimmer wall at the entrance on

Unit No. 2 intake will be set at El.-5.1 (MLW datum). This height is still below the extreme low water mark and should not attract fish to the intake along the surface. The velocity at the entrance will be 1.02 fps.

Should the installation of a fish sill in the Unit No. 2 intake prove successful, a similar sill will be considered for Unit No. 1.

A vertical traveling 3/8-inch screen will be employed in the screenwell of each unit to remove debris and fish which may be carried into the intake flumes. The screenwash sluiceway which is used to carry the debris from the screens will be discharged to the existing discharge flume for Unit No. 1. Because temperatures in this area are about the same as intake temperatures, any fish carried onto the traveling screens will not be subjected to sudden temperature increases before being returned to the receiving waters.

3.6 TERRESTRIAL ECOLOGY

The principal impact on the terrestrial ecology of the area will be due to construction activities. These effects are discussed in Section 3.9. As previously described in Section 3.1, careful consideration has been taken in the design of the proposed station to maintain air quality levels which will comply with the Federal and Massachusetts air quality standards. These standards have been adopted to prevent the occurrence of conditions of air pollution which is defined by the Massachusetts Department of Public Health (Ref. 21) as "the presence in the ambient air space of one or more air contaminants, or combinations thereof, in such concentrations and of such duration as to: a) cause a nuisance; b) be injurious, or be on the basis of current information potentially injurious to human or animal life, to vegetation, or to property; or c) unreasonably interfere with the comfortable enjoyment of life and property, or the conduct of business." On the basis that ground level concentrations of potential air contaminants resulting from two units operating with a 498-foot stack, one percent sulfur fuel, and electrostatic precipitators will be below the air quality standards, it is anticipated that station operation will have no adverse impact on the terrestrial ecology of the surrounding region. Actions to reduce noise levels as described in Sections 1.2.3.6, 2.5, and 3.3 indicate that there will be no increase in noise levels and that past noise levels will be reduced.

3.7 LAND USE COMPATIBILITY

Consideration of the Canal Plant site in Sandwich must acknowledge the presence of Canal Plant-Unit No. 1. Because the site has already been dedicated to power generation, Canal Plant-Unit No. 2 can be considered compatible with existing uses of the land.

The granting of a petition to the Commonwealth of Massachusetts Department of Public Utilities for variance from Town of Sandwich zoning regulations further defines the compatibility of locating Canal Plant Unit No. 2 at this site.

3.7.1 Population

The design of Canal Plant-Unit No. 2 incorporates certain features to minimize impact on the surrounding population. Among these features will be landscaping to minimize the aesthetic effect on the surrounding area. Noise abatement devices discussed in Section 3.3 will help minimize the sound levels associated with the plant operation.

3.7.2 Industry and Recreation

The addition of Unit No. 2 is expected to help the construction industry in Sandwich by decreasing the tax burden on residential property and thereby relieving tax burdens on the populace. The effect of this decrease in tax rates will help to attract home owners to the area.

Population growth in Sandwich will have a beneficial effect on consumer-related industry, such as retail stores and other service-related businesses.

3.7.3 Aesthetics

The profile of Canal Plant Unit No. 1 stands out against the sea-level Canal and shoreline as a functional irregularity in the landscape, but the effects made to render it as architecturally pleasing as possible are believed to be reasonably successful. Unit No. 2 will affect the present situation only as an enlargement of that irregularity. The new 498-foot stack of the enlarged station cannot be camouflaged and will be visible from a distance. However, none of the historic sites in the vicinity (Section 2.6.5) are near enough to the plant to suffer aesthetically from the contrast of either Unit No. 1 or the enlarged plant.

Landscaping where possible will be carried out at the plant perimeter to render the plant boundaries more pleasing to neighbors and passing motorists.

3.8 WATER USE COMPATIBILITY

3.8.1 Industry and Recreation

Industrial development along the shoreline of Cape Cod Canal is scarce. The Canal is owned by the Federal Government and is maintained by the United States Army Corps of Engineers for navigational purposes as shown in Table 2.7-1 which lists gross tonnage and ship passages for recent years. The use of Cape Cod Canal water for station purposes will not conflict with canal operation.

There do not appear to be any commercial fisheries on the canal. Commercial fishing boats do, however, dock at the East Boat Basin, as mentioned in Section 2.7.1, to unload catches. The addition of a second generating unit at the Canal Plant site should not present any incompatibility with this industry.

Although there are some commercial boat marinas in the East Boat Basin, other commercial developments catering to recreational boating aspects of the canal appear to be limited.

The use of Cape Cod Canal shoreline and water does not appear to be incompatible with its present uses.

Cape Cod Canal is used for recreation by residents and visitors to Cape Cod as described in Section 2.7.2. Sport fishery, boating and swimming appear to be the dominant water-related recreational activities in the Canal. There does not appear to be any conflict arising from production of electricity at the Canal Plant with these recreational activities. The discharge of coolant waters will not create currents sufficient to affect recreational boating in the Canal. Sport fisheries do not appear to be influenced by present plant operations according to an assessment by the Massachusetts Department of Natural Resources, Division of Marine Fisheries (Appendix No. 1). No deleterious effects on sport fisheries are expected with the expanded plant.

3.8.2 Aesthetics

In the context of the existing Canal Plant - Unit No. 1, the addition of Unit No. 2 will not represent a significant departure from the present shoreline of Cape Cod Canal as seen from the water. The present stack is used by mariners as a landfall feature marking the east entrance to the canal. By establishing gross navigational fixes with this sighting, the navigator can then use the range lights at the United States Coast Guard station at the Canal Plant site to effect safe entry into the canal. The higher stack to be constructed at this site will be of even greater benefit to mariners in this use, enabling an earlier sighting of the Cape Cod Canal entrance.

3.9 ENVIRONMENTAL IMPACT OF CONSTRUCTION

The environmental impact of construction can be classified under two main headings: (1) Noise from construction operations and (2) Visual effects of construction operations. There are also several side effects which will also be considered but these are all relatively minor items which do not present any major problems.

Work will be normally scheduled on an eight hour per day, five-day week basis. This should confine most "nuisances" to daylight hours Monday through Friday. Weekend construction activity will not be scheduled unless absolutely necessary.

3.9.1 Noise

The following precautions will be observed to minimize disturbing local residents by construction noise.

All gasoline- or diesel-powered equipment will have legally required mufflers; this includes pumps, welding machines, etc., as well as automobiles, pickups and trucks.

When feasible a vibratory type hammer will be used in pile driving to reduce noise although this system is not completely quiet. Most of the pile driving will be located on the north side of the plant adjacent to the Canal. This should reduce the noise level at the residential southerly side of the unit.

Little can be done to reduce noise during structure erection. However, the building siding will be installed at the earliest opportunity. All mechanical and electrical work will take place inside the building, thus reducing the noise levels at the property line.

Advance notice published in the local papers will be given of steam line blowout. Development of a muffler for this type of operation is being investigated.

3.9.2 Visual Effects

The excavation stage is naturally unattractive. However, this is only temporary and material removed from the excavation will be used for landscaping the plant area so that the final appearance of the unit will be as inconspicuous as possible.

Roads outside of the plant will be kept free of construction debris. During excavation it is inevitable that some soil will be carried out by the truck wheels. This will be cleaned up by washing and scraping as often as necessary.

The in-plant roads will be watered during dry periods to prevent construction traffic from causing a dust problem.

All materials stored outside will be laid out as neatly as possible to present a reasonable appearance from the road.

3.9.3 Miscellaneous Construction Related Impact

Atmospheric pollution from construction equipment will be a factor as will the increased number of motor vehicles using the area. This is not expected to be any problem.

All of the land area required for the new unit, including the switchyard extension, was cleared during construction of Unit No. 1. However, an area about 200 feet by 600 feet will have to be cleared and graded for construction of two additional oil storage tanks.

The dry soil produced by excavation for foundations, pipelines, intake, and discharge structures, etc. will be used on site for landscaping purposes. Excess dry soil produced by excavation will be disposed of on land under the transmission line right-of-way. This fill will be accomplished with the consent of cognizant State agencies regulating fill in inland waters. Approximately 2 acres of swampy land will be filled in this manner.

The wet soil from construction of the intake and discharge structures will be disposed of on land in a manner that will have no adverse impact on the disposal area. Of the approximately 12,000 cu yd produced, about 8,000 cu yd will be used as backfill. It is intended that the Contractor, in consultation with Canal Electric Company and Montaup Electric Company, Stone & Webster Engineering Corporation, and the appropriate officials in the Town of Sandwich, will determine a suitable area where the remaining 4,000 cu yd can be placed.

The impact of these activities on the marine ecology of the area is also expected to be minimal. The principal effects of dredging sections of the intake and discharge systems will be the temporary disruption of the natural ecological conditions of the bottom areas actually being dredged. It is expected that after the operations are completed, the affected area will be recolonized by benthic organisms from adjacent unaffected areas. This phase of construction calls for safeguards to be taken during dredging (by use of a clamshell dredge and deposit of dredged material on land) to provide protection against sediments being washed into neighboring areas and altering the benthic habitats there.

SECTION IV

UNAVOIDABLE ADVERSE ENVIRONMENTAL EFFECTS

SECTION IV

UNAVOIDABLE ADVERSE ENVIRONMENTAL EFFECTS

In considering the scenic aspect of Cape Cod, the construction of a higher stack at the Canal Plant may be deemed an adverse effect. However, in the context of air quality enhancement, the stack becomes a necessary feature of the proposed action.

The Canal Plant will add relatively small quantities of air contaminants to the ambient air, as described in Section 3.1. The resulting ambient concentrations of contaminant are expected to be well below those levels considered harmful by Federal and State standards. In fact, these levels are expected to be lower than those existing now.

Circulating water systems employing the once-through process will unavoidably entrain planktonic organisms. This effect is discussed in Section 3.5 and is expected to be minimal. Care has been exercised in the design of these systems to prevent possible harm to pelagic and benthic fish. These actions have been accomplished in agreement with the recommendations of the Commonwealth of Massachusetts Department of Natural Resources (Section 3.2). It is not expected that this proposed action will have any major adverse effect on fish found in Cape Cod Canal.

Chlorination is not expected to have an adverse effect on the receiving waters, but it is expected to contribute to the mortalities of planktonic organisms entrained through the condensers. Thermal stresses will also cause entrainment mortalities. However, as discussed in Section 3.5.1.1, the impact of entrainment on the ecology of the area is believed to be minimal.

The maximum sound level expected from Units No. 1 and No. 2 operated at full load is 49 dBA at the east, south, and west property lines and 70 dBA at the north property line. This is not expected to be any increase from present noise levels.

SECTION V

ALTERNATIVES TO PROPOSED ACTION

SECTION V

ALTERNATIVES TO PROPOSED ACTION

5.1 NO ACTION

The alternative of no action on this proposed addition to the Canal Plant does not offer a viable solution to the increasing New England power demand. Figure 5.1-1 is a projection of the annual peak load demand and generating capability of the New England Gas and Electric System from 1966 through 1980. The cross-hatched section on the histogram denotes the reserve on-line capability of all generators and purchase power sources available to the New England Gas and Electric System. Figure 5.1-2 is a projection of the Montaup System with an indication of generating capability and expected maximum demand. Figures 5.1-1 and 5.1-2 both include the addition of Canal Plant - Unit No. 2 in the total generating capability. Canal Electric Company and Montaup Electric Company will share equally the generating capability at Canal Plant. Even with the inclusion of the additional 560 MW Unit No. 2 capability, some difficulty is expected in maintaining the power generating reserve over the peak load demand recommended by the New England Power Exchange (NEPEX). The denial of an additional facility at Canal Plant without alternative solutions offered will create a potential for critical power shortages within ten years.

The projected peak load and annual generating capability for the entire New England area are shown in Figure 5.1-3. The NEPEX planning committee, who prepared Figure 5.1-3 on peak load in New England, suggests a reserve of 20 percent in 1971 to a reserve of 22 percent in 1980. If no action is initiated, the percent reserve capability of all New England generating systems to accommodate plant maintenance and repair will be markedly limited. In Figure 5.1-4 the percent reserve generating capability for the entire New England area is shown with and without the addition of Canal Plant - Unit No. 2. The effect of no action on this proposed addition is seen on this graph.

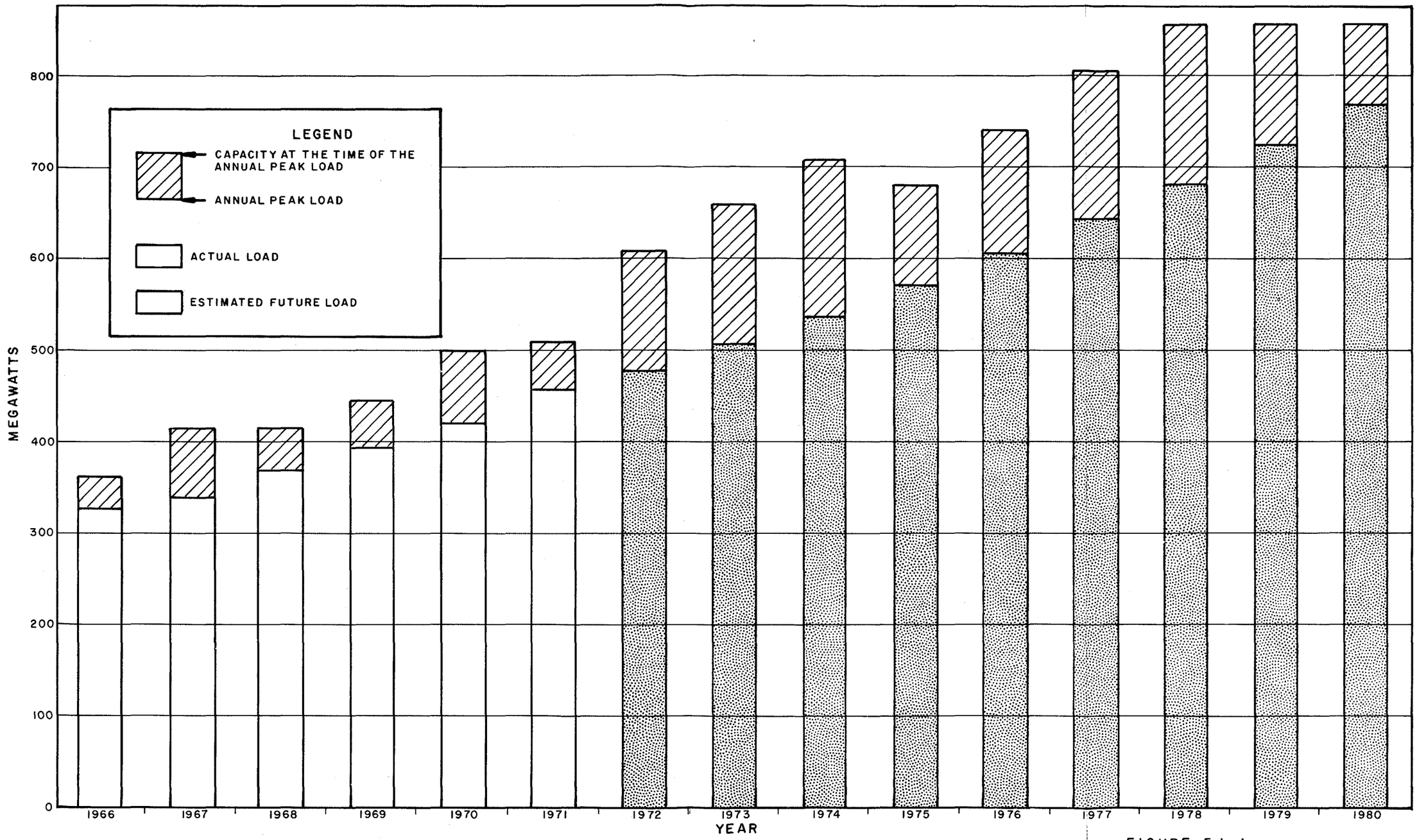

FIGURE 5.1-1

NEW ENGLAND GAS & ELECTRIC SYSTEM
ANNUAL CAPABILITY AND PEAK LOADS
1966 – 1980

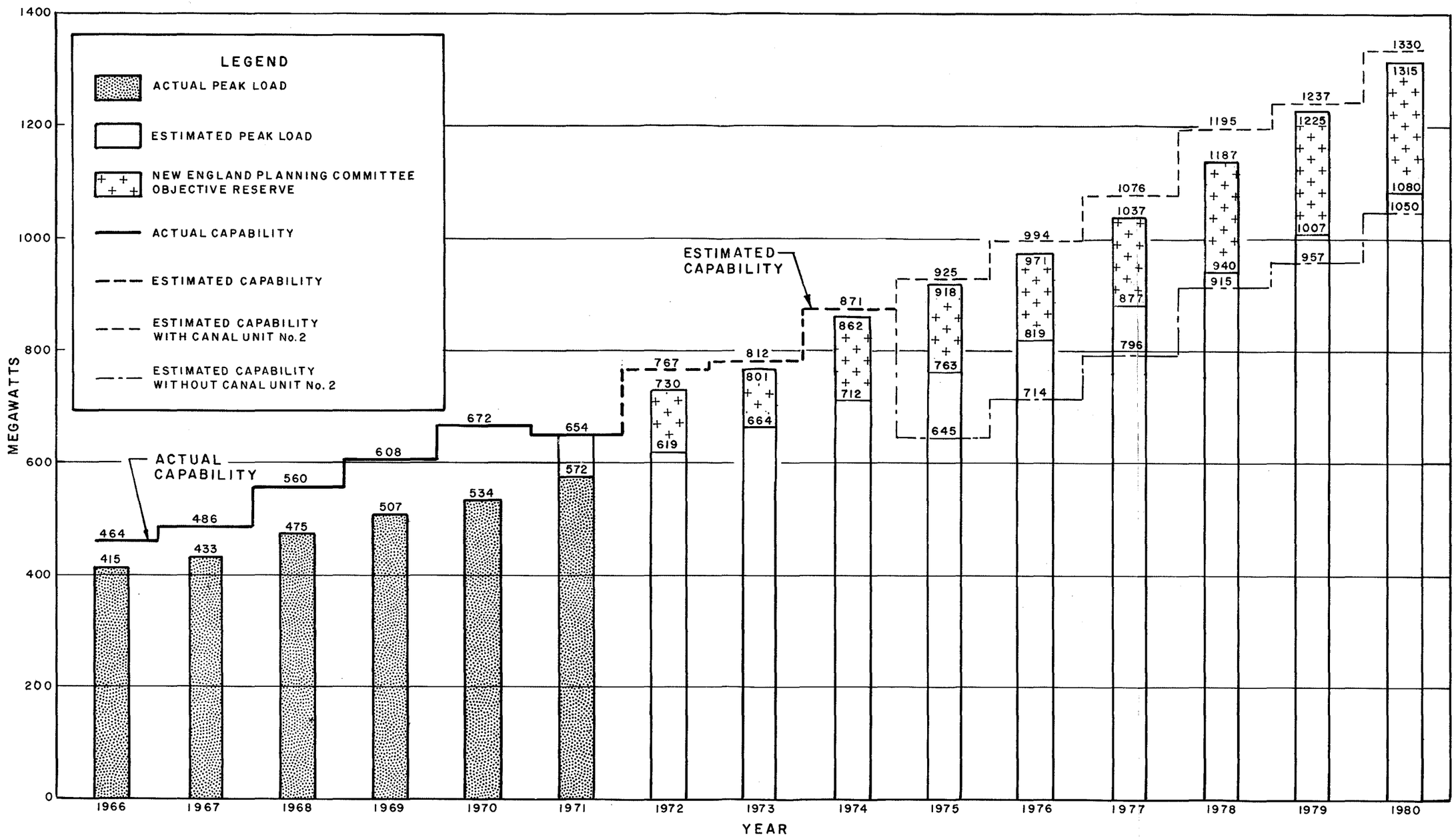

FIGURE 5.1-2
ACTUAL AND ESTIMATED PEAK LOAD
AND CAPABILITY OF MONTAUP SYSTEM
1966 - 1980

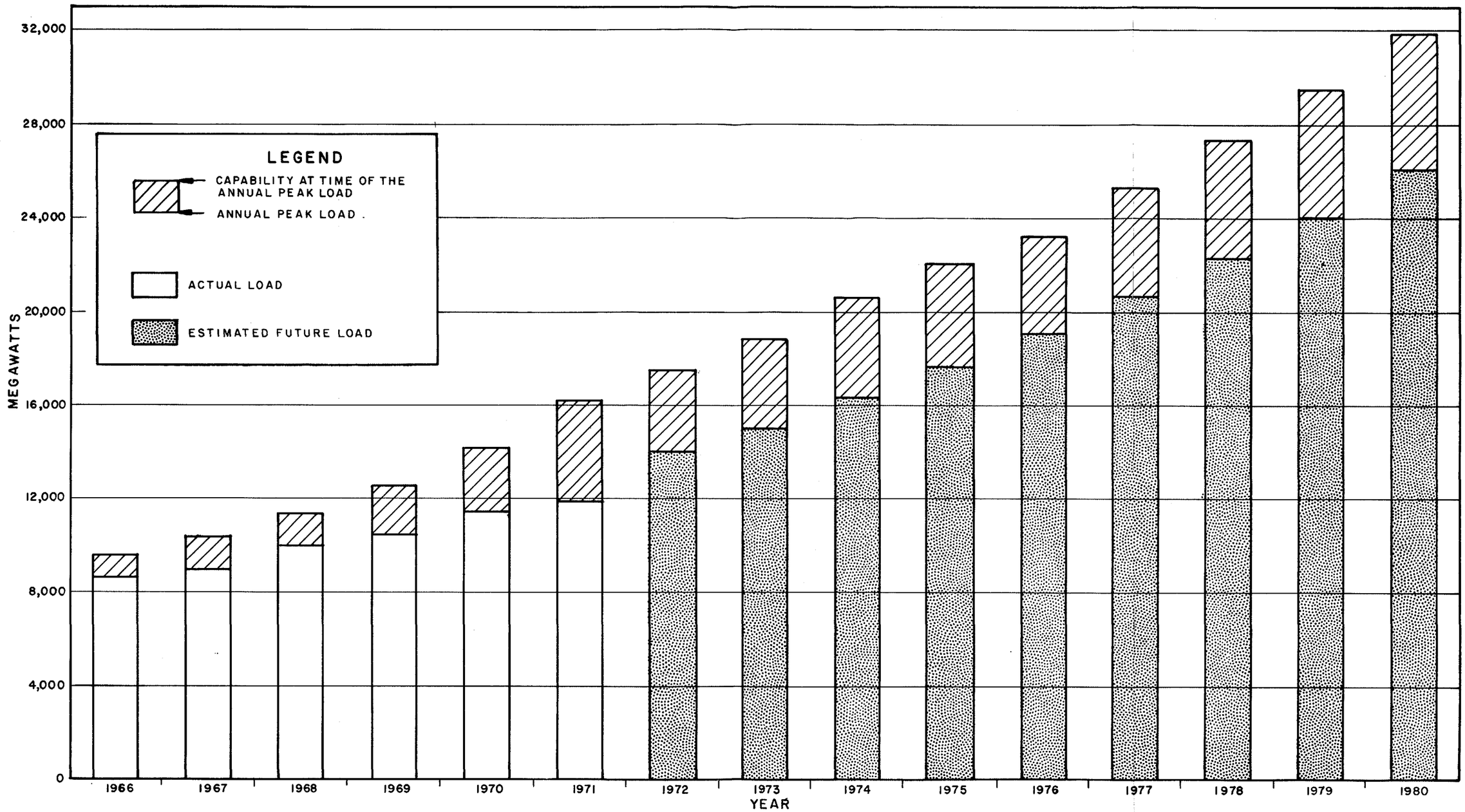

FIGURE 5.1-3
NEW ENGLAND AREA
ANNUAL CAPABILITY AND PEAK LOADS
1966 – 1980

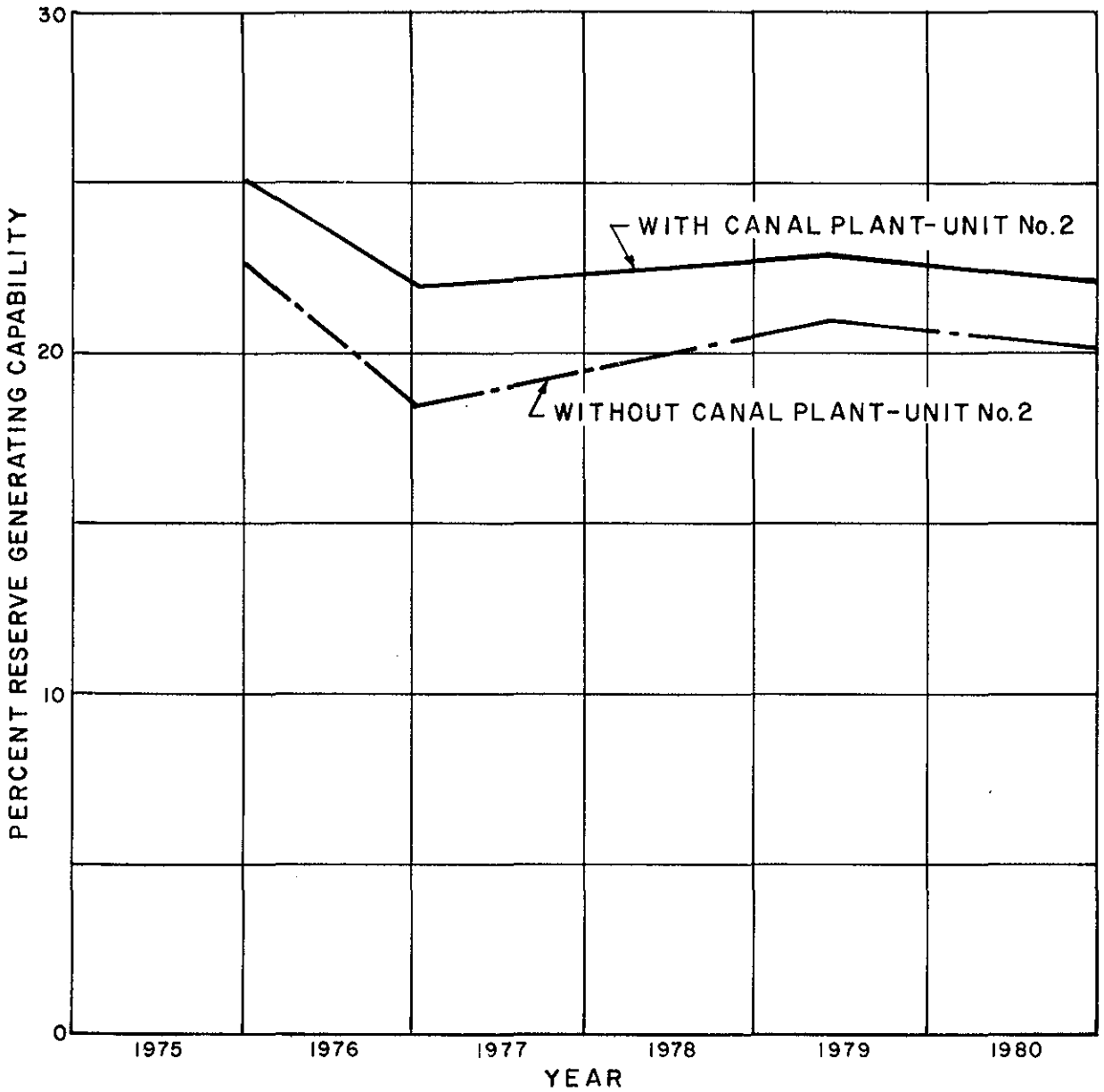

FIGURE 5.1-4

PERCENT RESERVE CAPABILITY FOR ENTIRE NEW ENGLAND AREA

CANAL PLANT UNIT No.2

CANAL ELECTRIC COMPANY

MONTAUP ELECTRIC COMPANY

5.2 PURCHASE POWER DEMAND

The possibility of purchasing power from sources outside of the New England area does not appear to be realistic. This conclusion is made in consideration of the projected generating capacity shortages of adjacent power pools. Both the New York Power Pool and the Pennsylvania-Jersey-Maryland Interconnection would not be able to provide extensive support of generating shortages in New England.

Canadian power sources available for use by American utilities in the Northeast would normally be from Hydro-Quebec or Ontario Hydro. The source of this energy would be hydroelectric stations. The principal requirement of this energy would be, as now, the electric demand of Quebec and Ontario. A limited amount of power from New Brunswick is presently being utilized in New England.

The purchase of some additional power in the immediate future appears to be possible. However, the long-term availability of this power is questionable. Exportation of energy to the United States would be a result of surplus available after Canadian needs are met. Because of the growth of urban areas in the eastern region of Canada, this source of power cannot be regarded as a reliable long-term source. Any purchased power to meet New England power needs must consider the long-term reliability of the source.

5.3 ALTERNATIVE SITES

Alternative sites must be considered with certain criteria in mind. Importance is placed on the availability of cooling water for unit condensers, availability of fuel oil, and availability of transmission systems. The proposed facility will augment presently available generating capacity at the site.

The Canal Plant location was selected as the most advantageous site because of three factors. First, the waters of Cape Cod Canal provide a more than ample source of cooling water for station condensers. Second, the existing fueling station at the New England Gas and Electric Association (NEGEA) basin can be used to provide the expanded plant with adequate fuel supply. This is especially advantageous since the Canal is readily approached and entered from deep water throughout the year. Finally, the existing 345-kV and 115-kV transmission lines to the New England Transmission System allow quick and efficient connection to the entire network.

In addition to satisfying the above criteria, several other considerations favor the Canal Plant site. The addition, Canal Plant – Unit No. 2, will be sited on land already occupied by an existing power plant of the same capacity and type. The shoreline of the site is man-made with banks of riprap in the intertidal zone. It is believed these factors must be acknowledged in considering the desirability of the chosen site. On a site less affected by man-made changes, ecological disruption of terrestrial and aquatic communities may be more pronounced.

The advantages of common systems for both Units No. 1 and No. 2 must also be noted.

5.4 ALTERNATIVE FUELS

The selection of a fuel for the Canal plant has taken into account present and future supply and price, potential security of the source, environmental impact resulting from the production, upgrading transportation and utilization of fuel, and efficiency of utilization with regard to conservation of energy resources. The following paragraphs discuss the alternative power generation means using gas, light oils, or coal as fuels.

5.4.1 Gas

Natural gas is the preferred fossil fuel from an environmental standpoint for many applications including the production of electricity. The supplies of domestic natural gas, however, are insufficient to fulfill all energy needs. The result is that reserves have been trimmed to a very low level and industrial users are finding it increasingly difficult, if not impossible, to purchase gas over long-term contracts. It is environmentally advantageous to conserve natural gas for premium end use, such as residential and commercial markets, where there is a need for elimination of low-level pollutant emissions.

Synthetic natural gas, liquefied natural gas, and Canadian natural gas will all supplement domestic natural gas supplies, but at this point it is unrealistic to expect that the total gas supply will increase to the extent that industrial use would be permitted from an economic and energy conservation standpoint over the next decade. For the longer term, it seems almost unavoidable that gas produced from coal will be a major component in the total energy supply picture, but in view of the fact that the first commercial coal gasification plant in the United States is yet to be built, this type of fuel can be considered as only a possible fuel for future conversion and power plant construction. Canal Electric Company is unable to obtain present or future contracts for sufficient natural or synthetic gas to supply the proposed unit at this time.

5.4.2 Other Oils

Alternatives to heavy residual low sulfur oil was considered in the light of national energy use and supply. The use of low sulfur crude oil or low sulfur topped crude would provide no environmental advantage over residual oil with regard to production, transportation, and utilization, but substantial use of crude would lessen environmental effects of refining and upgrading. However, this would result in a substantial drain on refinery needs resulting in an increased need to import oil to satisfy transportation and other fuel needs. This would also result in the build-up of unused residual oil.

The use of cleaner, higher cost, light oils instead of residual would result in similar supply-user dislocations. If residual

fuel was then used in other combustion facilities, the problem of providing control equipment for pollutant emissions would be forced on smaller consumers. Since they are far less able to cope with these problems, these consumers would probably produce an increased deterioration of ambient air quality. Provided that adequate pollution controls are used, the use of residual oil by the utility industry is best suited to the environmental and resource management needs of the nation.

5.4.3 Coal

The use of coal at the Canal plant would result in significant environmental impact in utilization in addition to impacts from production and transportation.

The problems associated with coal use most pertinent to a power plant at this time are particulate and sulfur oxide emissions, coal and ash handling, and disposal systems. Low sulfur coal, which could allow operation within sulfur emission standards without sulfur emission controls, is extremely limited in the Northeast and cannot meet demand in this area in the near future. Transportation costs associated with the use of low sulfur coals from western sources are prohibitive especially when one considers the possibility of required coal cleaning and stack cleaning systems for even low sulfur coals to meet more stringent emission standards.

Precleaning of coal to remove pyrites is useful for lowering sulfur values, but for the coals available to the Northeast, insufficiently low sulfur values would result. Economic and reliable stack gas desulfurization would, therefore, be a necessity in order to use coal as a fuel. To this date it has not been demonstrated that stack gas desulfurization can be performed economically without some adverse environmental impact. At best, such a system will, in the future, transform air pollutants into useful liquid and solid products without the development of water or land pollution problems. Utilization of sulfur and ash products will depend to a great extent on geographical location, and it would be unrealistic to assume that all power plants in the Northeast are in an advantageous market position.

When and if stack gas desulfurization technology develops to a point where maximum reliability and minimum environmental impact would result, coal again will become an economically and environmentally viable energy source. Coal cannot be considered presently for power production at this site for the near future, primarily because the state of development of stack gas desulfurization will not allow sufficient assurance of necessary environmental protection in the Canal Plant area.

5.5 ALTERNATIVE MEANS OF POWER GENERATION

5.5.1 Nuclear Power

The choice of a fossil fuel as the energy source at this location for nearer term appears to better fit the long-term environmental and resource management interests of the region and the country. Alternative means of generation of electricity at this site would investigate the developing technology in high temperature gas cooled breeder and nonbreeder reactors. Potential efficiency gains by the building of a nonbreeding high temperature gas cooled reactor would not only lessen thermal pollution problems but would also allow the possibility to change to breeder reactors using essentially the same components.

Commercial units of the high temperature gas cooled nonbreeder type are being built at this time, but there is limited developmental interest in breeder reactors of this type. The interest of providing adequate representation of all viable energy production alternatives to meet future energy demands is probably well enough served by those units presently planned. Moreover, the installation of a nuclear plant at this site would countermand the characteristics of an additional cyclic load unit at Canal Plant. Nuclear plants are generally more compatible with base-load requirements.

5.5.2 Other Electric Generating Systems

Other means of generating electricity which offer advantages from an environmental standpoint include hydroelectric, geothermal and tidal systems. Sites which are adaptable to this sort of power production, however, are not plentiful and are usually restricted to small geographic sections of any country and especially the United States. The Canal Electric Company system and franchise territory does not include sites which have suitable potential for geothermal, hydroelectric, or tidal power production.

5.6 ALTERNATIVE AIR QUALITY CONTROLS

The air quality control system of the combined Units No. 1 and No. 2 is based on burning low sulfur fuel, and the use of precipitators and a tall stack.

A possible alternative to the precipitator would be a baghouse filter. Only one such unit on a full sized station is known and its operation has been intermittent. Space requirements for this equipment are greater than that for precipitators, and operational problems would be anticipated. Because of the conditions necessary for operating baghouse filters (low exit gas temperatures), the planned cyclic operation of Unit No. 2 at Canal would result in moisture condensation within the baghouse filters when coming up to operating temperature or going off the line, which would cause an undesirable cleaning problem. Auxiliary heating would be necessary to avoid this.

The other alternative method of air cleaning would be to use a scrubbing system with the use of a chemical additive and either recover sulfur in some form or throw away the resulting collected solids. Thus far, the recovery systems have found little application and must be considered developmental and not commercially feasible at this time. "Throw away" systems are being installed at a number of power plants across the country, but total operating experience is limited. Scrubbers have been satisfactorily used for years in chemical processing, but the lower temperatures and particulate loading of boiler flue gas pose additional questions regarding their use in this application. Significant environmental impact would be expected due to the need to dispose of scrubber effluent by settling ponds and water treatment systems. Past experience and available space led to the decision to use electrostatic precipitators in this design.

5.7 ALTERNATIVE COOLING WATER SYSTEMS

The circulating water discharge system for the Canal Plant was designed to be compatible with the specific characteristics of Cape Cod Canal.

Alternative schemes would include systems such as cooling towers cr cooling ponds. Such alternatives would be more expensive than the scheme described in Section 1.2.3.3 and would not be site-specific in their implementation. Several factors must be addressed in both alternative schemes as mentioned. Cooling towers for utility operations generally are of the "wet" type. In these towers heat release to the atmosphere occurs by two mechanisms: (1) heat transfer between the passing stream of air and cooling water as it cascades over boards and (2) loss of heat from the cooling water as it evaporates to the atmosphere. Wet cooling towers are potential fog producing systems and may be objectionable considering the nature of Cape Cod Canal usage for transnavigation of Cape Cod. The construction of cooling towers will also require commitment of land not presently available at the Canal Plant site.

The use of dry towers for cooling water purposes for turbo-generator sets requires high back pressures in the condensers. To incorporate a dry tower at the Canal Plant would require an essentially new design for the unit's turbines. This is not considered necessary in view of the availability of ample cooling water from Cape Cod Canal.

The commitment of land for cooling towers is made even more extensive if cooling ponds are chosen for the proposed action. The possibility of fog over the Canal is also enhanced with this option along with its accompanying objections.

5.8 ALTERNATIVE CHEMICAL WASTE SYSTEM

The proposed chemical waste system is described in Section 1.2.3.5. In principle, liquid chemical wastes associated with operation of existing Unit No. 1 and proposed Unit No. 2 will be treated and recycled in closed systems with the exception of infrequent equipment cleaning operations and intermittent demineralizer regeneration cycles. These intermittent liquid wastes will be treated for removal of suspended solids and for pH control and completely mixed with the large circulating water flow prior to discharge to Cape Cod Canal.

The proposed liquid waste system will result in infrequent discharges of treated effluents to Cape Cod Canal which will contain, after complete mixing with large quantities of circulating water, dissolved solid levels which are slightly less (approximately 10 ppm) than ambient levels.

An alternative method of treating these wastes was considered which would include the use of a falling film evaporator. Liquid chemical wastes associated with infrequent equipment cleaning operations and intermittent demineralizer regeneration cycles would be fed into the evaporator which would produce a highly concentrated brine bottom and pure distilled overhead. The concentrated brine solution would be disposed of in an on-site storage pond which would be sufficiently large to incorporate natural precipitation. The evaporator overhead would be recycled for reuse within the station. This alternative chemical waste system would result in a zero discharge of liquid chemical wastes to Cape Cod Canal.

This alternative chemical waste system was discarded since the environmental benefits could not be justified in view of the extremely unfavorable economics associated with the high capital and operating costs of the evaporator and excessive land requirements for the disposal pond.

Alternative methods of controlling biofouling have been considered. Control of biofouling by mechanical means has both advantages and disadvantages. The advantages naturally are found in the elimination of chemicals harmful in certain dosages from the circulating water. Disadvantages of mechanical condenser cleaning systems lie primarily in their reliability, costs, and maintainability. Of these systems the two prominent ones are the MAN system using brushes blown through the condenser tubes and the AMERTAP system using rubber balls cycled through the tubes under pressure. The relative cost of a mechanical cleaning system over a chlorination system is about 30 to 1. Maintainability of these systems and reliability in areas where a high silt or transported sediment is expected in the circulating water are uncertain. Although the results are not conclusive, there is evidence to indicate that the combination of high

siltation of circulating water and mechanical cleaning results in shortened tube life and higher demand for condenser service.

The chlorination program at Canal Plant is expected not to exceed the 0.1 ppm suggestion of the assessment of marine ecology by the Massachusetts Division of Marine Fisheries (see Environmental Report Appendix No. 1). As such, the chlorination should not be of a high enough level to affect the marine biota as discussed in Section 3.5.1. Because of the high silt load in the circulating water from Cape Cod Canal, and because of the reliability of this chlorinating system, chlorination remains the most favorable biofouling control mechanism for Canal Plant.

SECTION VI

THE RELATIONSHIP BETWEEN LOCAL SHORT-TERM USES OF MAN'S ENVIRONMENT AND THE MAINTENANCE AND ENHANCEMENT OF LONG-TERM PRODUCTIVITY

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Possible long-term maintenance and enhancement of the Canal Plant environment would be little affected by the addition of Unit No. 2. The relative location of the Cape Cod Canal, and existing highways and railroad severely limit future land use to anything but that presently contemplated. Even without operating Unit No. 1, no long-term usage appears likely, except for more canal shoreline available for fishing, and the possibility of a few more home sites.

Considering the normal 30 years of a power plant's life, the economic gain to the local community due to the additional tax base resulting from Unit No. 2 would far outweigh that available from any other foreseeable land use of the site.

Due to the extensive efforts described elsewhere in this report for protecting the air and water portions of the environment, there should be no environmental effect brought about by Unit No. 2 that would adversely affect the long-term productivity of the present environment in any way.

At this time there are no definite plans for additional units. However, this site has the potential for four units depending on load growth and on where the power is needed. It will be seven years from the completion of Unit No. 1 to the completion of Unit No. 2 . Beyond that date there is the probability of an additional two units depending on load growth and other future developments as to best production of power.

SECTION VII

ANY IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES WHICH WOULD BE INVOLVED IN THE THE PROPOSED ACTION SHOULD IT BE IMPLEMENTED

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The consumption of fuel oil and other consumables by Canal Plant – Unit No. 2 represents the only irreversible and irretrievable commitment of resources in this proposed action.

The addition of a second generating unit at the Canal Plant site will be accomplished on land adjoining an artificial waterway. The banks of the canal are rip-rapped in the tidal zone to the canal bank elevation. Excavation for intake and discharge structures may temporarily disrupt limited sessile benthic communities. This disruption, however, will be minimal and will have little effect on benthic communities.

Use of water and air resources will be accomplished with minimal deleterious or deteriorative effect on the ecological system.

The uses of these resources cannot be considered as irretrievable. As discussed in Section 3.5, the loss of some fish eggs and larvae due to the operation of the station should not have a significant impact on the marine environment. The ichthyoplankton involved are a very small portion of the populations in the area and represent the spawn of a relatively few adult pairs. Commitment of human resources on this project is not generally regarded as an irretrievable action in terms of environmental impact.

SECTION VIII

COORDINATION WITH OTHERS

SECTION VIII

COORDINATION WITH OTHERS

8.1 PUBLIC PARTICIPATION

The owners petitioned the Commonwealth of Massachusetts Department of Public Utilities which held public hearings on the proposed action in the Town of Sandwich on March 25, April 8, and April 27, 1971. At these hearings the statements of abutters, town officials and other interested citizens concerning the proposed action were heard. The objections and suggestions made during the hearings were taken under advisement by Canal Electric Company and Montaup Electric Company and their agents. After consideration by the Department, an order dated November 22, 1971, was issued granting an exemption from the operation of zoning bylaws of the Town of Sandwich for construction of Canal Plant – Unit No. 2.

The general public at the hearings were largely opposed to the plans for expansion of the power plant, based primarily on their experience to date with Unit No. 1. Their opposition centered principally on the following objections, which are in the general order of significance as presented by the public:

Emissions of SO2
Emissions of acidic soot
Noise
Aesthetics
Water quality

All of these objections are dealt with in the proposed plans, and are discussed in detail throughout the impact statement. In simplified form, the measures to be taken to meet these objections may be summarized as follows:

1. A single 500-foot high stack is to be built to serve both units, and the present 300-foot high stack removed. This extra height has been computed to disperse the emissions and reduce concentrations of fallout below State and Federal standards for air quality.

2. Improved care and methods of startup of boilers which should minimize blowing out of acidic soot.

3. Improved noise control equipment and structures to reduce noise levels below those experienced in the past.

4. Planting and other means taken to blend the proposed structures into the area.

5. Improved discharge structures to diffuse and reduce temperatures of coolant waters to meet limitations

established by the Massachusetts Division of Marine Fisheries.

The position of the Board of Selectmen of the Town of Sandwich was favorable toward the construction and operation of a second generating facility at Canal Plant.

8.2 GOVERNMENT AGENCIES

Canal Electric Company and Montaup Electric Company and their agents have consistently sought the advice and guidance of various government agencies throughout the design of Canal Plant - Unit No. 2.

In February, 1971, an informal committee consisting of representatives from various state and federal regulatory agencies was formed at the suggestion of the Commonwealth of Massachusetts Department of Public Utilities. The purpose of this "Canal Plant Advisory Committee" is to facilitate the "...efficient dissemination and exchange of information..." to the various agencies concerned. The agencies initially comprising this committee included:

U.S. Army Corps of Engineers
Federal Aviation Administration
U.S. Environmental Protection Agency (Air Pollution Control, Water Quality Office)
U.S. Department of the Interior (Bureau of Sport Fisheries and Wildlife)
Massachusetts Department of Natural Resources (Division of Water Pollution Control, Director of Marine Fisheries)
Massachusetts Department of Public Works (Division of Waterways)
Massachusetts Department of Public Safety (Division of Fire Protection, Board of Boiler Rules)
Massachusetts Department of Public Health (Division of Air Pollution, Division of Environmental Health)
Massachusetts Department of Public Utilities.

This committee has been of great benefit in coordinating the various agency contacts made by Canal Electric Company, Montaup Electric Company, and their agents.

Several meetings were held in 1971 with the members of the "Canal Plant Advisory Committee" to discuss the design of Canal Plant - Unit No. 2.

On an individual agency basis, the agencies forming the "Canal Plant Advisory Committee" and other agencies have been consulted in the various permit applications made by Canal Electric Company and Montaup Electric Company.

Stone & Webster Engineering Corporation, in conjunction with its design activities on Canal Plant - Unit No. 2, has sought the advice of governmental agencies. Among these contacts, information and advice were sought from:

Agency	Subject
U.S. Army Corps of Engineers	1. Velocity effects of proposed discharge including a velocity survey conducted by the owners, their engineers, the Corps and the Massachusetts Division of Marine Fisheries.
	2. Shipping information on Cape Cod Canal.
	3. Soundings in Cape Cod Canal.
Massachusetts Department of Public Health	1. Water Well No. 3
	2. Stack emissions
Massachusetts Department of Public Utilities	1. Sound levels at Canal Plant.
	2. Hearings discussed in Section 8.1.
Massachusetts Department of Public Works (Division of Waterways)	1. Requirements for license.
Massachusetts Department of Natural Resources	1. Information on biota concerns.
	2. Applicability of regulations governing land fill
	3. Meeting with Water Resources Commission on comments received on circulating water system engineering report.
Town of Sandwich officials	1. Water Well
	2. Consultations on various matters concerning licenses.

The following is a partial list of permits applied for and granted by various government agencies:

Agency	Status
Federal Aviation Administration (Chimney)	Rec'd. Approval: 5-27-71
Mass. Aeronautics Commission (Chimney)	Rec'd. Approval: 5-26-71
Commonwealth of Massachusetts Water Resources Comm., Division of Water Pollution Control (Water Use Permit)	Rec'd. Approval: 8-4-72
Corps of Engineers (Waterfront Const. Permit)	Applied: 1-28-72
Commonwealth of Mass., Dept. of Public Health, Bureau of Air Use Management	Rec'd. Approval: 1-16-73
Commonwealth of Mass., Dept. of Public Works (Waterfront Const. Permit)	Rec'd Approval: 5-17-73
Commonwealth of Mass., Dept. of Public Utilities (Exemption from Zoning Bylaws)	Rec'd. Approval: 11-22-71
Commonwealth of Mass., Dept. of Natural Resources (Permit to fill inland waters)	Rec'd. Approval: 8-3-72
Occupational Safety and Health Administration (Variance from F.O. Tank Dike Height Regulation)	Rec'd. Letter of Exemption: 9-11-72
Town of Sandwich - Building permits	
Commonwealth of Mass., Dept. of Public Health, Bureau of Air Use Management	Rec'd. Approval: 1-16-73
Commonwealth of Mass., Dept. of Public Works (Waterfront Const. Permit)	Rec'd Approval: 5-17-73
Commonwealth of Mass., Dept. of Public Utilities (Exemption from Zoning Bylaws)	Rec'd. Approval: 11-22-71

Commonwealth of Mass., Dept. of Natural Resources (Permit to fill inland waters)	Rec'd. Approval: 8-3-73
U.S. Dept of Labor Occupational Safety and Health Administration (Variance from F.O. Tank Dike Height Regulation)	Rec'd. Letter of Exemption: 9-11-72
Town of Sandwich - Building permits	
Build Unit No. 2 Enclosure and Stack	No. 1915, issued: 4-17-72
Extend Existing Facilities to accomodate Unit No. 2	No. 2080, issued: 8-22-72

8.3 COMMENTS ON DRAFT ENVIRONMENTAL STATEMENT

Drafts of this environmental statement (July, 1973) were furnished to the following Federal, State, and local agencies, and to citizen groups who have an interest in the proposed addition of a second 560 MW oil-fired steam electric generating unit to the existing Canal Plant:

Advisory Council on Historic Preservation
U.S. Environmental Protection Agency
U.S. Coast Guard
U.S. Dept. of Commerce
U.S. Dept. of the Interior
U.S. Dept. of Housing and Urban Development
U.S. Dept. of Health, Education and Welfare
Federal Power Commission
New England River Basins Commission
Mass. Sec. of Environmental Affairs
Mass. Dept. of Commerce and Development
Mass. Dept. of Community Affairs
Mass. Dept. of Natural Resources
Mass. Dept. of Public Health
Mass. Public Works Dept.
Mass. Executive Office for Administration and Finance
Office of Planning and Programming Coordination
Marine Resources Council
Sierra Club
Natural Resources Defense Council
Mass. Audubon Society
National Foundation for Environmental Control
Environmental Information Center
Mass. Wildlife Federation, Inc.
Mass. Association of Conservation Commissions
New England Natural Resources Center
Board of Selectmen, Sandwich, Mass.
Public Library, Sandwich, Mass.
Cape Cod Chamber of Commerce
Canal Electric Company
Montaup Electric Company
Economic Development Administration

Deadline date for comment on the draft was September 24, 1973. Letters received from those agencies and interested parties are reprinted in their entirety in this section. Following these letters, the specific comments are again reprinted with the necessary response.

A news release was issued at the time the draft statement was distributed to notify all interested parties of the availability of the statement and to request their participation.

8.3.1 Letters

Comments on the draft environmental statement were received from the following agencies and groups:

U.S. Environmental Protection Agency
U.S. Coast Guard
U.S. Dept. of Commerce
U.S. Dept. of Housing and Urban Development
U.S. Dept. of Health, Education and Welfare
Federal Power Commission
Mass. Dept. of Commerce and Development
Mass. Dept. of Natural Resources
Mass. Division of Fisheries and Game
Mass. Executive Office for Administration and Finance
Natural Resources Defense Council - Striped Bass Fund
Cape Cod Chamber of Commerce

Letters received from the above agencies and interested parties are reprinted on the following pages.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 1

J.F. KENNEDY FEDERAL BUILDING, BOSTON, MASSACHUSETTS 02203

October 10, 1973

Mr. John Wm. Leslie, Chief
Engineering Division
United States Department of the Army
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Mr. Leslie:

RE: Draft Environmental Impact Statement for the Addition of Unit No. 2 of the Cape Cod Canal Generating Station Sandwich, Massachusetts

We have carefully reviewed the environmental impact statement for the Addition of Unit No. 2 of the Cape Cod Canal Plant. We have general comments pertaining to the procedural requirements of the Federal Water Pollution Control Act of 1972 and specific comments relating to the information supplied in the environmental impact statement.

GENERAL

It is suggested the applicant be apprised of the provisions of the 1972 Amendments to the Federal Water Pollution Control Act (the Act), which apply to the National Pollutant Elimination Discharge System in general and thermal discharges in particular.

Except as set forth below, Section 301 of the Act requires that effluent limitations which require the application of the "best practicable control technology currently available" or any more stringent limitations which would be necessary to meet water quality standards, shall be achieved no later than July 1, 1977, and that effluent limitations which require the application of the "best available technology economically achievable" shall be achieved no later than July 1, 1983. With respect to power plants in general, Section 301 would require off-stream cooling of condenser cooling water.

Where the application of best practicable control technology to the thermal component of an effluent would not be necessary to assure the protection and propagation of a balanced indigenous population of shellfish, fish and wildlife in and on the receiving waters, Section 316 (a) of the Act provides that the Agency may impose a less stringent limitation. In such cases, the effluent limitation in the permit would be established

to assure the protection and propagation of a balanced indigenous population of shellfish, fish, and wildlife in and on the receiving water.

If the applicant believes that off-stream cooling is not necessary to assure the protection and propagation of a balanced indigenous population of shellfish, fish, and wildlife in and on the receiving water, then he may request an exception under Section 316(a). If such an exception is requested, the applicant will be expected to demonstrate at a public hearing that such an exception will assure the protection and propagation of a balanced indigenous population of shellfish, fish, and wildlife in and on the receiving water.

The applicant should continue his coordination with Charles Corkin II, Esquire, of our Enforcement Division, to determine exactly how these provisions affect his application for a discharge permit.

AIR

The proposed addition (Unit No. 2) does not appear to meet all the criteria of the New Source Performance Standards for Fossil Fired Stream Generators which were promulgated on December 23, 1971. Some assurance of compliance should be documented in the final environmental impact statement. This should include provisions for notification, record keeping, performance testing, emission monitoring and full monitoring as specified in the December 23, 1971 Federal Register.

The use of 1 per cent sulfur oil will not be adequate to meet the required limit of .80 pounds per million Btu heat input. Since the air quality assessment is based on 1 per cent sulfur fuel, it seems that the plant proposes to run both units on 1 per cent sulfur fuel. This should be specifically addressed since the new unit will only be allowed approximately .75 per cent sulfur fuel under the provision of 40 CFR 60.43.

Although the problem of downwash apparently has not been significant, some consideration of this potential problem should be presented specifically with reference to the proposed location of the new stack and the height of the surrounding buildings.

Future plans for the monitoring network should be presented. We recommend the network for this area to be maintained to monitor compliance with the applicable air quality standards. A summary of the air quality data from the network should be presented.

CHEMICAL WASTES

The statement does not completely describe the treatment of the chemical wastes which will be generated. We suggest that the final environmental impact statement include this information. We also recommend that there be close coordination with the Permits Branch regarding this specific issue.

OIL AND HAZARDOUS MATERIALS CONTROL

The statement should provide additional information on the oil storage and handling facilities. The Environmental Protection Agency published proposed regulations on oil pollution prevention from non-transportation related on-shore and off-shore facilities in the Federal Register of July 19, 1973. The final regulations are expected to be published in October, 1973. These regulations, among other things, establish procedures for the preparation of spill prevention, control, and countermeasure plans including design and operation considerations to be incorporated in a storage facility.

The regulations apply to facilities which store more than 42,000 gallons below ground or 500 gallons above ground. Penalties are set for non-compliance. A copy of these proposed regulations is attached for your information.

In the particular case of transformer oil, it is important to note whether or not toxics such as flame retardants or polychlorinatedbiphenols are present.

NOISE

In the Preface of the report (Volume I, page xiii), a general statement is made pertinent to noise control methods to be used during blowing of steam lines while construction is underway on the proposed addition. No estimate of the noise levels generated by these blowing operations is given nor is it clear from the statement if these blowing operations occur during normal maintenance procedures as well as during construction. If the blowing of steam lines does occur as a part of normal maintenance procedures even at intervals of three to five years as suggested by Table 3.2-2 on page 3.2-14, this fact should be clearly stated. In addition, it would be useful to include some measured noise level data from typical blowing operations taken from Unit No. 1, particularly if these operations are periodic.

A second comment can be made with respect to the expected noise levels with both units running. At least three different interpretations of these expected levels are given in the draft statement:

1. In the Preface (Volume I, page xvi), the levels are 70 dBA, "not specified at this time", and 49 dBA.

2. In Section IV (Volume 2, page 4.0-2), the interpretation is, "The maximum sound level expected from Unit No.'s 1 and 2 operated at full load is 49 dBA at the east, south, and west property lines and 70 dBA at the north property line. This is not expected to be any increase from present noise levels."

3. In Section III (Volume 2, page 3.3-1), the interpretation is, ". . . the total sound levels in the vicinity of the plant will be no higher than,

and perhaps lower than, the present sound levels shown in Table 2.5-1"

In the interest of clarity, one of these three versions should be adopted as the design goal of the proposed project, and a clear statement to this effect should be made in the report.

The noise control methodology described in Section 3.3 is commendable. Attention to noise control problems at the early design stage is an expedient approach to environmental noise control. The exact methods to be employed and the reasoning behind the quoted noise level reductions however, could be more clearly explained.

For example, the octave band data shown on Figure 2.5-2 appears to be predominantly transformer noise as the highest band levels show up in the 31.5, 63, and 125 HZ bands. This suggests that any effective reduction in the present Unit No. 1 noise levels (at least at the Baksis Boulevard site represented in Figure 2.5-2) would have to be accomplished by attenuation of this transformer hum. The extent of this attenuation appears to be approximately 7 dB if the following assumptions are correct: First, that the Baksis Boulevard site is essentially on the property line; secondly, that the desired level at this location is 49 dBA; and finally, that the addition of the Unit No. 2 transformer will add 3 dB* to the current level at this location. (*This assumes a doubling of acoustic power at the source, essentially free field conditions, and no harmonic correlation between the two contributing phenomena. Because of the dominating transformer noise there is a possibility of harmonic correlation in which case the correction could be +6 dB rather than the +3 dB given above.) If a level of 49 dBA is to be met at this site, Unit No. 1 can contribute 46 dBA as can Unit No. 2, these two 46 dBA levels combining to give a level of 49 dBA, and the present level of 53 dBA (worst case of Figure 2.5-2) minus the 46 dBA allowable level gives a required reduction of 7 dB.

A noise level reduction of 7 dB could be difficult to obtain, particularly since there is already a sound barrier wall on autotransformer No. 1, and what is required is a further reduction of 7 dB. To justify the feasibility of this further noise level reduction, more information on the present noise barrier as well as the proposed addition to the noise barrier should be included in the report.

In terms of the noise impact of the proposed project, it appears that an upper limit to the possible impact would be an increase of 3 dB over the current noise level. Because of the noise control techniques to be applied to both the present and additional facilities, the noise impact would probably be somewhere between a 1 and 3 dB increase in noise levels (compared to "no increase" as suggested in the report).

SOLID WASTE

The draft environmental impact statement states that "Settled ash will be removed from the precipitator ash settling basin and disposed of in an approved manner (page 1.2)." The final environmental impact statement should indicate the specific disposal method, including the location of the disposal site and any pre-treatment (e.g., dewatering) given the waste. In addition, the final environmental impact statement should include the quantity of settled ash expected and its chemical and physical characteristics.

According to the statement "collected oil will be removed from the oil water separators and stored in 55 gallon drums for off-site disposal", the possibility of reclaiming this oil should be explored. It should not be disposed of in a dump or sanitary landfill.

The draft environmental impact statement does not include a discussion of the disposal method for approximately 3 acres of land clearing wastes for the storage tank area. We recommend that the brush and small logs be chipped and the chips be used on-site for landscaping and erosion control. An effort should be made to sell the larger logs to firewood wholesalers. Any remaining logs should be cut into sections not exceeding 4 feet and landfilled on-site or negotiations made and the wastes landfilled within the company's transmission line rights-of-way. Leachate from these wastes could result in contamination of the adjacent public or private wells which are so common on the Cape.

As specified in the Massachusetts Department of Public Health's "Regulations for the Disposal of Solid Wastes by Sanitary Landfill", the disposal of 4,000 cubic yards of excess dredge spoil will require a variance.

We appreciate the opportunity to comment on this draft environmental impact statement and would like to be included in the distribution of the final statement. We have rated this statement ER-2 on the basis of our national rating system, a copy of which is attached.

Sincerely yours,

Wallace E. Stickney

Wallace E. Stickney, P.E.
Director
Environmental Impact Office

Attachments

EXPLANATION OF EPA RATING

Environmental Impact of the Action

LO -- Lack of Objections

EPA has no objections to the proposed action as described in the draft impact statement; or suggests only minor changes in the proposed action.

ER -- Environmental Reservations

EPA has reservations concerning the environmental effects of certain aspects of the proposed action. EPA believes that further study of suggested alternatives or modifications is required and has asked the originating Federal agency to reassess these aspects.

EU -- Environmentally Unsatisfactory

EPA believes that the proposed action is unsatisfactory because of its potentially harmful effect on the environment. Furthermore, the Agency believes that the potential safeguards which might be utilized may not adequately protect the environment from hazards arising from this action. The Agency recommends that alternatives to the action be analyzed further (including the possibility of no action at all).

Adequacy of the Impact Statement

Category 1 -- Adequate

The draft impact statement adequately sets forth the environmental impact of the proposed project or action as well as alternatives reasonably available to the project or action.

Category 2 -- Insufficient Information

EPA believes that the draft impact statement does not contain sufficient information to assess fully the environmental impact of the proposed project or action. However, from the information submitted, the Agency is able to make a preliminary determination of the impact on the environment. EPA has requested that the originator provide the information that was not included in the draft statement.

Category 3 -- Inadequate

EPA believes that the draft impact statement does not adequately assess the environmental impact of the proposed project or action, or that the statement inadequately analyzes reasonably available alternatives. The Agency has requested more information and analysis concerning the potential environmental hazards and has asked that substantial revision be made to the impact statement.

If a draft impact statement is assigned a Category 3, no rating will be made of the project or action, since a basis does not generally exist on which to make such a determination.

DEPARTMENT OF TRANSPORTATION
UNITED STATES COAST GUARD

MAILING ADDRESS:
COMMANDER (oan-1)
FIRST COAST GUARD DISTRICT
150 CAUSEWAY STREET
BOSTON, MASS. 02114
Tel: 617-223-3633

3260
18 SEP 1974

From: Commander, First Coast Guard District
To: Division Engineer, New England Division, U. S. Army, Corps of Engineers

Subj: Draft Environmental Statement for Addition of Unit No. 2 Cape Cod Canal Plant, Sandwich, Massachusetts; review of

1. The review of the Draft Environmental Statement for the subject project has been completed. There are no ongoing or proposed U. S. Coast Guard projects which would appear to be affected by the proposed addition and, therefore, no objection is submitted.

2. It is requested, however, that sufficient safeguards be established to assure that the visibility of the Cape Cod Canal east entrance range lights will not be compromised during construction.

3. At this time, it is not possible to assess the relationship of the existing range lights to the enlarged plant. The ranges may be dwarfed to a point where they are no longer readily visible to the mariner. The Coast Guard wishes to reserve the right to request relocation and/or enlargement if in the future it is found to be necessary for the protection of navigation.

B. E. THOMPSON
By direction

OFFICE OF THE ASSISTANT SECRETARY OF COMMERCE
Washington, D.C. 20230

September 25, 1973

Mr. John Wm. Leslie
Chief, Engineering Division
New England Division, Corps of
Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Mr. Leslie:

The draft environmental impact statement for Addition of Unit No. 2, Cape Cod Canal Plant, Sandwich, Massachusetts, which accompanied your letter of August 7, 1973, has been received by the Department of Commerce for review and comment.

The statement has been reviewed and the following comments are offered for your consideration.

In our opinion, the subject documents are well prepared and informative. Recommendations offered by the Massachusetts Division of Water Pollution Control, Massachusetts Division of Marine Fisheries, Massachusetts Department of Public Utilities, and the U.S. Bureau of Sport Fisheries and Wildlife are well stated and appear to offer solutions that will avoid possible detrimental effects to the environment as a result of operational procedures.

A particularly noteworthy contribution to this environmental impact statement is the Massachusetts Division of Marine Fisheries' report entitled "An assessment of the effects of electrical power generation on marine resources in the Cape Cod Canal," included in Volume II as Appendix No. 1.

In addition, we offer the following specific comments:

1.2 PLANT DESCRIPTION

1.2.3.4 Fuel Oil Unloading and Storage

Page 1.2-16. In addition to the State regulations cited, the unloading operations and storage facilities may be subject to regulations issued or to be issued by the United States Coast Guard.

3.1 AIR QUALITY

3.1.1.1 Sulfur Dioxide

Page 3.1-1. In calculating the maximum sulfur dioxide concentration (Table 3.1-1) it does not appear that the situation of limited vertical mixing depth has been taken into account or that daytime stack emissions have been maximized, since average daily emissions have been used. Table 3.1-2 states in a footnote that "emissions in day-to-day operation may vary", presumably both greater and less than the average.

Assuming the mean afternoon mixing height (Holzworth, 1972, EPA report No. AP-101) of 1000 m, unstable conditions (Pasquill Type A) and a speed of 1 m/sec, we compute a maximum 1-hr. concentration at 1.3 km of 0.66 ppm for an average SO_2 emission rate of 2.19×10^5 lbs/day. Maximizing the emission rate to 2.5×10^5 lbs/day increases the concentration to 0.77 ppm. A conversion factor of 2600 microgram/m^3 = 1 ppm was used. The highest value shown in Table 3.1-1 is 0.22 ppm and the Mass Air Quality Standard for 1-hr. is 0.28 ppm.

3.5 EFFECTS OF PLANT OPERATION ON MARINE ECOLOGY OF CAPE COD CANAL

3.5.1.1 Effects of Entrainment of Plankton

Page 3.5-9. Although it is true that of the 24 species of fish for which eggs and larvae were collected, only 4 (cod,

tautog, mackerel, and winter flounder) are of direct sport or commercial importance, it should be noted that many other species--even those that may not have been well represented in the collections--are undoubtedly of significant indirect importance because of their role in the food web that supports the species of fish of concern to fishermen and other people.

We note that because "the investigators calculated that the number of eggs and larvae circulated through the plant would approximate the egg production of less than 50 cod and winter flounder and less than 1,000 mackerel," they concluded that "the comparatively small losses that may result from passage of eggs and larvae through the Canal generating station are deemed negligible."

We feel that two points should be stressed with regard to this conclusion:

First, the validity of this conclusion depends on the adequacy of the sampling program from which the estimates of egg and larval densities were derived.

Second, because the site "has the potential for four units depending on load growth and on where the power is needed" (Page 6.0-2), the estimated losses of various species of fish could conceivably at least quadruple if and when all four units become operational. Plans for a monitoring program to determine the effects on fish populations of entrainment of fish eggs and larvae by Units No. 1 and 2 should be described in detail.

3.5.2 Entrapment of Fish in the Circulating Water System

Page 3.5-11. It is stated that the operation of Unit No. 1 resulted in "flat fishes, primarily winter flounder, ... becoming entrapped in the vertical traveling screens and eventually damaged when released to the warm water of the Unit No. 1 discharge canal." Data on the number of fish that have been entrapped, impinged, and killed thus far by Unit No. 1 should be provided.

It is further stated that "a 9-foot high sill will be placed at the entrance of the intake flume (of Unit No. 2) to prevent access to the flume by benthic fishes (primarily flounder)." On the next page, it is stated that "Should the installation of a fish sill in the Unit No. 2 intake prove successful, a similar sill will be considered for Unit No. 1." The final environmental impact statement should describe in detail the plans for monitoring the impingement and mortality of fish at Units No. 1 and 2 to determine the effectiveness of the fish sill in preventing or mitigating these adverse effects.

Page 3.5-12. We note that fish that are impinged on the traveling screen will be discharged to the screenwash sluiceway and thence to the existing Unit No. 1 discharge flume, and that fish "will not be subjected to sudden temperature increases before being returned to the receiving waters." The final environmental impact statement should acknowledge that mortalities may result directly from impingement, as well as indirectly from thermal shock. For example, Marcy (1973)[1/] found that "approximately 80% of the total mortality of fish in the discharge canal of the Connecticut Yankee nuclear power plant was caused by mechanical damage and 20% was attributed to heat shock and prolonged exposure to temperatures above 28C." Furthermore, the possibility exists that the fish sill will not completely eliminate the entrapment/impingement problem, and that the problem may be seriously compounded by operation of Unit No. 2, and by subsequent generating units if and when they become operational.

5.7 ALTERNATIVE COOLING WATER SYSTEMS

Pages 5.7-1 and 5.7-2. This section should be greatly expanded to give the same depth of consideration to all reasonable alternative cooling water systems as to the proposed once-through cooling system. It is not sufficient to dismiss cooling towers and ponds merely because they are "more expensive" and not "site-specific in their implementation." These factors must be compared with the benefits to aquatic life of installing a closed-cycle cooling system at Unit No. 2 and all other units at this site.

With regard to the submerged multiport discharge system proposed for use to dilute the condenser cooling water flow for both units in the Canal, the environmental impact statement should recognize that pursuant to Section 301 of P.L. 92-500, all waste dischargers will be required to adopt best practicable treatment not later than July 1, 1977, and best available technology economically achievable by July 1, 1983. Currently, the Environmental Protection Agency is developing guidelines concerning these requirements. It would appear imprudent, impractical, and uneconomical (as well as poor environmental management) to permit establishment of any new waste discharges that may fail to meet these basic levels of treatment.

In particular, the environmental impact statement should discuss the thermal discharge in light of Section 316 of P.L. 92-500. It appears that under some circumstances discharge structures for thermal effluents that are constructed after October 18, 1972, may be considered exempt from best practicable treatment for a period of up to 10 years from the date the construction is completed. In order to adequately consider the impacts of this power plant on the environment, it would seem that the final environmental impact statement should fully discuss this aspect of P.L. 92-500, in view of the proposed use of once-through cooling.

Thank you for giving us an opportunity to provide these comments, which we hope will be of assistance to you. We would appreciate receiving a copy of the final statement.

Sincerely,

Sidney R. Galler

Sidney R. Galler
Deputy Assistant Secretary
for Environmental Affairs

Literature Cited

1. Marcy, Barton C., Jr. 1973. Vulnerability and survival of young Connecticut River fish entrained at a nuclear power plant. Journal Fisheries Research Board of Canada, Vol. 30, No. 8, pages 1195-1203.

DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT

AREA OFFICE
15 NEW CHARDON STREET
BOSTON, MASSACHUSETTS 02114

AREA OFFICES
Boston, Massachusetts
Hartford, Connecticut
Manchester, New Hampshire

REGION I
REGIONAL OFFICE
BOSTON, MASSACHUSETTS

September 21, 1973

IN REPLY REFER TO:
1.1PP

Mr. John William Leslie
Chief, Engineering Division
Department of the Army
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Mr. Leslie:

Subject: Draft Environmental Impact Statement
Addition of Unit No. 2
Cape Cod Canal Plant
Sandwich, Massachusetts

We have reviewed the Draft Environmental Impact Statement for the subject project which proposes to add a 560 MW electric generating unit to an existing unit of equal capacity, and to make modifications permitting usage of a common stack and common cooling water discharge system.

This statement as submitted is adequate with respect to those areas of concern to this Department. We would suggest that you submit this Draft Environmental Impact Statement to the appropriate regional planning agency for this project which is the Cape Cod Planning and Economic Development Commission, Mr. Norman Cook, Executive Director.

Thank you for the opportunity to review this statement.

Sincerely,

M. Daniel Richardson, Jr.
Area Director

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
REGION I
JOHN F. KENNEDY FEDERAL BUILDING
GOVERNMENT CENTER
BOSTON, MASSACHUSETTS 02203

OFFICE OF
THE REGIONAL DIRECTOR

SEP 4 1973

Mr. John Wm. Leslie
Chief, Engineering Division
Department of the Army
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Mr. Leslie:

The Draft Environmental Impact Statement for the Addition of Unit No. 2 to the Cape Cod Electric Plant, Sandwich, Massachusetts, has been reviewed by HEW's Regional Environmental Council.

The draft appears to be very comprehensive and detailed, covering all environmental factors of the project. Accordingly, we offer no comments as to the public health and welfare aspects of the plan.

Thank you for giving us the opportunity to comment on this statement.

Sincerely yours,

for Warren M. McGuigan
Robert Fulton
Regional Director

FEDERAL POWER COMMISSION
WASHINGTON, D.C. 20426

21 SEP 1973

Mr. John W. Leslie
Chief, Engineering Division
New England Division, Corps of Engineers
U. S. Department of the Army
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Mr. Leslie:

This is in response to your letter dated August 7, 1973, requesting comments on the Corps of Engineers' Draft Environmental Statement related to issuance of construction permits and discharge permits to the Canal Electric Company and the Montaup Electric Company, hereinafter referred to as the Applicants, for the addition of Unit No. 2 to the existing Cape Cod Canal Plant, located in the Town of Sandwich, Massachusetts.

These comments by the Federal Power Commission's Bureau of Power staff are made in compliance with the National Environmental Policy Act of 1969, and the April 23, 1971, Guidelines of the Council on Environmental Quality, and are directed to the need for the 560-megawatt electric generating unit, and related bulk power supply matters.

In preparing these comments, the Bureau of Power staff has considered the Corps of Engineers' Draft Environmental statement; related reports made in accordance with the Commission's Statement of Policy on Reliability and Adequacy of Electric Service (Docket R-362); and the staff's analysis of these documents together with related information from other FPC reports. The staff generally bases its evaluation of the need for a specific bulk power facility upon long-term considerations as well as upon the load-supply situation for the peak load period immediately following the availability of the new facility. It should be noted that the useful life of the Cape Cod Canal Unit No. 2 is expected to be 30 years or more. During that period, the unit will make a significant contribution to the reliability and adequacy of electric power supply in the Applicants' service areas.

The Canal Electric Company is one of three subsidiaries of the New England Gas and Electric Association (NEGEA). The Montaup Electric Company is an electric generating company wholly owned by the three operating subsidiaries of the Eastern Utilities Associates (EUA). Both Applicants,

through their parent holding companies, are members of the New England Power Pool (NEPOOL), the operating pool for the New England area, which coordinates the operation of the members' generating and transmission facilities. In addition, the Applicants, through their parent holding companies, are members of the Northeast Power Coordinating Council (NPCC) which coordinates the planning of the members' bulk power systems for the regional area which includes New England, New York, and the Canadian Provinces of New Brunswick and Ontario. The NPCC has established as a reliability standard that the probability of load exceeding generating capacity should not exceed one day in ten years. A National Electric Reliability Council (NERC) report dated September 1972 1/ indicates that an equivalent reliability standard for the New England Area systems is provided by a minimum reserve criterion of 22 percent of annual peak load. This criterion is used by the Bureau of Power staff for its analysis.

The proposed 560-megawatt unit is scheduled for commercial operation in July 1975. The capacity of the unit will be shared equally, 280-megawatts each, by the Applicants. The Applicants own the major portion of generating facilities of their respective holding companies and the effects of the capacity of the proposed Canal unit on these larger systems and also on the NEPOOL regional system is discussed herein. The New England systems are winter peaking systems and the analysis will be made for the 1975-1976 winter peak period, which is the peak load period immediately following the availability of the new unit. The following tabulations show the effects of the capacity of Cape Cod Canal Plant Unit No. 2 on the projected capabilities and reserve margins of the EUA and NEGEA systems for the 1975-1976 winter peak period.

1/ Review of Overall Adequacy and Reliability of the North American Bulk Power Systems.

1975-76 WINTER PEAK PERIOD LOAD-SUPPLY SITUATION

	EUA System 1/	NEGEA System 2/	NEPOOL 3/
Capability with Canal Unit No. 2 (560 Megawatts)			
Installed Capability - Megawatts	1,029	710.5	21,735
Net Load Responsibility - Megawatts	865 4/	512.3 5/	16,536 6/
Reserve Margin - Megawatts	164	198.2	5,199
Reserve Margin - Percent of Peak Load	19.0	38.7	31.4
Capability without Canal Unit No. 2			
Installed Capability - Megawatts	749	430.5	21,175
Net Load Responsibility - Megawatts	865 4/	512.3 5/	16,536 6/
Reserve Margin - Megawatts	-116	-81.8	4,639
Reserve Margin - Percent of Peak Load	-	-	28.1
Reserve Needs based on 22 Percent of Peak Load - Megawatts	190	113	
Reserve Deficiency - Megawatts	306	194.8	

1/ Data Source: EUA's FPC Form 12 dated December 31, 1972.

2/ Data Source: NEGEA companies' FPC Form 12 dated December 31, 1972.

3/ Data Source: NPCC Report 383-2 dated April 1, 1973.

4/ Load of 580 megawatts is corrected for firm purchases of 144 megawatts and firm sales of 429 megawatts.

5/ Load of 765 megawatts is corrected for firm purchases of 368.8 megawatts and firm sales of 116.1 megawatts.

6/ Load Responsibility corrected for net purchases of 195 megawatts.

The EUA system's projected internal load would be 580 megawatts for the 1975-76 winter peak period, which would result in a load responsibility of 865 megawatts when firm purchases of 144 megawatts and firm sales of 429 megawatts are considered. The installed capacity of 1,029 megawatts, which includes 280 megawatts of the Canal Electric Company's share of the proposed unit, would provide an estimated reserve margin of 164 megawatts or 19.0 percent of peak load on the EUA system. Without this share of the proposed unit, the reserve margin would be reduced to a negative 116 megawatts, and the EUA system would not have sufficient capacity to meet its projected 1975-76 winter peak load.

The NEGEA system's projected internal load would be 765 megawatts for the 1975-76 winter peak load period, which would result in a load responsibility of 512.2 megawatts when firm purchases of 368.8 megawatts and firm sales of 116.1 megawatts are considered. The installed capacity of 710.5 megawatts, which includes the Montaup Electric Company's share of the proposed unit, would provide an estimated reserve margin of 198.2 megawatts, or 38.7 percent of the peak load on the NEGEA system. Without this share of the proposed unit, the reserve margin would be reduced to negative 81.8 megawatts, and the NEGEA system would not have sufficient capacity to meet its projected 1975-76 winter peak load.

The proposed unit's capacity is 11.1 percent of the NEPOOL reserve margin. Unavailability of this unit would reduce the NEPOOL reserve margin from 31.4 percent to 28.1 percent of the pool's 1975-76 winter peak load responsibility. The member NEPOOL systems are heavily committed to large baseload nuclear units and the addition of this medium-sized oil-fired baseload unit would add flexibility to system operation.

The Draft Environmental Statement states that one new 115-kilovolt transmission line of unspecified length would be required by the addition of the proposed Unit No. 2 to integrate the plant's increased capacity to the existing transmission system. A description of the route of the right-of-way of the new 115 kilovolt line and a statement of compliance with existing State and Federal guidelines for design, construction and maintenance of this transmission line should be included in the final environmental statement. The discussions of alternate sources of power, plant sites, types of plants and fuels are adequate.

The Bureau of Power staff concludes the capacity of the Cape Cod Canal Plant Unit No. 2 is needed on the Applicants' systems to meet system demands and provide reserves to meet the regional reliability standard.

Very truly yours,

T. A. Phillips
Chief, Bureau of Power

The Commonwealth of Massachusetts
Department of Commerce and Development
Leverett Saltonstall Building, Government Center
100 Cambridge Street, Boston 02202

FRANCIS W. SARGENT
GOVERNOR
MARY B. NEWMAN
SECRETARY
MANPOWER AFFAIRS
FREDERICK A. CENTANNI
COMMISSIONER

727-3221

August 31, 1973

Mr. John W. Leslie, Chief
Engineering Division
Department of the Army
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Mr. Leslie:

Thank you for permitting us to review and comment on the addition of facility number 2 Cape Cod Canal unit. We have carefully evaluated the proposal noting output, location, equipment, special problems and environmentals concerns.

Under the following problem areas, we are in general agreement with your proposals to cope with them.

1. Plant can be seen from the heavily traversed Sagamore Bridge and the close proximity to a residential area

2. Thermal loading of canal water affecting fish

3. Air emissions and inversion

4. Chemical and liquid wastes

5. Added receipt and storage of fuel oil increases danger of spillage

We note that recommendations from state and federal agencies regarding environmental concerns have been built into the proposal.

For your information, I have included an intra-office memorandum that was used in our determination to support facility number 2 Cape Cod unit.

This office approves of the proposal and concludes that the economic gains do not degrade the environment using the stated protective measures.

Sincerely,

Frederick A. Centanni
Commissioner

FAC/mjb

Enc.

INTRA-OFFICE MEMORANDUM

SUBJECT: Review of Addition of Unit No. 2 Cape Cod Canal Plant, Sandwich, Massachusetts

DATE: August 20, 1973

Canal Electric Co. and Montaup Electric Co. plan an additional unit to their existing plant on the Cape Cod Canal. Because the facility is located within the city limit of Sandwich, Mass, special environmental controls must be considered.

PLANT LOGISTICS :

Total capability : 1,120 MW (ability of existing plant and unit 2)

Both units 1 and 2 will share the 500 foot stack and the recirculating water discharge system.

The plant is located one mile from the east entrance to the Cape Cod Canal from Cape Cod Bay. Access to the plant is provided by paved roads and railroad spurs from Penn Central at the east property line.

The generator and draft system consist of a cyclically operated (50% capacity nights and weekends) tandem-compound single reheat turbine generator coupled with two hydrogen cooled generators having a maximum sendout of 560,000kW.

PROBLEM : The plant is seen from the heavily traversed Sagamore Bridge; Sandwich has historic interest; residential area is near plant.

PROPOSAL :a. Plant facilities will be painted and landscaped to be visually unobtrusive.

b. Sound barrier constructed (15dB reduction) for the main power transformer. (Most noise is on north side of plant; residential area is on the south side.)

1. Forced draft fans will be in concrete rooms and the intake attenuated with silencers.

2. Induced draft fans enclosed in sound attenuated rooms.

3. Gas or diesal equipment provided with mufflers.

4. Vibratory type hammers used in pile driving to reduce noise.

c. The " corona discharge " causing electrical interference with radio/TV reception in area controlled.

d. No plant fog will hazard canal navigation or adjacent traffic.

e. Offensive odor detected only during unloading of oil.

PROBLEM : Thermal loading of canal water affecting fish .

PROPOSAL :a. Present level of 90 F kills fish; new system protects because temperature is reduced to 86F (temperature is only this high twice daily in July or August).

b. Dramatic changing temperature will be reduced :

1. Both plants unlikely to shut down - eliminates thermal stress.
2. Thermal stress is minimized by continuous recirculating water even in event of plant shutdown.

*c. Because of fecundity and distribution of fish, loss was determined negligible upon construction of unit 1; loss will double after construction of unit 2.

d. A 9 foot fish sill will be constructed to eliminate some fish from entering system.

PROBLEM : Air Emissions and Inversion

PROPOSAL : a. Proposed 500 foot stack will reduce ground levels of concentration to an annual average of : (sulfur dioxide - .00038ppm; suspended particulate - .024 ug/m3; nitrogen oxide : .00026 ppm.)

* Stable atmospheric conditions in area will cause a reduction of stack emmission dispersion.

** Atmospheric stack emmissions of particulate matter : 5,020 lbs./day.

b. Acidic soot fallout will be avoided; high stack temparature,etc.

c. Collected ash from precipitate will be conveyed to settling basin Ash sluicing will be in a closed system of 500gpm of water to sluice ash from hoppers to waste sump. Caustic will then be added for PH control and a wetting and defoaming agent used to minimize fly ash and foam formation.

d. Ground and elevated inversion reduced.

e. Furnace has balanced draft :

1. Minimum formation of particulate.
2. Automatic soot blowers use steam for cleaning.
3. Smoke monitoring is continous and particulate measurement available on request.

PROBLEM : Chemical Wastes (Chemical and solid waste table 3.2 - 14 Vol. II)

PROPOSAL : a. Chlorination of circulating water is not necessary from November to June. Then, sodium hypochlorite is used twice daily for 5 - 10 minutes. Because the residual is diluted 4 ways (by the two units), common discharge flume is less than .025 ppm.

b. Effluent from precipitator settling basin will be recycled to precipitator ash hoppers at 500gpm so no effluent can be discharged to recycling water system.

c. Liquid wastes :

1. Liquid wastes go to a waste retention basin where they are neutralized in a tank with the capacity of 50,000 gallons and which has a continuous PH monitor.

2. Boiler feed water is treated with ammonia to maintain a PH of 9 - 9.5 and with hydrazine to remove dissolved oxygen.

3. Boiler water is blown down - silica levels are below .20ppm.

4. Collected oil goes to an oil/water separator and is then stored in 55 gal. drums for offsite disposal.

5. Wash water (acidic and suspended solids) goes to the waste sump for PH control and then to precipitator ash basin.

6. Boiler is chemically cleaned (start-up and every 3-5 yrs.) with an alkaline boilout, acidic cleaning. Boiler will be back-flushed with water. Water and chemicals will go to basin for neutralization before discharge.

PROBLEM : Added receipt and storage of fuel oil increases danger of spillage.

PROPOSAL : a. Compressed air supply forces oil through unloading lines to avoid spillage.

b. Oil tanks are surrounded by a steel dike with 110% capacity of tank for leakage.

c. NEPCO has stored at site two different types of oil booms in the event of spillage. Also, the Coast Guard Office at Woodshole has containment equipment.

II. Recommendations from state and federal agencies

A. Pollution control agencies have recommended measures to reduce pollution of environment surrounding plant area. Most have been complied with in proposed plans. (See pp. viii - xvii)

B. Suggested alternatives to Unit 2 :

1. No action - non-feasible : a critical power shortage would ensue within ten years.

2. Purchase power - not realistic : power demands in other areas will not leave sufficient fuel for N.E. area.

3. Alternative sites for unit 2 - site chosen is most advantageous - 1) Units 1 & 2 can share common systems, 2) Area will be least affected (ecologically) by plant while yeilding all criteria needed fulfilled.

4. Alternative fuels :

   a. Gas - insufficient amounts
   b. Other oils - no environmental advantage; would create a substantial drain on refinery needs.
   c. Coal - environmental impact too damaging

5. Alternative Means of Power Generation

   a. Nuclear Power - breeder reactors not sufficiently developed.
   b. Other electrical systems - site is not available

6. Alternative Air Quality Controls

   a. Baghouse filter - only one unit known, service is intermittent
   b. Scrubbing system with chemical additive - developmental

7. Alternative Cooling water systems

   a. cooling towers or ponds - too expensive, more land needed, hazardous to canal.

8. Alternative Chemical Waste System

   a. Falling film evaporator - too expensive, but environmentally more beneficial than present system.
   b. Mechanical cleaning - too expensive, present system more favorable.

III. Conclusion

The remainder of the report focuses on the economic gains to the immediate community and the power source made available to the New England area. In addition, a group of tables, reports and appendices are included citing meetings held with civil groups and state and federal agencies regarding the installation of the new unit and its implications. Findings indicate that, because the proposed unit agrees to comply with recommendations made by the varous groups, the expanded plant will not harm the existing environment of that area.

DLT/cm

The Commonwealth of Massachusetts
Department of Natural Resources
Leverett Saltonstall Building
100 Cambridge Street, Boston 02202

FRANCIS W. SARGENT
GOVERNOR

ARTHUR W. BROWNELL
COMMISSIONER

September 18, 1973

Mr. John Wm. Leslie
Chief Engineering Division
USA Corps of Engineers N.E.D.
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Mr. Leslie:

The Department of Natural Resources has reviewed the draft environmental impact statement for the addition of Unit No. 2, Cape Cod Canal Plant, Sandwich, Massachusetts. The report is an adequate presentation of the existing knowledge of the environmental impact from this proposed facility on the resources of the Cape Cod Canal area.

In order to minimize the environmental effects of the new unit, particularly on the marine resources of the Canal area, the Department recommends that the Canal Electric Company undertake a definitive entrainment study after construction, to determine the extent of mortality of entrained organisms. We also recommend that a fish entrapment evaluation be conducted on the intake for Unit 2 after installation of the bottom sill.

In addition, we recommend that a study of the thermal plume be conducted to provide verification of the predictive model and the effects of the plume configuration on finfish within the Cape Cod Canal.

We anticipate that these recommendations will be considered in the final environmental statement submitted for the proposed project.

Yours truly,

Arthur W. Brownell
Commissioner

AWB/g

The Commonwealth of Massachusetts
Department of Natural Resources
Leverett Saltonstall Building
100 Cambridge Street, Boston 02202

FRANCIS W. SARGENT
GOVERNOR

ARTHUR W. BROWNELL
COMMISSIONER

September 24, 1973

Mr. John Wm. Leslie
Chief, Engineering Division
USA Corps of Engineers N.E.D.
424 Trapelo Road
Waltham, Mass. 02154

Dear Mr. Leslie:

The attached letter of review relative to the draft Environmental Impact Statement for the addition of Unit No. 2, Cape Cod Canal Electric Plant, Sandwich, Massachusetts was received from the Division of Fisheries and Game. Since it arrived subsequent to our departmental review and letter of comment, we are forwarding it as written for consideration in formulating the final environmental statement.

Yours truly,

Arthur W. Brownell
Commissioner

AWB/g

Attachment

The Commonwealth of Massachusetts
Division of Fisheries and Game
Leverett Saltonstall Building, Government Center
100 Cambridge Street, Boston 02202

JAMES M. SHEPARD
DIRECTOR

September 18, 1973

Mr. Charles F. Kennedy
Director and Chief Engineer
Division of Water Resources
100 Cambridge Street
Boston, Massachusetts 02202

Dear Mr. Kennedy:

Reference is made to the draft Environmental Statement concerning the addition of Unit No. 2, Cape Cod Canal Electric, Sandwich, Massachusetts, as prepared by the Army Corps of Engineers, 1973.

Please be advised that we anticipate little significant adverse effects as a result of this project to the wildlife and inland fisheries resources under the jurisdiction of this agency. We, therefore, concur with that which has been presented in this statement relative to these resources. Although, we do feel it should not go without mention that the list of resident and migratory species of wildlife observed in the project area could have been largely expanded to include non-game species.

Sincerely yours

James M. Shepard
DIRECTOR

JMS:AWN/cms

THOMAS O'BRIEN
DIRECTOR
OFFICE OF STATE PLANNING AND MANAGEMENT

The Commonwealth of Massachusetts

Executive Office for Administration and Finance

Office of State Planning and Management

Leverett Saltonstall Building, Room 909
100 Cambridge Street, Boston 02202

AREA CODE 617
727-5066

Mr. John William Leslie
Chief, Engineering Division
New England Division
Army Corps of Engineers
424 Trapelo Road
Waltham, MA 02154

October 18, 1973

Re: Addition of Unit No. 2, Cape Cod Canal Plant
Sandwich, MA - EIS
State Clearinghouse Id. 73080360

Dear Mr. Leslie:

The State Clearinghouse has reviewed the draft environmental impact statement for the addition of Unit No.2 of the Cape Cod Canal electrical generating plant, submitted in accordance with the provisions of the National Environmental Policy Act of 1969.

Review comments were requested from the following state agencies: the Executive Offices of Consumer Affairs and Environmental Affairs, the Departments of Community Affairs, Natural Resources, Public Health, and Public Works, the Division of Water Pollution Control, and the Division of Marine Fisheries.

The Bureau of Air Quality, Division of Environmental Health, Department of Public Health has responded as follows:

> "Information presented in the Environmental Impact Statement is acceptable to the Department except that described in Paragraph 3.1.1.3 which states that Nitrogen Oxides and oxidants can be assumed to be low in the summertime in the Cape Cod area where the plant is to be located, namely; in the vicinity of the Sagamore Bridge."

Comments of the Division of Water Pollution Control were incorporated into a letter sent directly to you by the Department of Natural Resources. Comments of the Division of Marine Fisheries were also forwarded independently (copies of both attached).

Any further comments made will be forwarded upon receipt by the Clearinghouse.

Sincerely,

Thomas O'Brien, Director

KM/js

CC: Cape Cod Regional Planning Commission

encl.

OCT 1 7 1973

September 18, 1973

Mr. John Wm. Leslie
Chief Engineering Division
USA Corps of Engineers N.E.D.
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Mr. Leslie:

The Department of Natural Resources has reviewed the draft environmental impact statement for the addition of Unit No. 2, Cape Cod Canal Plant, Sandwich, Massachusetts. The report is an adequate presentation of the existing knowledge of the environmental impact from this proposed facility on the resources of the Cape Cod Canal area.

In order to minimize the environmental effects of the new unit, particularly on the marine resources of the Canal area, the Department recommends that the Canal Electric Company undertake a definitive entrainment study after construction, to determine the extent of mortality of entrained organisms. We also recommend that a fish entrapment evaluation be conducted on the intake for Unit 2 after installation of the bottom sill.

In addition, we recommend that a study of the thermal plume be conducted to provide verification of the predictive model and the effects of the plume configuration on finfish within the Cape Cod Canal.

We anticipate that these recommendations will be considered in the final environmental statement submitted for the proposed project.

Yours truly,

Arthur W. Brownell
Commissioner

AWB/g

The Commonwealth of Massachusetts
Division of Fisheries and Game
Leverett Saltonstall Building, Government Center
100 Cambridge Street, Boston 02202

JAMES M. SHEPARD
DIRECTOR

Chrid

RECEIVED
SEP 19 1973
MASS. WATER RESOURCES COMM.
DIV. OF WATER RESOURCES

September 18, 1973

Mr. Charles F. Kennedy
Director and Chief Engineer
Division of Water Resources
100 Cambridge Street
Boston, Massachusetts 02202

Dear Mr. Kennedy:

Reference is made to the draft Environmental Statement concerning the addition of Unit No. 2, Cape Cod Canal Electric, Sandwich, Massachusetts, as prepared by the Army Corps of Engineers, 1973.

Please be advised that we anticipate little significant adverse effects as a result of this project to the wildlife and inland fisheries resources under the jurisdiction of this agency. We, therefore, concur with that which has been presented in this statement relative to these resources. Although, we do feel it should not go without mention that the list of resident and migratory species of wildlife observed in the project area could have been largely expanded to include non-game species.

Sincerely yours

James M. Shepard

James M. Shepard
DIRECTOR

JMS:AWN/cms

This letter was sent separately to the Corp since we received it subsequent to sending out the Departmental review letter.

8.3-2ff

Natural Resources Defense Council, Inc.

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NEW YORK, N.Y. 10036
212 869-0150

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John H. Adams, Esq.
Executive Director

September 19, 1973

John Wm. Leslie
Chief, Engineering Division
New England Division Corps
of Engineers
424 Trapelo Road
Waltham, Mass. 02154

Dear Mr. Leslie:

The Striped Bass Fund, Inc., submits the enclosed statement regarding the draft environmental impact statement prepared by the U.S. Army Corps of Engineers in relation to review of a construction permit pursuant to Section 10 of the Rivers and Harbors Act for the Cape Cod Canal Plant, Unit No. 2 at Sandwich, Mass. The major concern of the Striped Bass Fund, an organization of concerned citizens in the coastal states, is the protection of the striper fishery, its spawning and nursery waters and coastal waters. The Striped Bass Fund sponsors research, education and where necessary, legal action to protect the striper fishery.

It is of utmost concern to the Fund that the Corps of Engineers protect the public interest in the fishery by assuring that its regulatory control includes a thorough and careful analysis of the effects of plant operations on the aquatic biota of the waters in the vicinity of the Cape Cod Canal Plant. For the reasons enumerated in the enclosed statement, the Fund feels that the draft environmental statement does not provide such an analysis. The Fund hopes that this situation will be remedied before the issuance of the final environmental impact statement.

Yours sincerely,

Sarah Chasis

Sarah Chasis
Attorney for the Striped Bass
Fund, Inc.

SC/sp
Enclosure

COMMENTS OF THE STRIPED BASS FUND
ON THE DRAFT ENVIRONMENTAL STATEMENT
PREPARED BY THE UNITED STATES ATOMIC
ENERGY COMMISSION FOR THE CAPE COD
CANAL PLANT ADDITION OF UNIT NO. 2,
SANDWICH, MASSACHUSETTS.

SARAH CHASIS
Attorney for Striped Bass Fund
Natural Resources Defense
Council, Inc.
P.O. & Office Address
15 West 44 Street
New York, New York 10036
Te. No.: (212) 869-0150

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INTRODUCTION

The Cape Cod Canal Draft Environmental Statement must be assessed both substantively and procedurally with regard to its once-through cooling system. The first involves evaluating the plant structure, the hydrology of the waterway, and the aquatic population dynamics. The second involves considering the possibilities not studied, observations not explained, unsupported conclusions, inadequate methodology, etc.

The Cade Cod Plant as proposed will utilize a once-through cooling system. This type of system can be a potential hazard to the aquatic population in several ways:

- Impingement: Adult and juvenile fish (larger than mesh size which is commonly 3/8") become impinged upon the screens at the intake valve of the plant's cooling system.

- Entrainment: Eggs, larvae, and plankton may pass through the screens at the intake and travel with the coolant water through the entire plant, exposing them to mechanical and thermal abuse.

- Thermal pollution: The plant's condenser will continuously discharge heated water, which may be hazardous to the aquatic biota.

- Chlorination: Chemical effluents, particularly chlorine, can be toxic to certain populations if the concentration is permitted to exceed "acceptible levels". (Generally 1 ppm for chlorine.

- Salinity stratification: In an estuarine region, alteration of the natural salinity stratification sometimes results when a plant's discharge is received by water of different salinity from that at the intake.

I. SUBSTANTIVE CRITERIA

A. PLANT STRUCTURES

To evaluate the potential harm of the Cade Cod Plant, the environmental statement must consider the structure of the proposed plant, the hydrology of the canal and the dynamics of the aquatic population. Each of these are closely interrelated and must be considered together in determining any potential environmental impact. The following structural factors are relevant:

(1) Intake velocity: This determines, in party, the number of fish which will be lost by impingement. It affects the ability of the fish to swim away from the intake, and the force with which the fish may be smacked against the intake screen. The intake velocity at Cape Cod is expected to be 1.02 fps at the entrance and a maximum velocity at the screens of .94 fps at extreme low water. A safe velocity varies with the waterway and its biota.

(2) Screens: The screens will be traveling screens, which reduces impingement. However, the screens will be located "at

the downstream end of the intake structure" (DEC p. 1.2-12). Placement of screens flush with the banks of the waterway entraps fewer fish than when the screens are recessed in the intake canal. There is no apparent indication as to whether fish reaching the screens have the ability to swim out of the intake structure. Nor is there discussion of the mortality of those organisms washed off the screens into the sluiceway. Whether the screens would be operated as continuously traveling, as opposed to periodic, is also not mentioned.

It is interesting to note (DES Figure 1.2-3) that the sluiceway empties at a point along the canal which appears to be between the intake structures of Units I and II. The fish so released, if alive, will most likely have their swimming abilities at least temporarily impaired. Therefore, there is some probability that such fish would be drawn into an intake structure for a second time. The ability of fish to survive the experience for a second time is not necessarily discernable from data of solely Unit I operation.

(3) Size and Depth of intake opening: A nine-foot sill is proposed for the Unit II intake "to discourage bottom-swimming fish from entering the intake" (DES p. 1.2-11). This structure is recommended in response to the finding by the Massachusetts Department of Natural Resources, that substantial mortaility of winter flounder (which swim near the bottom) occurred by impingement on the Unit I intake screens. (DES, Appendix p.43.) Whether this structure will successfully mitigate the loss is uncertain.

(4) Temperature: The temperature of the water at the condenser outlets is estimated to be about 28°F above the ambient water temperature (DES p. 1.2-11). In warmer months, it is conceivable that mortality will result before the heat can be dissipated to "safe" levels.

The average seasonal temperatures are also generally given in the river hydrology portion of the environmental statements. Often these figures are forgotten when the temperature increase by the plant's operation is discussed. The environmental impact section tends to deal with change in temperature and will usually cite to literature indicating that fish can tolerate the predicted amount of increase. However, we urge that the precise temperatures be considered, particularly the raised temperature during the summer seasons. It may be that such temperatures cross the threshold of tolerance for at least some of the aquatic species inhabiting the affected water body.

(5) Proximity of structures: A curious design is proposed for the Cape Cod plant with the addition of Unit II. The proposed design envisions the intake of Unit II a distance of approximately 200 feet from the intake of Unit I. Whereas the discharge for Unit I is presently about 140 feet from the intake, the construction of Unit II calls for a closing-off of that discharge and the construction of a common discharge for both Units I and II together, at a distance approximately 800 feet further east along the canal. The rationales for this common discharge and its distance are not evident. (DES Figure 1.2-3.)

(6) Distance between intake and discharge: Figure 1.2-3 of the DES indicates that the combined discharge will occur approximately 800 feet east of the intake region. The section of the hydrology of the canal indicates reversing tides, but a net westerly flow. No discussion is presented on the question as to whether or not to what extent discharged water becomes again subject to the plant's intake.

Unit II circulating water flow would be 426 cfs, compared with Unit I's value of 372 cfs, yielding a total of approximately 800 cfs. Assessment of thermal and chemical dissipation based on 372 cfs, may not be truly applicable for 800 cfs, particulary given the narrow width of the canal in this region. (DES Figure 1.2-3.)

B. HYDROLOGY OF THE WATERWAY

The hydrology of the proposed site will effect the extent of the impact of the structure of the Cape Cod Plant. The width and depth of the canal as well as the natural movement of the water can minimize or intensify the impact of the plant.

The "land-cut portion" of the Cape Cod canal is 7 miles long and is 480 feet wide at the bottom. As it is described as steeply-sloped, the surface width is presumably not much wider. This fact is of great significance when evaluating the statement in the Appended technical report which served as the major basis for the draft impact statement (Appendix I p.11), that the thermal plume is dissipated "rapidly within 500 feet of the discharge

and was essentially complete at 2000 feet". One must note that those values were reported for Unit I discharge at 372 fps. With the addition of the proposed Unit II, the combined discharge will emerge at a rate of 800 fps. The character of the thermal plume will surely be affected by doubling the volume of heated discharge.

Considering the width of the canal, the rate of dissipation becomes a matter of some concern. Avoidance behavior which might ordinarily be exhibited by fish population of a wide river on which a plant is located cannot readily take place when the thermal plume extends virtually the entire width of the waterway. It is at least conceivable that behavioral alterations will occur as a result of a heat band across the canal. (This is an example of an issue that was not clearly represented in the impact statement, but emerges only upon correlation of distinct facts presented in the document.)

The water in the Cape Cod Canal is very turbulent (DES p. 2.2-4) and there is reportedly a reversing current every six hours (DES p. 2.2-1). Moreover, it is suggested that velocity is such that the canal is alternatively filled with Buzzards Bay water, than entirely with water from the Cape Cod Bay. If this is so, then absorbtion of effluents is readily facilitated, since dilution can be extended to these larger water masses. However, this composition hypothesis appears to be based upon temperature data obtained "at each end of the canal," together with the finding that Cape Cod Bay in summer is 15-20°F colder

than Buzzards Bay (DES p. 2.2-4). However, heat can flow without the movement of mass (second law of thermodynamics), and therefore, the conclusion presented in the study is not necessarily demonstrated by the temperature changes reported. On the other hand, the rapidity and vastness of the dramatic change should be noted. Dye experiments would be a more persuasive indication of the movement of the water mass. Temperature data is not conclusive on this point.

C. AQUATIC POPULATION DYNAMICS

The environmental statement should include more extensive data on the dynamics of the aquatic population. The effects on aquatic life must be examined in light of possible alterations in the food chain of that life and/or alterations in the spawning habits. Operation of the plant might directly kill only a few fish, but might disrupt the whole food chain, thereby altering the entire population. If plant operation discourages fish from spawning where they normally do, a whole species of fish could be wiped out.

In the Cape Cod Canal, adult forms of certain species have been found in the canal "in substantial numbers during their respective spawning seasons" (Appendix I, p. 30). In addition, it was reported that collection of eggs correlated with the spawning periods.

The presence of eggs and larvae elicits concern with regard to optimal and tolerable temperature levels for hatching

and development. While the Draft Environmental Statement makes no such comment, the appended technical report indicates that "discharge temperatures probably exceed the tolerable limits of egg and larval forms of at least the cod and mackerel during their respective spawning seasons." (Appendix I, p.34.) This is of extreme importance and should be further explored and explained.

II. PROCEDURAL CRITERIA

A. POSSIBILITIES NOT STUDIED

Apart from the substantive problems with the draft environmental statement, there are procedural problems. There is a tendency to ignore the impact on a species that cannot be adequately assessed and not to consider it in the cost-benefit analysis. This is a serious mistake because it assesses the costs of the plant at less than they actually are. The Draft Environmental Statement mentioned that the canal hosts striped bass, a "highly prized species," but did not undertake to assess the plant's impact on this species (DES Appendix I p.17). The report suggested that extensive personnel and effort would have been required and that fluctuations due to plant operation "would be undiscernable from changes due to naturally occurring fluctuations in abundance so typical of this species" (DES Appendix I, p.17). One should note that the report did not dismiss the possibility

that the plant's operation has a significant impact on the striped bass population. Yet, this is not considered in the environmental impact assessment nor the cost-benefit analysis.

B. OBSERVATIONS NOT EXPLAINED

Another problem with the draft is the observed but unexplained increase in temperature in the Cape Cod Canal. In the Canal, the waters have become progressively warmer each summer from 1967 to 1969, the period of study by the Massachusetts Department of Natural Resources, Division of Marine Resources. This trend of increasing temperature in the canal is revealed in Table 3 (DES, Appendix I, p.16) but no explanation is attempted. However, one cannot dismiss the possibility that the increase is related to the operation of the power station. If such be true, then the operation of a second plant as well may have serious long-run effects on the biota of the canal. This possibility is not discussed in the impact sections of the DES.

C. UNSUPPORTED CONCLUSIONS

With regard to the fish population of the Canal, the Draft Environmental Statement seems to include some unsupported conclusions. "Changes in the overall abundance of major fishes in the Cape Cod Canal have been attributed to natural population fluctuations since numbers varied along all transects, including those outside the area of power plant influence." (DES Appendix I, p. 23.) This statement is not necessarily persuasive, as it seems

they have assumed their own conclusion. Also, in view of the vast movement of water mass due to the tides, it would seem difficult to assert with certainty that specific regions are beyond the reach of the plant's influence. Moreover, a possible impact has been thereby disregarded in the assessment of the plant's impact on the environment, because there is no conclusive evidence.

D. ASSESSMENT METHODOLOGY

In assessing the methodology of the statement, our concern tends to be twofold. First, whether methods used give an accurate determination of the particular impact being studied. Second, whether the precise methodology is discernable from the description included in the environmental statement.

In the Cape Cod study, tows and seines were deemed unfeasible, and so creel census served as the basis of assessment instead. An example of the second type of difficulty is found in the Cape Cod study, where no indication is given as to how the rate of dissipation of the thermal plume was ascertained.

Caution may also be suggested against the inference that the effects of one plant at a given location will indicate the effects of a second plant at that same site. Here, it is necessary to consider possible cumulative effects, which in some cases may cross tolerable levels. Characteristics of the local flow will be important in determining the extent to which impacts of two plants will compound each other.

E. COST-BENEFIT ANALYSIS

A rather basic comment to be made is to note that the hazardous effects which have been discussed stem from the use of once-through cooling. Therefore, it should be urged that in the cost-benefit analysis, the detriment to the aquatic life should be weighed solely against the necessity of utilizing a once-through cooling system rather than alternative methods of cooling.

The tendency seems to be to weigh the damage against the total value or need for the power station in question. Alternative methods of cooling are then mentioned with the usual conclusion that cooling ponds require too much landspace and that cooling towers are too expensive.

It should be urged that the irreparable, continuous loss to the aquatic biota be weighed merely against the benefit (predominately initial monetary saving) derived from foregoing more expensive, but less detrimental, alternative cooling methods. Such is generally the real issue at stake.

If construction of the plant is too expensive when alternative cooling methods are indicated, then the plant should not be built. It would seem unorthodox to backtrack and undervalue the ramifications of the potential aquatic loss.

CAPE COD CHAMBER OF COMMERCE

Junction U. S. Route 6 (Mid-Cape Highway) & Route 132
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RICHARD J. VANDER MAY, Eastham

September 20, 1973

Mr. John Wm. Leslie
Chief, Engineering Division
Department of the Army
New England Division, Corps of Engineers
424 Trapelo Rd.
Waltham, Mass. 02154

Dear Mr. Leslie:

On reading through your draft environmental statement regarding Plant No. 2 of the Canal Electric Company, we are impressed with the details and effort that apparently have been undertaken to insure the protection of the environment.

There is little I can add by way of meaningful comment in this direction. I would, however, make only one further comment and urge that because the Canal Electric Company occupies a prominent position on our landscape, and is readily seen by those visitors to our area crossing the Canal Bridge, I would hope that a special effort above and beyond the normal landscaping effort might be made to beautify the area.

Thank you for your consideration.

Yours very truly,

CAPE COD CHAMBER OF COMMERCE

Michael J. Frucci

Michael J. Frucci
Executive Secretary

mjf/l

8.3-2uu

8.3.2 Comment - Response

U.S. ENVIRONMENTAL PROTECTION AGENCY

Comment:

Air

The proposed addition (Unit No. 2) does not appear to meet all the criteria of the New Source Performance Standards for Fossil Fired Steam Generators which were promulgated on December 23, 1971. Some assurance of compliance should be documented in the final environmental impact statement. This should include provisions for notification, record keeping, performance testing, emission monitoring and full monitoring as specified in the December 23, 1971 Federal Register.

The use of 1 percent sulfur oil will not be adequate to meet the required limit of .80 pounds per million Btu heat input. Since the air quality assessment is based on 1 percent sulfur fuel, it seems that the plant proposes to run both units on 1 percent sulfur fuel. This should be specifically addressed since the new unit will only be allowed approximately .75 percent sulfur fuel under the provision of 40 CFR 60.43.

Response:

The proposed Unit No. 2 at the Canal Plant is classified as an existing source under the definition of new and existing sources published by the Environmental Protection Agency in the Federal Register of December 23, 1971 (Volume 36, No. 247-page 24876-95). These definitions specifically referred to the applicability of the standards of performance for new stationary sources. They exclude all units on which a "continuous program of construction or modification" had begun, or on which a binding agreement was in effect for contractual obligation to undertake and complete, within a reasonable time, a continuous program of construction or modification prior to August 17, 1971.

Canal Electric Company authorized Stone & Webster Engineering Corporation to proceed with the design and construction of a new unit at the Canal Plant on November 1, 1970. A verbal commitment for the purchase of the boiler, the single most important piece of equipment, was given to Babcock & Wilcox on May 1, 1971, and a letter of intent was sent to Babcock & Wilcox on June 2, 1971. These dates clearly precede August 17, 1971, and therefore establish Unit No. 2 at Canal Plant as an "existing unit" for the purpose of the Federal New Source Standards. The Bureau of Air Quality of the Massachusetts Department of Public Health concurs in this opinion and has so stated in a letter to the Canal Electric Company and the Montaup Electric Company, dated March 5, 1973. The use of a residual fuel oil with a sulfur concentration

of not more than 1 percent will comply with all applicable Massachusetts emission standards.

Comment:

Although the problem of downwash apparently has not been significant, some consideration of this potential problem should be presented specifically with reference to the proposed location of the new stack and the height of the surrounding buildings.

Response:

The high stack gas exit velocities (between 80 and 90 fps at 100 percent load) and high stack gas exit temperatures (on the order of 300 F) in combination with the new 498 ft stack will avoid the occurrence of aerodynamic building downwash. The ratio of the height of the new stack to the maximum onsite building height (208 ft) is 2.4, and this compares well with the ratio of 2.5 which is sometimes used as a rough and very conservative guideline as to whether or not there is any possibility that aerodynamic building downwash could be a problem.

Comment:

Future plans for the monitoring network should be presented. We recommend the network for this area to be maintained to monitor compliance with the applicable air quality standards. A summary of the air quality data from the network should be presented.

Response:

The Applicant will continue the present air quality monitoring program for at least 15 months after Unit No. 1 comes on line with the new 498 ft stack. An air quality monitoring program in the vicinity of Canal Plant has been in progress since July 31, 1970, and has been under the direction of the GCA Technology Division, GCA Corporation. The monitoring system now consists of four continuous SO2 monitors and one high-volume sampler. Table 8.3-1 summarizes the results of this survey from August 1, 1971, through December 31, 1972. The maximum observed values of SO2 and particulate concentration are well below Federal and state air quality standards and the occurrence of these higher values shown in the table are rare.

TABLE 8.3-1

Comparison of Ambient Air Quality with Massachusetts Standards
(August 1, 1971 - December 31, 1972)

POLLUTANT	STATISTIC	CONCENTRATION		RATIO
		Max. Observed (PPM)	Mass. Standard (PPM)	Obs./Mass.Stand.
SO2	Annual Geom. Mean (1972)	0.008	0.025	0.32
	Max. 24-Hour	0.044	0.105	0.42
	Max. 1-Hour	0.148	0.280	0.53
Suspended Particulates	Annual Geom. Mean (1972)	22	75	0.29
	Max. 24-Hour	116	180	0.64

Comment:

CHEMICAL WASTES

The statement does not completely describe the treatment of the chemical wastes which will be generated. We suggest that the final environmental impact statement include this information. We also recommend that there be close coordination with the Permits Branch regarding this specific issue.

Response:

Chemical wastes associated with the operation of existing Unit No. 1 and proposed Unit No. 2 at the Canal Plant include the following:

Equipment washing wastes
Boiler chemical cleaning wastes
Floor and equipment drainage
Precipitator ash sluicing blowdown
Makeup water treatment wastes
Condensate polishing regeneration wastes
Boiler blowdown
Sanitary wastes

All of the above wastes will be treated and/or recycled prior to discharge in Cape Cod Canal via the Units No. 1 and No. 2 circulating water discharge system. The Applicant has filed for a discharge permit with the Permits Branch and continues to

coordinate closely with EPA officials on this matter. The following paragraphs describe in detail the treatment methodology for each waste.

Equipment Washing Wastes

Liquid wastes resulting from periodic washing of air preheaters, superheater and reheater sections and economizer sections of the Unit No. 1 boiler are presently collected and treated in a 400,000 gallon waste treatment basin. Since these wastes are intermittent in nature, the basin will also be used to collect and treat similar washing wastes associated with the operation of proposed Unit No. 2. It is expected that equipment washing will be required 2 to 4 times per year for each unit.

If equipment washing waste volumes should exceed the 400,000 gallon capacity of the waste treatment basin, one of the two precipitator ash sluicing basins can be dewatered to provide further means of collecting these wastes. The wastes retained in the precipitator ash sluicing basins will later be chemically treated in the waste treatment basin. This chemical treatment consists of adding sodium hydroxide until the pH is between 9 and 10. Laboratory studies have shown a maximum removal of trace heavy metals within this pH range. In general, equipment washing wastes contain high concentrations of soluble iron, nickel, vanadium, and suspended ash particles. After pH adjustment, the heavy metal constituents are chemically precipitated as insoluble hydroxides, with vanadium being the only notable exception. Based upon ongoing laboratory studies, it is believed that vanadium removal is largely caused by chemical precipitation as ferric metavanadate. If equipment washing wastes contain sufficient quantities of soluble iron, then vanadium removal will generally be greater than 99 percent. If iron is not present in sufficient quantities, ferrous sulfate will be added in conjunction with sodium hydroxide to the waste treatment basin.

After chemical addition, the wastes are recirculated from the basin to the 50,000 gallon waste neutralization tank and back to the basin by means of a surface skimmer and pump. After mixing via recirculation, the suspended solids, including precipitated metals, are removed during a quiescent sedimentation period. After sedimentation, the treated effluent is conveyed to the neutralization tank to reduce the pH within the 6.5 to 8.0 range prior to discharge at a maximum rate of 100 gpm to Cape Cod Canal via the Units No. 1 and No. 2 circulating water discharge system. The major constituents present in the treated effluent are sodium and magnesium sulfate.

Solids are periodically pumped from the basin and dewatered prior to offsite disposal.

Boiler Chemical Cleaning Wastes

Boiler chemical cleaning is performed approximately once every 2 to 3 years to remove scale and iron and copper deposits which accumulate on the internal surfaces of the boiler. If these deposits are not removed, eventual boiler tube failure will occur.

Boiler chemical cleaning reagents vary depending on the chemical constituents of the deposits which are to be removed. Previous pre-operational and post-operational chemical cleaning operations at the Canal Plant have included the following:

PRE-OPERATIONAL (UNIT NO. 1)

Alkaline Boilout

Disodium Phosphate	-0.1%
Trisodium Phosphate	-1.0%
Wetting Agent	-0.05%

Acid Cleaning

Hydroxyacetic acid	-2.0%
Formic acid	-1.0%
Inhibitor	-0.2%
Ammonium Bifluoride	-0.25%

Neutralization

Ammonium Hydroxide	-0.001%
Hydrazine	-0.05%

POST-OPERATIONAL (UNIT NO. 1)

Acid Cleaning

Same as above

Neutralization

Same as above

The decision as to which chemical cleaning operation is to be used will be based upon recommendations from the boiler manufacturer.

Boiler chemical cleaning wastes will be drained to the waste treatment basin for chemical precipitation of soluble metals as described above for equipment washing wastes.

Floor and Equipment Drainage

Drainage from station floor and equipment areas will be collected and conveyed to an oil separator for the removal of oil and suspended solids. Effluent from the separator will be either recycled within the station or discharged to Cape Cod Canal via the Units No. 1 and No. 2 circulating water discharge system, and the collected oil will be recycled.

Precipitator Ash Sluicing Blowdown

A wet ash sluicing system is currently being used to hydraulically remove fly ash from the Unit No. 1 electrostatic precipitator. A similar method of ash handling will be employed for proposed Unit No. 2.

Briefly, the Unit No. 1 ash sluicing wastes are treated in a closed system in which the suspended fly ash is removed in settling basins and the clarified effluent is recycled for further ash sluicing. Operating experience with this system has indicated the probable need for periodic blowdown of clarified sluice water to maintain dissolved solids within the system below levels which lead to eventual equipment scaling. If necessary, a quantity of sluice water will be periodically transferred to the waste treatment basin and ferrous sulfate will be added to remove soluble vanadium. After chemical addition the waste will be recirculated from the basin to the neutralization tank, followed by a sedimentation period of sufficient duration to insure settling of the insoluble metal precipitates. Overflow from the basin will be conveyed to the neutralization tank for pH adjustment within the range of 6.5 to 8.0 and then be discharged to Cape Cod Canal via the use of Units No. 1 and No. 2 circulating water discharge system. The major constituents of the treated effluent will be sodium and magnesium sulfates.

The Applicant is presently evaluating several methods for dewatering precipitator fly ash. After dewatering, the fly ash will be sold for vanadium and nickel recovery.

Makeup Water Treatment Wastes

Makeup water treatment wastes associated with the operation of existing Unit No. 1 include backwash and demineralizer regeneration wastes. These wastes are presently collected in the 50,000 gallon waste neutralization tank for pH adjustment to within a range of 6.5 to 8.0. The neutralized effluent then flows by gravity to the canal via the Units No. 1 and No. 2 circulating water discharge system.

Makeup water treatment wastes associated with the operation of Unit No. 2 will be treated in the plant neutralization system. The major constituent present in the neutralized makeup water treatment wastes is sodium sulfate.

Condensate Polishing Wastes

Condensate polishing wastes associated with the operation of Unit No. 2 will be neutralized and discharged to the canal via the Units No. 1 and No. 2 circulating water discharge system as described above.

Boiler Blowdown

Periodic boiler blowdown from Unit No. 2 will be conveyed to the precipitator ash sluice system as makeup water. There is presently no blowdown associated with the operation of Unit No. 1 since the unit incorporates the universal pressure boiler.

Sanitary Wastes

The existing sanitary waste disposal system will be expanded to include wastes from the operation of Unit No. 2. This system is comprised of a septic tank and leaching field.

Comment:

OIL AND HAZARDOUS MATERIALS CONTROL

The statement should provide additional information on the oil storage and handling facilities. The Environmental Protection Agency published proposed regulations on oil pollution prevention from nontransportation related on-shore and off-shore facilities in the Federal Register of July 19, 1973. The final regulations are expected to be published in October, 1973. These regulations, among other things, establish procedures for the preparation of spill prevention, control, and countermeasure plans including design and operation considerations to be incorporated in a storage facility.

The regulations apply to facilities which store more than 42,000 gallons below ground or 500 gallons above ground. Penalties are set for noncompliance. A copy of these proposed regulations is attached for your information.

In the particular case of transformer oil, it is important to note whether or not toxics such as flame retardants or polychlorinated-biphenols are present.

Response:

As stated on page 1.2-17 of the Draft Environmental Statement, the "... total fuel unloading, storage, and transfer system is owned by NEPCO Terminal, Inc...." NEPCO is required to obtain a license on an annual basis, in accordance with the Rules for Prevention and Control of Oil Pollution in the Waters of the Commonwealth, from the Commonwealth of Massachusetts Water Resources Commission. The U.S. Environmental Protection Agency

is presently preparing new regulations on fuel oil unloading, storage and transfer systems. NEPCO will be further regulated at such time when these rules become enforced.

The two new oil storage tanks being built in conjunction with Unit No. 2 will be filled using the existing unloading facilities, as described on page 1.2-17 of the Draft Environmental Statement. As stated on page 1.2-19, "All fuel transfer lines will be steam-traced and recirculation with external heating will also be available."

Each of the two new storage tanks will be surrounded by a steel dike. Each dike is designed to accommodate 110 percent of the storage tank volume it surrounds. An impermeable layer of compacted backfill will be placed within each dike to prevent seepage of oil into the ground should an oil spill occur.

Runoff is collected at the low grade point within the dike to facilitate the removal of rainwater from within each dike. The rainwater will be removed via a 1 1/2 in. pipeline which enters the dike at the low grade point. The pipe is fitted with a manually operated valve on the inside of the dike wall, and a quick closing ball valve on the outside of the wall. Before removal, the water will be inspected for traces of oil. If oil is found, the water will be pumped into tank trucks and carried to an oil separation facility for recycling.

The main and station transformers will not use polychlorinated-biphenols or flame retardants in the transformer oil. The outdoor transformers contain insulating mineral oils which are susceptible to microbial oxidation (biodegradable) in the environment.

Comment:

NOISE

In the Preface of the report (Volume I, page xiii), a general statement is made pertinent to noise control methods to be used during blowing of steam lines while construction is underway on the proposed addition. No estimate of the noise levels generated by these blowing operations is given nor is it clear from the statement if these blowing operations occur during normal maintenance procedures as well as during construction. If the blowing of steam lines does occur as a part of normal maintenance procedures even at intervals of three to five years as suggested by Table 3.2-2 on page 3.2-14, this fact should be clearly stated. In addition, it would be useful to include some measured noise level data from typical blowing operations taken from Unit No. 1 particularly if these operations are periodic.

Response:

The purpose of the boiler blowout operation is to clean the main steam lines and hot and cold reheat lines of debris left during pipe fabrication and construction. Steam is released from the boiler drum at approximately 845 psig, and travels at sonic velocity through the pipes and entrains the debris. Jumper lines are installed to bypass the turbine and allow the steam and debris to be vented outside the turbine and boiler buildings. The two 24 in. diameter jumper vent lines will carry a total of 3.3 million lbs/hr of steam. This operation is repeated until adequate cleaning is achieved.

The primary noise source is the high velocity steam jet exiting from the vent lines. Secondary noise sources are steam flowing through the valves and piping. The expected unsilenced sound pressure levels were predicted using a computerized adaptation of Lighthill's theory. A sound level of approximately 104 dBA would be expected at 500 ft from the unsilenced vent outlet.

The Applicant is committed by the Massachusetts Department of Public Utilities (DPU) to the five below listed items pertaining to blowout noise:

1. Public notice will be given, indicating the date and approximate times of the blowing operation.

2. Mufflers will be installed if feasible and practical.

3. The blowing will be limited to the hours of 9 A.M. to 5 P.M. and not be continuous for a period of more than 1 hr, with quiet periods of at least 1 hr between periods.

4. No blowing operations will be conducted on Sundays.

5. A recording sound level meter will be kept in operation during all blowing periods at a position determined by the Massachusetts Department of Public Utilities.

The Applicant has had several discussions with manufacturers of mufflers and has concluded that a reduction of approximately 20 to 25 dBA should be feasible. Two large dissipative mufflers, each approximately 17 ft high and 12 ft in diameter weighing 19,000 lbs, are being purchased for this purpose. A silenced sound level of 85 dBA at 500 ft is expected. Since the unsilenced steam vent noise has maximum sound levels at lower frequencies, additional noise reduction is difficult to achieve. The expected level of 85 dBA at 500 ft from the steam vent, together with the other precautions, should serve to effectively minimize the noise impact from the boiler blowout operation. It

should be emphasized that the boiler blowout operation is only conducted once during the life of the plant. Other references to blowing operations, such as in Table 3.2-2, refer to chemical cleaning processes which do not produce significant noise.

Comment:

A second comment can be made with respect to the expected noise levels with both units running. At least three different interpretations of these expected levels are given in the draft statement:

1. In the Preface (Volume I, page xvi), the levels are 70 dBA, "not specified at this time", and 49 dBA.

2. In Section IV (Volume 2, page 4.0-2), the interpretation is, "The maximum sound level expected from Unit No.'s 1 and 2 operated at full load is 49 dBA at the east, south, and west property lines and 70 dBA at the north property line. This is not expected to be any increase from present noise levels."

3. In Section III (Volume 2, page 3.3-1), the interpretation is, "... the total sound levels in the vicinity of the plant will be no higher than, and perhaps lower than, the present sound levels shown in Table 2.5-1."

In the interest of clarity, one of these three versions should be adopted as the design goal of the proposed project, and a clear statement to this effect should be made in the report.

Response:

The acoustical design criteria of non-degradation has been chosen for the addition of Unit No. 2. This will be achieved by adding additional noise control to both Units No. 1 and No. 2, so that their combined sound level will be equal to or less than the existing Unit No. 1 sound level. Sound level surveys were conducted in 1971 by Stone & Webster Engineering Corporation with Bolt, Beranek, and Newman, Inc. to determine the noise output of Unit No. 1. The A-weighted sound levels were measured at several locations around the Canal Plant property lines and in the surrounding community with Unit No. 1 in operation. This data is described in Section 2.5, Ambient Sound Levels. The measured sound levels became the basis for the DPU requirements (page xvi, DES), which state that sound levels are not to exceed 70 dBA at northerly property lines and 49 dBA at other property lines. The Applicant interprets this regulation as not applying to the railroad right-of-way that runs through Canal Plant property.

Comment:

The noise control methodology described in Section 3.3 is commendable. Attention to noise control problems at the early design stage is an expedient approach to environmental noise control. The exact methods to be employed and the reasoning behind the quoted noise level reductions however, could be more clearly explained.

For example, the octave band data shown on Figure 2.5-2 appears to be predominantly transformer noise as the highest band levels show up in the 31.5, 63, and 125 Hz bands. This suggests that any effective reduction in the present Unit No. 1 noise levels (at least at the Baksis Boulevard site represented in Figure 2.5-2) would have to be accomplished by attenuation of this transformer hum. The extent of this attenuation appears to be approximately 7 dB if the following assumptions are correct : First, that the Baksis Boulevard site is essentially on the property line; secondly, that the desired level at this location is 49 dBA; and finally, that the addition of the Unit No. 2 transformer will add 3 dB* to the current level at this location. (*This assumes a doubling of acoustic power at the source, essentially free field conditions, and no harmonic correlation between the two contributing phenomena. Because of the dominating transformer noise there is a possibility of harmonic correlation in which case the correction could be +6 dB rather than the +3 dB given above.) If a level of 49 dBA is to be met at this site, Unit No. 1 can contribute 46 dBA as can Unit No. 2, these two 46 dBA levels combining to give a level of 49 dBA, and the present level of 53 dBA (worst case of Figure 2.5-2) minus the 46 dBA allowable level gives a required reduction of 7 dB.

A noise level reduction of 7 dB could be difficult to obtain, particularly since there is already a sound barrier wall on autotransformer No. 1, and what is required is a further reduction of 7 dB. To justify the feasibility of this further noise level reduction, more information on the present noise barrier as well as the proposed addition to the noise barrier should be included in the report.

Response:

In order to conform to the non-degradation criteria, it was necessary to reduce the Unit No. 1 sound levels on the west, south, and east sides of the plant by 3 dBA or more. A detailed sound level survey of the site indicated that the major sources of noise on the south side of the plant were the No. 1 autotransformer and the forced draft fan inlets.

At the time of the 1971 sound level survey, the No. 1 autotransformer had a concrete block wall, 59 ft long and 29 ft high, which partially screened the southerly direction from noise but did not offer protection at Baksis Blvd. To further reduce

the noise, this wall was extended 11 ft east and then 51 ft north, at a height of 20 ft. This masonry wall extension was constructed of 8 in. Type A-1 Soundblox and provides approximately 10 dBA reduction of No. 1 autotransformer noise at Baksis Blvd.

The second major noise source on the southerly half of Unit No. 1 is the forced draft fans, each with an inlet silencer with dimensions of 15 ft x 28 ft x 9 ft, and weighing 51,000 lbs. These silencers were designed to provide attenuation of at least 37 dBA. A detailed acoustical study of the silencer installation revealed that the performance of the silencer was impeded because of aerodynamic noise generated by the intake louvres and screens. By removing the intake louvres and bird screens, and replacing them with a coarse mesh screen, an additional 12 to 15 dBA noise reduction of the forced draft fan intakes has been achieved.

Several noise control features have been incorporated into the design of Unit No. 2. The No. 2 autotransformer was installed in 1972 near the eastern end of the switchyard, approximately 300 ft from the Baksis Boulevard location. This transformer, while of similar 400 mva capacity to the No. 1 autotransformer, had 5 dBA noise reduction built in at the factory. This was accomplished with internal core redesign, a heavier tank, and vibration isolation. This transformer was then enclosed by a U-shaped concrete Soundblox wall for further noise control. This wall is 30 ft high and 40 ft long on each of the east, west, and south sides, and provides 10 to 15 dBA noise reduction at the Baksis Blvd. location. During a sound level survey conducted in 1972 with both autotransformers and Unit No. 1 with its new precipitator in operation, the sound levels at the Baksis Blvd. location ranged from 44 to 46 dBA, which is equal to or below the sound levels measured in 1971 which were 46 to 53 dBA. Each of the two forced draft fans will have an inlet silencer with dimensions of 32 ft x 20 ft x 10 ft, weighing 62,000 lbs. The silencers have 25 parallel fiberglass filled baffles, and are designed to provide at least 35 dBA attenuation. Further design features have been incorporated to reduce air flow noise at the forced draft fan intake louvres and glycol air preheaters.

The two induced draft fans for Unit No. 2 also required noise reduction. The fan noise, if left untreated, would radiate from the top of the stack and would be audible over a large area. To reduce this noise impact, silencers will be installed in each of the fan discharges. Each of the silencers will be 18 ft x 27 ft x 18 ft, and consist of five fiberglass packed parallel baffles with a total weight of 60,000 lbs. These silencers are designed to provide 20 dBA attentuation primarily in the mid and low frequencies.

To reduce the noise radiated by the fan casings, a large fan room will enclose both the fan and electric motor drives. This fan room is 57 ft wide x 90 ft long x 44 ft high, and is constructed

of masonry block and corrugated asbestos siding with fiberglass lining. The fan room doors and ventilation system are designed to maintain the acoustical performance of the walls. The induced draft fans will also radiate noise from the inlet, back through the ductwork and precipitator between the fans and the boiler house. To prevent this noise from radiating into the community, approximately 100,000 sq ft of combination thermal-acoustical lagging will be installed on the ductwork and precipitator. This lagging weighs 3.4 lbs/sq ft, and contains a layer of lead. The lagging is expected to provide 15 dBA noise reduction at the mid and low frequencies.

The induced draft ventilation system, in combination with the building siding, will limit the interior noise from radiating to the outside. Power roof ventilator fans have been selected for their low noise output. Each of the two main transformers has 5 dBA noise reduction built in at the factory. This reduction is achieved by providing a heavier tank, a larger core, stiffeners and vibration isolation.

Comment:

In terms of the noise impact of the proposed project, it appears that an upper limit to the possible impact would be an increase of 3 dB over the current noise level. Because of the noise control techniques to be applied to both the present and additional facilities, the noise impact would probably be somewhere between a 1 and 3 dB increase in noise levels (compared to "no increase" as suggested in the report).

Response:

The noise impact of the Unit No. 2 addition to the Canal Plant should be effectively minimized by the noise control features incorporated into both units. The Property Line Criteria adopted by the Department of Public Utilities will not be exceeded and, generally, the sound level output from Units No. 1 and No. 2 should be equal to or less than that of the output of Unit No. 1 in 1971.

Comment:

SOLID WASTE

The draft environmental impact statement states that "Settled ash will be removed from the precipitator ash settling basin and disposed of in an approved manner (page 1.2)." The final environmental impact statement should indicate the specific disposal method, including the location of the disposal site and any pre-treatment (e.g., dewatering) given the waste. In addition, the final environmental impact statement should include the quantity of settled ash expected and its chemical and physical characteristics.

Response:

Based on current operating experience with Unit No. 1 when burning 1 percent sulfur oil, it is estimated that with Units No. 1 and No. 2 operating, there will be 7,500 pounds per day of dry ash material to be processed. The ash removed from the settling basin is sold to commercial metal recovery companies as raw material.

Comment:

According to the statement "collected oil will be removed from the oil water separators and stored in 55 gallon drums for off-site disposal", the possibility of reclaiming this oil should be explored. It should not be disposed of in a dump or sanitary landfill.

Response:

The oil collected from the oil-water separators amounts to approximately one 55 gallon drum per month. This oil will be recycled.

Comment:

The draft environmental impact statement does not include a discussion of the disposal method for approximately 3 acres of land clearing wastes for the storage tank area. We recommend that the brush and small logs be chipped and the chips be used on-site for landscaping and erosion control. An effort should be made to sell the larger logs to firewood wholesalers. Any remaining logs should be cut into sections not exceeding 4 feet and landfilled on-site or negotiations made and the wastes landfilled within the company's transmission line rights-of-way. Leachate from these wastes could result in contamination of the adjacent public or private wells which are so common on the Cape.

Response:

The land clearing wastes were removed by the subcontractor to his private fill area.

Comment:

As specified in the Massachusetts Department of Public Health's "Regulations for the Disposal of Solid Wastes by Sanitary Landfill," the disposal of 4,000 cubic yards of excess dredge spoil will require a variance.

Response:

The excess dredged material will be used for grading purposes on the plant property.

U.S. COAST GUARD

Comment:

2. It is requested, however, that sufficient safeguards be established to assure that the visibility of the Cape Cod Canal east entrance range lights will not be compromised during construction.

Response:

To date, no known problems, including the now completed installation of screenwell sheet piling, have arisen during construction affecting the visibility of the Cape Cod Canal east entrance range lights.

Comment:

3. At this time, it is not possible to assess the relationship of the existing range lights to the enlarged plant. The ranges may be dwarfed to a point where they are no longer readily visible to the mariner. The Coast Guard wishes to reserve the right to request relocation and/or enlargement if in the future it is found to be necessary for the protection of navigation.

Response:

It is not believed that a problem will exist with the visibility of the range lights at the east entrance to the Cape Cod Canal after construction has been completed. If any problem should arise, the Applicant will cooperate with the U.S. Coast Guard.

U.S. DEPARTMENT OF COMMERCE

Comment:

3.1 AIR QUALITY

3.1.1.1 Sulfur Dioxide

Page 3.1-1. In calculating the maximum sulfur dioxide concentration (Table 3.1-1) it does not appear that the situation of limited vertical mixing depth has been taken into account or that daytime stack emissions have been maximized, since average daily emissions have been used. Table 3.1-2 states in a footnote that "emissions in day-to-day operation may vary", presumably both greater and less than the average.

Assuming the mean afternoon mixing height (Holzworth, 1972, EPA report No. AP-101) of 1000 m, unstable conditions (Pasquill Type A) and a speed of 1 m/sec, we compute a maximum 1-hr. concentration at 1.3 km of 0.66 ppm for an average SO2 emission rate of 2.19×10^5 lbs/day. Maximizing the emission rate to 2.5×10^5 lbs/day increases the concentration to 0.77 ppm. A conversion factor of 2600 microgram/m^3 = 1 ppm was used. The highest value shown in Table 3.1-1 is 0.22 ppm and the Mass Air Quality Standard for 1-hr. is 0.28 ppm.

Response:

The predicted ground level concentrations of sulfur dioxide presented in Table 3.1-1 were calculated by use of a mathematical dispersion model, utilizing a Gaussian dispersion equation in a manner similar to that described in "Workbook of Atmospheric Dispersion Estimates", (U.S. Department of Health, Education, and Welfare). The height of the expected thermal plume rise was estimated by the use of the optimized CONCAWE Plume Rise Equation. For the purpose of these calculations, both Units No. 1 and No. 2 were assumed to be operating at full load during the daytime hours (Ref. 10, p. 51). At night and on weekends, operation of Unit 2 was assumed to be reduced to 50 percent. The result presented in Table 3.1-1 did not consider the effect of inversions. Inversion effects are described in Section 3.1.3 of the Draft Environmental Statement.

Upper air sounding data from nearby Nantucket were assumed to be representative of the site and were used for the inversion analysis. It was concluded from the analysis that the maximum SO2 concentrations expected to occur would be 0.23 ppm under an inversion with a base located at an elevation of 300 meters and a 12 meter per second wind coincident with unstable conditions ("A" Stability) below the inversion. At lower wind speeds, the plume from the station is expected to completely or partially penetrate a 300 meter inversion.

Analysis of the Nantucket data revealed that only one inversion (from the 7,049 soundings examined) based at a height of greater than 300 meters was found having an unstable atmospheric condition beneath it. For this condition, the maximum hourly concentration of SO2 was estimated to be 0.06 ppm. As indicated in the Draft Environmental Statement, Section 3.1.3, the lowest height at which an inversion may occur and cause significant plume trapping is approximately 300 meters.

The maximum SO2 concentration that could result from plant operation at 100 percent under actual recorded conditions is estimated to be 0.09 ppm. The frequency of occurrence of slightly unstable ("C" Stability) conditions and 300 meter inversions is 0.07 percent. Inversions with bases greater than 600 meters will produce concentrations less than those estimated for 300 meter inversions as the stability conditions observed are neutral to stable.

Comment:

Second, because the site "has the potential for four units depending on load growth and on where the power is needed" (Page 6.0-2), the estimated losses of various species of fish could conceivably at least quadruple if and when all four units become operational. Plans for a monitoring program to determine the effects on fish populations of entrainment of fish eggs and larvae by Units No. 1 and 2 should be described in detail.

Response:

The present application is for Unit No. 2. If additional units are proposed at some future time, these additions will be addressed with respect to regulations and conditions existing at that time.

Comment:

3.5.2 Entrapment of Fish in the Circulating Water System

Page 3.5-11. It is stated that the operation of Unit No. 1 resulted in "flat fishes, primarily winter flounder, ... becoming entrapped in the vertical traveling screens and eventually damaged when released to the warm water of the Unit No. 1 discharge canal." Data on the number of fish that have been entrapped, impinged, and killed thus far by Unit No. 1 should be provided.

Response:

During the 3-year survey conducted by the Massachusetts Department of Natural Resources, intermittent observations in the screenwell by the principal investigators indicated that the numbers and kinds of fish and invertebrates entrapped on the

screens were minimal. A monitoring program of the screenwash sluiceway was therefore not initiated.

Since the termination of the above surveys, additional observations by the Department of Natural Resources at the screenwell reaffirmed the previous observations that fish impingement and entrapment is not a problem at the Canal Plant.

Entrapment and impingement studies prepared for the new addition of Unit No. 2 to Canal Plant are discussed in the response to comments received from the Massachusetts Department of Natural Resources letter of September 18, 1973.

Comment:

Page 3.5-12. We note that fish that are impinged on the traveling screen will be discharged to the screenwash sluiceway and thence to the existing Unit No. 1 discharge flume, and that fish "will not be subjected to sudden temperature increases before being returned to the receiving waters." The final environmental impact statement should acknowledge that mortalities may result directly from impingement, as well as indirectly from thermal shock. For example, Marcy (1973)[1] found that "approximately 80% of the total mortality of fish in the discharge canal of the Connecticut Yankee nuclear power plant was caused by mechanical damage and 20% was attributed to heat shock and prolonged exposure to temperatures above 28C." Furthermore, the possibility exists that the fish sill will not completely eliminate the entrapment/impingement problem, and that the problem may be seriously compounded by operation of Unit No. 2, and by subsequent generating units if and when they become operational.

Response:

Section 3.5.2 pertains to entrapment of fish on the vertical traveling screens. The statement that fish "will not be subjected to sudden temperature increases before being returned to the receiving waters" refers to fish which are removed from the circulating water system by the traveling screens. The screenwash sluiceway will discharge to the abandoned Unit No. 1 discharge canal which will be at ambient temperatures. Section 3.5.1.1 discusses the potential impact of the circulating water system on fish eggs and larvae which may pass through the screens. The approximations of impact on adult populations are based on the conservative assumption that 100 percent of the eggs and larvae experience mortality on passage through the circulating water system. The paper by Marcy (1973) refers to mortality of fish which are passing through the circulating water system of the plant, and is more appropriately compared to Section 3.5.1.1 on entrainment where it is assumed that mortality is 100 percent.

Comment:

5.7 ALTERNATIVE COOLING WATER SYSTEMS

Pages 5.7-1 and 5.7-2. This section should be greatly expanded to give the same depth of consideration to all reasonable alternative cooling systems as to the proposed once-through cooling system. It is not sufficient to dismiss cooling towers and ponds merely because they are "more expensive" and not "site-specific in their implementation." These factors must be compared with the benefits to aquatic life of installing a closed-cycle system at Unit No. 2 and all other units at this site.

With regard to the submerged multiport discharge system proposed for use to dilute the condenser cooling water flow for both units in the Canal, the environmental impact statement should recognize that pursuant to Section 301 of P.L. 92-500, all waste dischargers will be required to adopt best practicable treatment not later than July 1, 1977, and best available technology economically achievable by July 1, 1983. Currently, the Environmental Protection Agency is developing guidelines concerning these requirements. It would appear imprudent, impractical, and uneconomical (as well as poor environmental management) to permit establishment of any new waste discharges that may fail to meet these basic levels of treatment.

In particular, the environmental impact statement should discuss the thermal discharge in light of Section 316 of P.L. 92-500. It appears that under some circumstances discharge structures for thermal effluents that are constructed after October 18, 1972, may be considered exempt from best practicable treatment for a period of up to 10 years from the date the construction is completed. In order to adequately consider the impacts of this power plant on the environment, it would seem that the final environmental impact statement should fully discuss this aspect of P.L. 92-500, in view of the proposed use of once-through cooling.

Response:

The choice of a circulating water system must be predicated on specific site considerations. Section 316 of Public Law 92-500 specifies that the burden of proof lies with the applicant when attempting to justify a particular choice in cooling water systems. The proposed once-through cooling system incorporates design features to minimize impact on aquatic life. It is not believed that closed-loop cooling systems can necessarily improve upon these design features without other environmental impacts of a greater magnitude.

As described in Section 2.2, Hydrology, Cape Cod Canal is a rather unusual body of water. A manmade connection between

Buzzards Bay and Cape Cod Bay, the canal is completely flushed out into either Buzzards Bay or Cape Cod Bay with every cycle of the tide. This complete tidal flushing offers a unique opportunity to disperse heated effluent from the Canal Plant. This flushing capacity becomes a major parameter in any choice of cooling water alternatives.

Although possible benefits to aquatic life of installing a closed-cycle system should be considered, the benefits or detriments to the terrestrial environment should also be considered. Several other factors are also very important. The area around the location of the Canal Plant supports a substantial cranberry industry. It has been noted that the cranberry industry of Cape Cod and adjoining Plymouth County constitutes about 3/4 of the world's cranberry supply (Section 2.6.3, Agriculture). Cape Cod also supports a rather sizable resort and tourist industry, a large number of which reaches the Cape by crossing Cape Cod Canal over the Sagamore Bridge approximately two miles south of the plant (Section 2.6.2, Industry). The canal itself supports a heavy industry in the form of commercial and recreational vessels transnavigating Cape Cod (Section 2.7.1, Industry). Finally, Cape Cod Canal is essentially saltwater with salinities in the range of 31.2 to 31.6 ppt at the east entrance into the canal (Section 2.2, Hydrology).

In addition to once-through cooling water options, several closed-cycle cooling schemes were also considered. Among these are wet type natural draft cooling towers, wet type mechanical draft cooling towers, and spray canals.

Selection of the once-through cooling system using a multislot diffuser took into account the readily available supply of Cape Cod Canal water. It was determined, after extensive modeling, that the once-through system would be the best cooling option at this site. The visual impact of a once-through cooling system is minimal. Fog and salt drift are nonexistent. Accordingly, the impact of these phenomena on navigation in the canal and on adjacent agriculture is nonexistent.

As described in the hydrothermal studies described in Section 3.2, Water Quality, and in Appendix 3, the choice of once-through cooling for Canal Plant does not introduce any significant environmental stress into Cape Cod Canal.

When considering only the guidelines now under consideration by the Environmental Protection Agency under Sections 301 and 302 of the Federal Public Law 92-500, closed-loop cooling systems appear attractive. However, one must address the need for such a system and the environmental impacts associated with its use.

Wet natural draft cooling towers were not deemed feasible for use at the Canal Plant for several reasons. The major concern was

the problem of salt drift from the towers. The genus Vaccinium, of which the cranberry is a member, is very sensitive to foliar salt deposition. As previously stated, this area produces the majority of the world's cranberries. It is possible that the use of natural draft cooling towers and the salt drift associated with them could have a serious detrimental effect on cranberries. It was also felt that the physical size of natural draft cooling towers (approximately 400 ft high and 250 ft in diameter at the top) would detract from the natural beauty of the surrounding area.

Wet type mechanical draft cooling towers, while being smaller in size and with less impact in terms of salt drift, have other problems associated with their operation. The major drawback which eliminated them from being considered was the problem of ground level fogging. With the Canal Plant located directly adjacent to the Cape Cod Canal, it was feared that fog produced by the towers would be hazardous to boats using the canal.

Spray canals, which utilize floating spray modules arranged in a canal to dissipate waste heat, were eliminated from consideration due to the problem of ground level fogging as discussed above. Additionally, spray canals would require large parcels of land not available at the site.

FEDERAL POWER COMMISSION

Comment:

The Draft Environmental Statement states that one new 115-kilovolt transmission line of unspecified length would be required by the addition of the proposed Unit No. 2 to integrate the plant's increased capacity to the existing transmission system. A description of the route of the right-of-way of the new 115 kilovolt line and a statement of compliance with existing State and Federal guidelines for design, construction and maintenance of this transmission line should be included in the final environmental statement. The discussions of alternate sources of power, plant sites, types of plants and fuels are adequate.

Response:

The new 115-kV transmission line, which is 2.5 miles long, was installed in 1972, on the existing right-of-way between the Canal Plant switchyard and New Bedford Gas and Edison Light Company's Bourne Switching Station to complete a second 400-MW feed to the existing 115-kV system. The design and construction of this line is in full compliance with the National Electric Safety Code rules for the installation and maintenance of electric supply and communication lines. The Commonwealth of Massachusetts Code for Construction and Maintenance of Electrical Transmission Lines was also adhered to in this design and installation.

MASSACHUSETTS DEPARTMENT OF NATURAL RESOURCES

Comment:

In order to minimize the environmental effects of the new unit, particularly on the marine resources of the Canal area, the Department recommends that the Canal Electric Company undertake a definitive entrainment study after construction, to determine the extent of mortality of entrained organisms. We also recommend that a fish entrapment evaluation be conducted on the intake for Unit 2 after installation of the bottom sill.

Response:

The Applicant will monitor the types, numbers and sizes of fish collected on the screens of Units No. 1 and No. 2 for a 24-hr period each week for 1 yr following operation of Unit No. 2. This data will serve as a basis of comparison to establish the effectiveness of the bottom sill at Unit No. 2 and establish whether a sill should be installed at the entrance of the intake canal of Unit No. 1.

In addition to monitoring the intakes of Units No. 1 and No. 2 for screenable fish, studies will be conducted to determine the effect of station operation on entrained fish eggs and larvae. Replicate samples will be taken once every two weeks from the intakes of Units No. 1 and No. 2 and from the discharge flume prior to entering the diffuser. Comparisons of live vs. dead eggs and larvae will be made between the intakes and discharge to determine the mortality associated with mechanical and thermal effects on passage through the station.

Comment:

In addition, we recommend that a study of the thermal plume be conducted to provide verification of the predictive model and the effects of the plume configuration on finfish within the Cape Cod Canal.

Response:

The Applicant will conduct a plume verification study after Unit No. 2 is brought on line and steady state has been established at Canal Plant. This plume verification shall define the plume over a complete tidal cycle for 2 days. Temperatures of the water will be measured both by tracking with a moving boat using thermistors mounted on a drag chain at discrete water depths and by vertical profiling at specific locations. Vertical profiling of currents in the vicinity of the diffuser will be used to determine local velocity patterns.

Fluorescent tracer dye will be released into the discharge flume of Canal Plant during the above stated survey. Monitors placed at the intakes of each unit will be used for determining recirculation.

MASSACHUSETTS EXECUTIVE OFFICE FOR ADMINISTRATION AND FINANCE

Comment:

The Bureau of Air Quality, Division of Environmental Health, Department of Public Health has responded as follows:

> "Information presented in the Environmental Impact Statement is acceptable to the Department except that described in Paragraph 3.1.1.3 which states that Nitrogen Oxides and oxidants can be assumed to be low in the summertime in the Cape Cod area where the plant is to be located, namely; in the vicinity of the Sagamore Bridge."

Response:

While the Applicant did not monitor the ambient concentration of NO2 in the area, it is not believed that these concentrations are particularly high. Only four air quality control regions are adjudged by the EPA as having or possibly having concentrations of NO2 higher than the Federal annual ambient air quality standards. These regions do not include the Cape Cod area. Any concentration of NO2 which does occur in the area of the Canal Plant could only be due to automotive traffic and would only be of a very local and temporary nature. Furthermore, the plant's contribution to the ambient concentration of NOx is expected to be minimal as discussed in Section 3.1.1.3 of the Environmental Statement.

STRIPED BASS FUND, INC.

Comment:

(2) Screens: The screens will be traveling screens, which reduces impingement. However, the screens will be located "at the downstream end of the intake structure" (DES p. 1.2-12). Placement of screens flush with the banks of the waterway entraps fewer fish than when the screens are recessed in the intake canal. There is no apparent indication as to whether fish reaching the screens have the ability to swim out of the intake structure. Nor is there discussion of the mortality of those organisms washed off the screens into the sluiceway. Whether the screens would be operated as continuously traveling, as opposed to periodic, is also not mentioned.

Response:

The vertical traveling screens were not placed at the mouth of the intake canal because of potential problems associated with interference of canal traffic. However, as described in Section 3.5.2, the bottom sill will be placed at the entrance of the canal to limit access of benthic species. Although specific mortality studies of impinged fish were not conducted, viable flounder were observed in the connecting screenwash sluiceway.

The traveling screens will normally operate in response to a water level differential across the screens. However, if conditions warrant, this automatic operation can be by-passed and the screens operated continuously. As mentioned, the screenwash sluiceways will be routed to the abandoned Unit No. 1 discharge flume where temperatures will be at ambient conditions.

Comment:

It is interesting to note (DES Figure 1.2-3) that the sluiceway empties at a point along the canal which appears to be between the intake structures of Units I and II. The fish so released, if alive, will most likely have their swimming abilities at least temporarily impaired. Therefore, there is some probability that such fish would be drawn into an intake structure for a second time. The ability of fish to survive the experience for a second time is not necessarily discernable from data of solely Unit I operation.

Response:

It is believed that the routing of fish to an area such as the abandoned discharge flume of Unit No. 1 will increase their chances for survival. The temperatures in the abandoned flume will be at ambient conditions. In addition, this [illegible] will be relatively calm, thereby allowing the fish to recov[illegible] stress associated with impingement before exiting to the canal.

Comment:

(3) Size and Depth of intake opening: A nine-foot sill is proposed for the Unit II intake "to discourage bottom-swimming fish from entering the intake" (DES p. 1.2-11). This structure is recommended in response to the finding by the Massachusetts Department of Natural Resources, that substantial mortality of winter flounder (which swim near the bottom) occurred by impingement on the Unit I intake screens. (DES, Appendix p. 43.) Whether this structure will successfully mitigate the loss is uncertain.

Response:

That a bottom sill was recommended by the Massachusetts Department of Natural Resources as a result "that substantial mortality of winter flounder (which swim near the bottom) occurred by impingement on the Unit I intake screens" is incorrect. Referring to page 43 of Appendix No. 1, the DNR nowhere states that mortalities were "substantial". It states that observed losses were "not considered serious". The DNR cautions that additional units may present a problem if the intake design is not modified. Therefore, the bottom sill will be incorporated at the entrance of the Unit No. 2 intake flume to limit access of benthic species. As mentioned in Section 3.5.2, the efficiency of the bottom sill will be determined following plant startup.

Comment:

The average seasonal temperatures are also generally given in the river hydrology portion of the environmental statements. Often these figures are forgotten when the temperature increase by the plant's operation is discussed. The environmental impact section tends to deal with change in temperature and will usually cite to literature indicating that fish can tolerate the predicted amount of increase. However, we urge that the precise temperatures be considered, particularly the raised temperature during the summer seasons. It may be that such temperatures cross the threshold of tolerance for at least some of the aquatic species inhabiting the affected water body.

Response:

The design of the circulating water system discharge, discussed in Section 3.5.1, was developed for the protection of aquatic life. The diffuser discharge will limit temperatures in the upper 15 ft of the water column to a maximum of 86 F. This was adopted on recommendations by the Massachusetts Division of Marine Fisheries, as a result of the assessment studies described in Appendix No. 1.

Comment:

(5) Proximity of structures: A curious design is proposed for the Cape Cod plant with the addition of Unit II. The proposed design envisions the intake of Unit II a distance of approximately 200 feet from the intake of Unit I. Whereas the discharge for Unit I is presently about 140 feet from the intake, the construction of Unit II calls for a closing-off of that discharge and the construction of a common discharge for both Units I and II together, at a distance approximately 800 feet further east along the canal. The rationales for this common discharge and its distance are not evident. (DES Figure 1.2-3).

Response:

The design of a common discharge for Units No. 1 and No. 2 was decided on for several reasons. First, the existing surface discharge for Unit No. 1 will be blocked off. This will eliminate recirculation of heated water due to the proximity of the intake and discharge structures for Unit No. 1. The proposed common discharge will be a submerged diffuser. This diffuser will release the heated discharge at a higher velocity than would be possible with the surface discharge. This higher velocity at the discharge point will cause rapid mixing of the heated discharge with the ambient water. The result is a lower surface temperature than now experienced from the surface discharge.

By relocating the discharge further east of the intake structures, recirculation of unit water will be minimized. The discharge flume was moved as far east as possible while still remaining within the property line. The diffuser, of course, will be located on the banks of Cape Cod Canal which is the property of the U.S. Army Corps of Engineers.

Finally, the combining of the heated discharge from the two units will aid in lessening any possible thermal shock problem that might occur. It is not expected that both units will simultaneously be tripped, or taken off line.

Comment:

(6) Distance bewteen intake and discharge: Figure 1.2-3 of the DES indicates that the combined discharge will occur approximately 800 feet east of the intake region. The section of the hydrology of the canal indicates reversing tides, but a net westerly flow. No discussion is presented on the question as to whether or not to what extent discharged water becomes again subject to the plant's intake.

Response:

The maximum temperature rise at the intake which can be attributed to recirculation of the heated effluent is predicted to be 0.9 F. This temperature rise is considered to be insignificant. Due to the tidal nature of the canal, this maximum temperature rise is predicted to occur only under conditions of extreme low flow during ebb tide. At other times during ebb tide, the temperature rise will be less than 0.9 F.

These figures were derived from a model study conducted at the Ralph M. Parsons Laboratory, Massachusetts Institute of Technology (Ref. 14). The study showed that surface isotherms at the intake could reach 4 F during extreme conditions, but that the 9 ft skimmer wall at the entrance to the intake reduced the temperature rise in the canal to the maximum of 0.9 F previously stated.

Comment:

Unit II circulating water flow would be 426 cfs, compared with Unit I's value of 372 cfs, yielding a total of approximately 800 cfs. Assessment of thermal and chemical dissipation based on 372 cfs, may not be truly applicable for 800 cfs, particularly given the narrow width of the canal in this region. (DES Figure 1.2-3).

Response:

Assessment of the dissipation of both chemical and thermal discharges was based on the circulating water flow of 800 cfs and not 372 cfs.

Comment:

The "land-cut portion" of the Cape Cod Canal is 7 miles long and is 480 ft wide at the bottom. As it is described as steeply-sloped, the surface width is presumably not much wider. This fact is of great significance when evaluating the statement in the Appended technical report which served as the major basis for the draft impact statement (Appendix I p. 11), that the thermal plume is dissipated "rapidly within 500 ft of the discharge and was essentially complete at 2,000 ft". One must note that those values were reported for Unit I discharge at 372 fps (cfs and not fps). With the addition of the proposed Unit II, the combined discharge will emerge at a rate of 800 fps (cfs and not fps). The character of the thermal plume will surely be affected by doubling the volume of heated discharge.

Response:

The Cape Cod Canal is of prismatic cross-section with slopes of 1:2.5 below the intertidal zone and slopes of 1:2 in the rip-rapped tidal zone. As such, the surface distance from canal bank to canal bank will vary with the tide and would exceed in all instances a distance of approximately 1000 ft as determined at extreme low water at the discharge point. The character of the thermal plume for the combined discharge of Units No. 1 and No. 2 are shown in the Hydraulic Model Studies performed at M.I.T. (Ref. 14). Although the total volume of water discharge is doubled, the thermal plume is still rapidly dissipated by the mixing action caused by the submerged diffuser.

The high temperature isotherm of the plume will tend to be generally found along the southern shoreline of the canal due to the regular flow patterns developed in this area. At the slack tide periods when velocities in the canal approach zero, the plume will extend out farther across the canal with temperatures of 2 or 3 F above ambient occurring along the northern shore. However, even at the slack periods, the limits of the area of maximum temperature rise (6–8 F) will be within a short distance of the diffuser.

Comment:

Considering the width of the canal, the rate of dissipation becomes a matter of some concern. Avoidance behavior which might ordinarily be exhibited by fish population of a wide river on which a plant is located cannot readily take place when the thermal plume extends virtually the entire width of the waterway. It is at least conceivable that behavioral alterations will occur as a result of a heat band across the canal. (This is an example of an issue that was not clearly represented in the impact statement, but emerges only upon correlation of distinct facts presented in the document.)

Response:

The shape of the plume, and the distance it extends across the canal, varies with tide stage and current velocity. The depth of the thermal plume is also constantly being reduced in the direction normal to the canal, due to diffusion and subsequent cooling with ambient water. The thermal plume will extend across the canal, only for a short while during slack water, and then only as a thin surface layer near the northerly bank of the canal. It should be noted that the temperatures will never exceed 86 F in the upper 15 ft of the water column and will not exceed 2 to 3 F above ambient on the northern bank. Additionally, this 2 to 3 F above ambient will only occur during certain periods of low current velocity in the canal. Considering the wide variation in natural temperatures within the canal due to shifting tides, it is anticipated that temperature

increases of this magnitude will not adversely affect migratory responses of fish species.

Comment:

The water in the Cape Cod Canal is very turbulent (DES p. 2.2-4) and there is reportedly a reversing current every six hours (DES p. 2.2-1). Moreover, it is suggested that velocity is such that the canal is alternatively filled with Buzzards Bay water, than entirely with water from the Cape Cod Bay. If this is so, then absorption of effluents is readily facilitated, since dilution can be extended to these larger water masses. However, this composition hypothesis appears to be based upon temperature data obtained "at each end of the canal," together with the finding that Cape Cod Bay in summer is 15-20°F colder than Buzzards Bay (DES p 2.2-4). However, heat can flow without the movement of mass (second law of thermodynamics), and therefore, the conclusion presented in the study is not necessarily demonstrated by the temperature changes reported. On the other hand, the rapidity and vastness of the dramatic change should be noted. Dye experiments would be a more persuasive indication of the movement of the water mass. Temperature data is not conclusive on this point.

Response:

The second law of thermodynamics, as stated by Clausius may be given as follows: "It is impossible for any device to operate in such a manner that it produces no effect other than the transfer of heat from one body to another body at a higher temperature" (Ref. 22). While this may be interpreted as meaning that heat flows from a high temperature to a lower temperature, it is believed that the concept questioned in this paragraph could be more accurately described as free convection. In free convection, the transfer of energy and subsequent motion of fluid is caused solely by density differences resulting from temperature gradients. These temperature gradients are created by placing a body at one temperature in a uniformed temperature medium at a different temperature, higher or lower.

These effects can not solely be used to describe the turbulent mixing and mass heat transfer associated with a high velocity jet issuing from a diffuser. In addition, these effects can not be used to adequately describe the mass transfer found in the exchange of Buzzards Bay and Cape Cod Bay water as it passes through Cape Cod Canal.

The dramatic changes in water temperature are correctly attributed to the mass transfer of water through Cape Cod Canal. The dye survey proposed in this question could not materially add to this obvious exchange of water through Cape Cod Canal with resultant and dramatic temperature changes as observed in Section 2.2. Water temperature changes of this magnitude are an

indicator of mass transfer of Cape Cod Canal water. Dye-temperature analogies would only illustrate this process on a redundant basis.

Comment:

C. Aquatic Population Dynamics

The environmental statement should include more extensive data on the dynamics of the aquatic population. The effects on aquatic life must be examined in light of possible alterations in the food chain of that life and/or alterations in the spawning habits. Operation of the plant might directly kill only a few fish, but might disrupt the whole food chain, thereby altering the entire population. If plant operation discourages fish from spawning where they normally do, a whole species of fish could be wiped out.

In the Cape Cod Canal, adult forms of certain species have been found in the canal "in substantial numbers during their respective spawning seasons" (Appendix I, p. 30). In addition, it was reported that collection of eggs correlated with the spawning periods.

The presence of eggs and larvae elicits concern with regard to optimal and tolerable temperature levels for hatching and development. While the Draft Environmental Statement makes no such comment, the appended technical report indicates that "discharge temperatures probably exceed the tolerable limits of egg and larval forms of at least the cod and mackerel during their respective spawning seasons." (Appendix I, p. 34). This is of extreme importance and should be further explored and explained.

Response:

As discussed in Section 3.5.1.1, it is anticipated that operation of Units No. 1 and No. 2 will not have a significant impact on producer organisms or fish populations since the total area of influence is small in proportion to the receiving waters. In specific reference to fish populations, the estimates of entrainment mortality assumed a kill of 100 percent as indicative that "discharge temperatures probably exceed the tolerable limits of egg and larval forms of at least the cod and mackerel during their respective spawning seasons."

Again, the adoption of the diffuser discharge design will promote rapid dilution of the plume, with resultant lowering plume temperatures to acceptable levels.

Comment:

A. Possibilities Not Studied

Apart from the substantive problems with the draft environmental statement, there are procedural problems. There is a tendency to ignore the impact on a species that cannot be adequately assessed and not to consider it in the cost-benefit analysis. This is a serious mistake because it assesses the costs of the plant at less than they actually are. The Draft Environmental Statement mentioned that the canal hosts striped bass, a "highly prized species," but did not undertake to assess the plant's impact on this species (DES Appendix I, p. 17). The report suggested that extensive personnel and effort would have been required and that fluctuations due to plant operation "would be undiscernable from changes due to naturally occurring fluctuations in abundance so typical of this species" (DES Appendix I, p. 17). One should note that the report did not dismiss the possibility that the plant's operation has a significant impact on the striped bass population. Yet, this is not considered in the environmental impact assessment nor the cost-benefit analysis.

Response:

Although the striped bass was not specifically studied for the reasons noted in the DNR report, there is evidence available upon which to base some judgements. Eggs and larvae, or juvenile striped bass, were not observed in the canal throughout the study period. The spawning and nursery areas for striped bass are not located in this vicinity. As a result, there is no reason to expect that striped bass in these life history stages could be adversely affected by station operation. For the numerous reasons discussed in Section 3.5, it is believed that adult striped bass also would not be adversely affected by plant operation.

Comment:

B. Observations Not Explained

Another problem with the draft is the observed but unexplained increase in temperature in the Cape Cod Canal. In the canal, the waters have become progressively warmer each summer from 1967 to 1969, the period of study by the Massachusetts Department of Natural Resources, Division of Marine Resources. This trend of increasing temperature in the canal is revealed in Table 3 (DES, Appendix I, p. 16) but no explanation is attempted. However, one cannot dismiss the possibility that the increase is related to the operation of the power station. If such be true, then the operation of a second plant as well may have serious long-run effects on the biota of the canal. This possibility is not discussed in the impact sections of the DES.

Response:

It is not believed that the operation of the Canal Plant contributed significantly to the warming trend which occurred during the summer months from 1967 to 1969. (Appendix No. 1, Table 2, p. 16). Also, it should be noted that the temperatures cited in Table 2 are average monthly surface temperatures. The surface temperature of any body of water is extremely dependent upon the coincident meteorological conditions. Air temperature, wind speed and direction, and cloud cover all contribute greatly to the surface temperature at any given time at a specific point. A change in any one of these factors, or others, could result in a varying surface water temperature.

Also, since the design of Unit No. 2 utilizes a submerged diffuser to discharge the combined heated effluent from both units, the resultant temperature increase at the surface in the vicinity of the plant is expected to be less than that now experienced from Unit No. 1 alone.

Comment:

C. Unsupported Conclusions

With regard to the fish population of the Canal, the Draft Environmental Statement seems to include some unsupported conclusions. "Changes in the overall abundance of major fishes in the Cape Cod Canal have been attributed to natural population fluctuations since numbers varied along all transects, including those outside the area of power plant influence." (DES Appendix I p. 23). This statement is not necessarily persuasive, as it seems they have assumed their own conclusion. Also, in view of the vast movement of water mass due to the tides, it would seem difficult to assert with certainty that specific regions are beyond the reach of the plant's influence. Moreover, a possible impact has been thereby disregarded in the assessment of the plant's impact on the environment, because there is no conclusive evidence.

Response:

The model studies conducted at M.I.T. (Ref. 14) predicted the surface isotherms which could be expected with both units in operation for various tidal conditions. The isotherms indicate that the effects of the plant are localized, and predict the boundaries of the area within the plant's influence. Using the information obtained from the model studies in conjunction with the data presented in Appendix No. 1, it is believed that the following statement made by the Massachusetts Department of Natural Resources is a valid conclusion. "Changes in the overall abundance of major fishes in the Cape Cod Canal have been attributed to natural population fluctuations since numbers

varied along all transects, including those outside the area of power plant influence" (Appendix No. 1, p. 23).

Comment:

In the Cape Cod study, tows and seines were deemed unfeasible, and so creel census served as the basis of assessment instead. An example of the second type of difficulty is found in the Cape Cod study, where no indication is given as to how the rate of dissipation of the themal plume was ascertained.

Response:

The statement that "tows and seines were deemed unfeasible, and so creel census served as the basis of assessment instead" is misleading if taken out of context. Creel census was only one of many methods employed to determine the impact of plant operation. As discussed in Section 2.9 and Appendix No. 1, field studies also addressed hydrography, distribution and occurrence of fishes from SCUBA observations, fish egg and larvae abundance and distribution, distribution and abundance of benthic flora and fauna, as well as specific studies related to thermal, chemical and mechanical tolerances of selected species of fish.

The rate of dissipation of the thermal plume was ascertained through model studies conducted at M.I.T. (Ref. 14). A scale model of the canal, including the intakes and common diffuser, was built to study various outlet designs with respect to resultant temperature rises and surface velocities.

Using the basic equations of hydrodynamics, and heat transfer for heated discharges, the requirements for similitude were derived for the model. In order to determine these requirements, the following were considered: geometric similarity; densimetric Froude number similarity; and Reynolds number similarity. The final conditions used for the model are as follows:

Length ratio = 1:64
Velocity ratio = 1:8
Discharge ratio = 1:33,000

An array of 60 thermistor probes (reproducible to 0.05 F) were used to determine the dissipation of the thermal plume being released from the diffuser. The temerature of the model discharge was 28 F above the ambient water used in the model, which is the same temperature rise which will be experienced at the Canal Plant. The discharge rate used in the model studies simulated the combined release rate of 800 cfs for Units No. 1 and No. 2 at the Canal Plant.

These tests were conducted over the varying tidal conditions encountered in the Cape Cod Canal to determine the effects of the tides on the thermal plume.

Comment:

Caution may also be suggested against the inference that the effects of one plant at a given location will indicate the effects of a second plant at the same site. Here, it is necessary to consider possible cumulative effects, which in some cases may cross tolerable levels. Characteristics of the local flow will be important in determining the extent to which impacts of two plants will compound each other.

Response:

All studies and analyses performed were based upon both units in operation and considered the cumulative effects of the combined discharge rate of 800 cfs.

CAPE COD CHAMBER OF COMMERCE

Comment:

There is little I can add by way of meaningful comment in this direction. I would, however, make only one further comment and urge that because the Canal Electric Company occupies a prominent position on our landscape, and is readily seen by those visitors to our area crossing the Canal Bridge, I would hope that a special effort above and beyond the normal landscaping effort might be made to beautify the area.

Response:

The Canal Plant occupies a prominent position in the landscape of the area, and a sincere effort has been made in the past to keep the outside, as well as the inside, of the plant aesthetically pleasing to residents and visitors of the area. This effort will continue with the proposed addition of Unit No. 2.

In addition, special emphasis will be placed on natural landscaping in the vicinity of the plant. Along Tupper Road where fill material has been placed, the area will be graded and planted with ground cover, and seedlings will be set out. Between the northerly property line and the Canal Service Road, the ground cover will be clipped, and natural shrubbery along the fence line will be maintained. Landscaping at the entrance to the plant and near the Service Building will be continued, and structures will be kept painted and properly maintained.

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APPENDIX NO. 1

AN ASSESSMENT OF THE EFFECTS OF ELECTRICAL POWER GENERATION ON MARINE RESOURCES IN THE CAPE COD CANAL

An assessment of the effects of electrical power generation on marine resources in the Cape Cod Canal

by

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March 13, 1971

Massachusetts Department of Natural Resources

Division of Marine Fisheries

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Administrative-Technical Advisory Committee Report

In 1965 the Plymouth County Electric Company (now Canal Electric Company), a subsidiary of New England Gas and Electric Association, made application to the U. S. Army Corps of Engineers to construct a fossil fuel fired steam generating station on the easterly side of the Cape Cod Canal in Sandwich, Massachusetts. The company proposed to utilize seawater from the Canal for condenser cooling at the rate of 372 ft^3/sec, with a corresponding water temperature increase of 27.8F through the plant.

The Corps of Engineers referred the application to the U. S. Bureau of Sport Fisheries and Wildlife for comment on the potential effects on fish and wildlife resources. Subsequent discussions between the Bureau and the Massachusetts Division of Marine Fisheries revealed a lack of factual information relating to both the marine resources of the Canal and the effects of heated water discharges, which precluded a rational assessment of the environmental implication of the proposal at that time.

State and Federal agencies responsible for resource protection and management, recommended that comprehensive on-site and laboratory studies be undertaken prior to and during plant operation. Recognizing its responsibility in protecting the environment, the utility company agreed to fund the investigations to be performed under the direction of the concerned agencies.

An Administrative-Technical Advisory Committee consisting of representatives from the Bureau of Sport Fisheries and Wildlife, Bureau of Commercial Fisheries (now the National Marine Fisheries Service), Massachusetts Division of Marine Fisheries, and Canal Electric Company was formed to administer the studies and prepare recommendations to the utility.

Because the fishery resources of the Canal were of paramount importance to the State and Federal governments, the Division of Marine Fisheries contracted to conduct the on-site ecological studies and the Bureau of Sport Fisheries and Wildlife contracted to carry out laboratory and fish behavioral studies.

This report includes the results and recommendations of the ecological investigations from March 1966 to December 1970. Information from behavioral and laboratory studies performed by the Bureau at the Sandy Hook Marine Sport Fisheries Laboratory has been utilized throughout this report.

The Committee has agreed unanimously that the recommendations set forth in this study will provide adequate protection to the marine resources of the Cape Cod Canal. The committee recommends that Canal Electric Company adopt and implement recommendations applicable to the existing plant and incorporate those recommendations pertaining to proposed units in future planning and design.

The committee expresses its appreciation and special thanks to Mr. Fairbanks and Dr. Pearce for their work in the performance of these investigations.

Administrative-Technical Advisory Committee

U. S. Fish and Wildlife Service

Bureau of Sport Fisheries and Wildlife
- Thomas A. Schrader, Chairman, 1966-1970
- Donald Reese, Chairman, 1970-
- David Damon
- P. James Dalley
- Dr. Jack B. Pearce

Massachusetts Department of Natural Resources
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Abstract

A 560 megawatt steam electric station located on the Cape Cod Canal started commercial-scale operation on 1 July 1968. Objectives of this study were to assess the effects of power generation upon marine resources of the Canal, particularly the valuable sport fishery, and to propose power plant modifications necessary to protect these resources.

Thermal effluent flows from the generating station as a shallow surface layer. Heat dissipation occurs rapidly within 500 ft of the discharge point and is complete 2,000 ft down current. Excluding the immediate discharge area, only minor changes in the composition of benthic flora and fauna were recorded following plant operation. Losses of fish eggs and larvae resulting from passage through condensers were projected and considered negligible in view of distribution and fecundity of the species involved. Some changes in catch rates and composition of the sport fishery were recorded but not attributed to power plant influence. Fishes exhibiting local shifts in distribution toward the warm water discharge were pollock, Atlantic silversides and young-of-the-year menhaden. The latter two species congregated along the periphery of the thermal plume where they were periodically exposed to lethal temperatures and residual chlorine concentrations. Some mortality of winter flounders resulted from impingement on intake screens.

Recommendations to the electric company would limit summer discharge temperatures to 86 F and residual chlorine concentrations in coolant water to 0.1 ppm. Relocation of the opening in the seaward end of the intake flume is proposed as a possible means of precluding entrance and subsequent impingement of winter flounder on intake screens.

Introduction

The current trend of locating large steam electric stations (S.E.S.) on coastal waters has imposed new responsibilities upon governmental agencies charged with safeguarding marine resources. The lack of information regarding the effects of thermal and chemical additions upon marine organisms has precluded formulation of specific criteria for the siting, design and operation of these facilities. Electric companies have customarily been requested to fund investigations of the effects of individual power stations concurrent with the period of their construction and early operation. These studies serve to identify any aspects of plant operation that are obviously and grossly detrimental to marine species with direct economic importance and provide valuable insight into the nature, extent and significance of the indirect, more subtle effects of plant operation upon the marine environment.

On 1 March 1966 the Massachusetts Division of Marine Fisheries entered into a 2 year contract with the U.S. Bureau of Sport Fisheries and Wildlife, whereby the former would survey the marine environment of the Cape Cod Canal prior to its utilization as a source of condenser coolant for a proposed steam generating station. Funds for this program and a 2 year laboratory study to be conducted by the Bureau's Sandy Hook Marine Laboratory, Highlands, New Jersey, were provided by Canal Electric Company (formerly the Plymouth County Electric Co.) The above agencies and the Company were concerned over possible adverse affects of plant operation upon the valuable sport fishery based in the Cape Cod Canal.

A second contract was granted the Division of Marine Fisheries on 1 March 1968 for a 1 year study to evaluate effects of the Canal station, which commenced commercial operation on 1 July 1968. Due to operational difficulties, however, the plant was shut down 68% of the time between 1 July and the end of the contract period (28 February 1969). This level of operation was judged inadequate for evaluation purposes and a 1 year extension was re-

Plate 1 Aerial view of Cape Cod Canal looking from Cape Cod Bay westerly toward Buzzards Bay.
Photograph by B. S. Harrison

quested and granted, effective 1 March 1969. The latter contract was negotiated directly between the Division and the Company following passage of state legislation enabling the Division to accept grant monies from private sources. From 1 March through the end of December 1969, when field activities were terminated, the Canal station had operated at full generating capacity 69% of the time.

The plant, located on the southerly side of the Canal near the east entrance, is a fossil-fueled, 560 megawatt unit. Cooling water is drawn from the Canal at the rate of 372 ft sec and returned 26.0F above ambient. The discharge flume is 189 ft long and 15 ft wide with a bottom elevation of 8.5 ft below mean sea level (MSL). The intake flume is 137 ft long and 26 ft wide with a curtain wall across its entrance that extends to a depth of —13 ft (MSL). Bottom elevations of the intake flume range from —25 ft (MSL) at the entrance to —15 ft (MSL) at the shallowest point. Intake and discharge velocities vary with tide levels, ranging between 0.7 and 1.3 ft sec at the shallowest point of the intake flume and 1.9 and 5.9 ft sec in the discharge flume. Traveling screens of 3/8 inch mesh are located across the upper end of the intake flume behind a set of trash racks constructed of 1/4 x 3 inch bar stock placed vertically, 3 inches on center. Sodium hypochlorite, used for slime control in condenser tubes, is dispensed in the upper end of the intake canal through PVC piping. Other fouling organisms are controlled by re-cycling condenser cooling water until a temperature of 115-120F is reached. Other additives include air-heater-

wash which is released gradually into the discharge flume in 300,000 gal lots approximately four times annually. Prior to disposal, this material is stored in an outdoor retention pond where the pH is adjusted to the range of 6.8 - 8.5 and solids are allowed to settle for a 2 day period. Solids are collected and removed from the site after the clear liquor is drawn off through a floating plastic boom.

Original plans called for three additional generating units to be constructed on this site as needed. Construction of the second unit is currently being considered.

Investigations were conducted under the supervision of an Administrative-Technical Advisory Committee consisting of representatives of the Bureau of Sport Fisheries & Wildlife, Bureau of Commercial Fisheries, Canal Electric Company and the Massachusetts Division of Marine Fisheries.

Program objectives have been 1) to obtain hydrographic and biological data before and during plant operation that would provide the Committee with a basis for evaluating the impact of plant operation on the Canal sportfishery and 2) to maintain surveillance of the plant during operation with a view toward defining and correcting any thermal, chemical or mechanical aspects that were detrimental to marine resources.

Sampling techniques employed in this study were dictated by the unusual conditions that characterize the Cape Cod Canal. Strong currents, steep, rocky slopes and heavy boat traffic limited the use of much conventional sampling gear. U.S. Army Corps of Engineers policy prohibited the placing of untended nets, lines and buoys. SCUBA was used extensively to place and retrieve submersible instruments and test panels, collect bottom samples and obtain information on the distribution of fishes.

Acknowledgements

Appreciation is extended to the numerous individuals of the Woods Hole scientific community who provided assistance and advice concerning various facets of this project. Especially helpful were Robert R. Marak and John B. Colton of the Bureau of Commercial Fisheries who rendered assistance with fish egg and larvae identification, and the staff of the Marine Biological Laboratory-Systematics Ecology Program, who assisted David W. Frame with identification of invertebrate collections. Mr. Frame, a graduate student at the University of Massachusetts, performed analysis of test panels for the 1966-1967 period. Borer analysis was conducted under contract by Clapp Laboratories, Inc., Duxbury, Massachusetts, as was panel analysis for the 1968-1969 period. This work would not have been possible without cooperation of the United States Army Corps of Engineers who provided access to the study area, extended special diving privileges and permitted installation of recording equipment in Canal facilities. A. Russell Ceurvels is credited with conducting toxicity bioassays described herein.

The project leader wishes to thank members of the Advisory Committee for their guidance and support throughout the study period. Frank Grice provided encouragement, advice and administrative support throughout the study. W. Leigh Bridges reviewed the manuscript. Lastly, the Canal Electric Company is to be commended for recognizing marine resource values and its responsibility toward their protection.

Description of Study Area

The Cape Cod Canal was completed in 1914 and enlarged to its present size in 1940. Its land-cut portion, which is 7 miles long and 480 ft wide at the bottom, joins the westerly side of Cape Cod Bay to the northeasterly end of Buzzards Bay. Mid-channel depths range from 60 ft to a minimum maintained depth of 32 ft at mean low water. The steeply sloped banks of loose sand, gravel and rubble have been riprapped in the intertidal zone.

Hydrographically, the Canal is a unique body of water. The unusual flows and velocities for which it is noted are the result of differences in tidal phase and amplitude between the water masses at each end. High tide in Buzzards Bay occurs approximately 3 hr earlier than in Cape Cod Bay, and the mean tidal ranges at the east and west canal entrances are 9.5 ft and 3.5 ft, respectively (Tide Tables, United States Coast and Geodetic Survey, 1967). Consequently, the water surface at one end alternately rises above and falls below the level at the other end, creating a reversing current approximately every 6 hr. Average maximum velocities of the ebbing, or west-bound tide range between 4.5 knots (7.60 ft/sec) at the west end and 2.6 knots (4.39 ft/sec) at the east end; average maximum velocities of the flooding or eastbound tide range between 4.0 knots (6.76 ft/sec) at the west entrance to 2.4 knots (4.05 ft/sec) at the east end (Tidal Current Tables, United States Coast and Geodetic Survey, 1966). Slack water periods are very brief and do not coincide with high and low tide.

Hydrographic studies of the Canal have been conducted by Parsons (1918), Wilcox (1958) and Anraku (1964). Anraku defined a mass of "canal" water which flowed as far as the easterly Canal entrance on the east-bound tide and for some distance out into Buzzards Bay of the west-bound tide. His drift bottle investigations indicated a net movement of water through the Canal in a westerly direction.

Hydrography

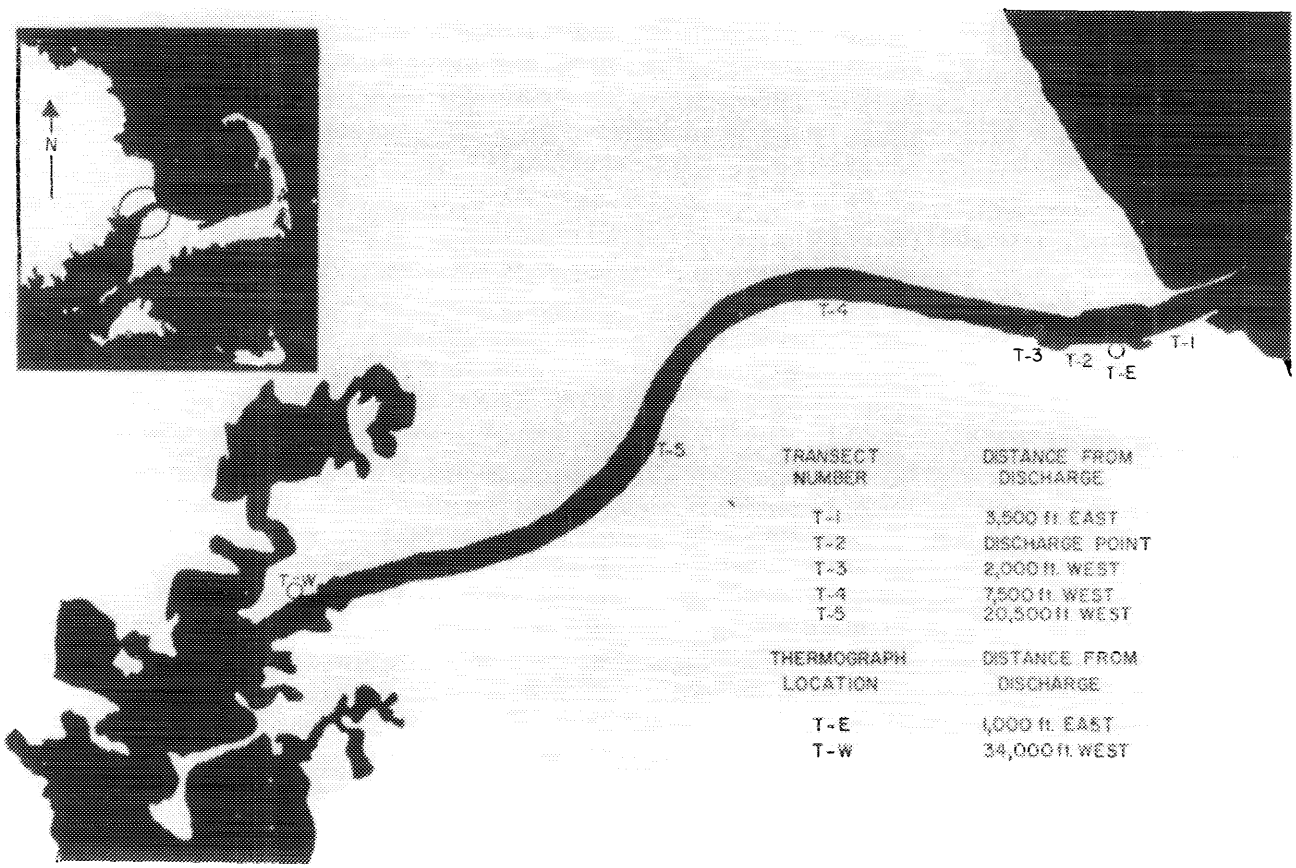
Water temperature and salinity are two important factors governing the occurrence and distribution of marine organisms. Continuous monitoring of these environmental parameters provides a basis for separating power plant effects from changes in the structure of marine communities resulting from naturally occurring variations in temperature and salinity.

METHODS:

Model 40 Foxboro temperature recorders were installed at the east and west entrances of the Cape Cod Canal on 29 August 1966 (Fig. 1). Sensor probes were located at depths of —10 ft (MLW). The east end instrument furnished temperature records through December 1969, except for the periods of 9 July - 28 August 1967, 26 November 1967 - 4 May 1968, 15 December 1968 - 19 April 1969 and 2 November - 15 November 1969, when the recorder was removed for repair. The west end instrument provided a continuous temperature record through 22 September 1968 at which time it was removed for repair and not replaced.

Model D, 30 day, Ryan submersible thermographs were periodically employed to monitor temperatures at depths and locations of specific interest. Water temperatures were routinely taken throughout the water column with a diver-held thermometer in conjunction with the sampling program. An ARA hydrographic thermometer equipped with a 50 ft cable and probe was used to monitor temperatures at intake and discharge flumes. Thermal plume configurations were determined from bathythermograph drops made throughout the discharge area.

Figure 1 Transect and Thermograph location in the Cape Cod Canal



Surface salinity measurements for the two water masses (Buzzards Bay and Cape Cod Bay) and supplemental temperature data were extracted from records maintained daily at each entrance to the Canal by the U.S. Army Corps of Engineers.

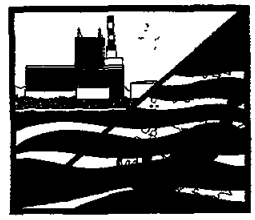
FINDINGS:

Excluding the immediate discharge area, no significant degree of thermal stratification was recorded in the land-cut portion of the Cape Cod Canal during the study period.

High and low temperature readings for each tidal cycle were extracted from Foxboro recording charts and used to calculate weekly mean temperature ranges for each end of the Canal (Figs. 2 and 3). To fill voids in these data resulting from malfunctioning instruments, weekly ranges were taken from the Corps of Engineers records of daily water temperature when readings coincided with periods of high and low slack water. Range limits are indicative of Cape Cod Bay and Buzzards Bay water temperatures and represent the magnitude of fluctuation that occurred during each tidal cycle. Buzzards Bay water was warmer during the spring, summer and fall months but cooler in the winter. For brief periods during March and November of each year, temperatures were nearly uniform throughout the system.

Maximum weekly ranges at the east entrance were 17.0F, 16.9F and 16.4F recorded during the weeks of 30 July 1967, 28 July 1968 and 3 August 1969, respectively. Maximum ranges at the west entrance were 20.3F, 18.8F and 17.0F, also recorded during these same weeks. The similarity of temperature ranges at the two entrances shows that the Canal is completely and alternately filled with Cape Cod Bay and Buzzards Bay water during each tidal cycle.

Weekly mean temperatures were determined for the periods Foxboro thermographs were operating by measuring the area beneath the recording chart tracing with a polar planimeter and calculating the radius of a circle of equal area. A reading of the weekly mean was obtained by applying this radius to a temperature chart (Fig. 4). While the weekly ranges were similar at both Canal entrances, the weighted means varied with the time each water mass persisted at the recording stations. Weekly means decreased from west to east during the summer months, but increased from west to east in the winter. The highest weekly means recorded were 65.3F (1967) and 65.9F (1968) at the west entrance and 61.1F (1968) and 66.2F (1969) at the east entrance.



The thermal plume configurations depicted in Figs. 5 and 6 are typical under average conditions of tide and current with the plant at full load. Heat dissipation occurred rapidly within 500 ft of the discharge and was essentially complete at 2,000 ft. The effluent flowed from the discharge flume as a surface layer that penetrated to an approximate depth of 20 ft initially and became gradually shallower in a down-current direction. Periods of departure from these dispersal patterns were very brief, occurring at slack water as the position of the plume changed with current direction. Temperatures at the mouth of the discharge flume were 26F above ambient with the plant at full load, and 13F at half load.

Monthly averages of surface salinities taken at the east and west entrances at low and high tide, respectively, ranged between 30.41‰ and 32.72‰ (Table 1). In general, Buzzards Bay water was slightly less saline during the study period, presumably due to an influx of fresh water from several streams and rivers that drain into upper reaches of the Bay.

DISCUSSION:

The lack of thermal stratification in the Cape Cod Canal can be attributed to the strong currents and extreme turbulence. Anraku (1964) recorded a maximum vertical temperature gradient of 19.8F for Cape Cod Bay and 5.4F for Buzzards Bay, but reported Canal water as a well mixed, slightly less saline mass that during the summer months separated the stratified waters of both bays. Despite Canal turbulence and velocity, power plant effluent dispersed as a shallow surface layer as predicted by Stone & Webster Eng. Corp. (1965).

Water temperature differences in Buzzards Bay and Cape Cod Bay were sufficient during most of the year to serve as a means of tracing the movement of the two water masses in and out of the Canal. During the mid-summer months, Buzzards Bay waters were typically 15F to 20F warmer than Cape Cod Bay waters. Approximately 1 hr after high slack tide, colder Cape Cod Bay water entered the Canal from the east and temperatures decreased abruptly. About 2½ hr later, cold water reached the west end of the Canal and

Figure 2 Weekly temperature ranges at the west entrance of the Cape Cod Canal September 1966 thru December 1969

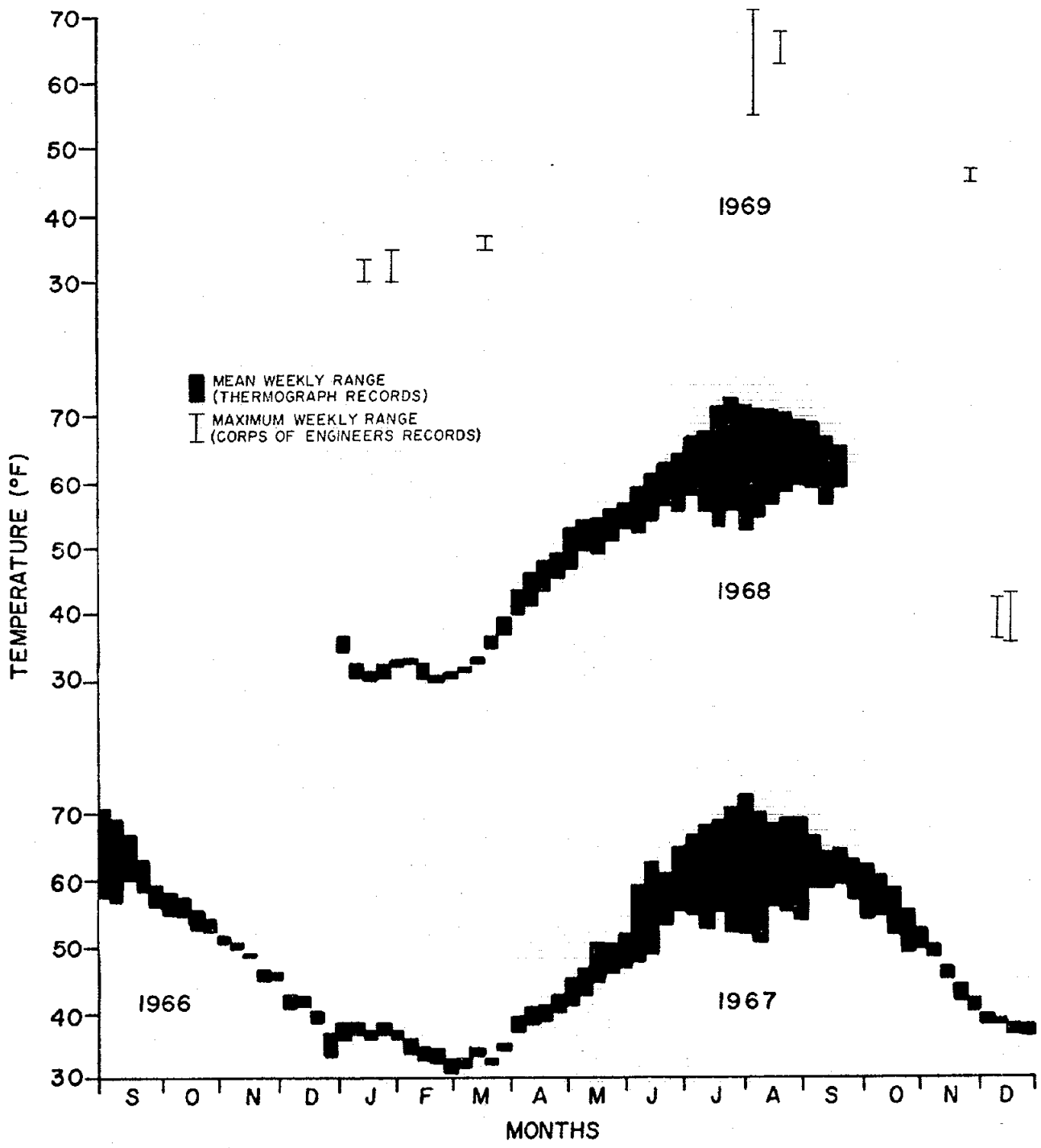


Figure 3 Weekly temperature ranges at the east entrance of the Cape Cod Canal September 1966 thru December 1969

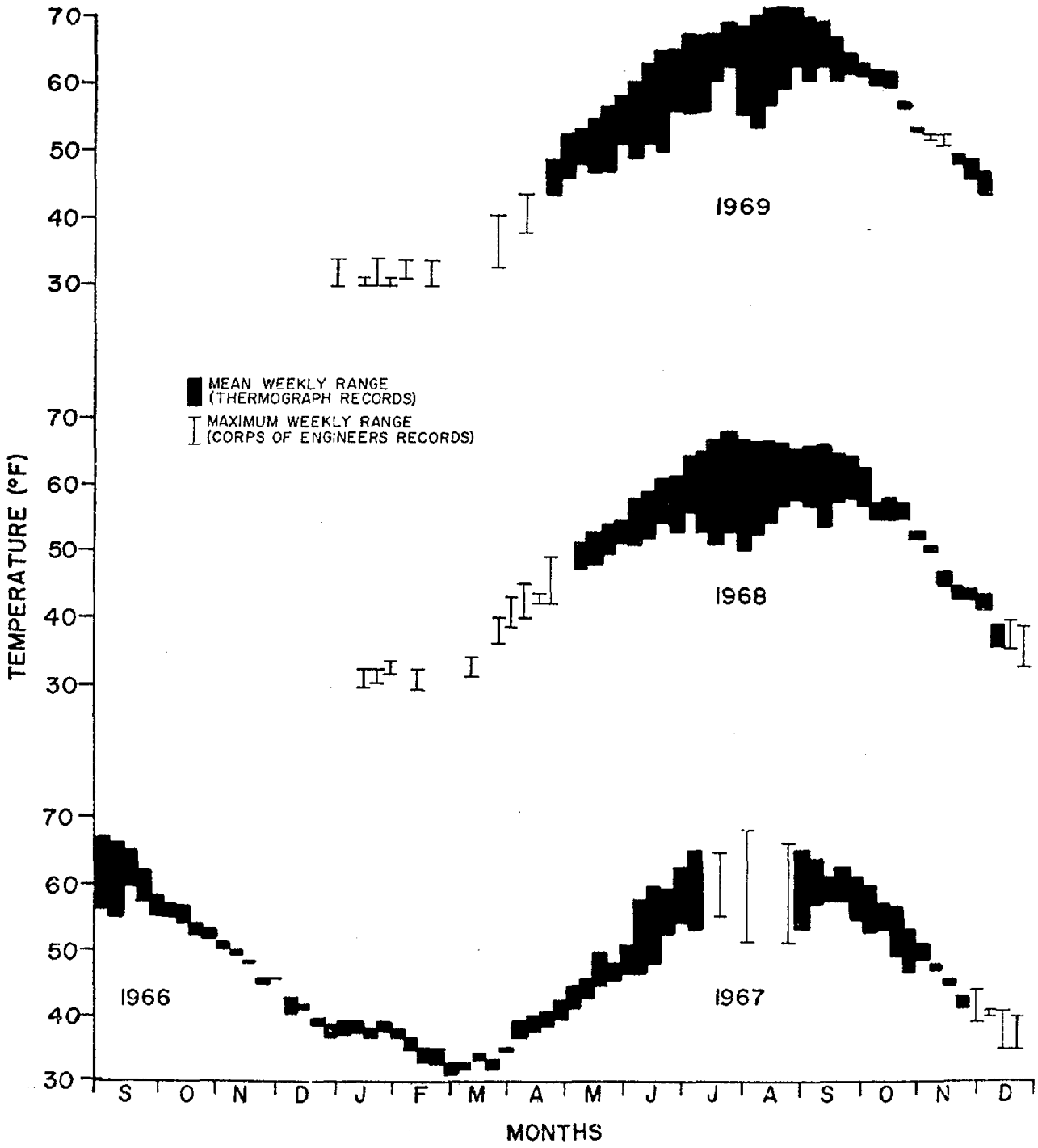


Figure 4 Weekly mean temperature at the east and west entrances of the Cape Cod Canal September 1966 thru December 1969

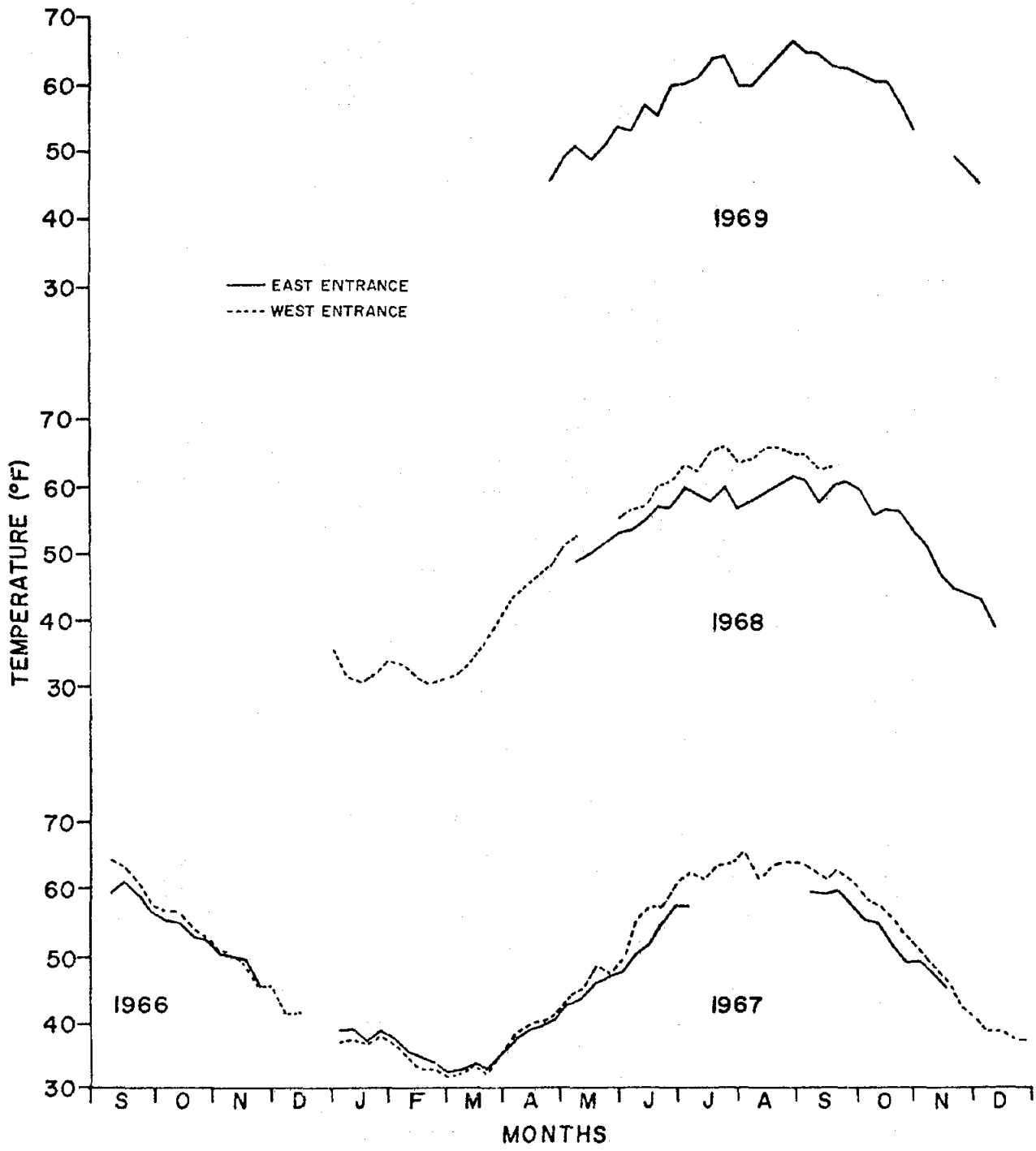


Figure 5 Typical thermal plume configuration on an eastbound or flooding tide (isotherms in °F)

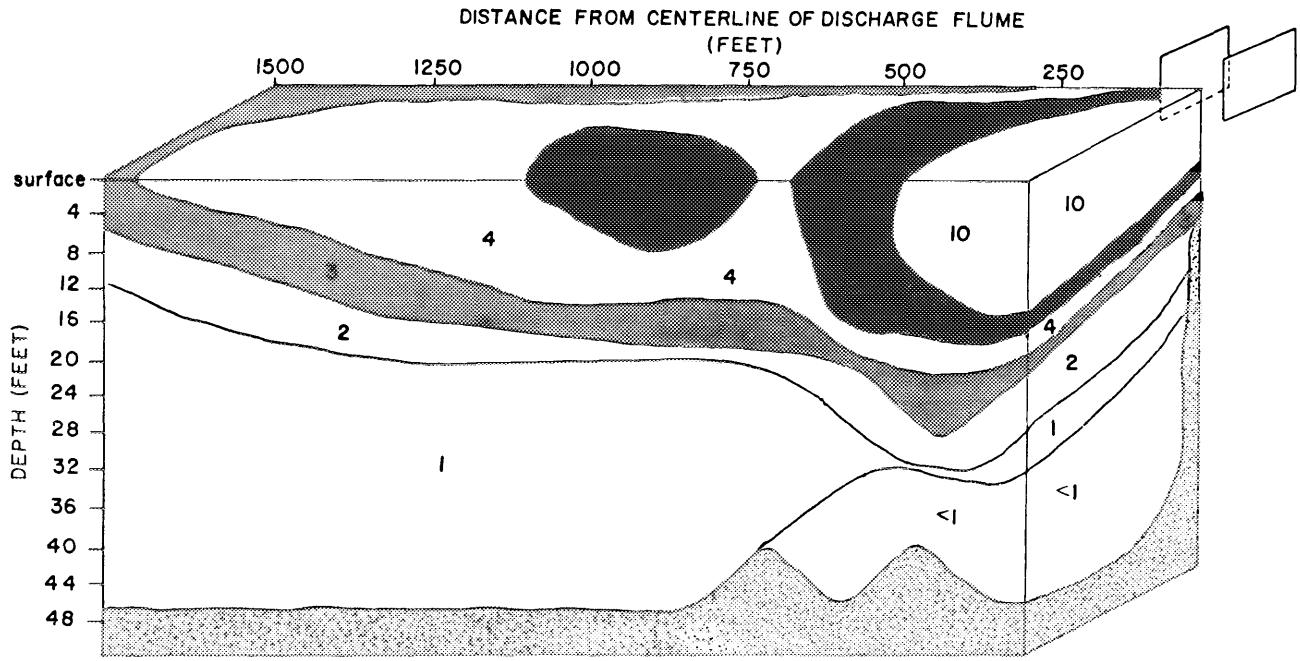


Figure 6 Typical thermal plume configuration on a westbound or ebbing tide (isotherms in °F)

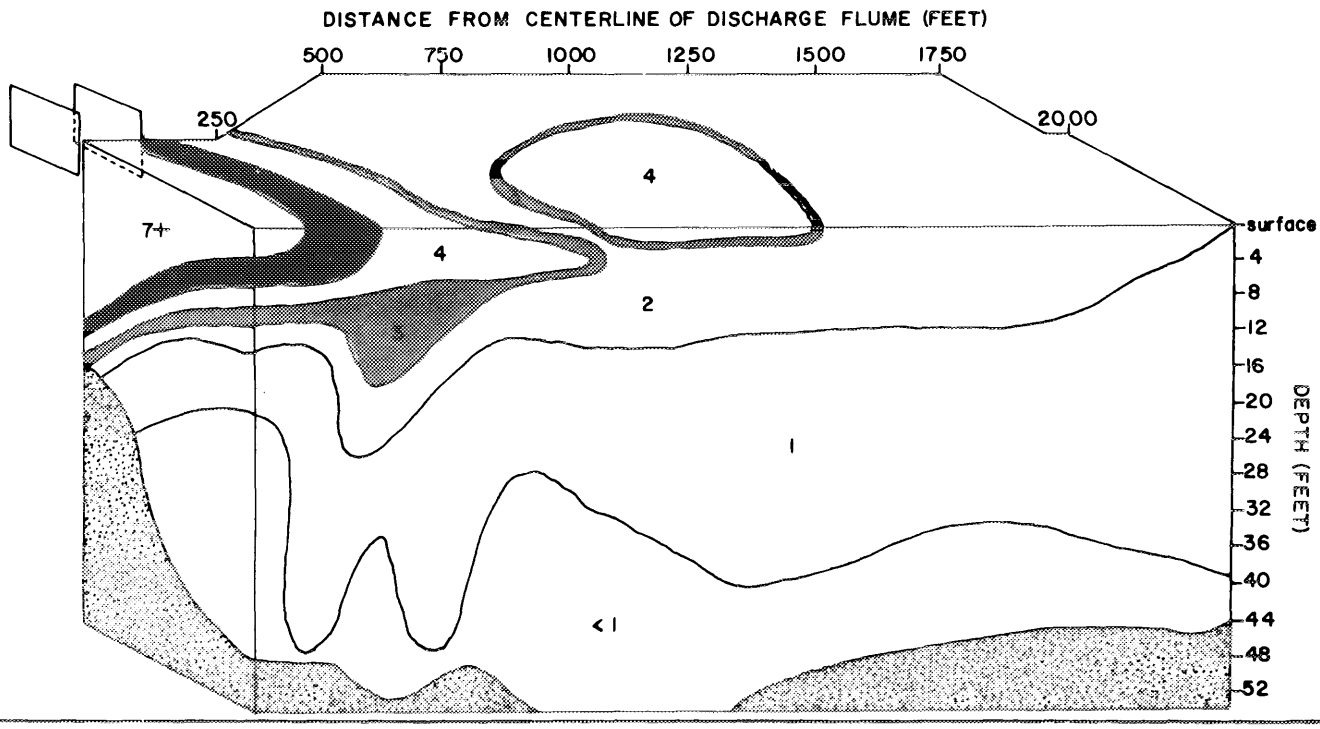


Table 1

AVERAGE MONTHLY SALINITIES (‰) AT HIGH AND LOW TIDE IN THE CAPE COD CANAL, JUNE 1966 - DEC. 1969

	1966		1967		1968		1969	
	High Tide	Low Tide	High Tide	Low Tide	High Tide	Low Tide	High Tide	Low Tide
January	-	-	31.48	31.45	30.71	31.29	31.53	31.95
February	-	-	31.04	31.59	30.87	31.39	31.26	32.28
March	-	-	30.77	31.50	30.41	31.44	31.60	32.19
April	-	-	31.02	31.55	30.46	31.65	30.70	32.07
May	-	-	30.53	30.91	31.00	31.48	31.23	31.59
June	31.53	31.64	30.67	31.11	31.28	31.18	31.72	31.75
July	32.58	31.75	30.89	31.49	31.74	31.47	32.11	31.86
August	32.72	32.06	31.29	31.67	31.81	31.81	32.03	31.97
September	31.74	31.80	31.48	31.63	32.16	32.06	32.28	32.22
October	31.81	31.99	31.46	31.73	32.31	32.20	31.72	31.86
November	31.42	31.81	31.25	31.42	31.79	31.90	31.46	31.76
December	31.53	31.45	30.63	31.61	31.16	31.43	31.14	31.88

Table 2

AVERAGE MONTHLY SURFACE TEMPERATURES (°F) BOSTON LIGHTSHIP 1967-1969

Month	1967	1968	1969
January	38.7	36.5	37.0
February	36.7	34.7	37.8
March	35.6	35.4	37.0
April	38.3	41.4	41.9
May	43.0	48.6	50.5
June	52.7	56.8	59.0
July	61.9	62.8	64.9
August	60.6	61.3	65.7
September	58.5	61.7	63.0
October	51.1	54.3	55.8
November	45.3	48.7	49.5
December	41.2	43.0	-

Table 3

AVERAGE MONTHLY SURFACE TEMPERATURES (°F) BUZZARDS BAY LIGHT STATION 1967-1969

Month	1967	1968	1969
January	39.8	34.9	36.5
February	36.9	33.8	34.2
March	34.3	34.7	35.2
April	37.8	42.1	43.2
May	46.9	50.0	52.2
June	55.2	56.5	60.3
July	62.1	64.6	63.5
August	64.9	65.5	66.6
September	59.4	63.7	64.0
October	58.6	59.7	-
November	50.9	52.0	-
December	42.6	43.2	-

continued to flow out into Buzzards Bay for another 2½ hr, at which time low slack water occured. Low temperatures persisted at the west entrance for approximately 1 hr following low water and then gradually increased at the rate of 4-5F/hr for 3 hr and 1-2F for 2 hr. Two hours after the onset of increasing temperatures at the west end, warmer water reached the east end recorder and temperatures increased at the rate of 4-5F/hr for 3 hr, or until high slack tide recurred.

The slight decrease in salinity and the gradual increase in water temperature recorded during the early stages of the eastbound tide suggest that water entering the Canal from Buzzards Bay is comprised initially of Cape Cod Bay water, Buzzards Bay water, and fresh water that have mixed in the upper reaches of Buzzards Bay. Conversely, Cape Cod Bay water enters the east entrance of the Canal in undiluted form as indicated in summer by a sheer temperature reduction shortly after the tide turns west. Consequently, Cape Cod Bay water persists in the vicinity of the power intake for 8 hr out of each 12½ hr tidal cycle. Assuming a typical summer temperature range of 53F to 68F and full load operation, coolant water is discharged at a temperature of 79F commencing 1 hr after high slack tide until 3 hr before the next high slack tide. At this time, Canal temperatures increase at the approximate rate of 5F/hr for 3 hr with a resulting rise of coolant water temperatures to 84F after the first hour, 89F after the second hour, and 94F after the third hour. Discharge temperatures remain at 94F for approximately 1 hr following the turn of the tide, then decrease abruptly to 79F.

The notable increases in weekly means and upper range limits recorded at the east entrance during the summer of 1969 are partially attributable to power plant influence on the east end recorder. Records from this instrument, located 1,000 ft easterly of the plants discharge, regularly indicated temperatures of 2F above ambient during the flooding or eastbound tide. The thermograph, however, was not subject to plant influence during the ebbing or west bound tide and lower range limits accurately reflect temperatures of Cape Cod Bay water entering the Canal. These records indicate, as do those from the Boston Lightship (Table 2), that waters northerly of Cape Cod have become progressively warmer in the summer months over the past 3 years. Buzzards Bay Light records (Table 3) show a corresponding but less significant increase in water temperatures.

Sport Fishery

The Cape Cod Canal offers approximately 14 miles of deep water access to the shore-based angler. Accessibility, abundance of sportfishes, and unlimited parking make the Canal one of the most popular fishing sites on the coast of Massachusetts.

One highly prized species occurring in the Canal is the striped bass (*Morone saxatilis*). During the months of May and June, fishing effort is concentrated in the vicinity of the Bournedale Herring Run, where large numbers of ascending alewives *(Alosa pseudoharengus)* act as an attractant to this gamefish. As the season progresses, bass change their feeding habits and are sporadically taken along the entire length of the Canal. The best fishing periods, which are a function of tide and time of day, are predictable to a degree but angler success varies markedly from tide to tide with the movement of bait species and the bass themselves. Due to the erratic fluctuation of year class strength of this species, the annual catch also varies widely.

Another important gamefish caught in the Canal is the bluefish *(Pomatomus saltatrix)*. This species invades Buzzards Bay in large numbers during the summer months. Their appearance at the east end of the Canal is usually associated with the influx of warmer Buzzards Bay water during the flooding tide. Bluefish, like the striped bass, periodically exhibit strong year classes.

The largest group of fishermen to pursue their sport on the Canal are the more casual anglers who seek a variety of smaller fishes. During January 1967, a creel census was implemented to obtain a measure of the success of this group of anglers. Fisherman concentration on the pier and along the bulkhead and riprap at the east entrance during daylight hours facilitated a large number of fisherman interviews with the limited manpower resources available for this phase of the study. To obtain similar information on the striped bass fishery would have required additional personnel and a greatly expanded censusing effort, especially during the early morning and late evening hours. Furthermore, it was felt that any changes in the annual catch rate of striped bass due to plant operation, would be undiscernible from changes due to naturally occuring fluctuations in abundance so typical of this species.

It was the objective of this creel census to obtain an index of fisherman success in a manner that could

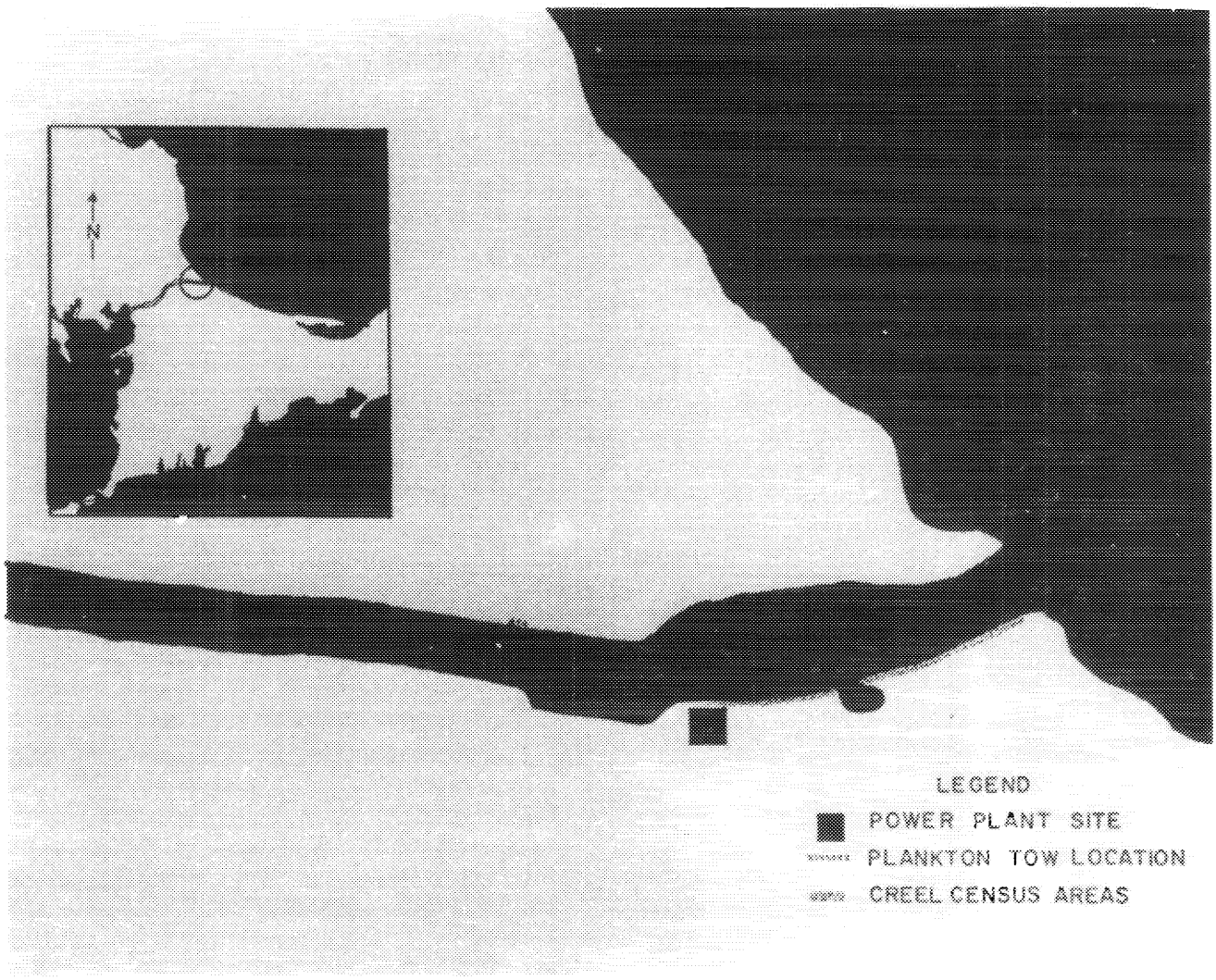


Figure 7 Plankton tow and creel census areas

be duplicated following plant operation, as a means of directly assessing plant influence upon the sport-fishery.

METHODS:

Two popular fishing areas at the east entrance of the Cape Cod Canal were selected for creel census purposes. Area I is that portion of the south bank between the power plant site and the base of the east jetty. This section is 3,500 ft long, of which approximately 2,000 ft have been bulkheaded. Area II is the state-operated fishing pier almost directly across the Canal from the power plant (Fig. 7).

Throughout the summer months, an interviewer was stationed at each area one day per week between 0900 and 1200 hr. During colder months, when angling pressure was light, periodic visits were made to each area during the interview period. All anglers were queried relative to the time they started fishing, the number and species caught and released, and species preference. The type gear employed was noted and catches were examined to determine number and species caught.

FINDINGS:

During the census period (January 1967 - December 1969) 3,797 anglers were interviewed who fished a total of 6,368.7 hr and caught 6,321 desireable fishes. Atlantic cod *(Gadus morhua)*, Atlantic mackerel *(Scomber scombrus)*, winter flounder *(Pseudopleuronectes americanus)*, pollock *(Pollachius virens)* and tautog *(Tautoga onitis)* comprised 91.7% of the total catch while bluefish, rainbow smelt *(Osmerus mordax)*, chub mackerel *(Scomber jabonicus)*, blue

Plate 2 Typical summer concentration of anglers along bulkheaded sections of Cape Cod Canal.

runner *(Caranx crysos)*, Atlantic tomcod *(Microgadus tomcod)*, red hake *(Urophycis chuss)* and American eel *(Anguilla rostrata)* accounted for the remaining 8.3%. Cunners *(Tautogolabrus adspersus)* were commonly taken but seldom retained, due to their small size. Sculpins *(Myoxocephalus spp.)*, skates *(Raja spp.)* and spiny dogfish *(Squalus acanthius)* were discarded.

The most useful statistic for comparing fisherman success between census years is the catch rate (the number of a particular species caught per unit of effort directed toward its capture). Canal anglers employed two basic fishing techniques. These were the use of weighted baits fished on the bottom (bottom fishing) and the use of artificial or suspended baits fished off the bottom (top-water fishing). Since the ratio of fishing time expended by each group varied between census years, catch statistics have been compiled seperately for each type of angling effort.

Total fishing effort by all the fishermen interviewed was 1,754.0 hr in 1967, 2,414.8 hr in 1968 and 2,199.9 hr in 1969. Time expended by bottom fishermen during 1967 and 1968 represented 79.3% and 78.1% of the total effort respectively, and decreased to 42.2% in 1969 (Fig. 8, Graph C). In spite of this shift in angling technique, seasonal distribution of bottom fishing effort was similar during each census year. Fishing pressure commenced in April or May, reached a peak in July and August and declined through November (Fig. 8, Graph B). Seasonal distribution of top-water angling effort exhibited a similar trend in 1967. However, in 1968 and 1969, fishing effort commenced in May, increased to a summer peak, decreased in September then increased again in October and November to near summer proportions (Fig. 8, Graph A).

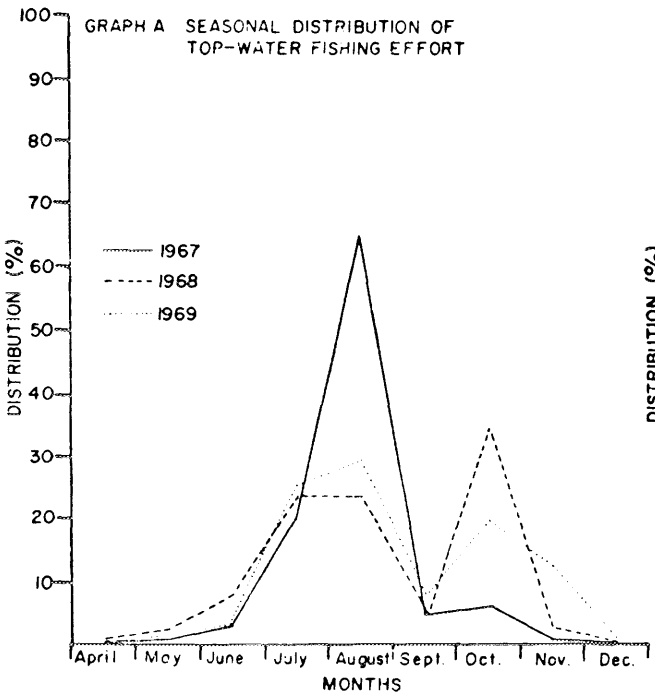
Table 4

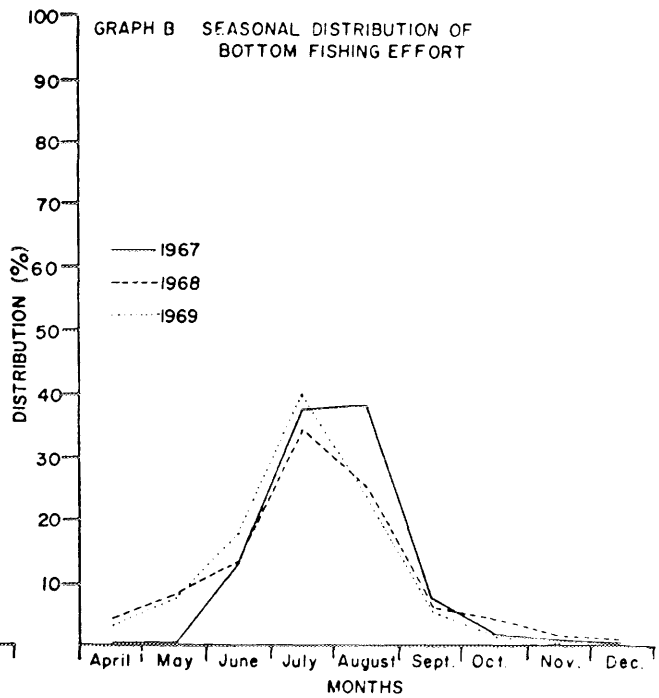
TOTAL NUMBER AND COMBINED CATCH RATE FOR ALL SPECIES COMPRISING THE CANAL SPORTFISHERY - 1967, 1968, 1969

	Top Water Fishery		Bottom Fishery	
Year	Total Number	Catch Rate	Total Number	Catch Rate
1967	415	1.14	511	.37
1968	928	1.75	580	.31
1969	3607	2.79	280	.31

The annual combined catch rate for top-water fishermen rose from 1.14 fish/hr in 1967 to 1.75 /hr in 1968 and 2.79 /hr in 1969 (Table 4). This increasing success was directly attributable to improving catches of Atlantic mackerel which were taken at rates of .81 (1967), 1.27 (1968) and 2.27 (1969) (Table 5). The pollock catch per unit of effort remained the same during the 3 years in both the top-water and bottom fisheries. Winter flounder, a bottom species also exhibited a constant catch rate. The rate at which tautog were caught by bottom fishermen increased slightly each year while the rate for cod decreased (Table 5).

Figure 8 Distribution of fishing effort expended by canal anglers 1967, 1968, 1969





GRAPH C DISTRIBUTION OF TOTAL FISHING EFFORT BY TECHNIQUE

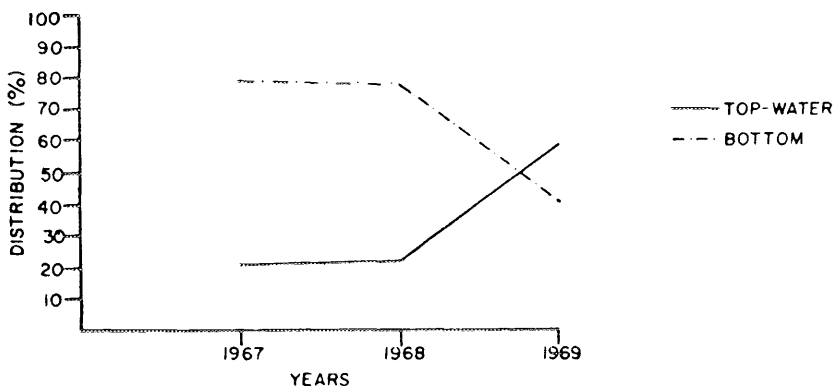


Table 5

TOTAL NUMBER AND CATCH RATES FOR MAJOR SPECIES COMPRISING THE CANAL SPORTFISHERY - 1967, 1968, 1969

Top Water Fishery

	Total Number			Catch Rate		
Species	1967	1968	1969	1967	1968	1969
mackerel	293	670	2941	.81	1.27	2.27
winter flounder	-	-	-	-	-	-
tautog	-	-	-	-	-	-
Atlantic cod	-	-	-	-	-	-
pollock	105	166	384	.29	.31	.30

Bottom Fishery

	Total Number			Catch Rate		
Species	1967	1968	1969	1967	1968	1969
mackerel	-	-	-	-	-	-
winter flounder	68	119	49	.05	.06	.05
tautog	20	42	33	.01	.02	.04
Atlantic cod	150	71	15	.11	.04	.02
pollock	272	313	159	.19	.17	.17

DISCUSSION:

Utilizing annual catch rates as criteria, the availibility of two important sportfishes, the pollock and winter flounder, remained unchanged throughout the census period; one species, the cod, decreased; and two others, the tautog and Atlantic mackerel, showed slight and marked increases, respectively. Declining catches of cod were offset by improving catches of tautog with the end result that bottom fishing remained equally productive during the three census years.

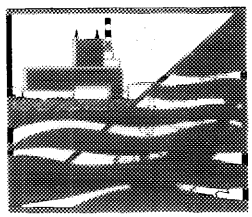
The sportfish exhibiting the most pronounced change in abundance and occurrence in the catch was the Atlantic mackerel. Shifts in the distribution of fishing effort relative to season and fishing technique are interpreted as angler response to the increasing availability of this one species. Mackerel supported a substantial top-water fishery in the Canal during the fall months of 1968 and 1969 whereas only a limited fishery had existed in 1967. Increasing success of these anglers apparently prompted many bottom fishermen to alter their methods of angling, hence the shift in emphasis to top-water fishing in 1969.

While notable changes were recorded in the rates at which Canal anglers caught Atlantic cod and mackerel, these changes were not attributed to power plant operation. The decline in abundance of cod indicated by catch statistics was also reflected along transects regularly examined by SCUBA, both within and outside the area of plant influence. Moreover, heated effluent from the Canal station stratified as a shallow surface layer and did not penetrate to the depths that cod were found in the Canal during the pre-operation survey of 1967. Improving catch rates of mackerel in 1968 and 1969 were due to movement of large numbers of this species into the Canal during the fall months. These fish probably comprised part of the northern contingent of the mackerel population that migrates southerly along the Massachusetts coastline late in the year (Bigelow and Schroeder, 1953). Due to the fast-moving, pelagic habits of mackerel, the SCUBA census technique did not provide a basis for comparing catch fluctuations with indices of abundance in parts of the Canal outside the area of plant influence. Full load plant operation during the eastbound or flooding tide did result in surface water temperature increases of up to 4F above ambient along the bulkheaded section of the Canal where most of the sportfishing effort was expended. It is noteworthy, however, that the plant was not operating during the fall of 1968 when these fish arrived in the Canal, but was operating at full generating capacity in 1969 when the greatest numbers of mackerel were harvested. While it is unlikely that the thermal discharge acted as an attractant to this fish, it is significant that mackerel were not repelled by plant operation.

Distribution and Occurrence of Fishes

An assessment of S.E.S. influence upon marine fisheries requires a knowledge of finfish abundance and distribution around the plant site, before and during plant operation. It became obvious during the early stages of these investigations that the array of nets, seines and trawls usually employed to sample fishes would have limited application in the Cape Cod Canal due to strong currents and heavy boat traffic. During the summer of 1966, 20 dives were made to examine the feasibility of using SCUBA to make systemmatic observations of fishes. The diver fish-census

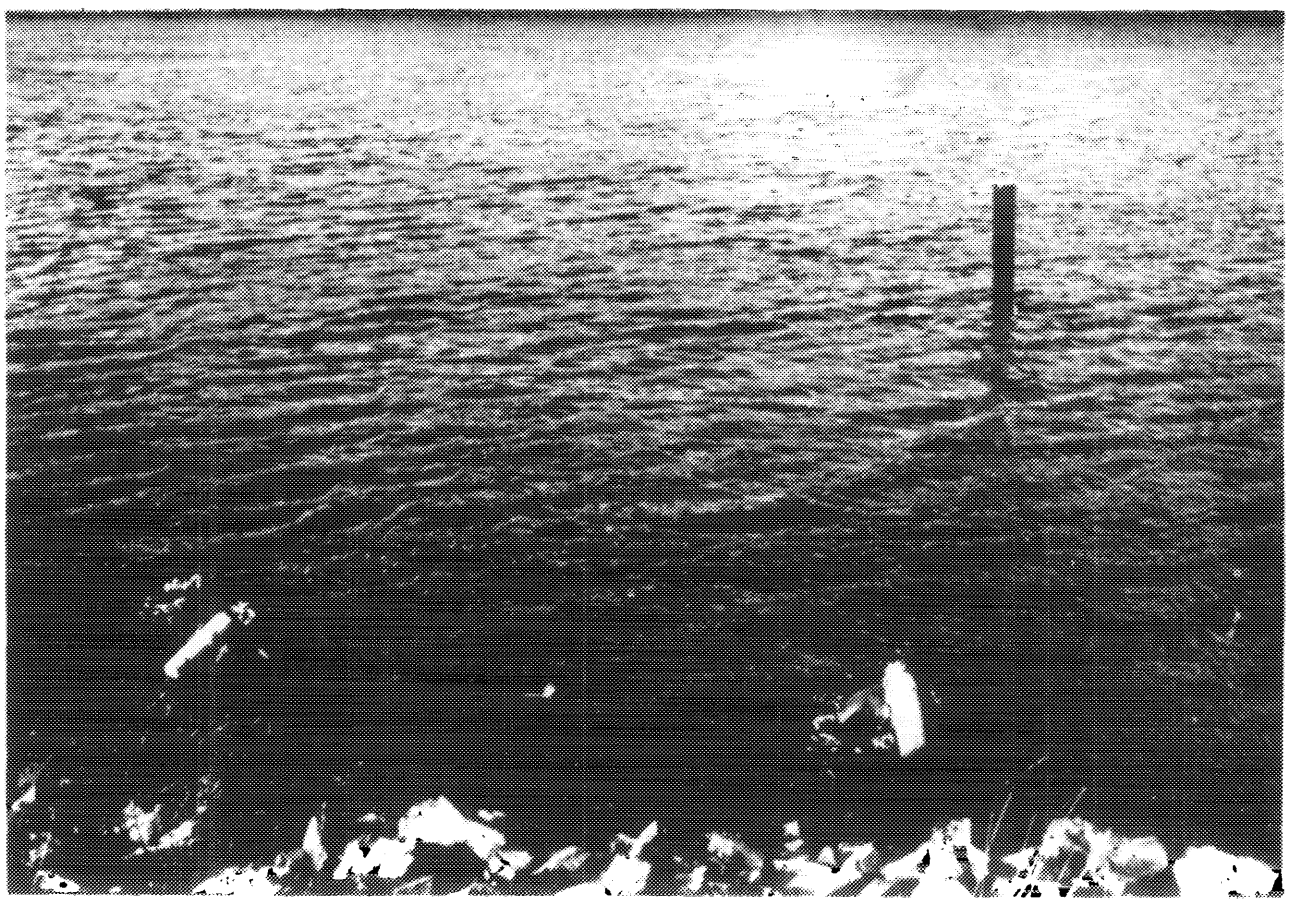
technique has been used by Turner, Ebert and Given (1964, 1965, 1966a and 1966b) and evaluated by Northcote and Wilkie (1963). Beginning in September 1966, SCUBA was utilized to obtain monthly counts of fishes along transects at various distances from the power plant site. Due to the rigors of cold-water diving and the lack of fishes encountered during the first winter (1966-1967) the winter survey was discontinued in subsequent years except on an irregular basis. Data collected and presented in this report reflect the abundance and distribution of fishes in the Canal during the May through October period in 1967, 1968 and 1969, and provide a basis for examining the nature and extent of power plant induced changes in finfish populations.



METHODS:

Five transects extending perpendicular to the shoreline of the Canal were established at the plant site; 3,500 ft east of the plant; 2,000 ft, 7,500 ft and 20,500 ft west of the plant (Fig. 1). Transect locations were selected to provide coverage throughout the zone of predicted temperature increase (Stone and Webster Eng. Corp., 1965). A total of 130 dives involving 1,300 individual observations were made during the study period. Diving was confined to the 30 to 45 min slack water periods during each tidal cycle. Finfish counts were made by two divers joined by a 15 ft line, the center of which was designated by a flourescent orange float. As divers descended slowly along the bottom they paused at each 10 ft depth interval to record the species observed, their numbers and estimated size range. When more than

Plate 3 **Divers embarking on finfish count along Transect 5. (Note connecting line and buoy that designates width of sample strips).**



20 individuals of one species were encountered in one 10 ft interval, numbers were estimated. Only those fishes occurring between each diver and the center float were tallied. Data obtained during each dive represented the total fishes encountered in two parallel strips, each 7½ ft wide, extending from the water line down the sloping bank and out onto the Canal bottom. Steel stakes driven into the bottom served to guide divers along each transect. Visibility measurements and temperatures were taken with a diver-held secchi disc and thermometer on the bottom and at each 10 ft while ascending. Upon completion of a dive, data were transferred from plastic slates to permanent record sheets.

FINDINGS:

A list of the fishes observed and recorded in the study area is given in Table 6. Several of these are bottom-dwelling forms that are of little or no sport or commercial value. Most abundant among these were the rock gunnel *(Pholis gunnellus)*, grubby *(Myoxocephalus aenaeus)* and longhorn sculpin *(Myoxocephalus octodecemspinosus)*. Skates, dogfish, goosefish *(Lophius americanus)*, sea raven *(Hemitripterus americanus)* and lumpfish *(Cyclopterus lumpus)* were occasionally observed.

Although common in the Canal, Atlantic mackerel and bluefish were two fishes seldom encountered by divers. Mackerel comprised a substantial portion of the sportfishing catch and bluefish were sporadically caught by Canal anglers. Alewives and blueback herring *(Alosa aestivalis)* congregated at the Bournedale Herring Run in April, May and June but were rarely sighted along Canal transects.

Six species encountered regularly and in substantial numbers were the Atlantic cod (in 1967 only), pollock, cunner, tautog, winter flounder and Atlantic silversides *(Menidia menidia)*. Winter flounders reached peak abundance during the spring and summer months while cunners were most abundant during summer and fall. Cod, tautog and adult pollock each exhibited spring and fall peaks. Most of the pollock recorded during mid-summer were small fish estimated at less than 6 inches in length. Cod and winter flounder were the only important species encountered from December 1966 through April 1967 and these were present in small numbers.

Schools of juvenile clupeid fishes were encountered by divers during late summer and early fall months but could not be positively identified in situ. Subsequent seine hauls made on several occasions netted Atlantic herring *(Clupea harengus harengus)* and Atlantic menhaden *(Brevoortia tyrannus)*, principally the latter. Striped bass were periodically observed, but never in large numbers.

The largest concentrations of silversides and clupeid fishes were encountered near the surface above 20 ft. Pollock were most abundant between 10 and 20 ft except in 1969 when this species was typically sighted to 30 ft on Transect 2. Cunners and winter flounders were commonly recorded at all depths but most abundantly between 10 and 30 ft (Fig. 9).

All major species exhibited changes in abundance in the Canal during the study period (Fig. 9). Cunners, silversides and clupeids increased in overall abundance each year while cod decreased. Pollock, tautog and winter flounders declined in numbers from 1967 to 1968, then increased in 1969.

Fishes exhibiting notable changes in both distribution and abundance were pollock and the clupeids. Of the total number of pollock recorded each year, the proportion occurring on Transect 2 increased from 13.3% in 1967 to 55.7% in 1968 and 75.4% in 1969. Clupeids were encountered only on Transect 1 in 1967, on Transects 1, 2, 4 and 5 in 1968 and on all 5 transects in 1969. These fishes also tended to concentrate on Transect 2 in 1968 and 1969 with 54.4% and 38.3% occurring here, respectively. Tautog were most numerous each year on Transect 5, but relative abundance on other transects varied erratically. Numbers of cod recorded in 1968 and 1969 were too small to provide meaningful information regarding the distribution of this species in the Canal. Cunners, winter flounders and silversides showed relatively stable patterns of distribution throughout the study period.

Turbidity seldom hampered finfish observations within the 7½ ft wide sample strips. Visibility measurements taken on each dive ranged between 7 and 30 ft with mean readings of 16 ft in 1967, 18 ft in 1968 and 20 ft in 1969. Readings taken throughout the water column on a single dive seldom varied more than 2 ft and never varied more than 4 ft.

DISCUSSION:

Changes in the overall abundance of major fishes in the Cape Cod Canal have been attributed to natural population fluctuations since numbers varied along all transects, including those outside the area of power plant influence. Greatest changes in abundance were exhibited by Atlantic cod and the clupeid

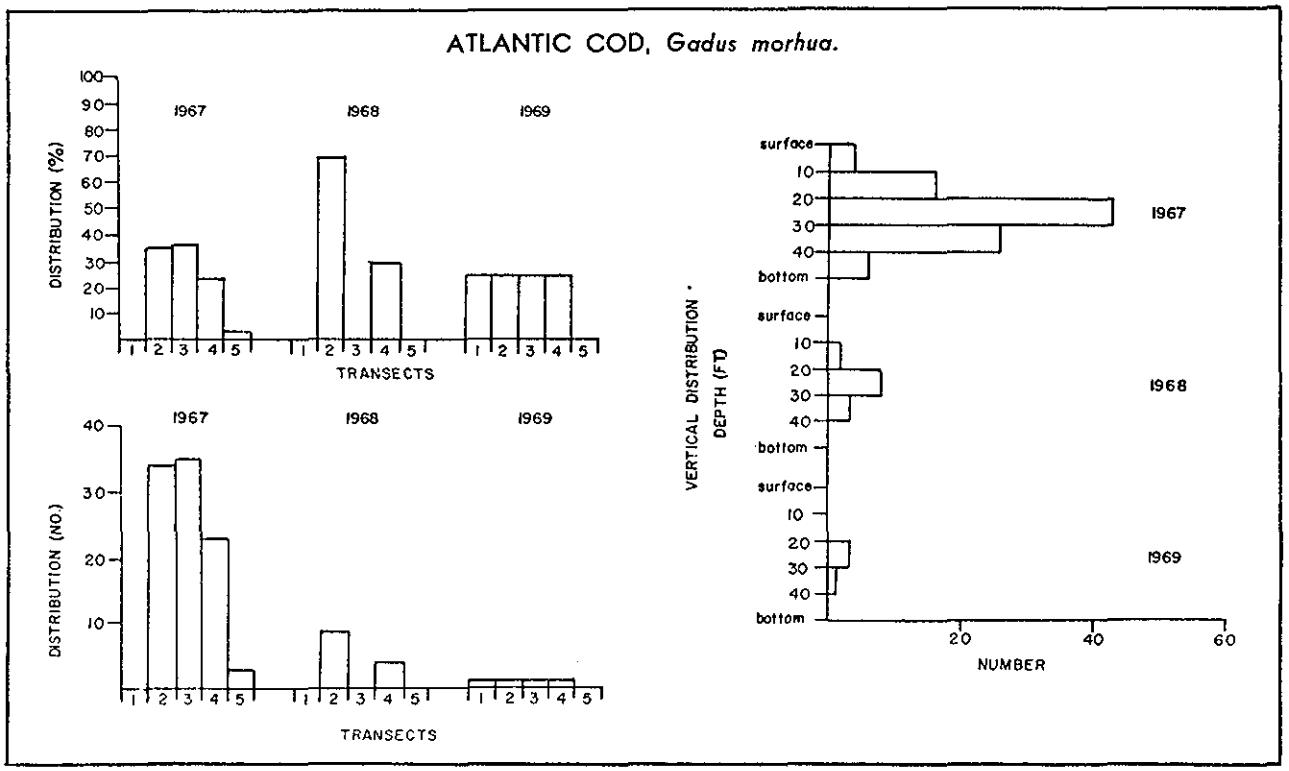
Table 6 LIST OF FISHES RECORDED IN THE CAPE COD CANAL MAY, 1966-NOV. 1969[1]

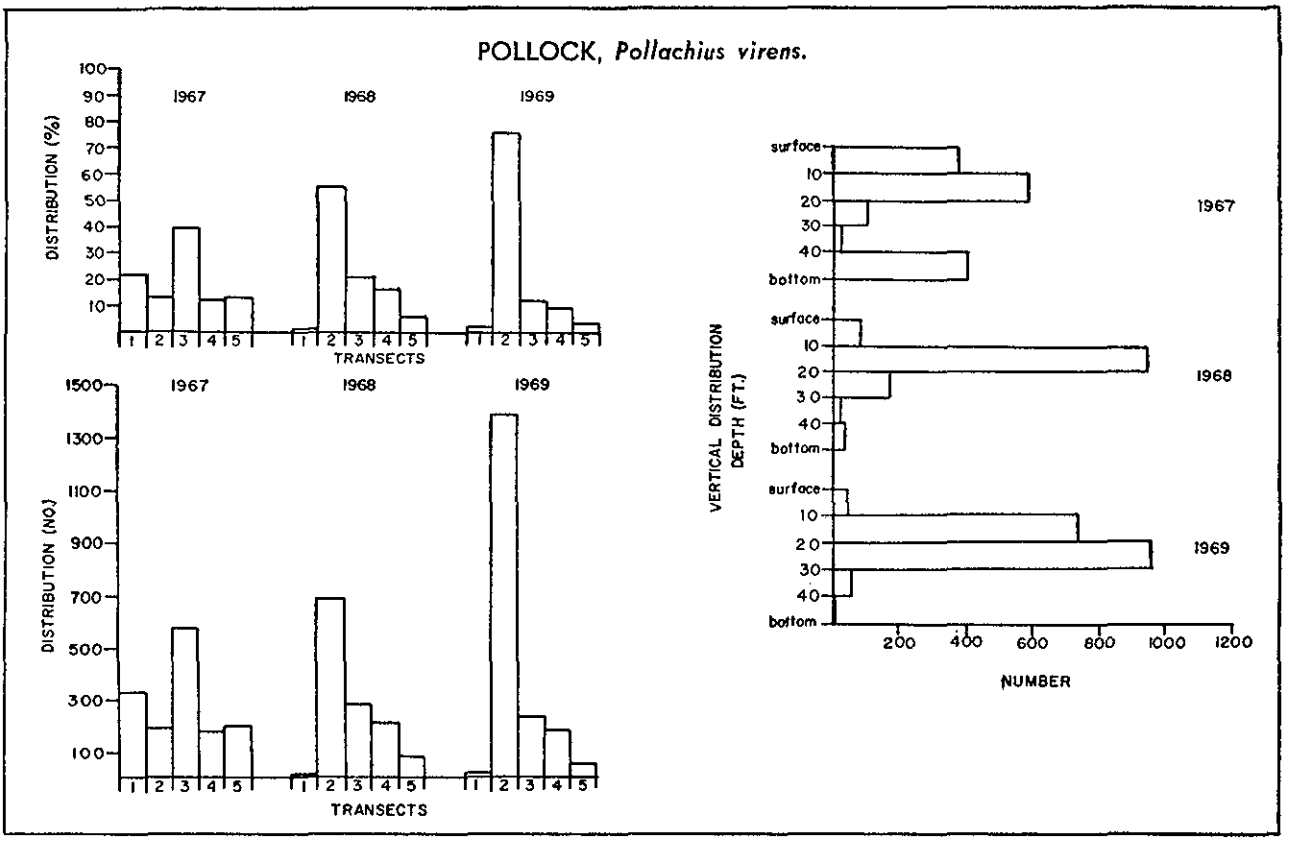
Class: Chondrichthyes - Cartiliginous fishes
- Order: Squaliformes
  - Family: Squalidae - dogfish sharks
    - *Squalus acanthias* Linnaeus - spiny dogfish
- Order: Rajiformes (Batoidei)
  - Family: Torpedinidae - electric rays
    - *Torpedo nobiliana* Bonaparte - Atlantic torpedo
  - Family: Rajidae - skates
    - *Raja laevis* Mitchill - barndoor skate
    - *Raja ocellata* Mitchill - winter skate

Class: Osteichthyes - Bony fishes
- Order: Anguilliformes (Apodes and Lyomeri)
  - Family: Anguillidae - fresh water eels
    - *Anguilla rostrata* (Lesueur) - American eel
- Order: Clupeiformes
  - Family: Clupeidae - herrings
    - *Alosa aestivalis* (Mitchill) - blueback herring
    - *Alosa pseudoharengus* (Wilson) - alewife
    - *Brevoortia tyrannus* (Latrobe) - Atlantic menhaden
    - *Clupea harengus harengus* Linnaeus - Atlantic herring
- Order: Salmoniformes
  - Family: Osmeridae - smelts
    - *Osmerus mordax* (Mitchill) - rainbow smelt
- Order: Lophiiformes (Pediculati)
  - Family: Lophiidae - goosefishes
    - *Lophius americanus* Valenciennes - goosefish
- Order: Gadiformes (Anacanthini)
  - Family: Gadidae - codfishes
    - *Enchelyopus cimbrius* (Linnaeus) - fourbeard rockling
    - *Gadus morhua* Linnaeus - Atlantic cod
    - *Microgadus tomcod* (Walbaum) - Atlantic tomcod
    - *Pollachius virens* (Linnaeus) - pollock
    - *Urophycis chuss* (Walbaum) - red hake
- Order: Atheriniformes (Beloniformes; Synentognathi; Cyprinodontiformes; Microcyprini)
  - Family: Cyprinodontidae - killifishes
    - *Fundulus heteroclitus* (Linnaeus) - mummichog
  - Family: Atherinidae - silversides
    - *Menidia menidia* (Linnaeus) - Atlantic silverside
- Order: Gasterosteiformes (Thoracostei; Hemibranchii; Lophobranchii; Solenichthyes)
  - Family: Syngnathidae - pipefishes and seahorses
    - *Syngnathus fuscus* Storer - northern pipefish
- Order: Perciformes (Percomorphi; Acanthopterygii)
  - Family: Percichthyidae - temperate basses
    - *Morone saxatilis* (Walbaum) - striped bass
  - Family: Pomatomidae - bluefishes
    - *Pomatomus saltatrix* (Linnaeus) - bluefish
  - Family: Carangidae - jacks and pompanos
    - *Caranx crysos* (Mitchill) - blue runner
    - *Seriola zonata* (Mitchill) - banded rudderfish
  - Family: Sparidae - porgies
    - *Stenotomus chrysops* (Linnaeus) - scup
  - Family: Labridae - wrasses
    - *Tautoga onitis* (Linnaeus) - tautog
    - *Tautogolabrus adspersus* (Walbaum) - cunner
  - Family: Stichaeidae - pricklebacks
    - *Ulvaria subbifurcata* (Storer) - radiated shanny
  - Family: Pholidae - gunnels
    - *Pholis gunnellus* (Linnaeus) - rock gunnel
  - Family: Ammodytidae - sand lances
    - *Ammodytes dubius* Reinhardt - northern sand lance
  - Family: Scombridae - mackerels and tunas
    - *Scomber scombrus* Linnaeus - Atlantic mackerel
    - *Scomber japonicus* Houttuyn - chub mackerel
  - Family: Stromateidae - butterfishes
    - *Hyperoglyphe perciformis* (Mitchill) - barrelfish
  - Family: Triglidae - searobins
    - *Prionotus carolinus* (Linnaeus) - northern searobin
  - Family: Cottidae - sculpins
    - *Hemitripterus americanus* (Gmelin) - sea raven
    - *Myoxocephalus aenaeus* (Mitchill) - grubby
    - *Myoxocephalus octodecemspinosus (Mitchill)* - longhorn sculpin
    - *Myoxocephalus scorpius* (Linnaeus) - shorthorn sculpin
  - Family: Cyclopteridae-lumpfishes and snailfishes
    - *Cyclopterus lumpus* Linnaeus - lumpfish
    - *Liparis atlanticus* (Jordan and Evermann) - seasnail
  - Family: Cryptacanthodidae - wrymouths
    - *Cryptacanthodes maculatus* Storer - wrymouth
- Order: Pleuronectiformes (Heterosomata)
  - Family: Bothidae - lefteye flounders
    - *Scophthalmus aquosus* (Mitchill) - windowpane
  - Family: Pleuronectidae - righteye flounders
    - *Limanda ferruginea* (Storer) - yellowtail flounder
    - *Pseudopleuronectes americanus* (Walbaum) - winter flounder
- Order: Tetraodontiformes (Plectognathi)
  - Family: Tetraodontidae - puffer
    - *Sphoeroides maculatus* (Bloch and Schneider) - northern puffer

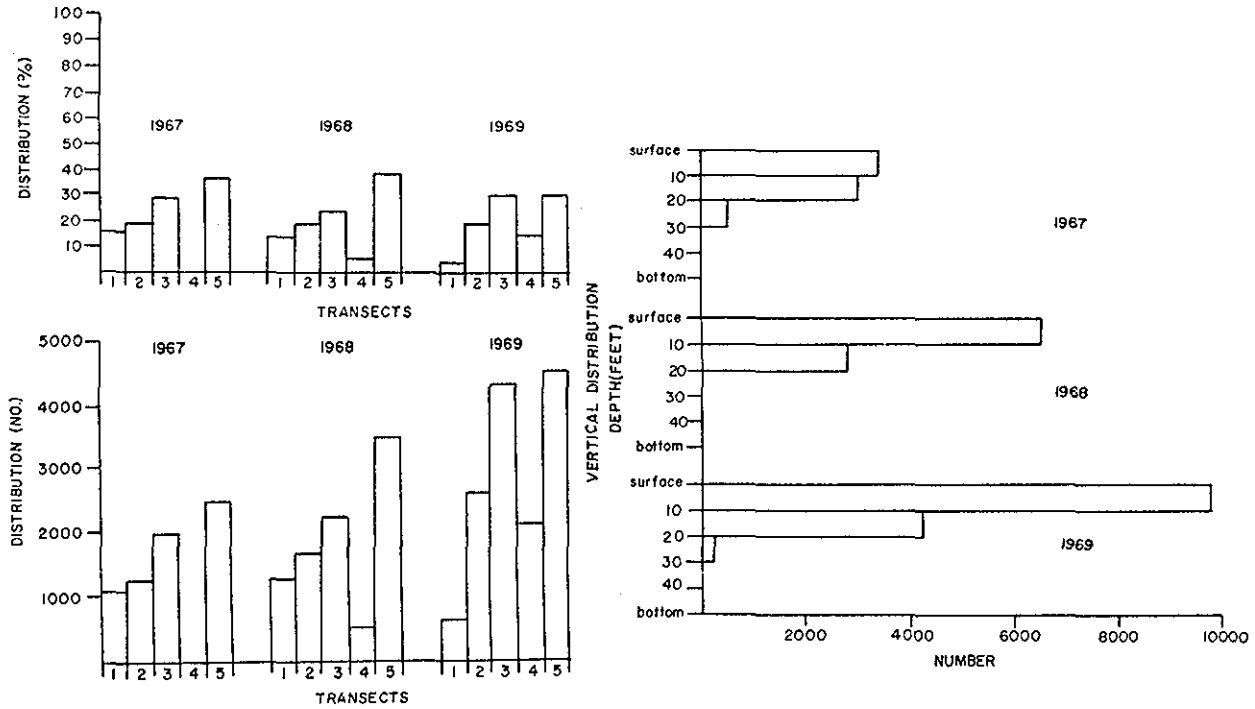
[1] Systematic listing after American Fisheries Society (1970).

Figure 9 Distribution of common fishes along five transects in the Cape Cod Canal-1967-1969





ATLANTIC SILVERSIDES, *Menidia menidia.*



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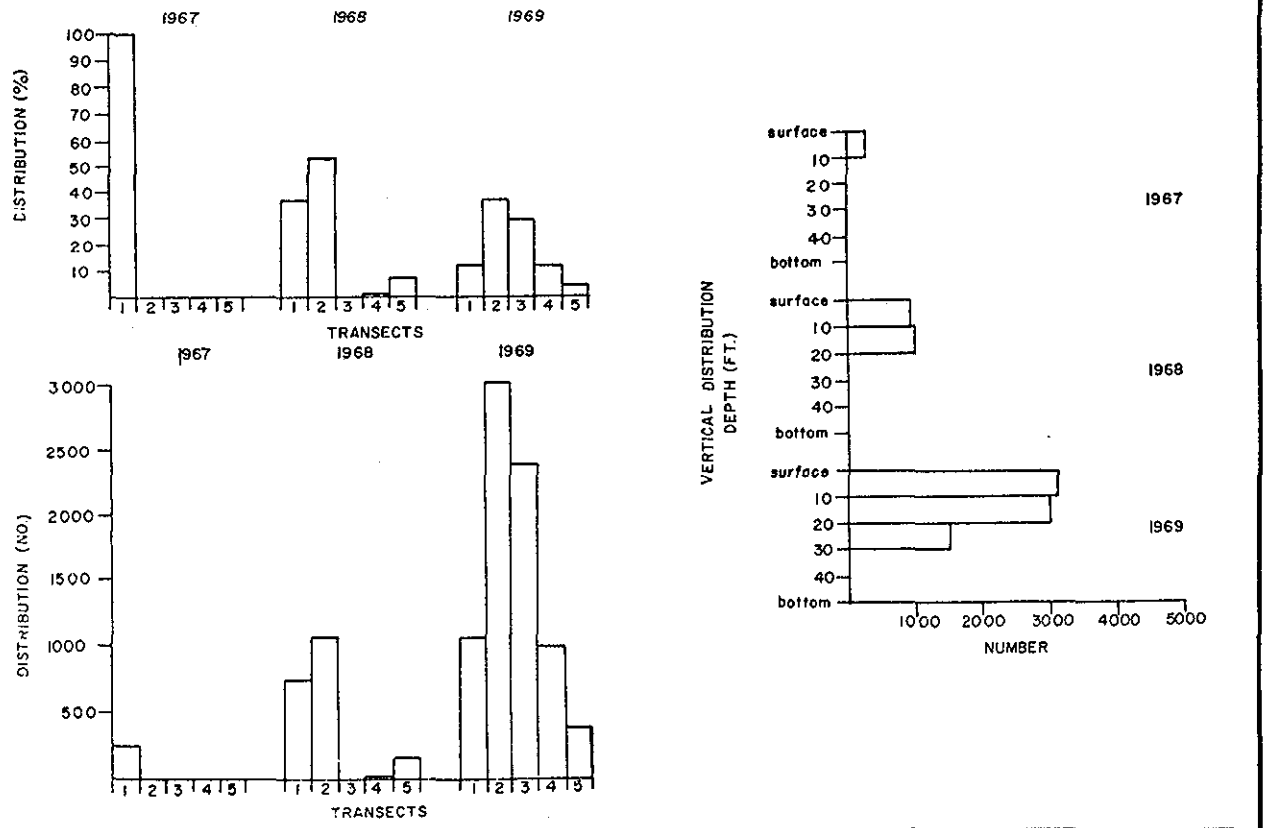
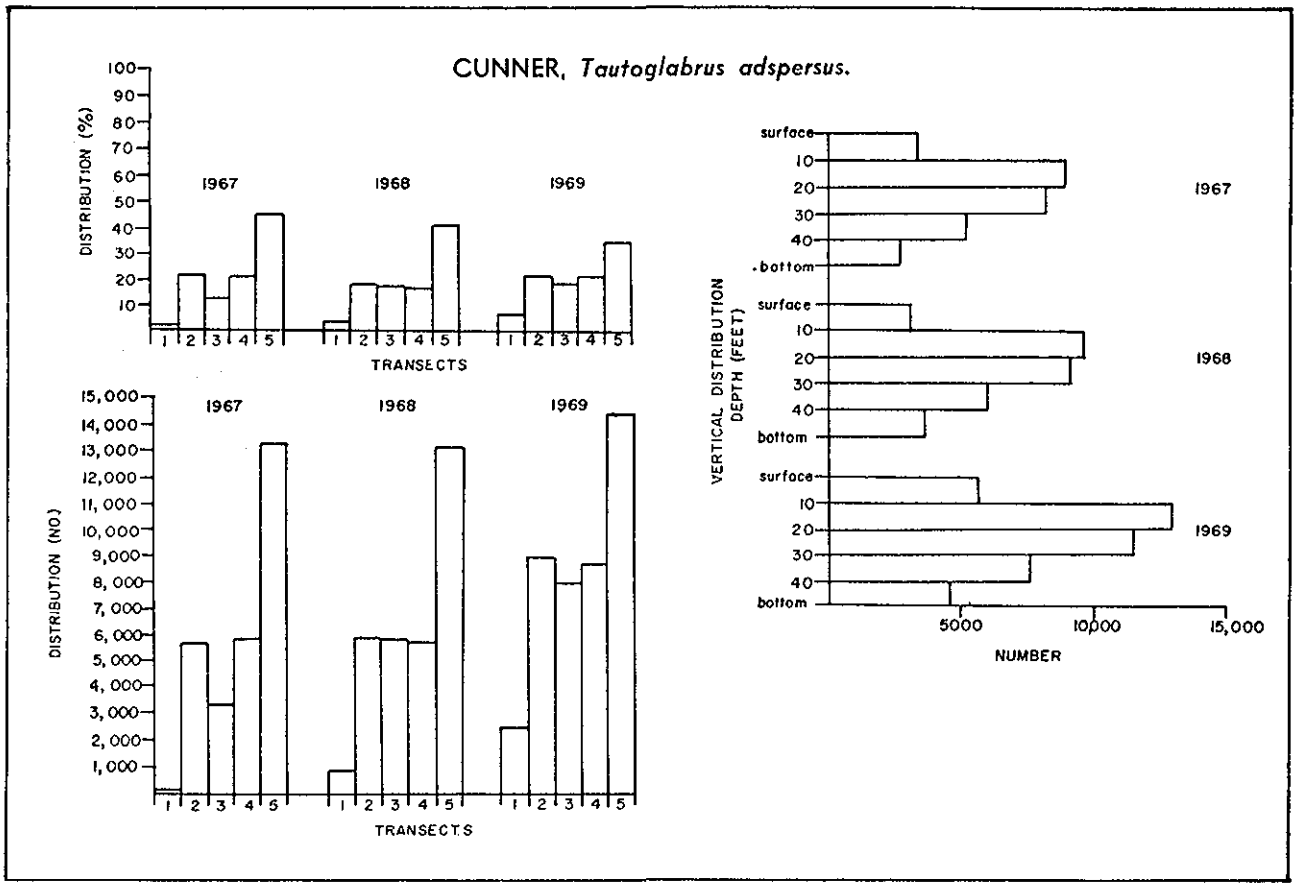
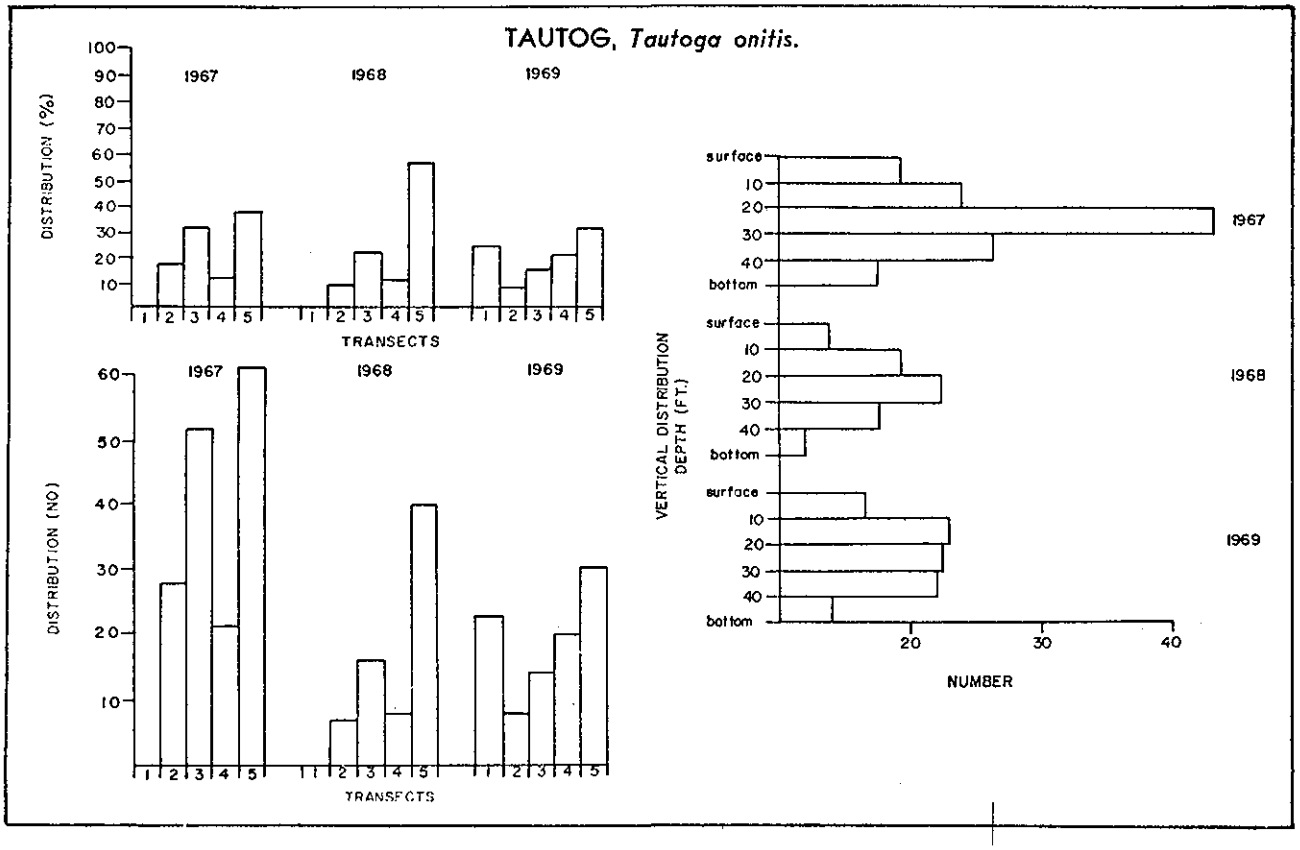
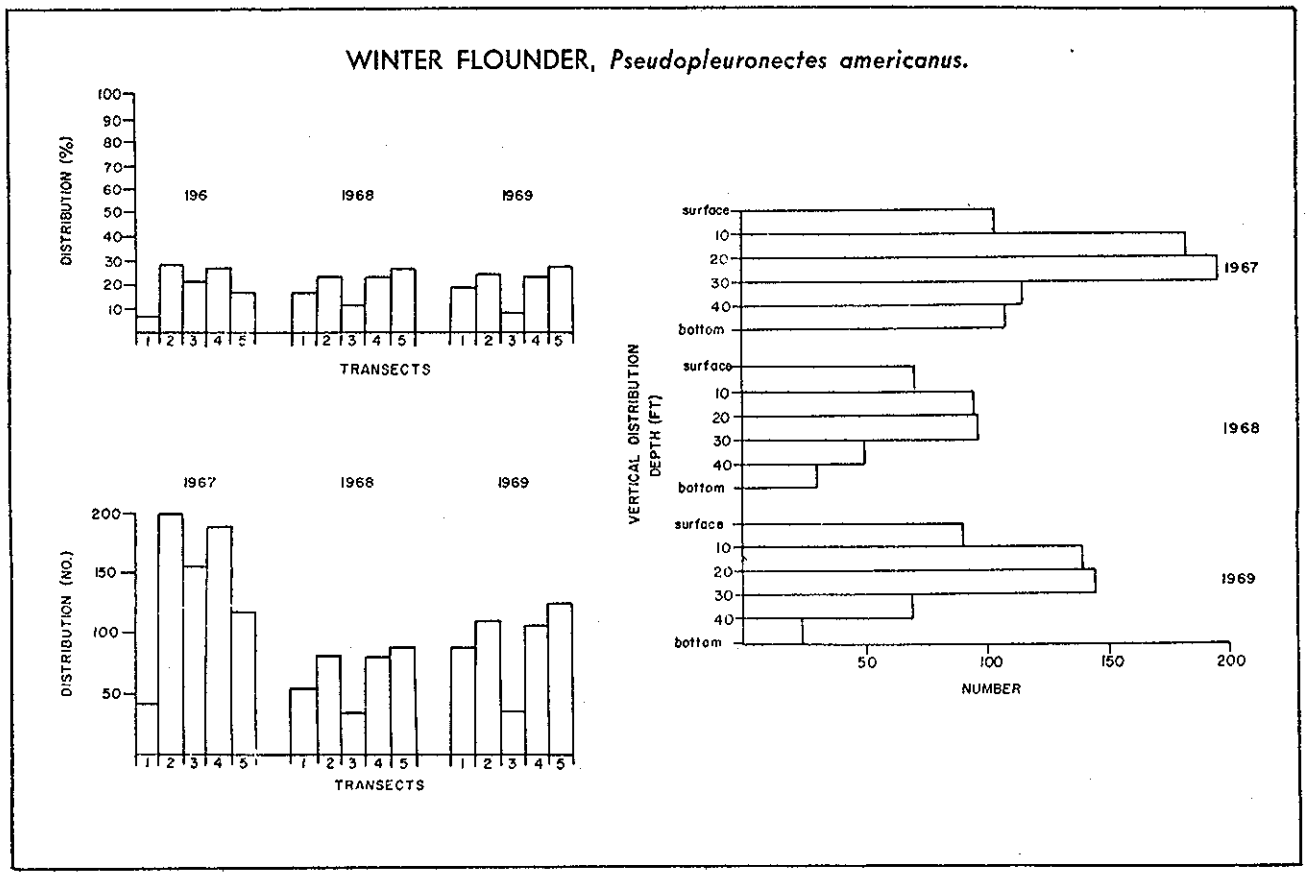



CUNNER, Tautoglabrus adspersus.
DISTRIBUTION (%)
1967
1968
1969
TRANSECTS
DISTRIBUTION (NO.)
VERTICAL DISTRIBUTION DEPTH (FEET)
surface
bottom
NUMBER


TAUTOG, Tautoga onitis.
DISTRIBUTION (%)
1967
1968
1969
TRANSECTS
DISTRIBUTION (NO.)
VERTICAL DISTRIBUTION DEPTH (FT.)
surface
bottom
NUMBER


WINTER FLOUNDER, *Pseudopleuronectes americanus.*
DISTRIBUTION (%)
196
1968
1969
TRANSECTS
DISTRIBUTION (NO.)
1967
1968
1969
TRANSECTS
VERTICAL DISTRIBUTION
DEPTH (FT)
surface
10
20
30
40
bottom
1967
1968
1969
NUMBER

fishes. While common in 1967, cod were seldom encountered in 1968 and 1969. Clupeids (principally menhaden) were observed in large schools in 1968 and 1969 on transects where they had not been recorded in 1967. A corresponding increase of juvenile menhaden in estuarine nursery areas from Long Island Sound to Woods Hole has been noted (W. R. Turner, personal communication).

Considering that fishes fluctuate in annual abundance, changes in relative numbers between Canal transects, rather than changes in actual numbers, have been used as the basis for evaluating finfish response to thermal addition. Histograms showing percentile distribution of major species facilitate comparison of data collected before and during plant operation and render any shifts in distribution toward or away from the power plant site more discernible (Fig. 9).

In addition to their increase throughout the Canal, clupeids tended to concentrate around the mouth of the discharge flume as indicated by their relative abundance on Transect 2 in 1968 and 1969. Pollock also showed a marked shift in distribution toward Transect 2 in 1968 and 1969. Whether this species was attracted by warmer water temperatures or concentrations of baitfishes is unknown. Pollock were observed feeding around the edge of the thermal plume on numerous occassions. In 1969, this species concentrated in deeper water on Transect 2 than they had in previous years, possibly to avoid the stratified effluent. Tautog declined in relative abundance each year on Transect 2. However, abundance fluctuated erratically and did not clearly suggest any power plant related shifts in the distribution of this species. As previously noted, the relative abundance of winter flounder, cunner and Atlantic silversides remained relatively stable on Canal transects, thus indicating little response by these fishes to the influx of heated effluent.

The thermal effluent from the Canal station stratifies rapidly as a shallow surface layer (Figs. 5, 6). It is unlikely, therefore, that temperatures exceeding the tolerable limits of winter flounder, cunner, tautog and cod prevail at the depths these benthic species were found to frequent, except in the immediate discharge area. Acclimation time and temperature are major factors influencing the tolerance of fishes to high water temperatures. While temperatures in the Canal fluctuate rapidly and radically during each tidal cycle, especially in the summer, most laboratory studies involving these species employed long-term acclimatization of fishes to a single temperature prior to exposure to test temperatures. Hoff and Westman (1966) showed thusly that a constant temperature of 29C (84.2F) caused 80% mortality in 1 hr to winter flounders that had been acclimated at 21C (69.8F) for 24 hrs. The more applicable tests of Pearce, Silverman and LeGoff (1968) demonstrated that winter flounders, when given the choice, would periodically leave water temperatures of 65F to feed at temperatures up to 88F, with no apparent adverse effects. These same fish avoided waters warmer than 88F. It is noted that none of the common benthic species encountered in the Canal exhibited any shifts in distribution that were clearly associated with plant operation.

In contrast, all pelagic, schooling fishes regularly encountered on the SCUBA survey showed some degree of response to the influx of heated effluent. Atlantic silversides were observed congregating around the periphery of the thermal plume although their distribution on Transect 2 did not change, suggesting a very local concentration of this species.

In final analysis, power plant related shifts in the distribution of fishes have been very local in nature and of little significance to the Canal sportfishery. Concentrations of pollock around the plant have not been exploited since most of the sportfishing effort is concentrated along the bulkheaded sections of the Canal. Creel census data indicate no increase in the availability of this species to bulkhead-based fishermen, suggesting further that plant influence has been local in nature. Only one species, the tautog, showed a decline in relative abundance around the plant site. If this decline was real, it was not reflected in the sportfishery where catch rates of this species increased slightly each year throughout the study period (Table 5).

Fish Eggs and Larvae

Egg and larval forms of many marine fishes are pelagic, or free-floating and carried passively by ocean currents. Those entering S.E.S. intakes will be exposed to sudden, short term temperature increases. While little is known of the ability of fish eggs and larvae to withstand rapid temperature fluctuations, temperature is recognized as a critical factor controlling hatching and normal development. The data collected during these investigations reflect egg and larvae densities that will be exposed to increased water temperatures resulting from operation of the Canal generating station and form a basis for projecting and evaluating losses.

METHODS:

During the period of 8 December 1966 through 13 December 1967, 51 fish egg and larvae samples were collected in the immediate vicinity of the power plant intake and discharge structures (Fig. 7). A ½ meter plankton net of 1 mm mesh was used initially but replaced prior to the 9 February tows with a meter net of ½ mm mesh. Both were flowmeter equipped. The net was towed laterally just beneath the surface with an outboard powered skiff. Collections were scheduled to coincide with periods of high and low water to obtain samples from Buzzards Bay and Cape Cod Bay waters, respectively. Towing time was 10 min except during the summer period of peak egg and larvae abundance when 5 min tows yielded samples of sufficient size. Collected material was returned to the laboratory immediately and examined in live condition. Eggs were grouped on the basis of size, and oil globule size and number when present, and stored at temperatures approximating those at time of collection to facilitate hatching and confirm indentification. The major source used to identify the collected material was Colton, Marak, and Miller (1969).

Flowmeter readings showed that an average volume of 690.0 ft^3 of water passed through the meter net during each minute of towing time. Volumes per minute, which ranged between 475.7 ft^3 and 931.2 ft^3 of water, varied widely with boat operator, wind direction and intensity and current velocity. To provide a measure of relative abundance, the average number of eggs and larvae per 1,000 ft^3 of water sampled was calculated (Tables 7, 8). Ensuing expressions of egg and larvae abundance are based upon these relative numbers rather than actual numbers collected. Eight collections containing exceptionally large numbers of eggs were subsampled and these values expanded to meet this 1,000 ft^3 requirement.

FINDINGS:

Twenty-four species were represented in the collected material: 1 by eggs only, 9 by larvae only, and 14 by both eggs and larvae. Six species represented have demersal eggs; 17 have pelagic eggs; and 1 species, the northern pipefish *(Syngathus fuscus)*, is viviparous. Eight species; the Atlantic cod, tautog, cunner, winter flounder, Atlantic mackerel, red hake, fourbeard rockling *(Enchelyopus cimbrius)* and northern sand lance *(Ammodytes dubius)* comprised 96.8% of the eggs and 85.7% of the larvae in the standardized samples. Cunner-tautog eggs[1] occurred in greatest abundance while cod was present in the largest number of samples.

Due to apparent differences in species occurrence and abundance in high and low tide collections, the data was separated and presented by tidal stage. (Tables 7, 8). Eggs or larvae of the cod, pollock, American plaice *(Hippoglossoides platessoides)*, winter flounder, red hake, mackerel, fourbeard rockling, haddock *(Melanogrammus aeglefinus)*, longhorn sculpin and snake blenny *(Lumpenus lumpretaeformis)*, occurred in both high and low tide samples but in greater total numbers in the latter. Fourspot flounder *(Paralichthys oblongus)*, northern sand lance, silver hake *(Merluccius bilinearis)*, cunner, tautog, menhaden, northern searobin *(Prionotus carolinus)* and rock gunnel were also collected at both high and low tide, but occurred in greater numbers in high tide samples. Windowpane *(Scophthalmus aquosus)*, witch flounder *(Glyptocephalus cynoglossus)*, butterfish *(Poronotus triacanthus)*, and Atlantic herring were collected exclusively at low tide, while two species, the northern pipefish and American eel were present only in high tide samples. Relative abundance of each species in high and low tide samples is given in Table 9

DISCUSSION:

Most of the 24 species present in the collected material typically spawn in high salinity waters along the New England coast (Bigelow and Schroeder, 1953). Egg or larval forms of all species except tautog, fourspot flounder, northern pipefish and rock gunnel were reported from the Gulf of Maine-Georges Bank area by Marak, Colton, Foster and Miller (1962); Marak, Colton and Foster (1962); and Marak and Colton (1961).

Periods of egg occurrence in the study area correlated well with the spawning periods described by Colton et al (1969). Adult forms of five species were recorded in the Canal in substantial numbers during their respective spawning seasons. These were the cunner, tautog, winter flounder, mackerel and longhorn sculpin. Close proximity of spawning populations of cunners and mackerel to the sampling station account for the large numbers of their eggs in plankton samples. Ripe and spent female winter flounders were taken from the study area during the period flounder eggs and larvae were occurring in samples. The presence of the demersal eggs of this species in surface collections is unusual, but not surprising, considering the extreme turbulence and velocity of Canal water.

[1] Due to their similarity, cunner and tautog eggs could not be readily separated. Samples hatched in the laboratory, indicated a 3:1 ratio of cunner to tautog.

Table 7

OCCURRENCE AND ABUNDANCE OF FISH EGGS AND LARVAE COLLECTED BIWEEKLY FROM CAPE COD BAY WATER IN THE CAPE COD CANAL 8 DECEMBER 1966 THROUGH 13 DECEMBER 1967

Common Name	Total Number		Frequency of Occurrence		Ave. No./ 1000 ft³		Period of Occurrence	
	Eggs	Larvae	Eggs	Larvae	Eggs	Larvae	Eggs	Larvae
Atlantic cod	990	30	17	4	9.1	.3	Nov 1-June 1	Nov 13-Apr 10
American plaice	40	7	7	3	1.0	.4	Jan 11-June 1	Apr 10-June 1
northern sand lance	-	105	-	8	-	2.0		Nov 27-Apr 25
rock gunnel	-	1	-	1	-	.3		Jan 26
snake blenny	-	27	-	3	-	2.0		Feb 24-June 1
longhorn sculpin	-	35	-	8	-	.7		Jan 26-May 17
winter flounder	230	22	4	4	12.8	1.0	Mar 27-June 1	Mar 27-May 17
fourbeard rockling	1110	67	13	6	24.6	2.7	May 17-Nov 13	July 17-Oct 11
haddock	21	26	3	3	1.3	2.7	Apr 25-June 1	June 1-June 28
fourspot flounder	24	-	2	-	2.8	-	May 17-June 1	
cunner-tautog (eggs)	1235	-	7	-	53.7	-	June 1-Aug 28	
cunner (larvae)	-	15	-	3	-	1.5		June 28-Sept 18
tautog (larvae)	-	3	-	2	-	.4		July 17-Sept 18
Atlantic mackerel	6017	16	5	2	336.6	2.4	June 1-Aug 3	June 28-July 17
northern searobin	5	2	2	1	.8	.5	June 16-Sept 26	July 17
witch flounder	66	40	5	3	3.6	4.1	June 1-Aug 28	June 28-Oct 11
silver hake	107	4	3	2	10.5	.7	June 1-Aug 28	Sept 18-Sept 26
Atlantic menhaden	70	1	6	1	3.7	.4	June 1-Sept 18	Sept 26
red hake	1399	32	10	4	42.8	2.0	June 1-Nov 1	June 28-Oct 11
windowpane flounder	-	5	-	2	-	.8		July 17-Sept 18
butterfish	-	16	-	1	-	4.7		Aug 15
pollock	52	-	4	-	1.6	-	Nov 11-Dec 13	
Atlantic herring	-	3	-	1	-	.4		Dec 13

Table 8

OCCURRENCE AND ABUNDANCE OF FISH EGGS AND LARVAE COLLECTED BIWEEKLY FROM BUZZARDS BAY WATER IN THE CAPE COD CANAL 20 DECEMBER 1966 THROUGH 8 DECEMBER 1967

Common Name	Total Number		Frequency of Occurrence		Ave. No./ 1000 ft³		Period of Occurrence	
	Eggs	Larvae	Eggs	Larvae	Eggs	Larvae	Eggs	Larvae
Atlantic cod	252	4	14	2	3.2	.4	Oct 23-May 9	Dec 8-May 9
American plaice	4	5	3	3	.3	.3	Apr 13-May 9	Apr 13-May 22
northern sand lance	-	502	-	8	-	9.7		Dec 28-May 9
rock gunnel	-	1	-	1	-	.4		Jan 26
snake blenny	-	4	-	2	-	.5		Jan 26-May 9
longhorn sculpin	-	85	-	7	-	2.0		Feb 9-May 9
winter flounder	83	98	6	6	2.1	3.2	Feb 28-May 22	Mar 27-June 7
fourbeard rockling	364	28	14	5	7.2	1.4	Apr 13-Nov 3	May 22-Nov 3
haddock	2	6	2	1	.2	1.8	Apr 24-May 9	July 6
American eel	-	1	-	1	-	.2		Apr 24
fourspot flounder	203	-	4	-	14.4	-	May 9-Oct 4	
cunner-tautog (eggs)	7608	-	9	-	271.0	-	May 22-Sept 20	
cunner (larvae)	-	701	-	5	-	43.6		May 22-July 21
tautog (larvae)	-	66	-	2	-	9.5		June 22-July 6
Atlantic mackerel	858	9	5	1	71.1	4.0	May 22-July 21	June 7
northern searobin	22	12	3	1	2.1	3.6	May 22-Aug 11	July 6
silver hake	30	-	1	-	13.3	-	June 7	
Atlantic menhaden	66	2	2	1	14.0	.9	June 7-July 21	June 7
red hake	212	-	6	-	9.7	-	July 6-Sept 20	
northern pipefish	-	3	-	3	-	.5		Aug 23-Oct 23
pollock	20	-	2	-	1.4	-	Nov 21-Dec 8	

Table 9

TOTAL EGGS AND LARVAE IN STANDARDIZED SAMPLES AND THEIR PERCENTILE DISTRIBUTION IN HIGH AND LOW TIDE COLLECTIONS

	Total Number		Distribution (%)			
			High Tide		Low Tide	
Species	Eggs	Larvae	Eggs	Larvae	Eggs	Larvae
Atlantic cod	198.9	1.9	22.5	36.8	77.5	63.2
American plaice	7.8	2.2	10.2	40.9	89.8	59.1
northern sand lance	-	93.7	-	82.8	-	17.2
rock gunnel	-	.7	-	57.1	-	42.9
snake blenny	-	6.9	-	14.5	-	85.5
longhorn sculpin	-	19.2	-	72.4	-	27.6
winter flounder	63.1	21.8	18.5	82.6	81.5	17.4
fourbeard rockling	410.9	23.1	24.7	29.4	75.3	70.6
haddock	4.2	9.9	9.5	18.2	90.5	81.8
American eel	-	.2	-	100.0	-	-
fourspot flounder	63.2	-	91.1	-	8.9	-
cunner-tautog (eggs)	2815.1	-	86.6	-	13.4	-
cunner (larvae)	-	222.7	-	97.9	-	2.1
tautog (larvae)	-	19.8	-	96.0	-	4.0
Atlantic mackerel	2038.7	8.9	17.4	44.9	82.6	55.1
northern searobin	7.9	4.1	78.5	87.8	21.5	12.2
witch flounder	18.0	12.4	-	-	100.0	100.0
silver hake	44.8	1.4	29.7	-	70.3	100.0
Atlantic menhaden	50.0	1.8	56.0	50.0	44.0	50.0
red hake	485.9	8.1	12.0	-	88.0	100.0
windowpane flounder	-	1.5	-	-	-	100.0
butterfish	-	4.7	-	-	-	100.0
northern pipefish	-	1.5	-	100.0	-	-
pollock	9.3	-	30.1	-	69.9	-
Atlantic herring	-	.4	-	-	-	100.0

It is not known whether the 16 species of egg and larval fishes occurring in both high and low tide samples originated north and south of Cape Cod, or were spawned in one area and carried through the Canal into the other. A gross difference in the relative abundance of several species in Buzzards Bay and Cape Cod Bay samples was noted, however. This differential rate of occurrence in the two water masses becomes a consideration when assessing power plant effects since Cape Cod Bay and Buzzards Bay waters are used for condenser cooling purposes at an approximate ratio of 2:1 respectively.

Of the eight species which comprised 96.8% of the eggs and 85.7% of the larvae, only four are of major sport of commercial significance in this area. These are the cod, mackerel, tautog and winter flounder. Although, little is known of the ability of fish eggs and larvae to endure sudden, short term temperature fluctuations, the upper temperature limit at which hatching and development will occur has been reported for at least two of the four species named above. Bonnett (1939) recorded 6C (42.8F) as optimal for hatching and development of the cod, and 12C (53.6F) as the upper limit at which any hatching would take place. Worley (1933) reported that typical development of mackerel larvae could be realized only between 11C (51.8F) and 21C (69.8F) under laboratory conditions. Sette (1943) collected mackerel larvae at sea in greatest abundance at 10C (50F) and not above 18C (64.4F). The eggs and larvae of the cod and mackerel were collected in the Canal at temperatures ranging from 31.3F to 50.6F and 46.3F to 66.6F respectively. This information indicates that discharge temperatures probably exceed the tolerable limits of egg and larval forms of at least the cod and mackerel during their respective spawning seasons.

To provide a basis for examining the significance of losses that may result, seasonal estimates of egg numbers subject to circulation through the plant have been calculated by assuming a full load pumping rate of 372 ft sec and applying average egg densities for important species to their respective periods of occurrence in each water mass. These numbers approximate the seasonal egg production of less than 50 cod and winter flounder and less than 1,000 mackerel (Bigelow and Schroeder, 1953). Considering the fecundity and distribution of these fishes and the fact that all three species are fished commercially on the spawning grounds, the comparatively small losses that may result from passage of eggs and larvae through the Canal generating station are deemed negligible.

Benthic Flora and Fauna

The degree and extent of power plant influence may be most clearly reflected in the benthic flora and fauna. Changes in the abundance of common sessile forms are apt to be more readily discernible than fluctuations in the abundance of highly mobile fishes. A study of the complete Canal biota, however, poses a monumental task not within the scope of this project. Rather, it has been the objective to compile information on the abundance and distribution of dominant forms as indicators of ecological change.

METHODS:

Steel stakes were driven into the substrate at the low slack water (LSW) mark and at 15, 30 and 45 ft depths along five transects in the Canal (Fig. 1). Depths were determined with an oil-filled, diver-held depth gauge. Each stake served as the point of attachment for a calibrated chain with which a circular plot 20 ft in diameter was defined. Sample plots were designated as A through D from surface to bottom (Fig. 10). As divers swam around each stake with the chain extended, the abundance of dominant algae and invertebrates and the nature of the substrate within each sample plot were noted on plastic slates. The intertidal portion of Station A (A-1) on each transect was examined at low tide. Organisms were counted when possible or placed in one of five categories of relative abundance. Unidentifiable species were routinely collected for laboratory examination.

Sampling was conducted in April-May, 1967 and 1969; July-August, 1967 1968 and 1969; and October-November, 1967 on Transects 2 and 3 only.

To provide a sample of the small organisms, a square foot frame was randomly placed on the bottom in each sample plot and the material within removed, placed in plastic containers and returned to the laboratory for examination. The depth of samples taken from sand and gravel substrates was approximately 2 inches. When the predominate substrate was rubble or boulder surfaces, the material within the sample frame was scraped into plastic containers.

Five test panel series were used to gather more detailed information on epifaunal and boring communities. Panel racks were located on Transects 1-5 at depths of 17, 11, 17, 11 and 13 ft (MLW) respectively. Rocky substrate prevented the uniform placement of panel racks with respect to depth. The mean tide range at these transects was 9.0, 8.6, 8.1, 7.4 and 4.9 ft from east to west (Wilcox, 1958). For purposes of discussion, panel locations have been designated Stations P-I through P-V from east to west.

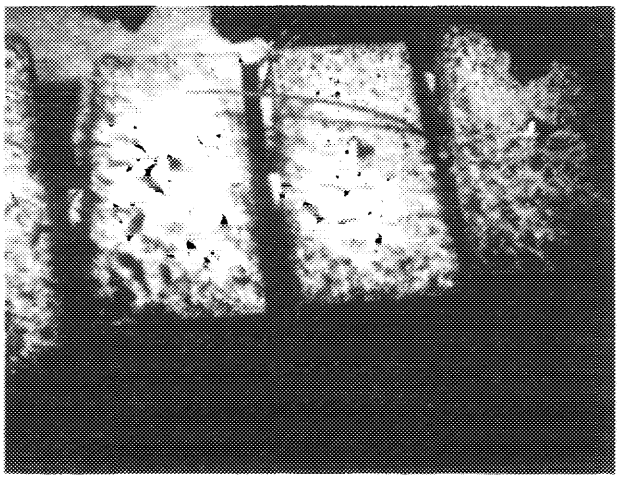


Plate 4 **Test panels in place at Station P IV after 1½ month's exposure.**

Each test panel series consisted of 12 white pine boards that measured 10 X 4 X 1 inches bolted to a 6 ft support bar of 1½ inch angle iron. Racks were horizontally positioned approximately 1 ft off the bottom and held in place by two, 3 ft legs driven into the substrate. One serial panel was removed from each rack monthly. To obtain information on the seasons of species attachment or settling, control panels were maintained at Stations P-I, P-IV and P-V through August 1967, and at all stations thereafter. Control panels were removed and replaced monthly.

FINDINGS:

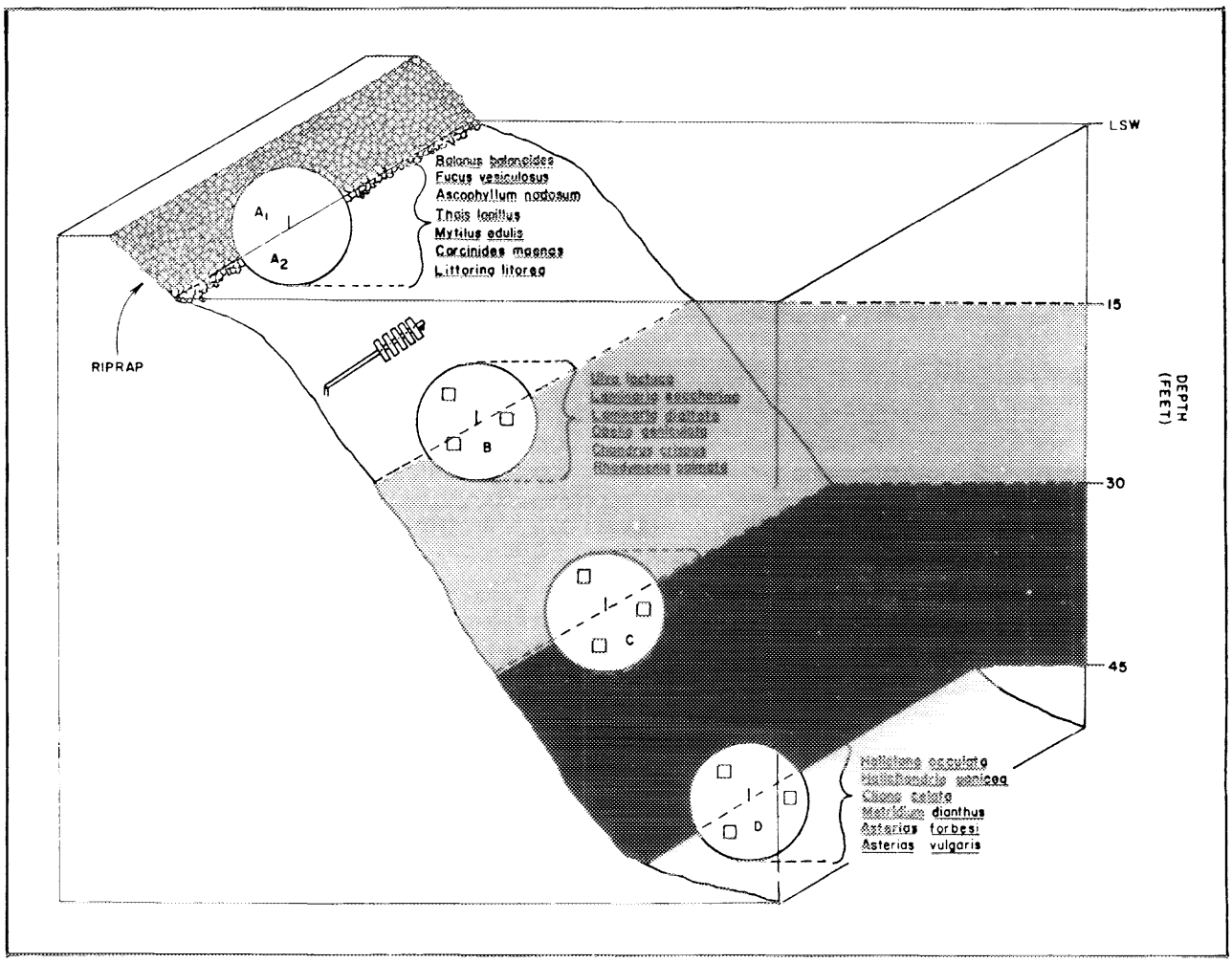
Approximately 100 species of invertebrates representing 11 phyla, 26 species of algae and one flowering plant were recorded in sample plots or on test panels (Appendix I).

Transect plot surveys conducted in 1967 provided information regarding typical distribution of dominant flora and fauna comprising the benthic community of the Cape Cod Canal prior to plant operation. Variations in species abundance constituted the major differences between transects and were clearly associated with the nature of the substrate. Transect 1 was characterized by a shifting gravel bottom which sloped gently from the intertidal zone to an approximate depth of 10 ft (LSW), then pitched sharply to a depth of 25 ft. Flora was limited to sea lettuce, *Ulva lactuca*, and an occasional strand of kelp, *Laminaria saccharina*. The green sea urchin, *Strongylocentrotus droehbachiensis*, the limpet, *Acmaea testudinalis*, the common periwinkle, *Littorina litorea*, and the starfish, *Asterias forbesi*, comprised the major fauna of this zone. Below 25 ft (LSW) the substrate was more stable, consisting of a combination of sand, gravel and shell. Dense concentrations of starfishes, *A. forbesi* and *A. vulgaris*, were recorded in this zone and the rock crab, *Cancer irroratus*, was commonly encountered here.

The substrate was more rocky from east to west in the Canal and supported an increasingly luxuriant biota. Discounting variations in species abundance, transects 2 through 5 exhibited similar vertical zonation of dominant flora and fauna. Typically, the riprapped intertidal zone was encrusted with the common rock barnacle, *Balanus balanoides*. Rockweeds, *Ascophyllum nodosum* and *Fucus vesiculosus*, occurred in irregular patches extending from the mid-tide line to slightly below the low water mark. The dog whelk, *Thais lapillus*, a predator of the barnacle and blue mussle, *Mytilus edulis*, was recorded in this zone as was the green crab, *Carcinus maenus*. The common periwinkle, *L. litorea*, reached highest concentrations from the low water mark out onto the shallow water shelf which varied in width and slope from transect to transect, but terminated at about the 10 ft depth (LSW). This shelf frequently supported dense sets of *M. edulis* but this species was not restricted to these depths. The green algae, *U. lactuca* and *Enteromorpha spp.*, grew on the shelf and into slightly deeper water but were only rarely recorded below 20 ft (LSW). The substrate between the 10 and 25 ft depths (LSW) was dominated by the kelps, *L. saccharina* and *L. digitata*, which in turn supported a variety of small invertebrate forms. Most noticeable among these was the hydroid, *Obelia geniculata*, which grew profusely on the blades of kelp. Irish moss, *Chondrus crispus*, and dulce, *Rhodymenia palmata*, were common in the kelp zone but extended into deeper water. *C. crispus* formed a dense algal mat over rocky substrates that trapped silt and provided favorable habitat for numerous small invertebrates. Commonly represented in this group were several families of polychaete worms *(Nereidae, Polynoidae, Serpulidae)*, the isopod, *Idotea phosphorea*, the mud crab, *Neopanope texana* and the Arctic saxicave, *Hiatella arctica*. Below 35 ft (LSW) the principal encrusting forms were the sponges, *Haliclona oculata*, *Halichondria panicea* and the sea anemone, *Metridium dianthus*. *A forbesi* and *A. vulgaris* were widely distributed from mid to lower depths and reached peak abundance over beds of *M. edulis*. Rock crabs, *C. irroratus*, Jonah crabs, *C. borealis* and American lobsters, *Homarus americanus*, were present at all depths but varied in abundance with cover type.

Seasonal fluctuations in abundance of dominant flora and fauna were detectable but not conspicu-

Figure 10 A sketch showing the placement of sample plots, test panel racks, and typical distribution of some of the dominant flora and fauna



ous in most instances. Notable exceptions were the variations exhibited by the hydroid, *Tubularia crocea*, tube-dwelling amphipods, Corophiidae, and certain nudibranchs. Although absent during the spring survey, *T. crocea* was recorded along all transects in July and August, so abundantly in some instances that it formed a solid pink mat over the gravel substrate *(Appendix II-Tables 6-10)*. By early fall this species had shed most of its polyps, leaving only the pedicels or stalks which persisted throughout the fall and winter months. Tubes of the corophiid amphipods covered the rubble bottom along Transects 4 and 5 during April and May *(Appendix II-Tables 4 and 5)* but were notably absent during the summer survey. Nudibranchs, especially *Dendronotus frondosus* and *Coryphella rufibranchialis* were more abundant during the colder months.

Variations in species composition among transects were few. The green sea urchin, *S. droehbachiensis*, was recorded commonly on Transect 1 and only rarely elsewhere; the boring mollusc, *Zirfaea crispata*, was confined to the stretches of hard clay bottom that existed at mid-depths at Transects 4 and 5; corophiid amphipods were recorded in abundance only on Transects 4 and 5; and eelgrass, *Zostera marina*, grew densely on the shallow water shelf at Transect 5 but was not present at other transects.

During preliminary survey work in September 1966, a dense set of *M. edulis* was encountered along Transect 1 between the 30 ft and 45 ft depths (LSW). The length of 120 individuals selected at random ranged between 0.60 and 1.70 inches with a mean length of 1.2 inches. A large number of *C. irroratus*

Plate 5 **Diver recording benthic flora and fauna. (Steel stake designates center of sample plot).**

were noted crawling on and burrowing beneath the mussel cover. A total of 58 crabs were sampled in the 20 ft diameter sample plot at 45 ft (Station D). Mussels were being heavily preyed upon by starfishes, *A. forbesi* and *A. vulgaris*, which occurred in dense patches up to 10 ft in diameter. This transect was re-sampled on 30 November 1966 and no live mussels were found. *Mytilus* shell covered the bottom and *Asterias spp.* remained in high concentrations. Only 14 rock crabs were recorded at Station D.

A set of smaller mussels was recorded along Transect 3 during August 1966. A sample of 119 individuals ranged between 0.13 and 0.75 inches with an average length of 0.47 inches. *Asterias spp.* were abundant but the effects of predation were not readily observable. On 4 May 1967 a sample of 117 individuals collected from this same area ranged from 0.13 to 1.40 inches with a mean length of 0.51 inches. *Asterias spp.* had increased and were concentrated in patches similar to those observed the previous summer at Transect 1. Examination of the Station D, Transect 3 revealed 232 rock crabs burrowed beneath the mat of *M. edulis*. When resurveyed on 9 August 1967 no live mussels were observed. *Asterias spp.* remained in abundance but no rock crabs were encountered in this sample plot.

During subsequent surveys in 1968 and 1969, several notable changes in the abundance or occurrence of dominant plant and animal forms were recorded. The kelp, *L. saccharina*, showed an obvious increase in abundance toward the easterly Canal entrance. During the fall survey of 1968, small fronds of this alga (approximately 1 ft in length) were recorded on the gravel substrate at Transects 1 through 3, especially in the 30 ft sample plots below the existing kelp zone. By the summer of 1969, blade length had increased to several feet and individual plants with the stones to which they had attached were being

carried along the bottom by Canal currents. Kelp recorded at Station D on Transects 1 through 4 in 1969, had not grown here naturally but was deposited in this manner. There was a corresponding increase of the hydroid, *O. geniculata*, growing on the blades of *L. saccharina*. The hydroid, *T. crocea*, exhibited peak hydranth production during mid-summer of 1968, as in 1967, but flourished during the spring period of 1969. Following eradication of mussel beds by the starfishes on Transects 1 and 3 in 1966 and 1967, respectively, no new set occurred until the summer of 1969 when mussel spat formed a mat over the entire substrate along these same transects. Another noteworthy change was the occurrence of *Codium fragile* at Station B on Transects 2 and 5 in 1969.

Test panel surfaces were regularly colonized by two hydroids, *T. crocea* and *Bougainvillia superciliaris*, the barnacle, *B. balanus;* the blue mussel, *M. edulis*, eight encrusting ectoprocts and two tunicates, *Mogula companulata* and *Botryllus schlosseri*. The aforementioned changes in the occurrence of *T. crocea* and *M. edulis* on the natural substrate were also reflected on panel surfaces and, excepting marine borers, constituted the major variations in panel communities.

The degree of test panel infestation by *Limnoria* and *Teredo* is shown in Appendix III. These data reflect only those periods in 1968 and 1969 when the Canal generating station was operating, at least intermittently, and the corresponding periods prior to operation in 1966 and 1967. *Limnoria* were present throughout the study period but damage to panels never exceeded trace amounts. Panel infestation by *Teredo* during the pre-operation period was "trace" to "slight" at Stations P-I through P-III, "trace" to "moderate" at Station P-IV, and "moderate" to "moderate heavy" at Station P-V. Panel data for 1968 showed a corresponding increase in *Teredo* activity from east to west but greater infestation at all stations. Levels of *Teredo* attack in 1969 were similar to 1968 levels at Stations P-I, P-III and P-IV, but increased again at Stations P-II and P-V to "heavy" and "very heavy", respectively. Settlement of larvae on control panels occurred during early August through mid-September each year, suggesting this as the peak spawning period. Since June, July and August, panels for 1966 were not analyzed for borer activity, it is possible spawning commenced earlier that year although no embryonic forms occurred on control panels prior to August in subsequent years.

Cape Cod is recognized as a geographical boundary that limits the north-south distribution of many marine plants and animals. The Cape Cod Canal comprises a unique environment that is transitional between the so-called Transatlantic Province to the south and the colder Boreal Province to the north. The Canal biota is representative of both water masses but limited to those species that can tolerate the extreme conditions of each. An increase in Canal water temperatures would induce an advance of warm water species while reducing the number of cold water forms. A measure of the nature and extent of such changes provides one basis for determining the range of power plant influence.

Following commencement of plant operation the substrate within the discharge flume was rapidly colonized by a fauna largely characteristic of the southerly side of Cape Cod. While no permanent sampling station was established here, frequent inspections were made with the aid of SCUBA. The slipper shell, *Crepidula fornicata*, the barnacle *Balanus amphitrite*, the bryozoan, *Schizoporella unicornis*, and a serpulid worm tube together with an unidentified hydroid and anemone, completely matted the rubble substrate. The American oyster, *Crassostrea virginica*, was commonly observed in 1969. Crevices in the rubble bottom were heavily utilized by the green crab, *Carcinus maenus*, and the mud crab, *Neopanope texana*. The cockle shell, *Cardium pinnatulum*, was also abundant here and small quahogs, *Mercenaria mercenaria*, were found in the fine sediment that collected between rocks. In the mixing zone immediately outside the discharge canal, the rubble substrate was dominated by the green algae, *Ulva lactuca* and *Codium fragile*. Many of the invertebrates common to the discharge flume were present here also, but less abundantly.

By mid-summer, 1969, most of the invertebrates colonizing the discharge flume had suffered extensive mortality. The shell of *C. fornicata* and *C. pinnatulum* littered the bottom and only the shells of *B. amphitrite* and vacant serpulid tubes remained on rock surfaces. Summer discharge temperatures, which regularly reached 95F, presumably exceeded the tolerable limits of these species although the treatment of coolant waters with chlorine may have been a factor contributing to this mortality.

While the foregoing constitutes a radical alteration of the benthic community in response to grossly elevated water temperatures, it is emphasized that these conditions prevailed only over a very local area. Proceeding away from the discharge canal there was a rapid return to the typical Canal biota. Seventy-

five feet easterly of the center line of the discharge flume (Transect 2) only minor changes in the benthos occurred that have been attributed to power plant operation. One such change was the occurrence of *Codium fragile*. Since its inadvertant introduction in Oyster River, Chatham, Massachusetts in 1961, this species has steadily spread throughout southern Massachusetts waters and currently reached troublesome abundance over many shellfish producing areas. Although Silva (1955) and Coffin and Stickney (1966) have reported *Codium fragile* as flourishing during the winter months, its abundance in the Canal plant's discharge flume suggests that water temperature may be one factor inhibiting initial establishment of this species in Cape Cod Bay. Its occurrence on Transect 5 appears to indicate a natural advance of this species into Canal waters, however.

The relative increase in the severity of borer attack on test panels at Station P-II has also been attributed to elevated water temperatures resulting from plant operation. The breeding season of Teredinedae is largely controlled by water temperature. Warmer water results in prolonged spawning hence greater infestation and damage (Wallour, 1959). Pannell, Johnson and Raymont (1962) attributed increased *Teredo* activity in the vicinity of the Marchwood Power Station, Southampton, England to a 5F rise. The sensitivity of Teredinedae to temperature is further indicated by the natural increases in panel infestation from east to west in the Canal. Since the temperature range throughout this waterway is nearly uniform, this increase is apparently a response to gradually rising mean temperatures from east to west. Damage to panels at Station P-II resulting from an increase in borer activity at the plant site did not, however, approach that occurring naturally at Station P-V.

There was no apparent correlation between plant operation and the previously noted changes in abundance or occurrence of other flora and fauna. The widespread abundance of the hydroid, *T. crocea*, throughout the Canal during the spring of 1969 and its subsequent loss of hyranths prior to mid-summer, contrasted to its peak hydranth production during mid-summer in previous years, indicates a response by this species to naturally increasing Canal temperatures. Hydranth production and loss in this hydroid is closely controlled by water temperature. Morse (1969) found that hydranth loss occurred when ocean water reached 20C (68F). This temperature was reached considerably earlier throughout the Canal in 1969 than in the previous two years.

Marked fluctuations in the abundance of both the kelp, *L. saccharina*, and the blue mussel, *M. edulis*, were interpreted as natural changes of a recurrent nature that, in turn, grossly influence the abundance of associated biota. While *L. saccharina* persisted along westerly transects where large rocks provided for permanent attachment, this alga occurred only temporarily on the gravel substrate toward the east end of the Canal. Its growth and subsequent removal by Canal currents significantly altered the abundance of associated and epiphytic forms. Extensive beds of *M. edulis* occurred periodically on Transects 1 and 3 but were subject to heavy predations and rapid depletion by the starfishes, *Asterias spp.* during their second growing season. There was a corresponding increase and decline in a variety of invertebrate forms (most notably the crabs, *Cancer spp.*) that utilized mussel beds for cover and as a source of food. It is noted that alterations of the benthic community associated with natural fluctuations of dominant flora and fauna were decidedly more obvious than were changes in Canal biota attributed to power plant operation.

Specific Problems Associated with Power Generation

Beginning with operation of the Canal Generating Station, a special effort was made to define any chemical, thermal or mechanical factors of plant operation that were obviously and grossly detrimental to fish life with a view toward recommending corrective modifications. Surveillance procedures included:

1. Monitoring of intake and discharge temperatures.
2. Routine inspection of the substrate in and around the discharge flume with the use of SCUBA.
3. Routine examination of material collected from intake screens during the wash cycle.
4. Periodic observations of fish life in and around the discharge flume during periods of air-heater-wash disposal and chemical treatment of coolant waters.

CHEMICAL-RELATED FISH MORTALITIES

During late August and early September of 1968, several baitfish kills resulted from the twice daily treatment of coolant water with sodium hypochlorite. Chlorine residuals in the range of 0.8 to 1.5 ppm (orthotolidine determination) incapacitated juvenile menhaden within minutes after application. The num-

ber of menhaden involved in observed kills ranged from an estimated several hundred to several thousand. When the chemical was dispensed during the westbound tide, large numbers of moribund individuals collected on intake screens, suggesting that recovery was slight. Losses were greatest when the plant was operating at 50% capacity and resulting lower discharge temperatures attracted large numbers of menhaden to the upper end of the discharge canal where they were exposed to the chemical.

A review of the literature revealed no information relative to the tolerance of this particular species to free chlorine or chlorine compounds. However, the very high toxicity of chlorine to fishes has been known for a considerable time. Doudoroff and Katz (1950) reviewed the older literature and have shown that the results of a number of investigations with other fishes indicate thresholds well below 1ppm. Whether chlorine is present in a free state or combines with ammonia to form chloramines is apparently not a major consideration. Jones (1964) suggests that the toxicity of the chloramines and that of free chlorine must be of the same order since toxicity is clearly related to the total amount of residual chlorine present.

In an effort to determine the toxicity of sodium hypochlorite to menhaden, approximately 200 fish (3-4 inches in length) were collected in the Cape Cod Canal and transported by tank truck to the the Division of Marine Fisheries Laboratory at the Shellfish Purification Plant, Newburyport, Massachusetts where bioassays were conducted. Upon arrival, fish were transferred to two 100 gal tanks of sea water that was recirculated through a 2,000 gal storage tank. Many menhaden were badly bruised enroute and died in the holding tanks. Only those fish that survived a two day acclimation period and appeared healthy were used as test animals in bioassays.

Bioassays were conducted in four 10 gal glass aquaria each containing 16 liters (4.20 gal) of sea water. Ten menhaden were used in each tank in the first two series of tests. In the third series only five were placed in each tank due to limited numbers of fish available. Sodium hypochlorite was obtained from Canal Electric Company, and was a stock solution containing 12% active chlorine by weight. Chlorine concentrations in the aquaria were measured at 15 min intervals and corrected to the desired levels when necessary, except in the first series of tests when chlorine concentrations were measured at the start and finish of the test. Tanks were covered and unaerated to reduce diffusion rates of the volatile chlorine gas. A maximum TLm time of 1 hr was considered adequate since the fish kills observed at the plant site occurred within 15 min after the start of the 7 min treatment cycle.

Water temperature in the aquaria was 18C ± 1C (64.4 F ± 1.8 F); dissolved oxygen was 6 ppm ± 1 ppm; and the salinity was 32°/oo. Water used was from the same supply circulated through the holding tanks. Results are shown in Table 10.

Table 10

TOXICITY OF CHLORINE TO YOUNG-OF-THE-YEAR MENHADEN

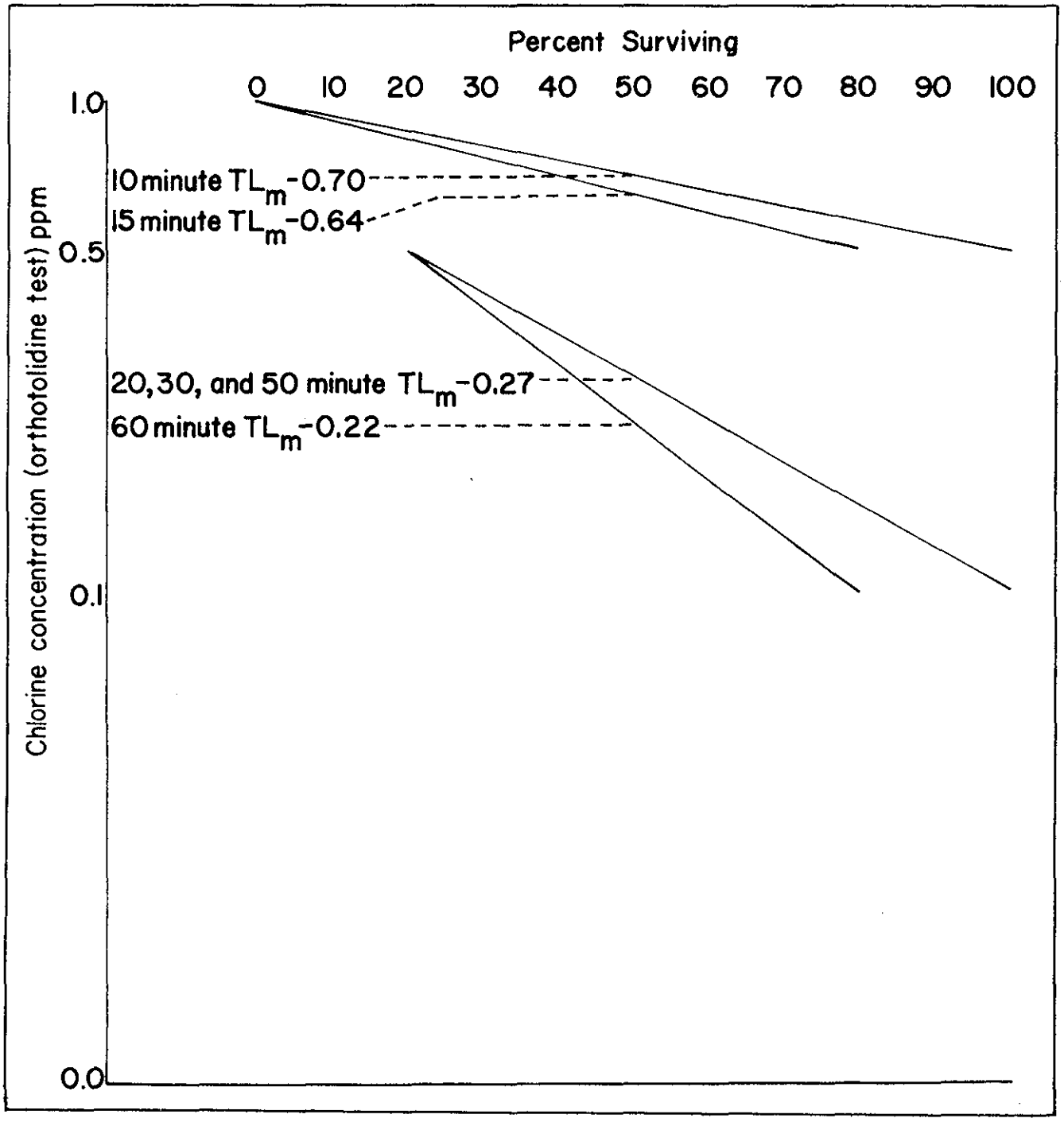
(Brevoortia tyrannus)

Bioassay No. 1				
Chlorine concentration	0	0-0.1	0.1-0.15	0.15-0.3
Number of fish	10	10	10	10
Number of survivors after 1 hour	10	10	10	10
Bioassay No. 2				
Chlorine concentration	0	0.75	1.0	1.0+
Number of fish	10	10	10	10
Number of survivors after				
5 minutes	10	9	6	4
10 minutes	10	2	0	0
15 minutes	10	0	0	0
Bioassay No. 3				
Chlorine concentration	0	0.1	0.5	1.0
Number of fish	5	5	5	5
Number of survivors after				
10 minutes	5	5	5	0
15 minutes	5	5	4	0
20 minutes	5	5	1	0
30 minutes	5	5	1	0
50 minutes	5	5	1	0
60 minutes	5	4	1	0

Bioassay No. 3 encompasses the critical concentration range through a 50 min exposure period. The critial concentration range is defined as the interval between the highest concentration of chlorine at which all the test animals survive and the lowest at which they all die. The TLm, or midpoint of this range, has been graphically interpreted (Fig11).

The 10 min TLm of 0.7 ppm is of greatest significance in this instance since this exposure period most closely approximates the length of the treatment cycle at the plant. From this point it is necessary to extrapolate to a safe concentration below the critical concentration range. One tenth of the

Figure 11 Graphic interpretation of the median tolerance limits of juvenile menhaden to chlorine



TLm is commonly considered a safe dilution (Jackson, 1967). In this case chlorine residuals of 0.1 ppm have had no apparent adverse effects in the field and have thus far prevented fouling of condenser tubes according to plant officials.

Due to limitations of laboratory equipment, possible synergistic effects of chlorine and temperature upon menhaden could not be tested. While these results must be considered preliminary in nature, a more intensive study of the combined temperature-chlorine tolerances of several marine species is currently underway. Results of current investigations will be applied to the problem of determining safe chlorine levels in thermal discharges.

TEMPERATURE-RELATED FISH MORTALITIES:

A second series of fish kills that occurred during late summer of 1968 were attributed to high water temperatures in the vicinity of the power plant discharge. Losses were confined to a 1½ hr period around high slack tide when the warmer Buzzards Bay water had penetrated to the east end of the Canal and was circulated through the plant. Surface temperatures at the mouth of the discharge flume reached 94F. Fishes affected were young-of-the-year menhaden and Atlantic silversides. Large schools of both species congregated at the periphery of the thermal plume where temperatures as high as 87F were recorded. These fishes appeared distressed but no mortality was observed until they strayed into the area directly in front of the discharge canal where temperatures exceeded 90F.

Observations of the behavior of menhaden under heat stress agree closely with the laboratory findings of Lewis and Hettler (1968). They reported that young-of-the-year menhaden exposed to temperatures above 30C (86F) swim near the surface with heads up, gulp air, stop schooling, are less active, and can easily be touched with a probe. Test temperatures above 33C (91.4F) caused death. The duration of fish survival at high test temperatures depended, in part, upon acclimation time and temperature. Fish acclimated to 29C (84.2F) for 100-500 hr survived longer at high test temperatures than did fish acclimated to 21C (69.8F) and exposed to the same test temperature.

The rate of change from acclimation temperature to test temperature was another factor influencing survival. Twenty fish acclimated at 22.5C ± 1C (72.5F ± 1.8F) for one month and subjected to a 1C (1.8F) per day increase to a maximum of 35C (95F), sustained 50% mortality in 20 hr in contrast to 1½ hr for fish brought to the same test temperature in a 13 hr period.

The tolerance of Atlantic silversides to high water temperatures in the laboratory has been reported upon by Hoff and Westman (1966), and Pearce, Silvermann and LeGoff (1968). Fish acclimated at 21C (69.8F) suffered no mortality in 1 hr at 30C (86.0F), 20% mortality in 1 hr at 31C (87.8F), and 80% mortality in 1 hr at 32C (89.6F) (Hoff and Westman, 1966). Fish held at 62.2F for 5 days died before a temperature of 90.5F was attained, 2hr and 14 min after the initial temperature increase (Pearce et al, 1968).

These investigators also examined the ability of fishes to recover from heat stress. Lewis and Hettler (1968) exposed 20 menhaden acclimated at 23C (73.4°F) for one month, to 34.8C (94.6F) in 2 hr. When fish showed signs of stress, the temperature was lowered in 1 hr to its former level. Six of the 20 fish survived the experiment. Hoff and Westman (1966) reported that silversides recovered from heat shock. This was confirmed by Pearce et al (1968) who noted that survivors of an 86F exposure for 72 hr were alive 12 days after being re-exposed to the original holding temperature.

In summary, laboratory experiments show that water temperatures above 85F are potentially lethal to young menhaden and Atlantic silversides. The tolerance of these fishes to high test temperatures is *strongly influenced by acclimation time and temperature* and the rate at which temperatures are increased. Of the two species, menhaden possess only a limited capability to recover from heat stress.

In Cape Cod Canal, these fishes are exposed to rapid and radical temperature fluctuations resulting from the interchange of Cape Cod Bay and Buzzards Bay waters through the Canal. While maximum discharge temperatures occur at high slack tide as Buzzards Bay water is circulated through the plant, fishes in the vicinity of the discharge canal are exposed to the much cooler waters of Cape Cod Bay during each tidal cycle. During mid-summer of 1968, when fish kills occurred, temperatures of water entering the Canal from Cape Cod Bay typically ranged as low as 53F. Under these conditions both menhaden and silversides exhibited symptoms of heat stress at 86F and were rapidly incapacitated at 90F. Furthermore, recovery rates of fishes suffering from thermal shock was less in the Canal than in the laboratory since fishes so affected were subject to heavy predation by gulls.

During the summer of 1969, the range between maximum discharge temperatures and the minimum Canal temperatures was sustantially reduced due to the natural warming of Cape Cod Bay. Fishes were acclimated to higher Canal temperatures and apparently, more tolerant of peak discharge temperatures, with the end result that losses of both species were reduced. Reversal of this warming trend in subsequent years could be expected to cause a recurrence of the problem, however. If the possibility of temperature-related fish kills is to be eliminated, surface temperatures around the mouth of the existing discharge structure must be kept below 90F. Discharging beneath the surface is one means by which a temperature reduction may be accomplished. A subsurface discharge is recommended when a large volume of coolant water is available and sharp temperature gradients near the surface are undesireable (Federal Water Pollution Control Administration, 1968).

A solution applicable to future units would involve increased pumping rates whereby waste heat would be diluted in a larger volume of coolant water, thereby reducing discharge temperatures. This modification would require larger intake flumes to avoid increased intake velocities.

MECHANICAL-RELATED FISH MORTALITIES:

Although intake velocities do not exceed 1.3 ft/sec, certain flatfishes, principally winter flounder, suffered mortality from impingement on intake screens. Losses were greatest during the spring months and appear to be associated with an influx of this species into the Cape Cod Canal from Buzzards Bay. Records of SCUBA observations showed an initial build-up of flounders on the western-most transect (Transect 5) followed by an increase in numbers toward the easterly Canal entrance as the season progressed. During a prior tagging study by the Division of Marine Fisheries, 41% of the returns from flounders tagged in upper Buzzards Bay came from the Canal and Cape Cod Bay (Coates, Howe and Peterson, 1970).

SCUBA observations further suggest that Canal currents aid this dispersal. Flounders were commonly observed swimming steadily with the current several feet off the bottom. It appears that impingement on intake screens occurs as fish follow currents generated by the plants circulator pumps. Whether mortalities result directly from impingement or indirectly from thermal shock when fish are washed from intake screens into the discharge flume with other debris, is not known. Viable individuals were removed from the connecting sluiceway during the screen wash cycle. However, up to 50 dead flounders were observed on the bottom of the discharge flume and around its mouth during a single inspection. While losses of this magnitude are not considered serious, they will be compounded with construction of additional generating units unless intake design is modified.

Entrapment of fishes in intake bays has been the single, most damaging aspect of operation at several coastal generating stations. Intake screen placement and intake velocities have, consequently, been recognized as major considerations in S.E.S. design if fish problems are to be avoided. Based on research at the Contra Costa plant by Kerr (1953) the preferred system of the Pacific Gas and Electric Company (P. G. and E.) is the shoreline intake where screens are placed flush with the shoreline and intake velocities are below 1.5 ft/sec (Adams, 1968). This system allows "a complete tidal current swing across the face of the screens with no traps or pockets". By P. G. and E. standards, intake velocities at the Canal Electric station are acceptable. Intake screens at the Canal site are deeply recessed, however. While alignment of screens with the natural bank of the Canal would probably reduce the incidence of finfish impingement, a more readily accomplished and satisfactory solution in this instance may be relocation of the opening in the seaward end of the intake flume.

Summary

The Cape Cod Canal is a man-made waterway that joins two distinct water masses to the north and south of Cape Cod. As the tide ebbs and floods, the Canal is alternately filled with Cape Cod Bay and Buzzards Bay water, the latter being as much as 20F warmer during mid-summer and slightly colder in the winter. Strong currents and turbulence thoroughly mix Canal water preventing any significant degree of thermal stratification. Salinity differences throughout the system are slight.

A fossil-fueled, 560 Mw generating station located on the southerly side of the Canal near the easterly entrance commenced commercial operation in July 1968. Condenser coolant is drawn from the Canal at the rate of 372 ft^3/sec and returned 26F above ambient. The thermal effluent flows from the discharge flume as a surface layer that penetrates to an approximate depth of 20 ft initially and gradually becomes shallower in a downcurrent direction. Heat dissipation occurs rapidly within 500 ft of the discharge point and is essentially complete at 2,000 ft.

Due to its location near the east end of the Canal, the power station utilizes Cape Cod Bay water for condenser cooling purposes 8 hr out of each 12½ hr tidal cycle. Sodium hypochlorite is periodically released in coolant water to control fouling of the plants condenser tubes.

The Canal supports a valuable sportfishery for a variety of smaller fishes in addition to the striped bass. During 1967, 1968 and 1969, 3,797 anglers were interviewed who fished a total of 6,368.7 hr and caught 6,321 desirable fishes. Cod, mackerel, winter flounder, pollock and tautog comprised 91.7% of the total catch. Utilizing annual catch rates per unit of fishing effort as a basis for analysis, the availability of pollock and winter flounder, remained unchanged throughout the study period; cod decreased; and tautog and mackerel showed slight and marked increases, respectively. Declining catches of cod were offset by increasing catches of tautog, with the result that bottom fishing remained equally productive during the three census years. The sportfish exhibiting the most pronounced change in the catch was the Atlantic mackerel. Shifts in the distribution of fishing effort relative to both season and fishing technique were interpreted as angler response to the increasing availability of this species. While there was no apparent correlation between changing catch rates of mackerel and elevated temperatures resulting from power plant operation, it is significant that this species was not repelled by the thermal discharge.

Project personnel recorded over 40 species of fishes along transects surveyed with the aid of SCUBA. Those encountered regularly and in substantial numbers were cunner, winter flounder, pollock, cod (1967 only), tautog, Atlantic silversides and juvenile herrings, principally menhaden. All these fishes exhibited changes in abundance or distribution along Canal transects during the study period. Distribution patterns of benthic species suggested natural population fluctuations, which were unrelated to power plant operation. The thermal discharge had a concentrating effect upon the common pelagic fishes, however. Juvenile clupeids and silversides were clearly attracted to the periphery of the thermal plume. It is not known whether pollock also responded to elevated water temperatures or were attracted here by concentrations of these baitfishes. Pollock concentrations were local in nature and were not reflected in the catch of the intensive sportfishery based along the bulkheaded portions of the Canal easterly of the plant site.

The eggs or larvae of 24 fishes were collected in weekly plankton tows made opposite the power plant site in 1967. Eight species: cod, tautog, cunner, mackerel, winter flounder, red hake, fourbeard rockling and sand lance comprised 96.8% of the eggs and 85.7% of the larvae in standardized samples. Of these species, only cod, tautog, mackerel and winter flounder are of direct sport or commercial importance. Available information indicates that discharge temperatures exceed the tolerable limits of at least the cod and mackerel during their respective periods of occurrence, although the tolerance of egg and larval forms of these species to sudden, short-term temperature fluctuations is not known. Considering the fecundity and distribution of these four fishes and the fact that all except tautog are fished commercially on the spawning grounds, the losses of eggs and larvae that may result from circulation through the plant's cooling system are deemed negligible.

Vertical zonation of dominant flora and fauna comprising the benthic community of the Canal was evident on the steeply sloped banks of this waterway. The substrate became more rocky from east to west and supported an increasingly luxuriant biota. With few exceptions, variations in species abundance rather than species composition accounted for major differences between transects.

Test panel infestation by Teredinidae was greater towards the westerly end of the Canal, both before and during plant operation, as an apparent result of naturally increasing water temperatures from east to west. *Limnoria* were generally present on panel surfaces throughout the study period, but never exceeded trace amounts. Excluding the immediate discharge area, only minor changes in benthic biota have been attributed to elevated water temperatures resulting from plant operation. These included the establishment of the green alga, *Codium fragile*, in shoal water next to the discharge flume and an increase in *Teredo* activity on wooden test panels at this same location. Natural fluctuations in the abundance and occurrence of kelp, *L. saccharina*, beds of the blue mussel, *M. edulis*, and subsequent variations in the abundance of associated organisms, were decidedly more obvious than were changes in Canal biota attributed to power plant operation.

With operation of the Canal Electric Station, an effort was initiated to define any thermal, chemical or mechanical aspects of plant operation that were directly detrimental to fish life with a view toward examining and recommending possible solutions to any problems encountered. The periodic treatment of coolant waters with sodium hypochlorite and sub-

sequent chlorine residuals in the range of 0.8 to 1.5 ppm caused substantial mortality of juvenile menhaden that concentrated in and around the discharge flume. Bioassays were conducted and confirmed the high toxicity of chlorine to this species. A reduction of chlorine residuals to 0.1 ppm has prevented further mortality of menhaden and reduced levels have adequately controlled fouling of the plants condenser tubes, according to power company officials. A second series of fish kills occurred during the brief period around high slack tide when the warmer Buzzards Bay water had penetrated to the east end of the Canal and was circulated through the plant. Juvenile menhaden and Atlantic silversides congregated around the periphery of the thermal plume showed signs of heat stress when discharge temperatures reached 86F and succumbed rapidly when temperatures exceeded 90F. If the possibility of continuing temperature-related fish kills is to be eliminated, discharge temperatures must be reduced during the critical high tide period in July, August and September. Lastly, losses of flatfishes, principally winter flounder, resulted from impingement on intake screens and their subsequent disposal in the discharge flume during the screen wash cycle. While resulting losses have been small to date this problem stresses the need for careful consideration of intake design and screen placement during the planning stages of future generating units.

Conclusions and Recommendations

Large volumes of water flowing by the Canal Electric Station rapidly dissipate waste heat. Subsequent effects of thermal addition upon Canal biota have been very local and of little significance to the sportfishery. The most detrimental aspects of plant operation have involved the attraction of certain fishes to the periphery of the thermal plume where they were periodically exposed to lethal conditions, both thermal and chemical. Other mortalities resulted from impingement of winter flounders on intake screens. While losses attributed to these causes have not significantly reduced fish stocks around the plant site, they indicate problem areas that could be of greater detriment in the future. Certain of these damaging aspects of plant operation may be corrected through minor alterations while others would require major structural modifications that can best be accomplished in conjunction with the planned enlargement of the present facility.

Recommendations with regard to the existing generating unit are as follows:

1) . . . . that residual chlorine levels in discharge water be maintained at or below 0.1 ppm during the 7 min treatment cycle. This value may be subject to adjustment following completion of other laboratory studies of temperature-chlorine tolerances of selected fishes.

2) . . . . that a residual chlorine recorder be installed to facilitate prompt detection of changing chlorine demand and appropriate adjustment of treatment levels.

3) . . . . that the Canal Electric Company implement a means of maintaining water temperatures at the mouth of the existing discharge flume below 90F.

4) . . . . that the screen wash sluiceway be rerouted to discharge into the Cape Cod Canal rather than into the discharge flume as is presently the case. Viable fishes entrapped on screens will be returned to water of ambient temperature and not abruptly subjected to elevated discharge temperatures.

These modifications should be considered conditions of operation in the final licensing of the existing unit by the Massachusetts Water Resources Commission, Division of Water Pollution Control.

With reference to future generating units to be constructed on the site, the following recommendations are made:

1) . . . . that sodium hypochlorite dispensing apparatus be designed and placed to permit treatment of each half of each condenser alternately. Chlorine concentrations may then be increased if necessary, due to the two-fold dilution afforded by mixing of treated and untreated water on the exhaust side of the condensers.

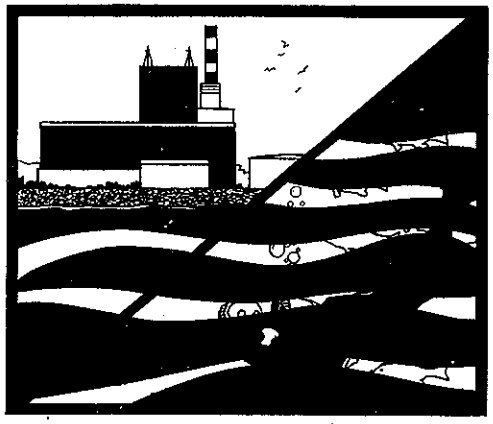
2) . . . . that the common discharge flume recommended by Stone and Webster Engineering Corporation (1965) be installed with construction of a second generating unit. This will eliminate any possibility of coolant water recirculation and provide a capability of diluting chlorine concentrations still further by treating each unit separately.

3) . . . . that the design of future units be such that coolant water temperatures at the point of discharge into the Canal proper not exceed 86F. If this is accomplished through increased pumping rates and the subsequent dissipation of waste heat in larger volumes of coolant water, intake flumes must be enlarged to maintain intake veloci-

ties at or below 1.5 ft/sec.

4) . . . . that the lower edge of the opening in the seaward end of intake flumes be no less than 9 ft above the Canal substrate. It is felt that this provision will discourage bottom dwelling fishes, particularly winter flounder, from entering intake flumes where they are subject to impingement on screens. If during a trial period, this measure effectively reduces or eliminates flounder losses, the opening in the existing intake flume should be raised in a like manner.

Lastly, it is recommended that the Administrative-Technical Advisory Committee formed to supervise these investigations remain intact for the purpose of aiding Canal Electric Company with implementation of the aforementioned recommendations.



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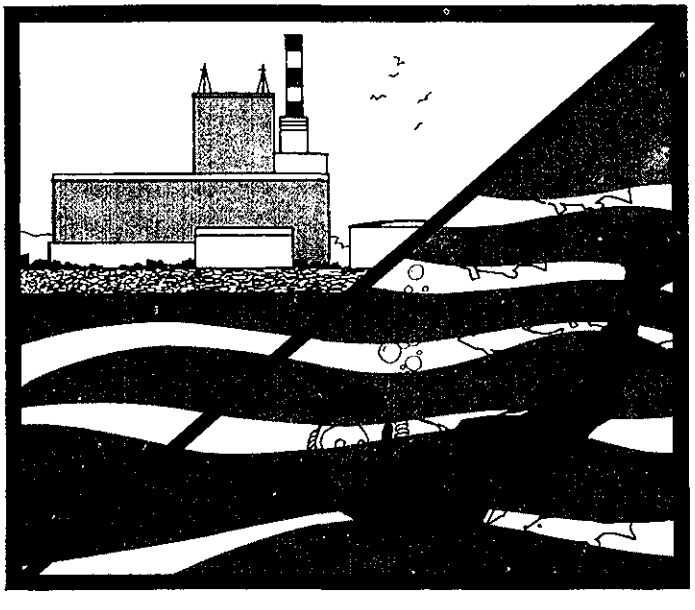
An assessment of the effects of electrical power generation on marine resources in the Cape Cod Canal

APPENDIX



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Appendix I

Algae and Invertebrates Recorded in the Cape Cod Canal[1]

[1] Algae classified after Taylor (1957)
Invertebrates classified after Smith (1964)

ALGAE

Division:	**Chlorophyta**	green algae
Order:	**Ulotrichales**	
	Enteromorpha linza (Linnaeus) J. Agardh	
	Enteromorpha spp.	
	Ulva lactuca Linnaeus	
Order:	**Cladophorales**	
	Chaetomorpha sp.	
	Cladophora sp.	
Order:	**Siphonales**	
	Codium fragile	staghorn

Division:	**Phaeophyta**	brown algae
Order:	**Ectocarpales**	
	Ectocarpus sp.	
	Ectocarpus siliculosus (Dillwyn) Lyngbye	
Order:	**Fucales**	
	Ascophyllum nodosum (Linnaeus) LeJolis	knobbed rockweed
	Fucus vesiculosus Linneaus	rockweed
Order:	**Laminariales**	
	Chorda tomentosa Lyngbye	
	Chorda filum (Linnaeus) Lamouroux	spaghetti weed
	Laminaria digitata (Linnaeus) Lamouroux	kelp
	Laminaria saccharina (Linnaeus) Lamouroux	kelp
	Laminaria sp.	
Order:	**Punctariales**	
	Scytosiphon lomentaria (Lyngbye) C. Agardh	
Order:	*Chordariales*	
	Chordaria sp.	

Division:	**Rhodophyta**	red algae
Order:	**Bangiales**	
	Porphyra miniata (Lyngbye) C. Agardh	
Order:	**Ceramiales**	
	Antithamnion cruciatum (C. Agardh) Nageli	
	Callithamnion baileyi Harvey	
	Ceramium sp.	
	Ceramium rubriforme Kylin	
	Ceramium rubrum (Hudson) C. Agardh	
	Polysiphonia denudata (Dillwyn) Kutzing	
	Polysiphonia elongata (Hudson) Harvey	
	Polysiphonia harveyi Bailey	
	Polysiphonia urceolata (Lightfoot) Greville	
	Polysiphonia novae – angliae Taylor	
	Polysiphonia nigra (Hudson) Batters	
	Polysiphonia nigrescens (Hudson) Greville	
	Polysiphonia sp.	
Order:	**Gigartinales**	
	Chondrus crispus Stackhouse	Irish sea moss
	Phyllophora interrupta (Greville) J. Agardh	
Order:	**Rhodymeniales**	
	Rhodymenia palmata (Linnaeus) Greville	dulce

FLOWERING PLANT

Zosterea marinus	eel grass

INVERTEBRATA

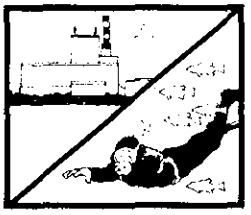
Phylum: Porifera – Sponges	
Class: Calcarea	
Leucosolenia sp.	*sponge*
Scypha sp.	sponge
Class: Demospongiae	
Order: Haplosclerida	
Haliclona oculata (Linnaeus, 1759)	eyed finger sponge
Order: Halichondria	
Halichondria panicea (Pallas, 1776)	crumb of beard sponge
Order: Poecilisclerida	
Microciona prolifera (Ellis & Solander, 1786)	red bearded sponge
Order: Hadromerida	
Cliona celata (Grant, 1826)	sulphur sponge
Phylum: Cnidaria (Coelenterata) Polyps	
Class: Hydrozoa	
Bougainvillia superciliaris (L. Agassiz, 1849)	long tentacled hydroid
Obelia geniculata (Linneaus, 1758)	hydroid
Sertularia pumila (Linnaeus, 1758)	wreathed hydroid
Tubularia crocea (L. Agassiz, 1862)	pink hearted hydroid
Class: Anthozoa	
Subclass: Zoantharia	
Order: Actiniaria – Sea Anemones	
Metridium dianthus (Ellis)	sea anemone
Metridium senile (Linnaeus)	sea anemone
Phylum: Platyhelminthes – Flatworms	
Class: Turbellaria	
Order: Polycladida	
Notoplana atomata (O.F. Muller,1776)	*flatworm*
Phylum: Nemertea – Ribbon Worms	
Class: Anopla	
Order: Heteronemertea	
Cerebratulus lacteus (Leidy, 1851)	ribbon worm
Phylum: Aschelminthes – Round Worm	
Class: Nematoda	
Phylum: Annelida – Segmented Worms	
Class: Polychaeta	
Family: Cirratulidae	
Family: Nereidae	
Nereis (Nereis) pelagica Linnaeus, 1758	sea worm
Family: Pectinariidae	
Pectinaria (Cystenides) gouldii (Verrill, 1873)	
Family: Opheliidae	
Family: Phyllodocidae	
Eulalia viridis (Linnaeus, 1767)	worm
Family: Polynoidae	
Harmothoe imbricata (Linnaeus, 1767)	scale worm
Lepidonotus sp.	
Lepidonotus squamatus (Linnaeus, 1758)	scale worm
Family: Sabellidae	
Family: Serpulidae	
Spirorbis sp.	
Spirorbis (Laeospira) granulatus (Linnaeus, 1767)	coiled worm
Spirorbis (Paradexiospira) violaceus Levinsen, 1883	coiled worm
Family: Terebillidae	

Phylum: Arthropoda	
Class: Pycnogonida	
Class: Xiphosurida	
Limulus polyphemus (Linnaeus)	horseshoe crab
Class: Crustacea	
Subclass: Cirripedia	
Order: Thoracica	
Balanus (Semibalanus) balanoides (Linnaeus, 1767)	rock barnacle
Balanus (Balanus) balanus (Linnaeus, 1758)	acorn barnacle
Subclass: Lower Malacostraca (Peracarida)	
Order: Isopoda	
Edotea triloba (Say, 1818)	isopod
Idotea phosphorea Harger, 1873	isopod
Limnoria lignorum (Rathke, 1799)	gribble
Nerocila munda Harger, 1873	
Chiridotea coeca (Say, 1818)	
Cirolana concharum (Stimpson, 1853)	
Order: Amphipoda	
Family: Gammaridae	
Family: Ampithoidae	
Ampithoe longimana Smith, 1873	amphipod
Family: Caprellae	
Caprella geometrica (Say)	amphipod
Caprella linearis (Linnaeus)	amphipod
Aeginella logicornis (Kroyer)	amphipod
Family: Corophiidae	
Jassa sp.	
Corophium volutator (Pallas)	tube building amphipod
Corophium cylindricum	tube building amphipod
Subclass: Higher Malacostraca (Decapoda & Stomatopoda)	
Section: Caridea	
Family: Hippolytidae	
Hippolyte sp.	
Section: Brachyura	
Family: Cancridae	
Cancer irroratus Say, 1817	rock crab
Cancer borealis Stimpson, 1859	Jonah crab
Carcinus maenas (Linnaeus) *(Carcinides maenas)*	green crab
Neopanope texana sayi (Smith, 1869)	
Pinnotheres sp.	
Planes minutus (Linnaeus)	commensal crab
Section: Astracura	
Family: Homaridae	
Homarus americanus Milne – Edwards, 1837	American lobster
Section: Anomura	
Family: Paguridae	
Pagurus longicarpus Say, 1817	hermit crab
Class: Insecta	
Subclass: Pterygota	
Order: Diptera	
Family: Chironomidae	
Phylum: Mollusca	
Class: Gastropoda	
Subclass: Prosobranchia	
Order: Archaeogastropoda	
Acmaea testudinalis Muller	limpet
Order: Mesogastropoda	
Littorina litorea (Linnaeus)	common periwinkle
Littorina obtusata (Linnaeus)	obtuse periwinkle
Littorina saxatilis (Olivi)	rough periwinkle
Turritella erosa (Couthouy)	screw shell
Lacuna vincta (Montagq)	common lacuna
Lunatia heros (Say) *(Polinices heros)*	moon snail
Polinices sp.	

Margarites helicinia (Fabricius)	top shell
Margarites (Solariella) obscura Couthouy	top shell
Crepidula fornicata (Linnaeus)	slipper shell
Bittium alternatum (Say)	alternate bittum
Order: Neogastropoda	
Mitrella lunata (Say)	lunar dove shell
Anachis avara (Say)	greedy dove shell
Nassarius vibex (Say)	mottled dog whelk
Nassarius trivittatus (Say)	
Thais lapillus (Linnaeus)	dog whelk
Subclass: Opisthobranchia	
Order: Nudibranchia	
Dendronotus frondosus (Ascanius, 1774)	bushy-backed sea slug
Onchidoris muricata (Muller, 1776)	nudibranch
Tergipes despectus (Johnston, 1835)	nudibranch
Aeolidia papillosa (Linnaeus, 1761)	plumed sea slug
Acanthodoris pilosa (Abildgaard, 1789)	nudibranch
Coryphella rufibranchialis (Johnston, 1832)	vermillion-gilled nudibranch
Class: Bivalvia	
Subclass: Lamellibranchia	
Order: Adapedonta	
Hiatella arctica (Linnaeus)	artic saxicave
Zirfaea crispata (Linnaeus)	rough piddock
Teredo navalis (Linnaeus)	common shipworm
Order: Anisomyaria	
Modiolus modiolus Linnaeus	horse mussel
Mytilus edulis Linneaus	edible blue mussel
Anomia aculeata Gmelin	common jingle shell
Order: Heterodonta	
Cardium pinnatulum Conrad	cockle shell
Tagelus gibbus (Spengles)	
Tellinidae	
Phylum: Ectoprocta	
Class: Gymnolaemata	
Order: Cyclostomata	
Crisia eburnea (Linnaeus, 1758)	colonial bryozoan
Order: Cheilostomata	
Bugula cucullifera Osborn, 1912	bryozoan
Bugula simplex Hincks, 1886	bryozoan
Bugula turrita (Desor, 1848)	bryozoan
Callopora aurita (Hincks, 1877)	bryozoan
Cryptosula pallasiana (Moll, 1803)	disk encrusting bryozoan
Electra crustulenta (Pallas, 1766)	bryozoan
Electra hastingsae Marcus, 1938	bryozoan
Electra pilosa (Linnaeus, 1767)	White oval windowed bryozoan
Schizoporella unicornis (Johnston, 1847)	bryozoan, brick red
Scruparia ambigua (d'Orbigny, 1841)	bryozoan
Tegella unicornis (Fleming, 1828)	bryozoan
Phylum: Echinodermata	
Class: Asteroidea	
Asterias forbesi (Desor, 1848)	common starfish
Asterias vulgaris Verrill, 1866	purple starfish
Class: Ophiuroidea	
Amphipholis squamata (Delle Chiaje, 1828)	long armed snake star
Ophiopholis aculeata (Linnaeus, 1767)	daisy brittle star
Class: Echinoidea	
Strongylocentrotus drobachiensis (O.F. Muller, 1776)	green sea urchin

Phylum: Chordata
Class: Ascidiacea
Order: Phlebobranchia
Ciona spp.
Order: Stolidobranchia

Botryllus schlosseri (Pallas, 1766)	colonial ascidian
Dendrodoa (Styelopsos) carnea (Agassiz, 1850)	red solidary ascidian
Molgula complanata Alder & Hancock, 1848	sea grapes



Appendix II

Occurrence and Distribution of
Benthic Flora and Fauna Recorded in
Sample Plots Along Five Transects in the
Cape Cod Canal

Key

A – Rare: occasionally occurring in the area.

B – Sparse: widely scattered throughout the area but nowhere numerous.

C – Common: unevenly present throughout the area and occasionally numerous.

D – Abundant: unevenly distributed throughout the area but frequently numerous.

E – Very abundant: numerous and evenly distributed throughout the area.

Numbers represent actual count.

Symbols in parentheses indicate occurrence within square foot sample plots.

Symbols not in parentheses indicate occurrence within 20-foot diameter sample plots.

Table I Dominant Plants and Animals (excluding fishes) Recorded in Sample Plots Along Transect 1

During April – May, 1967, 1968 & 1969

Species	A-1 (intertidal) 1967	A-1 1968	A-1 1969	A-2 (subtidal) 1967	A-2 1968	A-2 1969	B (15 ft.) 1967	B 1968	B 1969	C (30 ft.) 1967	C 1968	C 1969	D (45 ft.) 1967	D 1968	D 1969
Algae															
Chlorophyceae															
Ulva lactuca							A		C			B			
Phaeophycaea															
Laminaria saccharina							B		B	B		B	A		B
Chorda tomentosa									B						
Rhodophyceae															
Chondrus crispus												A			
Rhodymenia palmata									B			B			
Invertebrata															
Coelenterata															
Metridium dianthus										1					A
Obelia geniculata									B			C			C
Tubularia crocea									A			B			C
Annelida															
Nereidae												(1)	(3)		
Phyllodocidae													(6)		(2)
Polynoidae									(1)			(2)	(1)		(1)
Arthropoda															
Cancer irroratus							3		2	7		1	13		
Carcinus maenas										1					
Gammaridae									(11)						(1)
Corophium volutator															(1)
Chiridotea coeca															(1)
Nemertea															
Cerebratulus lacteus												(1)			(1)
Mollusca															
Coryphella rufibranchialis							1								
Aeolidia papillosa										1					
Acmaea testudinalis							C			C		A			A
Littorina litorea							C		D	C		B			B
Mytilus edulis							A			B					
Nassarius trivittatus												(1)			
Echinodermata															
Asterias forbesi							C		C	D		B	D		B
Asterias vulgaris										C		B	D		B
Amphipholis squamata													(1)		
Strongylocentrotus drobachiensis							B			C					

NO SAMPLES (SHIFTING GRAVEL SUBSTRATE)

NO SAMPLES (SHIFTING GRAVEL SUBSTRATE)

NO SAMPLES

NO SAMPLES

NO SAMPLES

Table II Dominant Plants and Animals (excluding fishes) Recorded in Sample Plots Along Transect 2

During April – May, 1967, 1968 & 1969

Species	A-1 (intertidal) 1967	A-1 1968	A-1 1969	A-2 (subtidal) 1967	A-2 1968	A-2 1969	B (15 ft.) 1967	B 1968	B 1969	C (30 ft.) 1967	C 1968	C 1969	D (45 ft.) 1967	D 1968	D 1969
Algae															
Chlorophyceae															
Ulva lactuca				A			D		D	A		A			
Phaeophyceae															
Ascophyllum nodosum	D			E											
Laminaria saccharina				A			D		C	B		D			B
Laminaria digitata				A			C		A						
Chorda tomentosa							C		B						
Ectocarpus sp.				D											
Rhodophyceae															
Chondus crispus				B			B		B	C		B			
Rhodymenia palmata							B		C	B		C			
Invertebrata															
Porifera															
Haliclona oculata				A			A		A	B		A			A
Halichondria panicea									B	A		B			B
Coelenterata															
Obelia geniculata							D		C	C		D			C
Bougainvillia superciliaris										B					
Sertularia pumila				C											
Metridium dianthus				B					A	1					
Tubularia crocea									B						D
Nemertea															
Cerebratulus lacteus															(3)
Annelida															
Cirratulidae									(1)				(4)		
Nereidae							(2)					(1)			
Phyllodocidae							(8)			(1)					
Polynoidae							(2)		(3)			(5)	(1)		(1)
Opheliidae										(1)					
Pectinaria gouldii									(4)			(1)			
Arthropoda															
Balanus balanus															
Balanus balanoides	C			B								B			
Gammaridae									(7)			(1)			(1)
Idotea phosphorea										(1)					
Homarus americanus							2		1	1		1			
Cancer irroratus							2		1	1		3	1		
Cancer borealis							5		6			1			
Carcinus maenas				2											
Neopanope texana												1(1)			
Limulus polyphemus										1			1		
Corophium volutator									(1)			(1)			
Pagurus spp.															1
Mollusca															
Acmaea testudinalis				C								A			
Littorina litorea	C			D			B		A						
Lacuna vincta													(1)		
Mytilus edulis	B			B											
Modiolus modiolus													A		
Tellinidae									(1)						
Nassarius trivittatus									(14)						
Mitrella lunata															(1)
Echinodermata															
Asterias forbesi				B			C		C	C		B	C		C
Asterias vulgaris							A		C	B		B	D		B
Amphipholis squamata							(1)					(7)			(2)
Strongylocentrotus drobachiensis															1

NO SAMPLES

Table III Dominant Plants and Animals (excluding fishes) Recorded in Sample Plots Along Transect 3

During April – May, 1967, 1968 & 1969

Species	A-1 (intertidal) 1967	1968	1969	A-2 (subtidal) 1967	1968	1969	B (15 ft.) 1967	1968	1969	C (30 ft.) 1967	1968	1969	D (45 ft.) 1967	1968	1969
Algae															
Chlorophyceae															
Enteromorpha sp.			B			B									
Ulva lactuca				B		D	C		C	A					
Chaetomorpha sp.				B			A								
Cladophora sp.							B								
Phaeophyceae															
Ascophyllum nodosum	B		B												
Fucus vesiculosus	A					A									
Laminaria saccharina							B		E			E			A
Laminaria digitata							C		C			B			
Chorda tomentosa							D								
Chordaria sp.						C									
Rhodophyceae															
Chondrus crispus							C		C			C			
Rhodymenia palmata							B		C						
Invertebrata															
Porifera															
Haliclona oculata							B								A
Halichondria panicea							B								A
Cliona celata													A		
Coelenterata															
Obelia geniculata							B		E			E			B
Tubularia crocea						A						C	(A)		E
Metridium dianthus							B					A			A
Bougainvillia superciliaris									B			B			
Nemertea															
Cerebratulus lacteus															(1)
Annelida															
Nereidae							(26)			(18)		(2)	(6)		(2)
Phyllodocidae										(2)					
Polynoidae							(1)		(6)	(3)		(9)			(8)
Serpulidae									(1)						
Arthropoda															
Balanus balanoides	E		E	B		E									
Gammaridae							(1)		(5)						(3)
Idotea phosphorea									(35)	(2)			(3)		(1)
Homarus americanus							2		1			1			
Cancer borealis							11			4			1		
Cancer irroratus							6		1	20		1	232		
Neopanope texana									(1)						
Mollusca															
Coryphella rufibranchialis							B			C					
Acmaea testudinalis							B								
Littorina litorea	C		C	C			B								
Littorina obtusata							(1)								
Lacuna vincta							C								
Mytilus edulis	E			E			C			E		A	D		
Zirfaea crispata									(1)						
Mitrella lunata															(24)
Hiatella arctica							(1)								
Echinodermata															
Asterias forbesi				A		B	D		C	E		C	E		C
Asterias vulgaris							C			E			E		C
Ophiopholis aculeata							(1)			(1)			(1)		
Strongylocentrotus drobachiensis									(1)						
Chordata															
Tunicata															
Molgula sp.									(2)						

NO SAMPLES

Table IV Dominant Plants and Animals (excluding fishes) Recorded in Sample Plots Along Transect 4 During April – May, 1967, 1968 & 1969

Species	A-1 (intertidal) 1967	A-1 1968	A-1 1969	A-2 (subtidal) 1967	A-2 1968	A-2 1969	B (15 ft.) 1967	B 1968	B 1969	C (30 ft.) 1967	C 1968	C 1969	D (45 ft.) 1967	D 1968	D 1969
Algae															
Chlorophyceae															
Ulva lactuca	C			C		C	C			A		A			
Enteromorpha sp.	C					B									
Cladophora sp.							B								
Chaetomorpha sp.				C											
Phaeophyceae															
Ascophyllum nodosum	D		D	C		B									
Fucus vesiculosus	B		C			C									
Laminaria saccharina				C			E			B		C			
Laminaria digitata				B			B			B		B			
Chorda tomentosa				B											
Chordaria sp.						D									
Rhodophyceae															
Chondrus crispus	C			D		B	C			D		D	C		C
Rhodymenia palmata	A			A			C					B			
Invertebrata															
Porifera															
Haliclona oculata				C		A				C		B			A
Halichondria panicea				B		A				C		C	B		A
Cliona celata															A
Coelenterata															
Obelia geniculata							B			B		C	A		
Bougainvillia superciliaris										(C)		C	B		D
Tubularia crocea						B						B			B
Annelida															
Nereidae										(12)		(7)	(4)		(1)
Phyllodocidae							(10)			(2)			(3)		
Polynoidae							(1)			(7)		(4)			(1)
Serpulidae										(C)					
Arthropoda															
Balanus balanoides			B			B									
Balanus balanus				B			B			(A)					
Gammaridae							(10)			(23)		(4)	(3)		(1)
Corophiidae							(C)			(D)			(C)		
Idotea phosphorea							(8)						(1)		
Homarus americanus	1						(B)			(C)		(9)	(4)		
Pagurus longicarpus				1			2			1		2			
Cancer irroratus							1								
Cancer borealis							3			3		(1)	2		
Neopanope texana												1			
Carcinus maenas										(12)		(1)			
Pinnotheres sp.						2	2								
Mollusca															
Dendronotus frondosus															
Acanthodoris pilosa				2						C					
Coryphella rufibranchialis				1											
Acmaea testudinalis										(1)					
Littorina litorea	1														
Littorina obtusata	C		D	C		C						A			
Lacuna vincta	A		A												
Lunatia heros							C								
Mytilus edulis										1					
Hiatella arctica	B					B						C			A
Zirfaea crispata							(B)			(B)					
Mitrella lunata							C					B(1)			
												(5)			(14)
Echinodermata															
Asterias forbesi															
Asterias vulgaris	1					B				C		C	C		C
Ophiopholis aculeata	1											C			C
Amphipholis squamata										(7)					
							(1)			(2)		(2)			
Chordata															
Tunicata															
Molgula sp.										(1)					

NO SAMPLES

Table V Dominant Plants and Animals (excluding fishes) Recorded in Sample Plots Along Transect 5

During April – May, 1967, 1968 & 1969

Species	A-1 (intertidal) 1967	A-1 1968	A-1 1969	A-2 (subtidal) 1967	A-2 1968	A-2 1969	B (15 ft.) 1967	B 1968	B 1969	C (30 ft.) 1967	C 1968	C 1969	D (45 ft.) 1967	D 1968	D 1969
Algae															
Chlorophyceae															
Ulva lactuca	A			B			B		C						
Phaeophyceae															
Laminaria saccharina							E		D	B		B			
Laminaria digitata							C		C						
Rhodophyceae															
Rhodymenia palmata							B		C	B					
Chondrus crispus				B			E		D	D		C	B		
Flowering Plants															
Zosterea marinus				D											
Invertebrates															
Porifera															
Cliona celata										C		B	B		C
Haliclona oculata							C		C	C		C	B		A
Halichondria panicea							C		B	C		C	C		C
Coelenterata															
Obelia geniculata							(C)		C			C			
Bougainvillia superciliaris							(A)		C	(C)		C	(A)		C
Metridium dianthus							B		A	B		B	A		A
Tubularia crocea									B			B			B
Annelida															
Nereidae							(6)		(8)	(6)		(5)	(3)		(3)
Phyllodocidae							(2)			(2)			(4)		
Polynoidae							(10)		(10)	(9)		(4)			(5)
Serpulidae							(D)								
Arthropoda															
Balanus balanus												A			B
Balanus balanoides	E			D											
Gammaridae							(B)		(18)	(8)		(3)			
Corophiidae							(C)			(E)			(C)		
Caprella linearis													(1)		
Idotea phosphorea							(C)		(68)	(C)		(10)	(2)		(1)
Homarus americanus							4		8	13		15	3		3
Cancer irroratus									1				2		1
Cancer borealis							1		2	4		3			2
Neopanope texana							(1)		(10)	(4)		(1)	(1)		
Pyconogonida													(2)		
Mollusca															
Dendronotus frondosus							(1)								
Acanthodoris pilosa							(2)								
Coryphella rufibranchialis													(1)		
Littorina litorea	D			D					A						
Lacuna vincta							C								
Mytilus edulis	D			D								A			
Modiolus modiolus							B								B
Cardium pinnulatum							(2)								
Hiatella arctica							(C)			(D)			(B)		
Zirfaea crispata							B		(1)			(8)			(2)
Nassarius trivittatus									(1)						(1)
Mitrella lunata									(4)						
Polinices sp.															1
Echinodermata															
Asterias forbesi							B		B	C		B	C		D
Asterias vulgaris															B
Ophiopholis aculeata							(1)			(2)					
Amphipholis squamata							(1)		(6)			(6)	(1)		
Chordata															
Tunicata															
Molgula sp.							(B)		(3)	(D)		(8)			

NO SAMPLES

Table VI Dominant Plants and Animals (excluding fishes) Recorded in Sample Plots Along Transect 1

During July – August 1967, 1968, 1969

Species	A-1 (intertidal) 1967	1968	1969	A-2 (subtidal) 1967	1968	1969	B (15 ft.) 1967	1968	1969	C (30 ft.) 1967	1968	1969	D (45 ft.) 1967	1968	1969
Algae															
Chlorophyceae															
Ulva lactuca							B	D	C		A	A			
Enteromorpha sp.							B	B							
Phaeophyceae															
Laminaria saccharina								C	D	A	C	C			B
Ectocarpus sp.							C								
Chorda filum								A	C		A				
Chordaria sp.									B						
Rhodophycea															
Rhodymenia palmata									B			A			
Invertebrata															
Coelenterata															
Tubularia crocea	NO SAMPLES (SHIFTING GRAVEL SUBSTRATE)			NO SAMPLES (SHIFTING GRAVEL SUBSTRATE)			C	D	A	E	E		D	E	
Metridium dianthus										1	A	A			
Obelia geniculata									B			B			A
Annelida															
Polynoidae							(5)	(8)	(8)		(1)	(1)		(6)	(3)
Nereidae							(3)		(1)		(1)				(2)
Phyllodocidae									(2)			(1)			
Arthropoda															
Gammaridae							(2)	(7)	(1)		(2)	(1)		(2)	(2)
Cancer irroratus							1		2	2		(1)	1	(1)	(3)
Idotea phosphorea									(1)					(4)	(1)
Pyconogonida								(9)			(26)	(1)		(11)	(7)
Pagurus sp.														1	
Platyhelmia												(7)			
Mollusca															
Littorina litorea							D		(1)B	C		B	B		A
Acmaea testudinalis													B		
Lacuna vincta									(37)B			(2)			
Mytilus edulis									C			D			E
Polinices sp.												1			2
Dendronotus frondosus											A	(1)		(3)C	A
Coryphella rufibranchialis								(2)							
Mitrella lunata										(7)				(1)	(3)
Pagurus sp.														1	
Echinodermata															
Asterias forbesi							B	B	B	B	B	C	B	C	C
Asterias vulgaris							B	B		B		B	B	B	C
Strongylocentrotus drohbachiensis										3			3		
Amphipholis squamata							(1)	(1)							

Table VII Dominant Plants and Animals (excluding fishes) Recorded in Sample Plots Along Transect 2

During July – August 1967, 1968 & 1969

Species	A-1 (intertidal) 1967	1968	1969	A-2 (subtidal) 1967	1968	1969	B (15 ft.) 1967	1968	1969	C (30 ft.) 1967	1968	1969	D (45 ft.) 1967	1968	1969
Algae															
Chlorophyceae															
Ulva lactuca						C	D	D	D	B	B	A			
Codium fragile						B			A						
Enteromorpha sp.			A			B									
Phaeophyceae															
Laminaria saccharina						B	D	D	D	C	C	D		B	C
Laminaria digitata							C	B		B	B	B			
Chorda filum								C	C						
Fucus vesiculosus			B			B									
Ascophyllum nodosum			B												
Chordaria sp.						B									
Rhodophyceae															
Chondrus crispus						A	C	B	B	B	B	B			
Rhodymenia palmata							C	B	B	A	B	C			
Flowering Plants															
Zosterea marinus						B									
Invertebrata															
Porifera															
Haliclona oculata							B	B	B	A	B	A			
Halichondria panicea							B	A	A	B	A	B	B	B	B
Coelenterata															
Tubularia crocea							C	D	B	D	E	C	D	E	D
Metridium dianthus						C	1	A	A		A	A			
Obelia geniculata							C	B	C	C	B	C	C		B
Bougainvillia superciliaris							B				A	A	B	B	
Ectoprocta	NO SAMPLES	NO SAMPLES		NO SAMPLES	NO SAMPLES										
Bugula turrita							B								
Annelida															
Nereidae								(1)		(3)	(2)	(1)	(3)	(1)	(3)
Phyllodocidae													(1)		
Polynoidae								(1)	(3)	(18)	(3)	(5)	(17)	(3)	(5)
Serpulidae								(1)							
Cirratulidae								(1)			(1)				
Terebellidae									(1)						
Pectinaria gouldii								(2)	(1)		(1)			(1)	
Nemertea															
Cerebratulus lacteus								(1)							
Arthropoda															
Cancer irroratus							1	4			3	(1)		(1)	
Cancer borealis							5	2		3	7			1	
Homarus americanus							4	3	2	1		1			
Gammaridae							(1)		(1)	(2)					
Nerocila munda										(1)					
Idotea phosphorea													(1)		
Pycnogonidia							(1)			(1)			(1)		
Balanus balanoides			B												
Carcinus maenas						3									
Mollusca															
Littorina litorea			D			D	B					B			
Littorina saxatilis										(1)			(1)		
Modiolus modiolus										A			1		
Hiatella arctica							(2)								
Turritella erosa							(1)			(1)		(2)			(1)
Nassarius vibex							(3)								
Nassarius trivittatus								(5)	(4)			(1)			(1)
Mitrella lunata									(7)			(3)			(1)
Lacuna vincta															(1)
Mytilus edulis								A			A			A	
Echinodermata															
Asterias forbesi			A			B	B	B	C	C	C	C	C	C	C
Asterias vulgaris							B	B		B	B	B	C	C	B
Strongylocentrotus drobachiensis							(2)				(2)				
Amphipholis squamata												(1)			

Table VIII Dominant Plants and Animals (excluding fishes) Recorded in Sample Plots Along Transect 3

During July – August 1967, 1968 & 1969

Species	A-1 (intertidal) 1967	A-1 1968	A-1 1969	A-2 (subtidal) 1967	A-2 1968	A-2 1969	B (15 ft.) 1967	B 1968	B 1969	C (30 ft.) 1967	C 1968	C 1969	D (45 ft.) 1967	D 1968	D 1969
Algae															
Chlorophyceae															
Ulva lactuca				B			B	B	C		A				
Phaeophyceae															
Ascophyllum nodosum				A											
Fucus vesiculosus				A											
Laminaria saccharina							E	E	E		E	D			B
Laminaria digitata							C	C	C						
Rhodophyceae															
Chondrus crispus							C	B	D		B	B			
Rhodymenia palmata							C	B	C			C			
Invertebrata															
Porifera															
Haliclona oculata							A	B							
Halichondria panicea							A	B	A						
Cliona celata													A		
Coelenterata															
Tubularia crocea							D	C	C	C	C	D	B	E	E
Obelia geniculata							D	D	C		A	C			B
Bougainvillia superciliaris								B	C		B	B		A	
Metridium dianthus								B	A		A				
Sertularia sp..													B		
Annelida	SAMPLES	SAMPLES	SAMPLES		SAMPLES	SAMPLES									
Nereidae								(2)	(5)	(2)	(1)	(13)	(5)	(2)	(3)
Phyllodocidae															(1)
Polynoidae							(4)	(3)	(7)	(2)	(3)	(7)		(1)	(4)
Arthropoda															
Cancer irroratus							6		2	2	1	2	(1)		2
Cancer borealis							1	5	1						
Homarus americanus							10	3	5			1			
Idotea phosphorea								(16)	(3)		(1)	(1)		(2)	
Cirolana concharum												(1)			
Balanus balanoides				C											
Balanus balanus								A							
Carcinus maenas				1											
Gammaridae							(4)	(5)						(3)	
Pycnogonida							(2)	(1)			(1)			(4)	
Caprellidae							(3)								
Mollusca															
Littorina litorea				C								B			
Littorina obtusata				A											
Mytilus edulis				D			A	A		A		(D)C		(E)	E
Thais lapillus				B											
Mitrella lunata							(2)	(5)	(77)			(8)		(1)	(7)
Zirfaea crispata									(4)			(1)			
Lacuna vincta								(1)	(2)		(1)	(1)			(1)
Nudibranchia									(2)						
Nassarius trivittatus															(1)
Acmaea testudinalis												(1)			
Echinodermata															
Amphipholis squamata							(1)	(2)			(2)	(3)			
Asterias forbesi				C			C	C	C	D	B	C	E	C	C
Asterias vulgaris							C	B	B	C	B	B	D	C	C
Strongylocentrotus drobachiensis											(2)	(1)			(1)
Chordata															
Tunicata															
Molgula sp.									(1)						

Table IX Dominant Plants and Animals (excluding fishes) Recorded in Sample Plots Along Transect 4

During July – August 1967, 1968 & 1969

Species	A-1 (intertidal) 1967	1968	1969	A-2 (subtidal) 1967	1968	1969	B (15 ft.) 1967	1968	1969	C (30 ft.) 1967	1968	1969	D (45 ft.) 1967	1968	1969
Algae															
Chlorophyceae															
Ulva lactuca				E			B	D		A		B			
Enteromorpha sp.				C											
Phaeophyceae															
Ascophyllum nodosum				D				A							
Fucus vesiculosus				C											
Laminaria saccharina							E	D		C	C	D			A
Laminaria digitata							C	B		B	B	C			A
Rhodophyceae															
Chondrus crispus				D			C	C		C	C	D	B	B	B
Rhodymenia palmata							C	C		B	C	C		C	A
Invertebrata															
Porifera															
Haliclona oculata				B			B	B		B	A	B	B		A
Halichondria panicea							B	A		B	C	C	B	B	B
Coelenterata															
Tubularia crocea							B			B	B		C	C	D
Obelia geniculata							E	C		C	C	C			
Bougainvillia superciliaris										C	B	C	C	C	
Sertularia sp.													B		
Annelida															
Nereidae	NO SAMPLES	NO SAMPLES	NO SAMPLES		NO SAMPLES	NO SAMPLES			NO SAMPLES	(16)		(2)	(2)	(3)	(4)
Phyllodocidae												(1)	(1)	(2)	
Polynoidae										(2)		(6)	(3)		(2)
Arthropoda															
Cancer borealis							1	3		5	1	4		1	
Cancer irroratus								2			(2)				(3)
Homarus americanus								6		5	3	1	2		
Hippolytidae														(1)	
Balanus balanus				C				B			A	A			
Carcinus maenas				3						(1)					
Neopanope texana										(6)		(1)			
Idotea phosphorea										(5)		(12)	(1)	(7)	
Gammaridae											(2)		(2)	(2)	(2)
Mollusca															
Littorina litorea				C				(1)		A			B		A
Mytilus edulis				C				B			B	C		A	
Zirfaea crispata								B		B	(10)C	(5)C			
Hiatella arctica										(8)	(1)				
Nassarius trivittatus												(11)			
Mitrella lunata								(10)				(55)		(1)	(8)
Lacuna vincta								(1)				(1)			
Echinodermata															
Asterias forbesi				B			C	B		8	C	C	D	C	C
Asterias vulgaris							B			B			C	B	B
Amphipholis squamata								(5)		(4)					
Strongylocentrotus drobachiensis								2							

Table X Dominant Plants and Animals (excluding fishes) Recorded in Sample Plots Along Transect 5

During July – August 1967, 1968 & 1969

Species	A-1 (intertidal) 1967	A-1 1968	A-1 1969	A-2 (subtidal) 1967	A-2 1968	A-2 1969	B (15 ft.) 1967	B 1968	B 1969	C (30 ft.) 1967	C 1968	C 1969	D (45 ft.) 1967	D 1968	D 1969
Algae															
Chlorophyceae															
Ulva lactuca							A	B	B		A				
Codium fragile									B						
Phaeophyceae															
Laminaria saccharina							D	D	C	B	B	B			
Laminaria digitata							B	B	A	A	A	A			
Rhodophyceae															
Chondrus crispus								C	D	D	C	D			
Rhodymenia palmata							B	C	B	B	B				
Flowering Plants															
Zosterea marinus							C								
Invertebrata															
Porifera															
Haliclona oculata							C	C	C	D	C	D	B	B	B
Halichondria panicea							C	C	C	D	C	C	C	B	C
Cliona celata							B	B		C	B	C	B	B	C
Coelenterata															
Tubularia crocea							B	B		D	C	B	E	D	C
Metridium dianthus							B	B	B	C	B	B	1	A	B
Obelia geniculata							E	D		B	B				
Bougainvillia superciliaris							B	C	D	B	D	D	B	C	B
Sertularia sp.								B			A		B		
Ectoprocta															
Bugula turrita							C			B					
Annelida															
Nereidae							(1)		(1)	(8)	(8)	(2)	(6)	(1)	(3)
Phyllodocidae												(3)			(2)
Polynoidae							(1)	(6)	(2)	(7)		(8)	(1)	(1)	(3)
Serpulidae									(4)						
Nemertea															
Cerebratulus lacteus							(1)								
Arthropoda															
Cancer irroratus													1		(2)
Cancer borealis							1	2	4		1	1	1		
Homarus americanus							9	6	6	10	8	18	7	2	4
Balanus balanus							B	B	(1)B	C	B		A	A	A
Balanus balanoides							C								
Carcinus maenas							1								
Gammaridae							(1)		(1)	(2)			(1)		(1)
Idotea phosphorea							(1)	(1)	(2)	(1)					
Neopanope texana								(1)	(2)	(6)	(3)	(23)	(1)		
Planes minutus							(1)								
Corophiidae								(2)							
Mollusca															
Littorina litorea	C		D				E	A		A				A	A
Littorina obtusata	A						A								
Littorina saxatilus	B														
Mytilus edulis	C		C				E		A	B	B			B	
Thais lapillus	B		B												
Mitrella lunata							(12)		(31)	(8)		(9)			(1)
Tagelus gibbus												(3)			
Zirfaea crispata															(1)
Nassarius trivittatus									(20)						
Modiolus modiolus											B				B
Echinodermata															
Asterias forbesi							B	C		B	C	C	C	D	E	D
Asterias vulgaris								B			B			C	C	B
Amphipholis squamata									(1)	(1)	(10)					(1)
Strongylocentrotus drobachiensis								(1)		A						(1)A
Ophiopholis aculeata												(3)			
Chordata															
Tunicata															
Molgula sp.										(3)					(1)

NO SAMPLES

Table XI Dominant Plants and Animals (excluding fishes) Recorded in Sample Plots Along Transect 1

During October – November, 1967*

Species	A-1 (intertidal)	A-2 (subtidal)	B (15 ft.)	C (30 ft.)	D (45 ft.)
Invertebrata					
Annelida	NO SAMPLES	NO SAMPLES			
Nereidae			(5)		(3)
Arthorpoda					
Gammaridae			(5)		(3)
Idotea phosphorea			(2)	(2)	(4)
Cancer irroratus				(1)	
Corophium volutator				(1)	
Pycnogonidia				(2)	(4)
Caprellidae					(1)
Mollusca					
Acmaea testudinalis				(1)	

*Square foot samples only

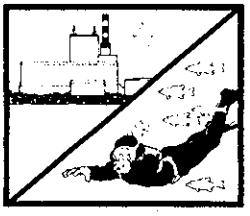


Table XII Dominant Plants and Animals (excluding fishes) Recorded in Sample Plots Along Transect 2

During October – November, 1967

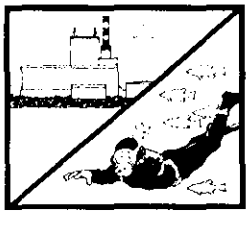
Species	A-1 (intertidal)	A-2 (subtidal)	B (15 ft.)	C (30 ft.)	D (45 ft.)
Algae					
Chlorphyceae					
Ulva lactuca			C		
Phaeophyceae					
Laminaria saccharina			D	B	
Laminaria digitata			C	B	
Rhodophyceae					
Chondrus crispus			C		
Rhodymenia palmata			B		
Invertebrata					
Porifera					
Haliclona oculata			B	B	B
Halichondria panicea				A	
Coelenterata					
Obelia geniculata	NO SAMPLES	NO SAMPLES	E	C	C
Metridium dianthus			A		A
Bougainvillia superciliaris				C	B
Ectoprocta					
Bugula turrita			B		
Annelida					
Nereidae				(3)	(1)
Phyllodocidae			(1)		
Polynoidae			(2)	(3)	(4)
Arthropoda					
Cancer borealis			5	3	
Cancer irroratus			5	4	
Homarus americanus			1	1	
Gammaridae			(6)	(1)	
Idotea phosphorea			(20)		
Caprellidae				(1)	(2)
Neopanope texana					(1)
Mollusca					
Mytilus edulis			A		
Littorina litorea				A	A
Corophyella rufibranchialis					(3)
Echinodermata					
Asterias forbesi			C	C	C
Asterias vulgaris			D	C	C
Strongylocentrotus drobachiensis				(1)	

Table XIII Dominant Plants and Animals (excluding fishes) Recorded in Sample Plots Along Transect 3

During October – November, 1967

Species	A-1 (intertidal)	A-2 (subtidal)	B* (15 ft.)	C (30 ft.)	D (45 ft.)
Algae					
Phaeophyceae					
Laminaria saccharina				B	
Rhodophyceae					
Rhodymenia palmata				A	
Invertebrata					
Porifera					
Cliona celata					A
Coelenterata	NO SAMPLES	NO SAMPLES			
Tubularia crocea				A	A
Obelia geniculata				B	
Bougainvillia superciliaris				C	C
Sertularia sp.				B	
Annelida					
Nereidae			(2)		(3)
Polynoidae			(2)	(1)	
Arthropoda					
Gammaridae			(1)	(2)	
Idotea phosphorea			(9)	(1)	(1)
Caprellidae				(1)	
Cancer irroratus				2	
Mollusca					
Dendronotus frondosus					3
Echinodermata					
Asterias forbesi				C	C
Asterias vulgaris				C	B

*Square foot samples only



Appendix III

Teredinidae and *Limnoria spp.* Activity on Wooden Test Panels in the Cape Cod Canal 1966 – 1969

Key*

Total No. of tunnels per panel	*Limnoria spp.*	Attack Rating
Up to 132 tunnels		Trace (T)

Teredinidae

Up to 5	Trace (T)
6 to 25 (10%)	Slight (S)
26 to 100 or 25% filled	Moderate (M)
101 to 250 or 50% filled	Medium heavy (MH)
Over 250 or 75% filled	Heavy (H)
Filled, riddled or destroyed	Very Heavy (VH)

*Rating system of William F. Clapp Laboratories, Inc.
Duxbury, Massachusetts

STATION P I

Exposure Panels				Control Panels (1 month exposure)		
Months Exposure	Date Removed	*Limnoria spp.*	Teredinidae	Date Removed	*Limnoria spp.*	Teredinidae
4	9/21/66	T	T	No Controls		
5	10/20/66	T	S			
6	11/21/66	T	S			
1	6/29/67	T	–			
2	7/17/67	T	–	No Controls		
3	8/24/67	–	–			
1	7/3/68	–	–	7/3/68	–	–
2	8/7/68	–	–	8/7/68	–	–
3	9/13/68	–	S	9/13/68	–	–
4	10/14/68	–	M	10/14/68	T	–
5	11/15/68	T	M	11/15/68	–	–
1	6/30/69	–	–	6/30/69	–	–
2	7/30/69	–	–	7/30/69	–	–
3	8/29/69	T	–	8/29/69	T	–
4	9/30/69	T	S	9/30/69	–	–
5	10/30/69	T	S	10/30/69	–	–
6½	12/18/69	T	M	12/18/69	–	–

STATION P II

Exposure Panels				Control Panels (1 month exposure)		
Months Exposure	Date Removed	*Limnoria spp.*	Teredinidae	Date Removed	*Limnoria spp.*	Teredinidae
4	9/19/66	–	T	9/19/66	–	T (embryonic)
5	10/19/66	T	S	10/19/66	–	–
6	11/17/66	–	S	11/17/66	T	–
1	6/16/67	–	–	6/16/67	–	–
2	7/25/67	–	–	7/25/67	–	–
3	8/17/67	–	–	8/17/67	–	–
1	7/3/68	–	–	7/3/68	–	–
2	8/7/68	–	–	8/7/68	–	–
3	9/13/68	T	S	9/13/68	–	T (embryonic)
4	10/14/68	T	M	10/14/68	–	–
5	11/15/68	T	M	11/15/68	–	–
1	6/30/69	–	–	6/30/69	–	–
2	7/30/69	–	–	7/30/69	–	–
3	8/29/69	–	M	8/29/69	–	–
4	9/30/69	T	M	9/30/69	–	–
5	10/30/69	–	M H	10/30/69	–	–
6½	12/18/69	–	H	12/18/69	–	–

STATION P III

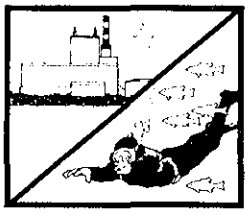
Exposure Panels				Control Panels (1 month exposure)		
Months Exposure	Date Removed	*Limnoria spp.*	Teredinidae	Date Removed	*Limnoria spp.*	Teredinidae
4	9/16/66	–	S			
5	10/18/66	–	S	No Controls		
6	11/15/66	T	S			
1	6/12/67	–	–			
2	7/19/67	T	–	No Controls		
3	8/21/67	–	–			
1	7/3/68	–	–	7/3/68	–	–
2	8/8/68	–	–	8/8/68	–	–
3	9/12/68	–	S	9/12/68	–	T (embryonic)
4	10/15/68	–	M	10/15/68	–	–
5	11/15/68	–	S	11/15/68	–	–
1	7/2/69	–	–	7/2/69	–	–
2	8/4/69	–	–	8/4/69	–	–
3	9/3/69	–	S	9/3/69	–	–
4	10/1/69	–	S	10/1/69	–	–
5	10/31/69	–	S	10/31/69	–	–
7	12/29/69	–	M	12/29/69	–	–

STATION P IV

Exposure Panels				Control Panels (1 month exposure)		
Months Exposure	Date Removed	*Limnoria spp.*	Teredinidae	Date Removed	*Limnoria spp.*	Teredinidae
4	9/16/66	–	T	9/16/66	–	T (embryonic)
5	10/17/66	–	S	10/17/66	–	–
6	11/14/66	T	M	11/14/66	–	–
1	6/26/67	T	T	6/26/67	–	T (embryonic)
2	7/20/67	T	–	7/20/67	–	–
3	No Data			No Data		
1	7/2/68	T	–	7/2/68	–	–
2	8/6/68	T	T	8/6/68	–	–
3	9/12/68	T	M	9/12/68	–	S (embryonic)
4	10/15/68	–	M	10/15/68	–	–
5	11/15/68	T	M H	11/15/68	–	–
1	7/2/69	–	–	7/2/69	–	–
2	8/4/69	T	–	8/4/69	–	–
3	9/3/69	–	T	9/3/69	–	–
4	10/1/69	T	S	10/1/69	–	–
5	10/31/69	T	M	10/31/69	–	–
7	12/30/69	T	M H	12/30/69	–	–

STATION P V

Exposure Panels				Control Panels (1 month exposure)		
Months Exposure	Date Removed	*Limnoria spp.*	Teredinidae	Date Removed	*Limnoria spp.*	Teredinidae
4	9/20/66	T	M	9/20/66	–	MH (embryonic)
5	10/20/66	T	MH	10/20/66	–	–
6	11/18/66	T	MH	11/18/66	–	–
1	6/23/67	T	–	6/23/67	–	–
2	7/24/67	T	–	7/24/67	–	–
3	8/23/67	T	–	8/23/67	–	–
1	7/2/68	–	–	7/2/68	–	–
2	8/8/68	–	–	8/8/68	–	–
3	9/12/68	T	MH	9/12/68	T	M (embryonic)
4	10/15/68	T	MH	10/15/68	–	–
5	11/15/68	T	H	11/15/68	–	–
1	7/2/69	–	–	7/2/69	–	–
2	8/4/69	–	–	8/4/69	–	–
3	9/3/69	–	M	9/3/69	T	–
4	10/1/69	–	MH	10/1/69	–	–
5	10/31/69	–	VH	10/31/69	–	–
7	12/29/69	T	VH	12/19/69	–	–



APPENDIX NO. 2

ESTIMATING EFFECTS OF LARGE ELEVATED SOURCE EMISSIONS ON NEIGHBORING AIR QUALITY

ESTIMATING EFFECTS OF LARGE ELEVATED SOURCE EMISSIONS ON NEIGHBORING AIR QUALITY

1. Distribution of Gas Concentrations

Various theoretical studies on atmospheric diffusion have greatly contributed to the understanding of the physical processes involved. However, the results of only two studies, namely Bosanquet and Pearson[1] and Sutton[2], are widely applied to specific problems of gas plume diffusion. Of these two studies, the latter has been used more.

There is a trend in the analysis of gas diffusion to use a more general basis than that given by Sutton's equation and to relate the diffusion characteristics to meteorological variables which are more intimately related to the diffusion process. In these methods, statistical properties of gas concentration distributions, as represented by their standard deviations, are used in place of the diffusion coefficients and turbulence index of Sutton's equation.

Pasquill[3] of the British Meteorological Office devised a method cf computing dispersion from an elevated or ground level source in terms of the height and width of the plume of airborne material, based primarily on diffusion measurements taken during Project Prairie Grass (Cramer et al, 1958)[4]. Gifford[5,6] has transformed values of Pasquill's parameters of height and width to the standard deviations of plume concentration distribution in vertical and horizontal directions. Based on the assumption that the plume has a Gaussian distribution in both the horizontal and vertical dimensions, the dispersion formula is as follows:

$$C = \frac{Q}{\pi \mu \sigma_z \sigma_y} \cdot \exp \frac{-H^2}{2\sigma_z^2} \cdot \exp \frac{-Y^2}{2\sigma_y^2}$$

where:

C is the concentration at ground level, assuming total reflection of the plume takes place at the earth's surface

Q is the source strength (mass per unit time)

μ is the mean wind speed affecting the plume

σ_y and σ_z are the standard deviations of plume concentration distribution in the vertical and horizontal directions, respectively

H is the effective height of emission (stack height plus plume rise)

Y is the crosswind distance from the plume center line

The values of σy and σz must be in terms of downwind distance, X. The computation of concentration is, consequently, made for specific downwind distances.

This formula, together with standard deviations published by Gifford,[7] is the basis for Stone & Webster's computer analysis of dispersion from single stacks.

2. Plume Rise

Many procedures have been developed for estimating the rise of gas plumes. Some are entirely empirical in their development, while others are based on theoretical analyses with subsequent modification resulting from experimental information. During the past 15 years, the improved capability for estimating plume rise has resulted in more accurate and confident assessments of diffusion problems. At present, all plume rise equations have been postulated for isolated stacks in an atmosphere with motion uncomplicated by obstructions, i.e., buildings or topographical features.

In 1963 the Tennessee Valley Authority (TVA), under the sponsorship of the Public Health Service, initiated a plume rise study at six of its electric generating stations. The purpose of this study was to compile plume rise observations from these plants under a wide variety of operational and meteorological conditions. These observations were later correlated with postulated plume rise formulas to determine the most appropriate equation for a generalized dispersion study.

From this study TVA concluded that several formulas can be used effectively to estimate the rise of gas plumes. These formulas were optimized by regression analysis to best fit TVA data. The CONCAWE and Csanady equations, along with the "2/3 Power Law" relation, were selected as the three best equations. The CONCAWE equation was considered preferable for most general investigations since it correlated well with both TVA and European data. The Holland equation, developed for small units (less than 200 MW) at Oak Ridge and Watts Bar (two small TVA plants), was found to agree with observed data at other TVA plants, but tended to slightly underestimate the plume rise. The "2/3 Power Law" is currently being used by the TVA for estimating plume rise. This equation, along with the Csanady equation, requires a value for the temperature structure of the atmosphere. Since this information is not readily available from most of the sources of weather data, i.e., airports, the "2/3 Power Law" and the Csanady equation find limited use in a generalized dispersion study.

Stone & Webster Engineering Corp. has also conducted a study to determine the most realistic and conservative plume rise equation for use in such a study. Its staff has concluded that several semi-empirical plume rise formulas were derived from observations

of small sources and that these equations give erroneous results when extrapolated beyond this range. For example, the Holland equation tends to underestimate plume rise in some cases and overestimate in others when compared to the CONCAWE equation. These differences depend on the heat emission (megawatts per stack), stack gas exit velocity (no credit for exit velocity is given in the CONCAWE equation), atmospheric stability (CONCAWE equation is independent of stability) and wind speed. As a result, much ambiguity exists in asserting that one equation gives more conservative plume rise estimates, hence higher ground level contaminant concentrations, than another. Also, selecting a plume rise equation solely on a conservative basis is unrealistic.

Stone & Webster concluded that selecting a plume rise equation for a generalized dispersion study depends on many variables, e.g., unit size, exit velocity, and most importantly, meteorological parameters - with the CONCAWE equation finding wider application. The CONCAWE plume rise equation was used for the analysis of the Canal Plant dispersion.

The CONCAWE equation, optimized to fit TVA data, is as follows:

$$h = 0.414 \frac{Q^{0.444}}{\mu^{0.694}}$$

where:

Q (calories per second) is the heat emission from the stack

μ (meters per second) is the mean horizontal wind speed

3. Zero Plume Rise

When stack gas exit velocity is lower than the wind speed, whether due to low load or high winds, a condition of zero plume rise exists. In such a case, stack gases do not rise (hence plume rise formulas are inapplicable); instead, they extend levelly from stack top or flow partially down the sides of the stack. Once the stack exit velocity is less than 1.5 times the wind speed[14], the probability of zero plume rise occurrence is high.
Stone & Websters' analysis incorporates this cutoff number as the point beyond which plume rise is set equal to zero.

4. Effect of Meteorological Factors

a. Stability Classes

The values of both σy and σz of the dispersion equation will depend on the turbulent structure of the atmosphere. If measures

of horizontal and vertical motions of the air are made (as with a bivane), the resultant records may be used to estimate σy and σz. If wind fluctuation measurements are not available, σy and σz may be estimated from wind measurements at the standard height of 10 meters and estimates of net radiation, as given by Pasquill.[3]

Weather stability categories (A through F) appear in the following tabulation in terms of insolation during daytime (radiation received from the sun) and amount of cloud cover at night:

Surface Wind Speed		Insolation			Night	
M Per Sec	Mph	Strong	Moderate	Slight	>4/8 Low Cloud	3/8 Cloud
<2	<4.5	A	A	B	-	-
2-3	4.5 - 6.7	A-B	B	C	E	F
3-5	6.7 - 11.2	B	B-C	C	D	E
5-6	11.2 - 13.4	C	C-D	D	D	D
>6	>13.4	C	D	D	D	D

Strong insolation corresponds to a solar altitude (above the horizon) greater than 60 degrees with clear skies; it may occur on a sunny midday in midsummer. Slight insolation corresponds to a solar altitude from 15 to 25 degrees with clear skies; it may occur on a sunny midday in midwinter. However, cloudiness will generally decrease insolation and should be considered along with solar altitude in determining insolation. Insolation that would be strong with clear skies might become moderate with broken middle clouds and slight with broken low clouds. Night refers to the period from one hour before sunset to one hour after sunrise. The neutral category D should be assumed for overcast conditions during day or night.

b. Meteorological Conditions

Gas diffusion rates depend upon atmospheric turbulence, which is divided into two types, convective and mechanical. Mechanical turbulence arises from movement of air over the earth's surface and is influenced by nonthermal features of buildings and any objects which resist air motion. It increases with irregularity of the surface and its intensity increases with wind speed.

Convective turbulence is caused largely by differences in temperature between the the surface and the overlying air stream. The range of temperature gradients may be divided into unstable, neutral and stable. The neutral case will show primarily mechanical turbulence, while the unstable adds convective turbulence and the stable suppresses mechanical turbulence.

While certain thermal conditions produce convective turbulence, others may suppress mechanical turbulence instead of producing turbulence. Thermal and mechanical influences generally occur simultaneously in varying ratios. Convective turbulence tends to have longer period fluctuations, but the two cannot be completely separated.

Pasquill's six atmospheric stability classes (A to F)[3] are related to turbulence, and each class is associated with a plume of certain geometrical form and gas concentration distribution. A looping plume occurs with a high degree of turbulence, especially convective, and is typical of a daytime condition with intense solar heating of the earth's surface causing unstable thermal conditions. (Stability Class A represents these conditions at low wind speed and extreme instability.) Rapid diffusion occurs and maximum ground level concentration may occur within one to three stack heights away. Highest peak concentrations will occur momentarily with this condition. As wind speed increases and/or solar radiation decreases, Stability Class B occurs. Peak concentrations are lower than with Class A and maximum ground level concentrations may occur three to five stack heights away. Reduced solar radiation and/or increased wind speed creates a coning plume, approximately represented by Class C, when thermal conditions are more nearly neutral and mechanical turbulence is predominant. Maximum ground level concentrations may occur 10 to 13 stack heights away.

As solar radiation becomes insignificant (because of cloud cover and/or darkness) and wind speed intensifies, the coning plume begins to change to a fanning plume. This condition is caused primarily by isothermal conditions, and vertical diffusion becomes less rapid than that of Class C. Class D stability can occur during both day and night at any time during the year and in fact is present most of the year. Classes E and F represent progressively more stable conditions at night, with Class F occurring at lower wind speeds than Class E. Mechanical turbulence is suppressed and very little vertical diffusion occurs. Consequently, maximum ground level concentrations may occur more than 50 stack heights away. A fanning plume is likely to occur under these stable conditions, and the plume will remain intact for a considerable downwind distance. Pasquill does not classify the very stable condition which may occur at even lower wind speeds than those of Class E or F.

The vertical diffusion is minimal and cannot be detected at great downwind distances.

Table A-1 summarizes the effects of meteorological conditions for the six atmospheric Classes A to F.

Table A-1

Effects of Meteorological Conditions

Stability Class	Stability Condition	Plume Description	(For Tall Stacks) Peak Concentrations Distance*	Intensity	Angular Width of Wind Trace	Relative Type of Turbulence	Wind Speeds, Knots	Time of Day	Season
A	Very unstable	Looping	1-3	Very high	Very large	Largely thermal	1-5	1000-1500 only	Uncommon in winter
B	Moderately unstable	Looping	3-5	Moderately high	Large	Largely thermal	1-9	0900-1600	Mostly summer
C	Slightly unstable or near neutral	Coning	10-13	High	Moderately large	Mostly mechanical	1-11	0600-1800	Any
D	Neutral	Fanning	20-40	Low	Moderately small	Mechanical	Any	Night or day with/ without heavy cloud cover	Any
E	Slightly stable	Fanning	50	Moderately low	Small	Mechanical	4-10	Night	Any
F	Moderately stable	Fanning	50	Very low concentration	Small	Negligible	4-10	Night	Any

* In multiples of stack height

5. Multiple Stack Plumes

Strom[8] states that when two or more stacks are closely grouped, they have mutual influences and their plumes tend to merge into one. Limits on this effect are given in a paper by Bosanquet et al[9] where it is stated that plumes from multiple stacks will rise higher than a plume from only one of them, but not as high as a plume from one stack replacing all of them. As more data of the type obtained by Gartrell et al[10] at TVA become available, the analysis of multiple-stack effects will be improved.

Hawkins and Nonhebel[11] concluded that when the distance between the stacks is less than about three times their height, the concentration due to all the stacks together is the sum of the concentrations due to each individual stack. They also concluded that maximum concentration is not reduced by discharging the flue gas from a power station through several stacks, even if the stacks are set as far apart as practicable. In addition, a single large stack will have a greater effective height than two or more smaller stacks carrying the same quantity of gas. Hence, a large stack will produce a smaller maximum ground level concentration. This conclusion, i.e., one large stack is better than several smaller stacks, is strengthened as the temperature and quantity of the flue gas increase, because stack height becomes a smaller fraction of the effective height of emission. Recent English field studies agreeing with this concept have led to the construction of multiflue tall stacks.

At a 1965 symposium on air pollution problems, Gartrell[12] discussed TVA's extensive monitoring experience with single and multiple stacks. Utilizing results of recently completed full-scale dispersion studies [13] and plume rise studies in progress, maximum expected concentrations were computed for a 1-, 2-, 3-, or 4-stack plant.
The results , shown in the following tabulation, are based on 500-foot stacks, with each stack discharging combustion gases from 500 MW capacity:

Stack Spacing, Ft	No. Of Stacks	Relative Value of Maximum SO2 Concentration: Plume Direction in Line with Stacks	Plume Direction Normal to Stacks
257	1	1.0	1.0
257	2	1.8	1.8
257	3	2.4	2.6
257	4	3.0	3.3
150	1	1.0	1.0
150	2	1.8	1.9
150	3	2.6	2.8
150	4	3.3	3.6

These results suggest that conclusions reached by Hawkins and Nonhebel are conservative. TVA sources also report, for instance, that an increase in number of units from 1 to 10 has resulted in an increase of only 5.3 times in ground level concentrations. This nonlinearity is attributed to the merging of heated plumes and the increased buoyancy resulting from the very large volumes of hot gas. The thermal rise component becomes substantially greater, thereby increasing plume height and effective stack height. Stone & Webster, after investigations of other multiple-stack plants, has refined the dispersion program to account for these phenomena.

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APPENDIX NO. 3

INVESTIGATION OF A SUBMERGED, SLOTTED PIPE DIFFUSER FOR CONDENSER WATER DISCHARGE FROM THE CANAL PLANT, CAPE COD CANAL

R71-39 DSR 73307

RALPH M. PARSONS LABORATORY

FOR WATER RESOURCES AND HYDRODYNAMICS

Department of Civil Engineering

Massachusetts Institute of Technology

INVESTIGATION OF A SUBMERGED, SLOTTED PIPE DIFFUSER FOR CONDENSER WATER DISCHARGE FROM THE CANAL PLANT, CAPE COD CANAL

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ABSTRACT

The Canal Plant, Units No. 1 and 2, will discharge condenser cooling water into the Cape Cod Canal by means of a submerged outfall structure. The discharge is constrained with respect to surface temperatures, surface velocities and physical location, in order to protect the marine environment and to ensure that there will be no hazard to navigation in the canal.

A series of hydraulic scale model tests were conducted to investigate different designs of submerged outfalls under various ambient cross flow conditions.

The final proposed design exhibits some unique features which deviate from conventional submerged diffusers. A tradeoff had to be found which keeps the dilution higher than a required minimim (temperature criterion), but low enough to minimize the total flow-away in a warm water layer near the surface (velocity criterion). Given the constraining characteristics of the canal geometry a distributed low-velocity discharge by means of a slotted pipe laid along the slope, parallel to the longitudinal axis of the canal, seems to satisfy these requirements in an optimal manner.

A semi-empirical relationship allowing prediction of surface velocities for the given geometry as a function of design parameters was developed.

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Mr. Roy Milley, machinist, gave valuable assistance in the model construction. Miss Kathleen Emperor typed the manuscript.

Technical supervision was provided by Dr. D. R. F. Harleman, Professor of Civil Engineering. The investigation was carried out by G. Jirka, E. E. Adams and M. Watanabe, Research Assistants in the Ralph M. Parsons Laboratory for Water Resources and Hydrodynamics, Department of Civil Engineering, M.I.T.

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I. Introduction

The Canal Electric Company and Montaup Electric Company propose the addition of a second generating unit to the Canal Plant located on the Cape Cod Canal in Sandwich, Massachusetts. The proposed Unit No. 2 will be 560 MW oil-fired steam electric generating station which utilizes a once-through circulating water system for condenser cooling. The consulting engineers for this project are Stone and Webster Engineering Corporation of Boston, Massachusetts. This report describes a model investigation of submerged diffusers for the circulating water discharge carried out at the Ralph M. Parsons Laboratory for Water Resources and Hydrodynamics of the Department of Civil Engineering at M.I.T.

1.1 Background and Objectives

This study deals with the design of a submerged outfall structure for the discharge of heated condenser cooling water from the Canal Plant, Units No. 1 and 2, into Cape Cod Canal. The discharge is subject to constraints with respect to temperature, velocity and location in order to protect the marine environment and to ensure that there will be no hazard to navigation. Based on studies by the Massachusetts Division of Marine Fisheries, it has been recommended that water temperatures in the discharge area not exceed 86°F in the upper 15 ft. layer. The Corps of Engineers have recommended that velocities perpendicular to the longitudinal axis of the Canal in the surface layer (upper 5 ft.) should be limited to values similar to the present surface discharge of Unit No. 1. The Unit No. 1 discharge structure will become obsolete after installation of the new submerged outfall for Units No. 1 and 2.

A series of hydraulic scale model tests were conducted investigating different designs of submerged diffusers. Preliminary design concepts based on theoretical calculations were provided by Stone and Webster Engineering Corporation.

The objectives of the study were (a) to evaluate various outlet designs with respect to resultant temperature rises and surface velocities, (b) to establish the variability with submergence, location, orientation of the outlet and under conditions of tidal currents, (c) to determine the

amount of recirculation of heated water into the condenser water intakes during ebb tide.

1.2 Site Description

The Canal Plant is located on the southerly bank of the Cape Cod Canal about one mile from the east entrance from Cape Cod Bay (Fig. 1.1). The Cape Cod Canal is a sea-level canal of trapezoidal cross-section connecting Cape Cod Bay with Buzzards Bay and is about seven miles long and 480 feet wide at the bottom. Typical channel depths in the site vicinity are about 40 to 45 ft. below mean sea level (MSL el. 0.0 ft.).

Tidal currents of considerable mangitude are created by marked differences in tidal phase and amplitude in Cape Cod Bay and Buzzards Bay. Fig. 1.2 shows water levels, current velocities and discharge at the site. The duration of flood (eastward flow) is 6.35 hours with a mean velocity of 3.0 fps and a maximum velocity of 4.25 fps. Ebb lasts for 5.95 hours with 3.15 fps and 4.45 fps as mean and maximum velocities, respectively.

Natural water temperatures exhibit both strong seasonal changes and semi-diurnal variations in connection with the tidal movements. Highest temperatures occur during the summer months and thus are most important in design with respect to the temperature constraint. Furthermore, in this summer period Buzzards Bay waters are typically 15°F to 20°F warmer than Cape Cod Bay waters. This temperature differential results in a continuous rise of the water temperature at the site location in the latter part of the flood tide as warm water is advected from Buzzards Bay. The temperature maximum is reached at high water slack (HWS) and maintained for about an hour thereafter until colder water from Cape Cod Bay arrives at the site and the temperatures drop abruptly. This situation is illustrated in Fig. 1.3 for a typical tidal cycle in July.

No natural stratification exists in the canal due to high ambient turbulence.

1.3 Plant Description

Canal Plant - Unit No. 2 will be located adjacent to the Canal Electric Company's existing Unit No. 1. Both units are designed for 560 MW electrical output.

Fig. 1.4 shows the layout of the circulating water system of the plant. Both units draw water from Cape Cod Canal through separate intakes located

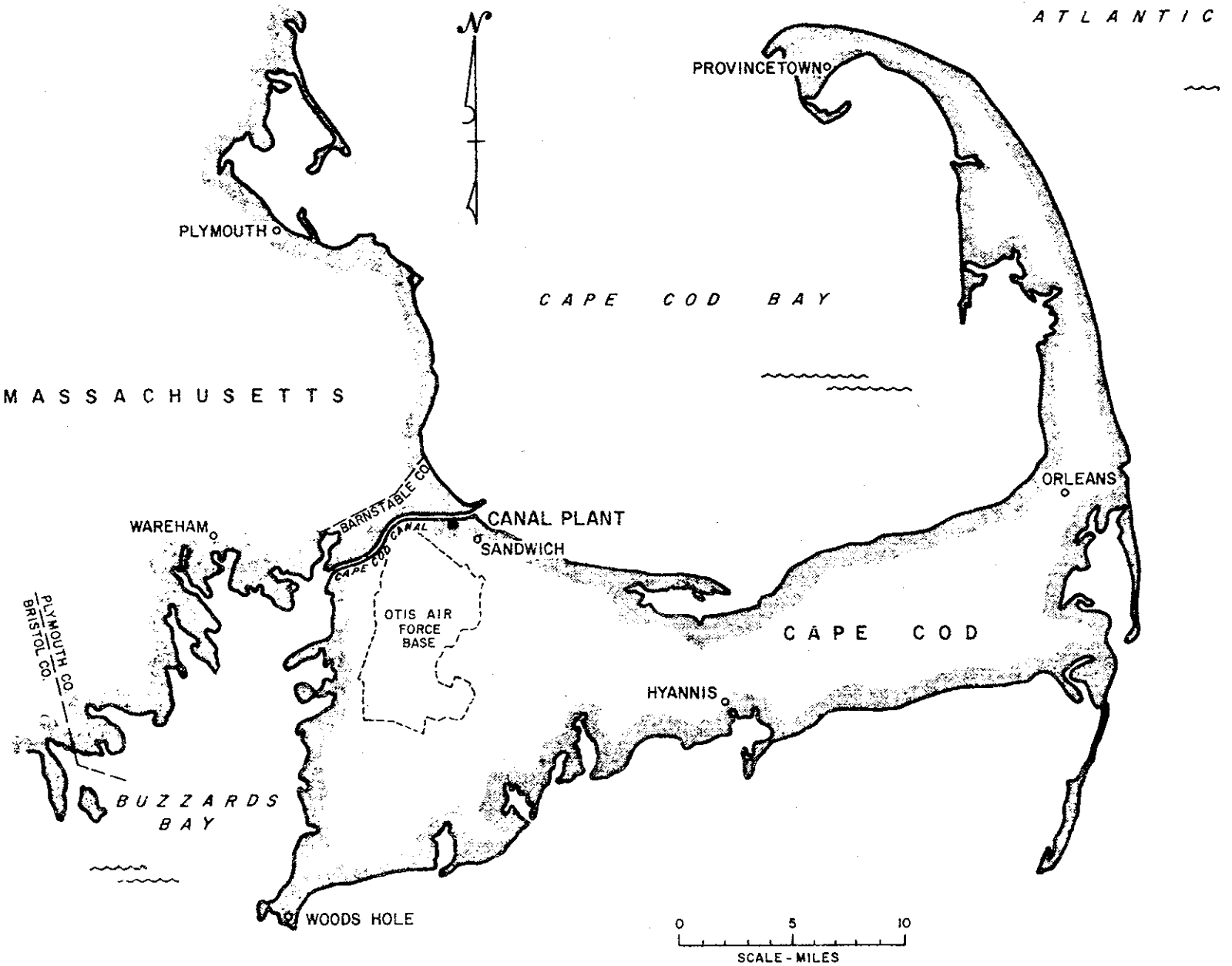


Fig. 1.1 GENERAL LOCATION MAP

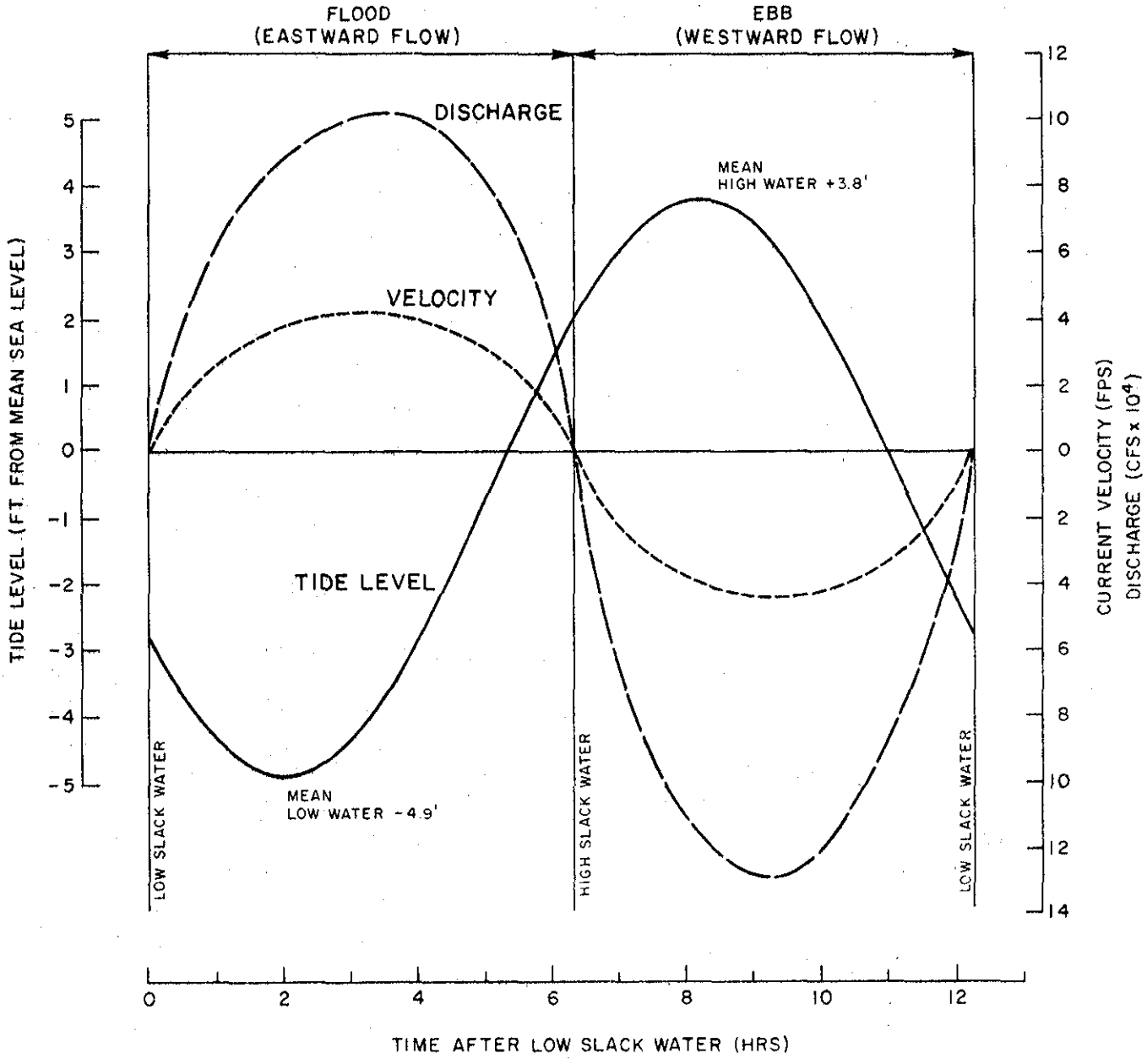


Fig. 1,2 TYPICAL TIDE LEVEL, CURRENT VELOCITY AND DISCHARGE CURVES

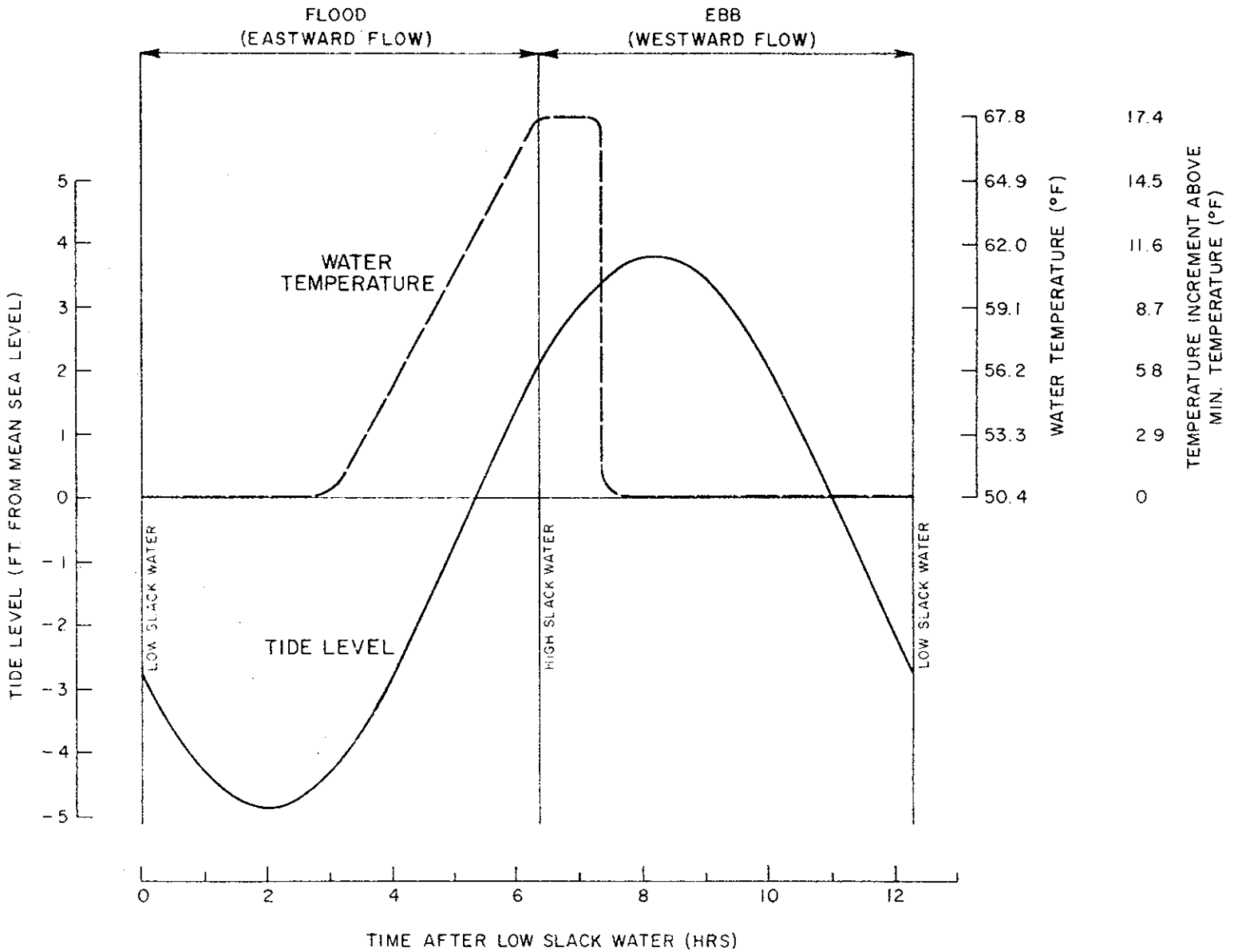


Fig. 1.3 TYPICAL WATER TEMPERATURE AND TIDE LEVEL CURVES FOR JULY

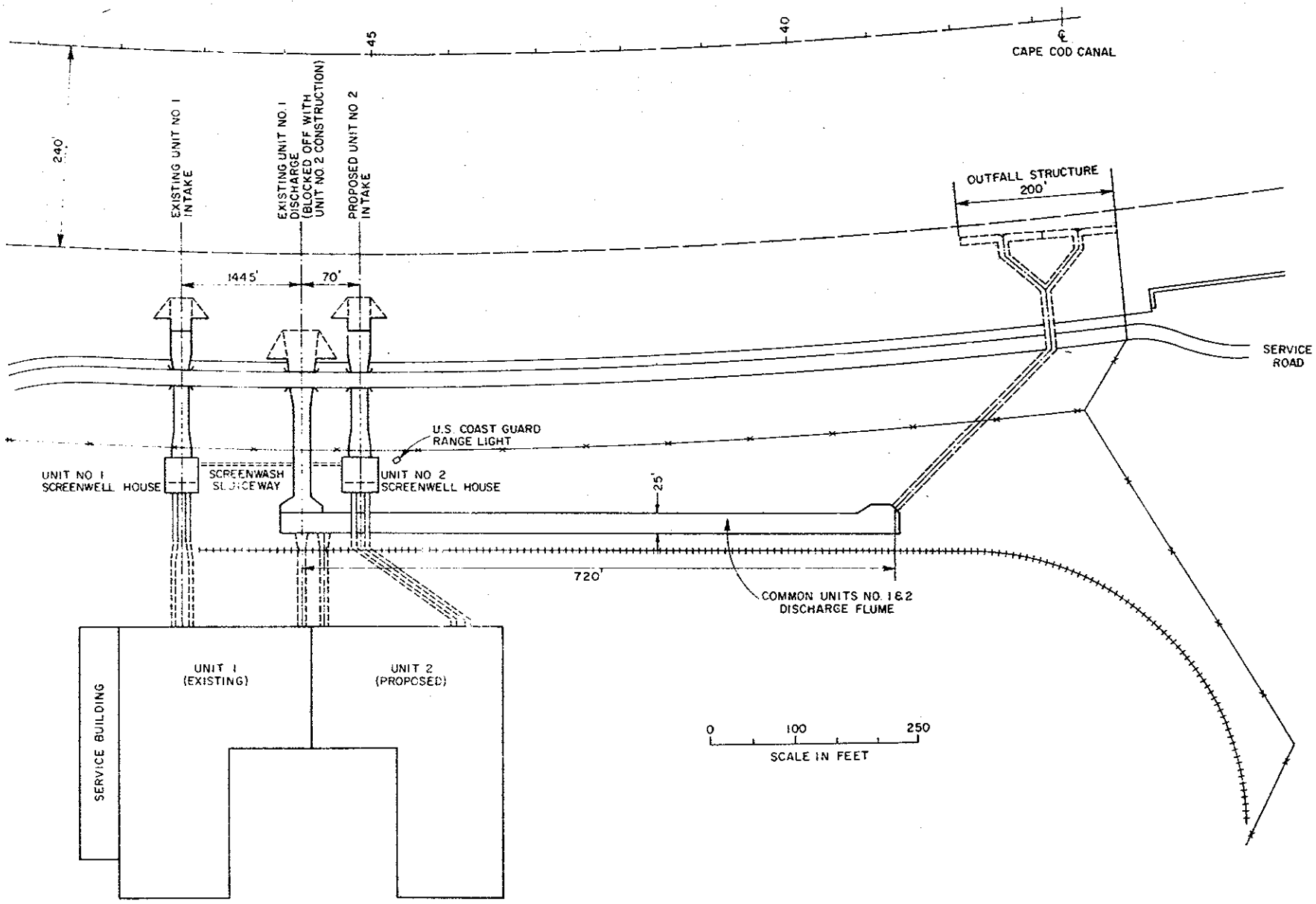


Fig. 1.4 PLAN OF CIRCULATING WATER SYSTEM

at the canal bank. Upon passing through the condensers the flows from Unit No. 1 (372 cfs) and Unit No. 2 (426 cfs) will be combined in a common discharge flume. The total flow of about 800 cfs (258,000 gpm) is conveyed eastward and subsequently discharged through a submerged diffuser located on the slope of the canal bank. (The main channel between the two prismlines has to be kept free for navigation.) The existing surface discharge of Unit No. 1 will be blocked off with the construction of Unit No. 2. The temperature rise through the condensers will be about 28°F.

1.4 Design Considerations

The discharge of the circulating water flow back into Cape Cod Canal was to conform to the following criteria:

a) Water temperatures in the top 15 ft. layer should not exceed 86°F to prevent harmful effects on fish populations. This criterion is based on a survey conducted by the Massachusetts Division of Marine Fisheries. The same survey indicated a maximum ambientwater temperature of 72°F (observed during the critical one hour period at HWS as indicated in Fig. 1.3) as a design basis. As a consequence of the temperature rise across the condenser of 28°F and a maximum allowable temperature of 86°F it follows that the submerged diffuser should be designed to provide a dilution by a factor of at least 2.0 at an elevation 15 ft. below the HWS level (i.e. -13.0 ft. below MSL). Effects of recirculation of heated water at the intakes may require values for the dilution higher than 2.0.

b) Velocities in the surface layer perpendicular to the canal axis should be limited to values similar to the present surface discharge of Unit No. 1. This is to prevent any hazard to navigation. A velocity survey of the existing surface discharge showed an average velocity perpendicular to the canal axis of about 1.6 fps and this was adopted as the appropriate surface velocity criterion.

1.5 Method of Analysis:

Figure 1.5 shows a submerged outfall located on the slope of the cross-sectional prism. The ambient water has a depth, d, a temperature, T_a, and a velocity, V_a. The total condenser flow, Q_o, with temperature, T_o, is discharged through a structure with vertical dimension, B, horizontal dimension, L, vertical orientation, α , and a submergence, h. Depending on the hydrodynamic and geometric characteristics of discharge and ambient water the buoyant jet will rise to the surface in a trajectory with velocities, u, and temperatures, T, along the trajectory. Upon impinging on the surface, a stratified layer with depth, ℓ, velocity, u_s, and temperature, T_s, will form .

Analytical techniques (1), (2), (3) to predict trajectories, centerline temperatures and velocities for the buoyant jet presume an unlimited supply of ambient water. Thus, the boundary effect introduced by the slope of the prism may not be accounted for. Furthermore, no analytical models are presently available to predict the conditions in the stratified surface layer or the degree of recirculation at the cooling water intakes. Therefore, hydraulic scale model tests are necessary to assess the performance of various outfall configurations.

1.6 Modeling Considerations:

Referring to Figure 1.5 the following functional relationship between dependent and initial variables may be expressed in dimensionless form:

$$\left.\begin{aligned} \frac{T - T_a}{T_o - T_a} &= \\ \frac{u_s}{u_o} &= \end{aligned}\right\} \text{functions}\left(\frac{u_o}{\sqrt{(1 - \frac{\rho_o}{\rho_a})\, gB}} \quad \frac{u_o B}{\nu}, \ \frac{B}{d}, \ \frac{h}{d}, \ \alpha, \ \frac{V_a}{u_o} \right)$$

where ρ_o and ρ_a are the densities of heated and ambient water and ν is the kinematic viscosity. To explore the variability of resultant temperatures and surface velocities a certain range of each of the initial variables has to be tested.

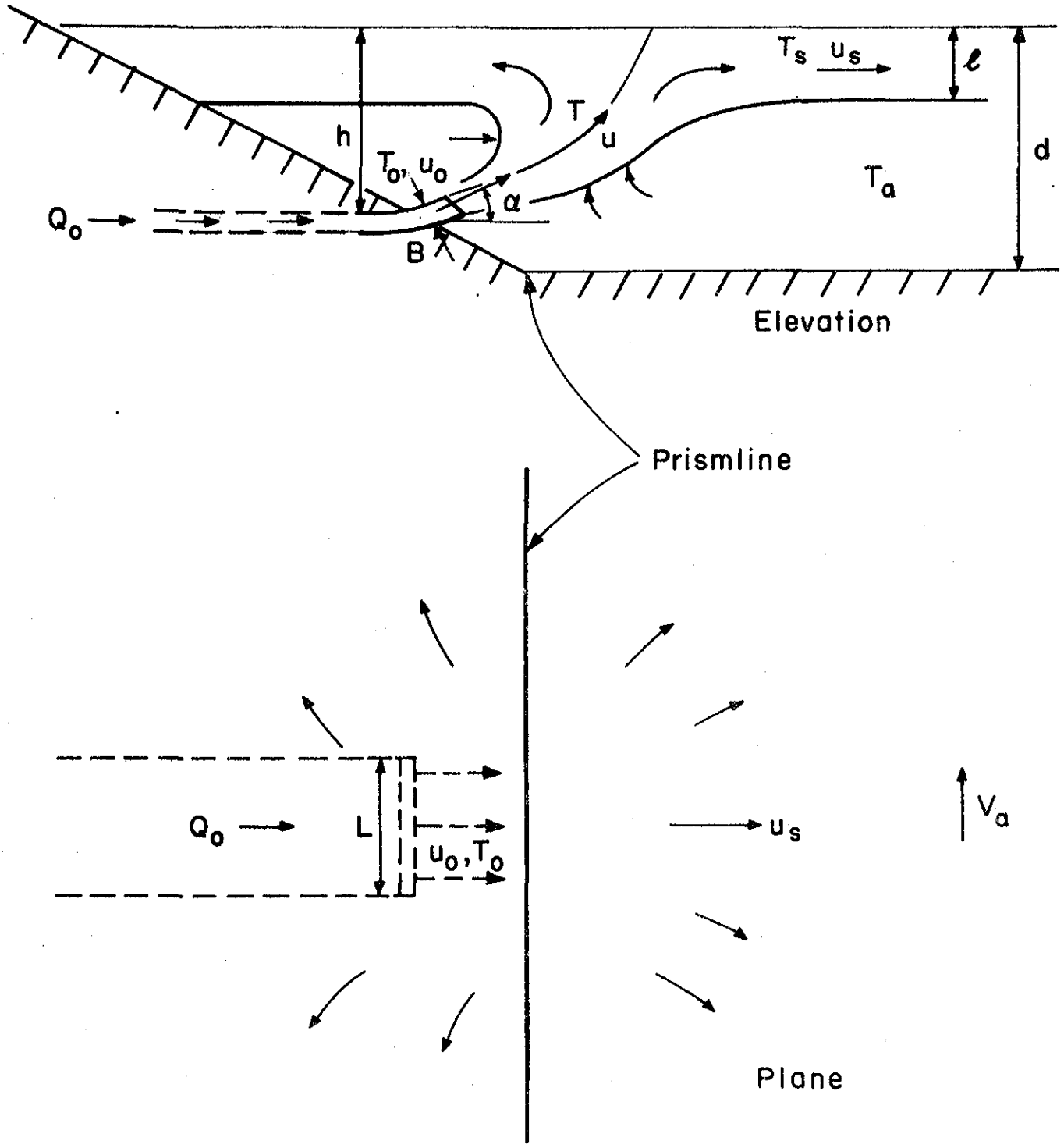


Fig. 1.5 Schematic of a Submerged Outfall Located at the Bank of the Canal Prism.

Similitude requirements for the hydraulic scale model are derived using the basic equations of hydrodynamics and heat transfer for heated discharges (4):

(a) Froude similarity: The densimetric Froude number, $\mathbb{F}$,

$$\mathbb{F} = \frac{u}{\sqrt{\frac{\Delta\rho}{\rho} g y}}$$

where u = characteristic velocity

$\Delta\rho$ = characteristic density difference

ρ = density of ambient water

g = gravitational acceleration

y = characteristic vertical dimension

should be the same for model and prototype, $\mathbb{F}_m = \mathbb{F}_p$.

(b) Geometric similarity: A model reproducing a near field submerged jet region should be undistorted.

(c) Reynolds similarity: To insure a sufficient level of turbulence in the model the Reynolds number,

$$\mathbb{R}_m = \frac{u_m y_m}{\nu}$$

should be no less than about 1000.

The model scale was chosen to be as large as possible in order to increase accuracy and convenience of measurements while reproducing a certain canal length including intakes and the opposite bank within the available laboratory facility. Therefore an undistorted model of scale 1:64 was chosen.

The model laws described earlier are used to calculate the velocity and flow ratios (subscript r) corresponding to this scale ratio assuming that $(\Delta\rho/\rho)_r = 1.0$, i.e. that the model and prototype have the same initial density difference.

In actuality the density differences and hence the Froude numbers are slightly sensitive to the temperatures used in modeling:

$$\frac{\Delta\rho}{\rho} g \quad 72°-100° = 0.158 \text{ and } \frac{\Delta\rho}{\rho} g \quad 55°-83° = .103$$

Theoretical calculations are based on the former value (for ambient temperatures = 72°F) providing a lower (and more conservative) Froude number than in actual prototype conditions.

Thus:	length ratio	$\ell_r = 1:64$
	velocity ratio	$u_r = 1:8$
	discharge ratio	$Q_r = 1:33,000$

II. The Test Program

2.1 Experimental Set-up

Information on prototype layout and dimensions was obtained from charts and recent depth sounding surveys conducted by the Corps of Engineers. On the basis of these data the following schematization of the canal cross-section was adopted: (see Fig. 2.1)

a) A constant average depth of the channel bottom below mean sea level (MSL) of 45 ft., b) the mooring basin on the bank opposite the plant site was not modeled in detail, but rather a constant slope of 1:2.5 was assumed in combination with a widening of the channel bottom, thus maintaining the same cross-sectional area. This schematization is desirable from the point of view of model construction and is believed to have no influence on the model prediction.

The model was constructed in a 46' x 28' x 1.5' laboratory basin, thus allowing replication of 2950' prototype canal length. Figures 2.2, 2.3, 2.4 show the experimental set-up. The banks of the canal were built of 8' x 2.5' x 1" marine plywood sheets treated with wood filler and two coats of marine paint. A 5" x 2-1/2" steel beam was attached to each sheet to prevent buoyancy. Twelve such modules were fabricated and placed along the prism lines of the canal at the slope 1:2.5. The joints between bottom and plywood were sealed with construction sealant. To minimize structural requirements of the modules the basin area outside the modeled area was also filled with water. Intake (with skimmer wall and fishsill) and discharge structures were installed at the proper locations. The different discharge structures tested in the program could be easily exchanged.

A circulating water system was set up for the generation of tidal cross currents in the canal in both directions. Two 13' x 4" pipe manifolds were installed in two 1' wide channels at either end of the basin. Two pumps (5 HP, 250 gpm and 15 HP, 500 gpm) and a system of valves allowed current generation for both flood and ebb tide. An elbow meter for circulating flow measurement was included in the pipeline and calibrated. The lateral uniformity of the cross current was established by constructing overflow weirs which were adjustable in height at the basin ends.

The condenser water circulation was simulated in the following way: water was withdrawn from the two intakes by the individual small pumps, the flow rate

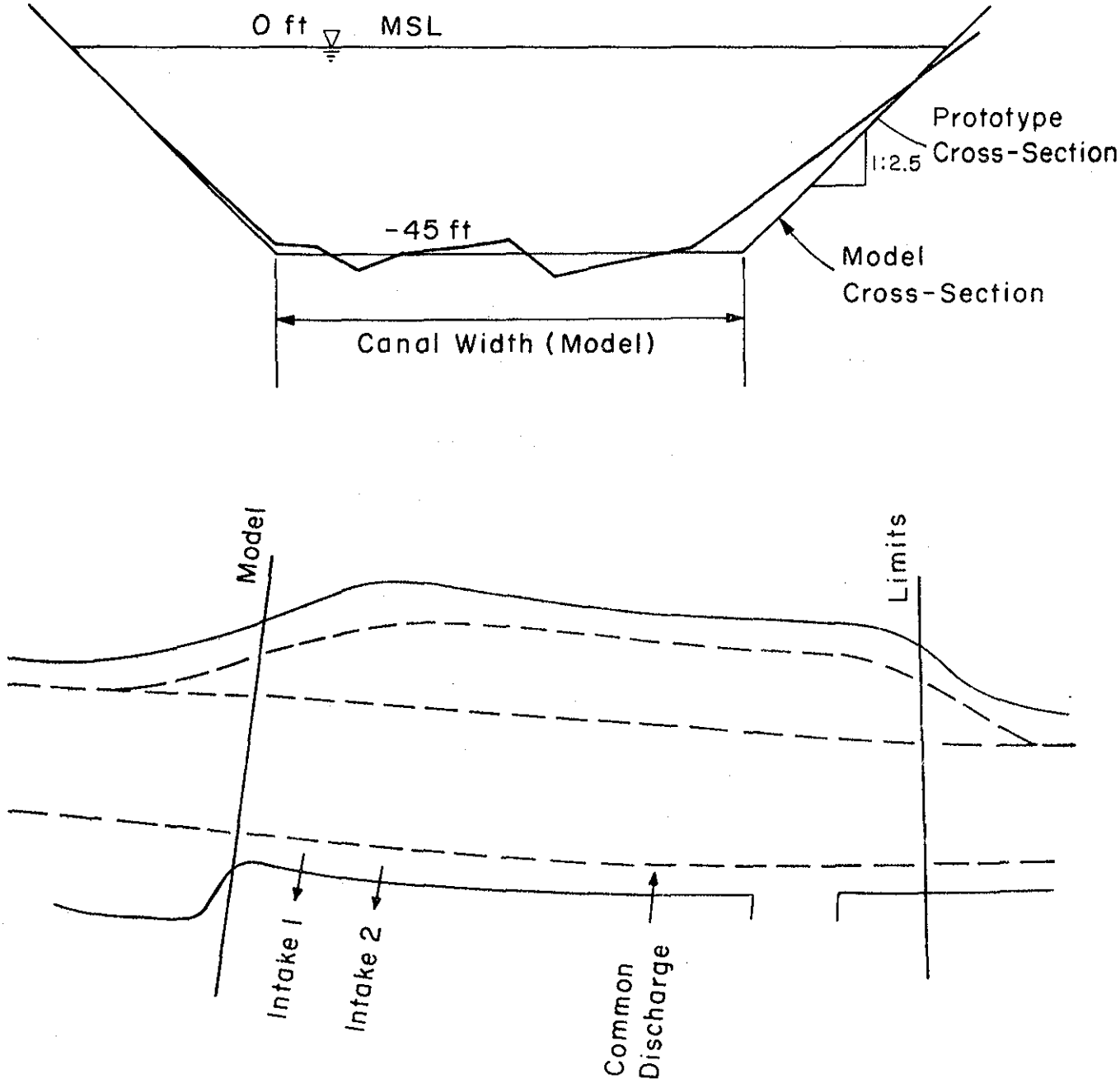


Fig. 2.1 Schematization of Prototype Layout in Scale Model.

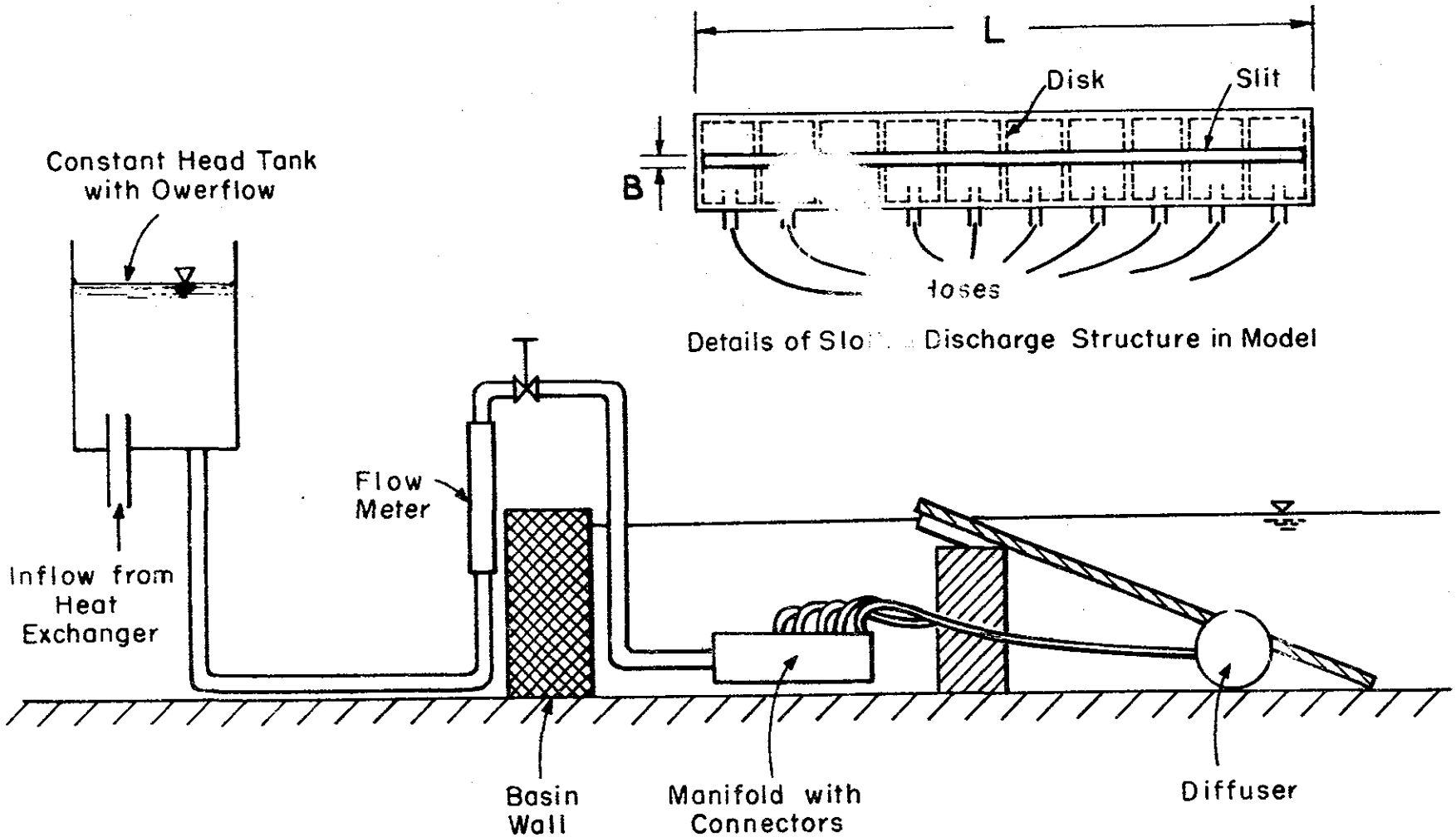


Fig. 2.2 Cross-Section View of Experimental Set Up. (Slotted Discharge).

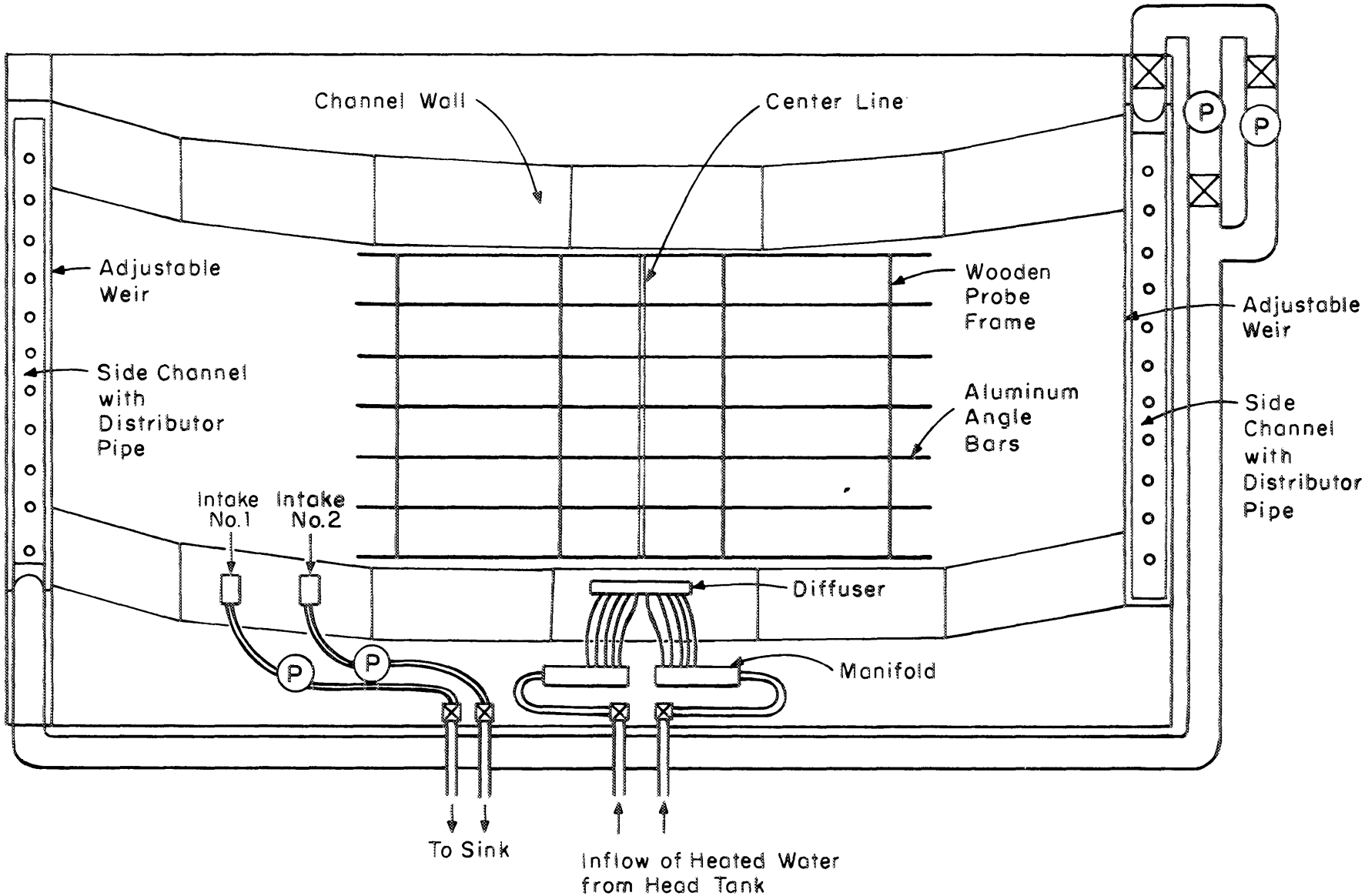
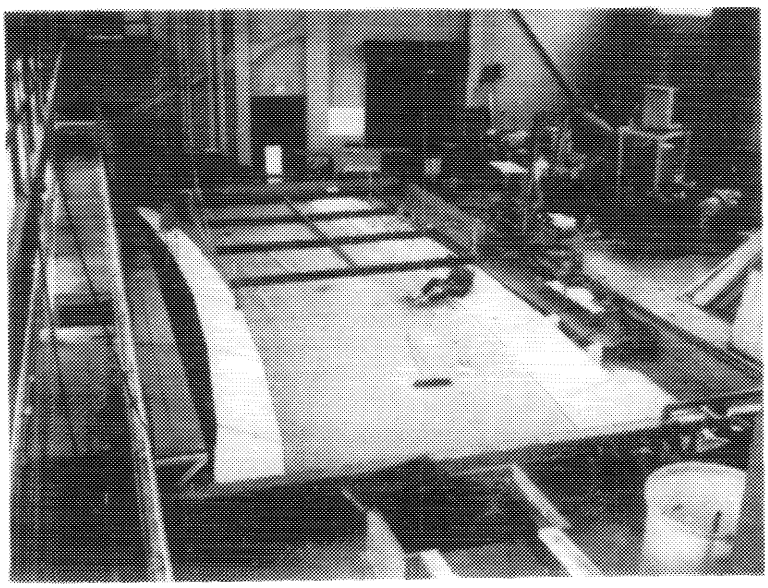


Fig. 2.3 Plan View of Experimental Setup.



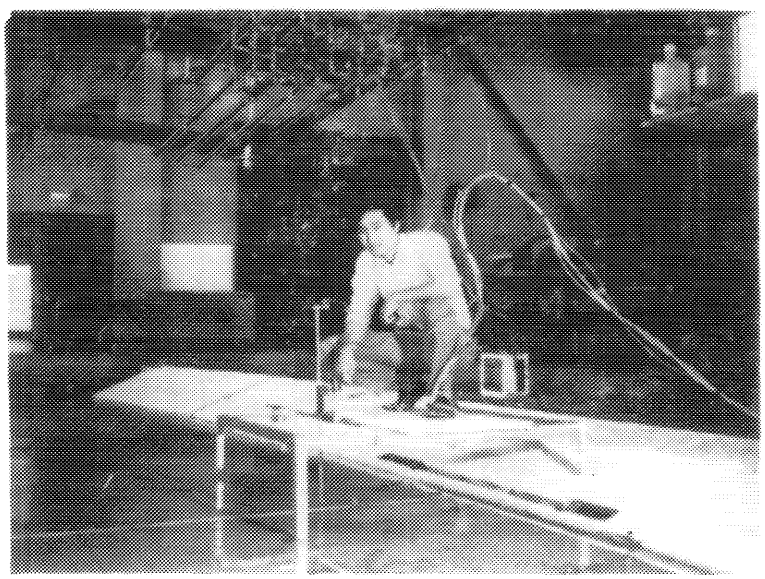


Fig. 2.4. Photographs of the Model Set-up

being monitored by Brooks rotameter flowmeters, and discharged in a drain. Simultaneously, heated water (with a temperature rise of about 28° above the intake water temperature) was obtained from a steam heat exchanger. To insure constant flow and temperature a constant head mixing tank was placed in the discharge line. The flow from the tank to the submerged outfall was measured by a pair of Brooks rotameter flowmeters (capacity 6.3 gpm). Descriptions of the outfall models will be given in the following section.

Extensive instrumentation was used to determine both temperatures and velocities:

a) An array of 60 Yellow Springs Instrument thermistor probes (time constant 7 sec. reproducibility 0.05°F) were individually calibrated and mounted in fixed positions in the model area. Most of these probes recorded surface temperatures and were mounted on a frame which held them suspended about 1/4" to 1/2" below the water surface. The frame could be lifted by hoists to allow working underneath; additional probes were used to monitor intake, discharge, ambient and bottom temperatures. The probes were scanned and the temperatures printed on paper tape to the nearest 0.1°F by an automatic system manufactured by Digitec-United Systems.

b) A movable, calibrated Fenwal thermistor probe (time constant 0.6 sec.) was mounted on a monitorized point gage. The probe could be shifted on a 3' x 4' aluminum frame to the desired location, where a vertical scan was then taken and recorded on an x-y plotter. Horizontal scans were possible by shifting the probe by hand at a certain elevation.

c) A mini-flowmeter propeller current meter allowed measurement of velocity components, depending on its orientation, with a threshhold of about 1.5 in/sec corresponding to prototype speeds of 1 fps. The current meter was calibrated in a circulating flume and could be mounted on the same aluminum frame as the movable thermistor probe.

d) Photographic techniques were also utilized. The buoyant rise of the jets was observed with an underwater camera. Surface velocity

patterns were determined by throwing paper chips on the water surface and taking a time exposure picture with a camera with calibrated shutter speeds. However, effects of surface tension, even when applying wetting agents, affected the accuracy of this measurement, so that these pictures were used only in a qualitative way to observe velocity patterns.

2.2 Experimental Procedure

Before the start of a run the water level in the basin was brought to the correct elevation. The water was thoroughly mixed to assure that no initial stratification existed. The hot water was adjusted well in advance to reach a steady temperature in the mixing tank. The establishment of the desired temperature difference of 28°F was only approximately possible due to transients in the system. However, actual differentials were kept between 27°F and 29°F, the deviations having a negligible dynamic effect.

The test was then started and, when visual observation had shown that the heated jet had reached a steady state behavior, measurements were taken.

2.3 Experimental Results

Tests on three different submerged outfall schemes were conducted. These were: a) a round pipe discharging perpendicularly to the prism line, b) a double-slot outfall structure discharging at 15° to the prism line, and c) a slotted pipe laid parallel to the prism line and discharging perpendicularly to the cross current. A detailed description of these tests is given below.

2.3.1 Tests with a Submerged Round Pipe

The discharge was modeled with a PVC pipe. Only half of the cooling water discharge was simulated in these runs. Five tests were performed with varying pipe diameter, D, (related to exit velocity, $u_o = Q_o / \frac{\pi D^2}{4}$, submergence, h, and angle of inclination, α. Table 2.1 gives a summary of initial parameters for both model and prototype. All tests were performed at LWS (elevation -2.8 ft. below MSL) with no tidal current.

The results of the test are presented in Table 2.2 in terms of prototype values. The table shows maximum observed surface velocities, u_s, perpendicular to the canal centerline and maximum observed surface temperatures, $T_{s_{max}}$. The table also includes a value for dilution, S_o, at the surface. Dilution is defined as

Table 2.1 Test Parameters for Round Pipe Tests

Run No.	MODEL D (in)	MODEL u_o (fps)	MODEL h (in)	MODEL α	T_a (°F)	$T_o - T_a$ (°F)	$\mathbb{F}_o = \frac{u_o}{\sqrt{\frac{\Delta\rho}{\rho_a} gD}}$	PROTOTYPE D_o (ft)	PROTOTYPE u_o (fps)	PROTOTYPE h (ft)	PROTOTYPE α
1	1.380	1.17	4.16	0°	72.4	27.3	8.70	7.37	9.40	22.2	0°
2	1.049	2.05	4.16	0°	71.5	26.9	17.20	5.60	16.2	22.2	0°
3	1.500	.99	4.16	0°	75.8	28.6	7.10	8.00	7.95	22.2	0°
4	1.380	1.17	4.16	-10°	72.8	27.6	8.70	7.37	9.40	22.2	-10°
5	1.380	1.17	5.10	0°	74.9	27.6	8.70	7.37	9.40	27.2	0°

Table 2.2 Results of Round Pipe Tests

Run No.	OBSERVED VALUES u_s (fps)	OBSERVED VALUES $T_{s_{max}}$ (°F)	OBSERVED VALUES S_o	$\mathbb{F}_o$	PREDICTED VALUES (Ref. 1) S_m
1	3.55	8.1	3.37	8.70	3.00
2	3.70	4.9	5.50	17.20	5.15
3	4.30	9.1	3.14	7.10	2.63
4	2.15	3.9	7.10	8.70	not available
5	3.00	7.0	3.95	8.70	3.80

$$S_o = \frac{T_o - T_a}{T_{s_{max}} - T_a}$$

Observed dilutions are also compared with theoretical predictions given by Abraham (1) for a buoyant jet in an unconfined field.

The comparison is made at an elevation corresponding to the surface elevation in the model.

$\mathbb{F}_o$ is the densimetric Froude number based on discharge pipe diameter, $\frac{u}{\sqrt{\frac{\Delta\rho}{\rho} gD}}$. The results indicate the effectiveness of a high velocity discharge in providing high dilutions of the discharge flow. However, the resulting velocities normal to the canal axis are also high. The effect of increased submergence is seen by comparing Run 5 with Run 1; similarly the effect of downward discharge (-10°) is seen by comparing Run 4 with Run 1. Both Run 4 and 5 result in an increased path length of the rising jet thereby prolonging the turbulent entrainment process and improving dilution and velocity reduction. The results compare rather well with theoretical predictions, thus showing that boundary effects due to the presence of the canal banks and bottom are negligible. Therefore preliminary theoretical calculations which had shown that it was impossible to obtain low surface velocities when using a high velocity discharge from two or several round pipes are validated.

2.3.2 Tests with a Double-Slot Outfall Structure Discharging at 15° to the Prism Line

Figures 2.5 and 2.6 show the basic outfall arrangement as developed by Stone & Webster. The objective is to discharge at a certain angle to the prism line so that as the jet reaches the surface the velocity component perpendicular to the prism line would be small. The structure discharges symmetrically with respect to the canal cross section.

Three tests providing some variation in both outlet geometry, (length to width ratio) and exit velocity, u_o, were conducted. A summary is given in Table 2.3.

Plexiglass models were constructed with three different slot geometries (Figure 2.6). The tests were run with LWS and no cross current velocities.

Results of the tests are summarized in Table 2.4, giving surface velocity

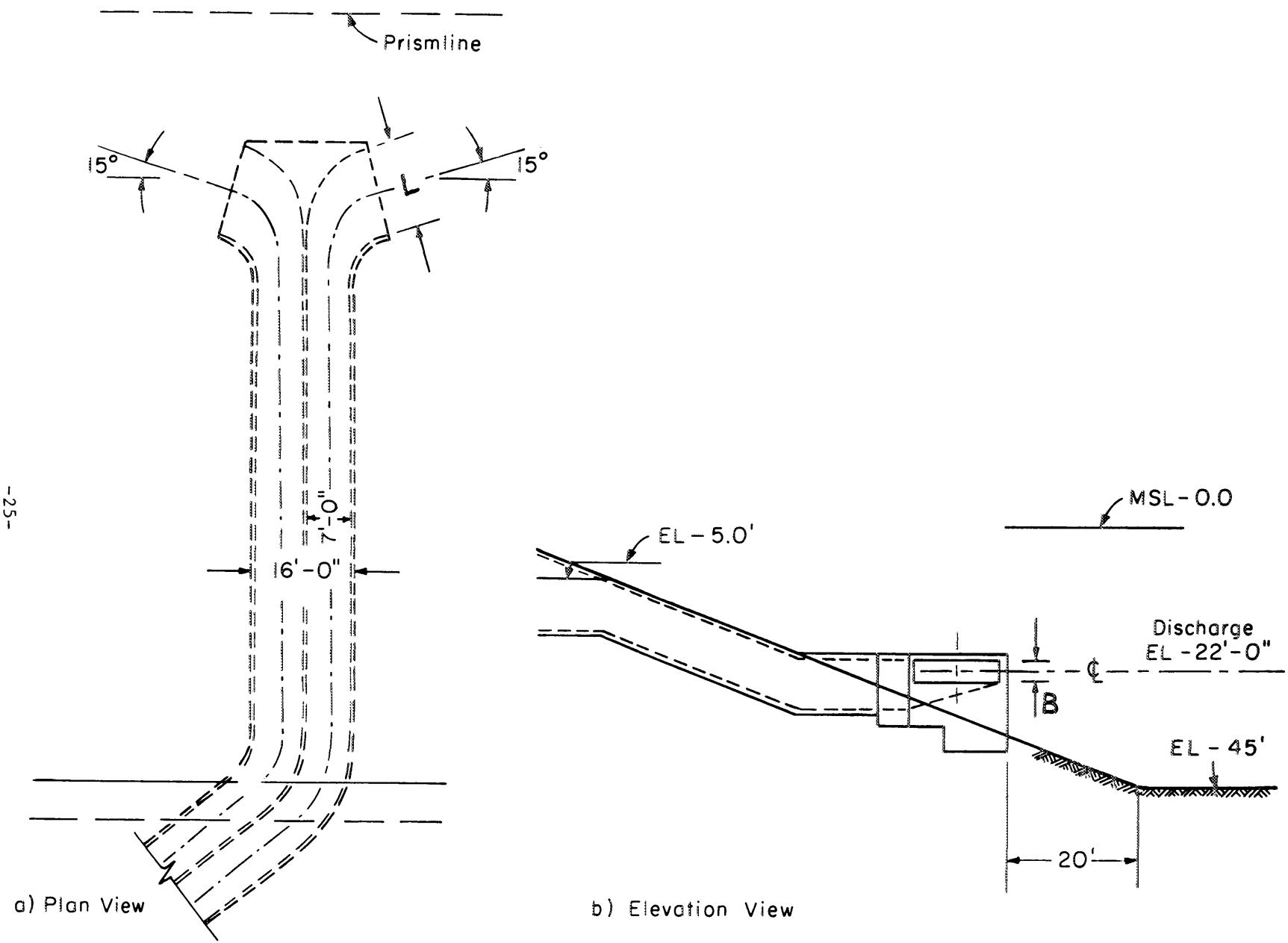


Fig. 2.5 Arrangement of Double Slot Outfall Structure.

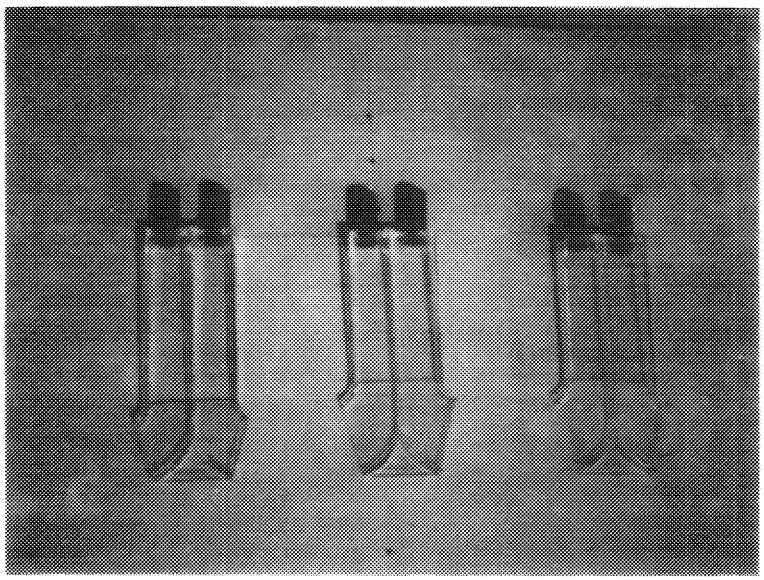


Fig. 2.6. Plexiglass Models of Double-Slot Outfall Structures

Table 2.3 Test Parameters for Double-Slot Outfall Structure

Run No.	MODEL B x L (in)	MODEL u_o (fps)	MODEL h (in)	T_a (°F)	$T_o - T_a$ (°F)	$\mathbb{F}_o = \frac{u_o}{\sqrt{\frac{\Delta\rho}{\rho_a} gB}}$	PROTOTYPE B x L (ft)	PROTOTYPE u_o (fps)	PROTOTYPE h (ft)
19	2.62x0.656	1.02	3.50	75.5	27.9	10.95	14 x 3.5	8.15	19.2
20	3.37x0.562	0.92	3.50	73.4	28.8	10.72	18 x 3.0	7.39	19.2
21	3.37x0.842	0.62	3.50	76.9	28.8	5.83	18 x 4.5	4.93	19.2

Table 2.4 Test Results for Double-Slot Outfall Structure

Run No.	Surface Velocity Component Perpendicular to Prism Line (fps)	Surface Temperature Rise ($T_{s_{max}}$)	S_o
19	1.5	6.9	4.05
20	1.65	7.1	4.06
21	1.30	7.3	3.95

components perpendicular to the canal prism line and surface temperature rises. No measurements of the absolute surface velocity were made. However, photographic and visual observation showed that the absolute velocities were about 2 to 3 times higher than the component given in Table 2.4. Figure 2-7 shows a typical surface velocity pattern looking toward the bank. The tests showed reasonable agreement with calculated values although some boundary effects, inasmuch as the jets are discharged relatively close to the bank, should have been present. Thus at slack tide, this scheme should generate low surface velocities perpendicular to the canal and adequate dilution. However, no satisfactory agreement can be anticipated under conditions of tidal cross currents. Then the momentum of the oncoming current will deflect the jet branch issuing against the current toward the center of the canal. Therefore high surface velocities perpendicular to the canal will be generated. Thus no tests under cross flow conditions were initiated.

2.3.3 Tests with a Slotted Pipe

The above described tests showed that submerged outfalls with concentrated high velocity discharge will not provide sufficiently low surface velocities. Subsequently, a different design concept, using a low velocity discharge from a slotted pipe which distributes the cooling water flow over a certain distance along the shore, was used. In this scheme the velocities at the surface will be less dominated by the initial jet momentum, but rather a density current in a warm water layer at the surface will be generated by the local pressure increase (surface rise) where the plume impinges on the surface.

A limited test program was carried out in which the initial jet parameters were varied in a systematic way in order to determine the sensitivity of the surface velocity as a function of these parameters. These tests were conducted in a stagnant ambient water (LWS or HWS). In addition the effects of cross currents and current reversals were tested for an arrangement feasible under stagnant conditions.

A PVC pipe with a milled slot was supplied with hot water at both ends and was used in a first series of runs (Runs 6 to 15). However, poor uniformity of the exit flow even when using wire mesh and horse hair to vary the resistance along the pipe did not yield a consistent set of data. Thereafter a 2-1/2" PVC pipe with a milled slot was divided into compartments 3.75" long (20 ft. prototype) and each compartment was connected to an individual hot water feeder line. This diffuser design is shown as a detail of Figure 2.2. Good uniformity of exit

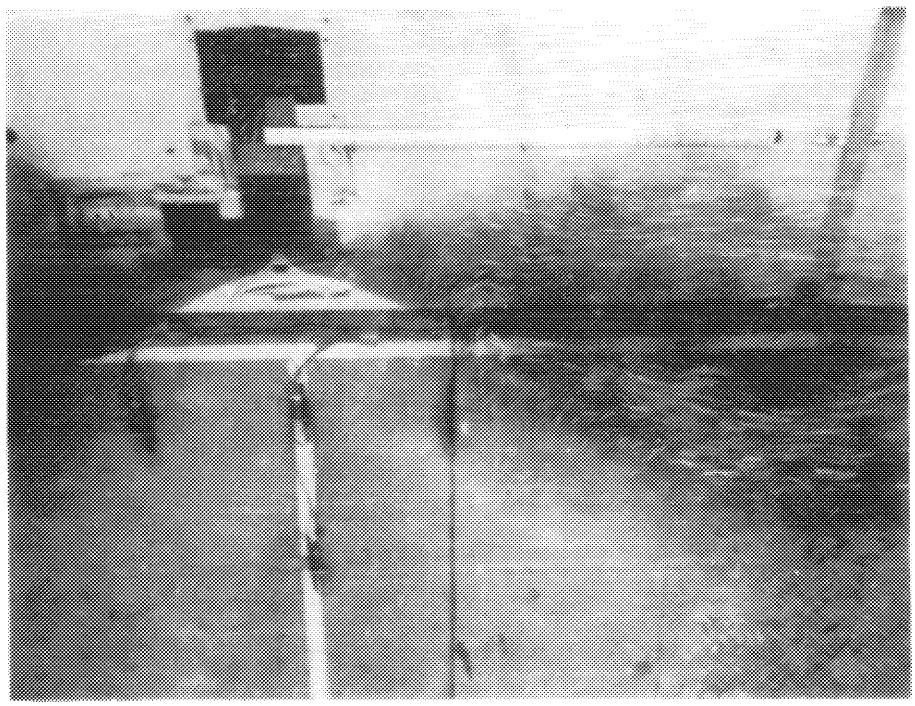


Fig. 2.7. Surface Velocity Pattern for Double Slot Discharge (The outfall structure is located in the upper left quarter of the picture) (Run 19)

velocities was obtained for these runs (22 to 35).

A summary of the runs is given in Table 2.5. The jet model Reynolds number $\mathbb{R} = \frac{u_o B}{\nu}$ for these tests is about 1000. Based on the work by Albertson, et.al. (4) this value is sufficient to attain full turbulence in the model.

2.3.3.1 Tests with No Cross Currents

In runs with stagnant ambient conditions the following behavior was observed: the buoyant plume rose to the surface either vertically ($\alpha = 90°$) or deflected sharply ($\alpha = 0°$ or $45°$). From the line of impingement, the flow spread in a warm water layer in both directions, forward into the canal and backward against the bank (see Figure 2.8). The fractions of forward and backward flow were somehow dependent on the jet angle, more backward flow being introduced for vertical discharge ($\alpha = 90°$). Experimental results for tests with no cross currents are shown in Table 2.6. Observed maximum surface velocities are average values of a group of measurements taken over a distance corresponding to the pipe length. Some turbulent fluctuations were observed with deviations of $\pm$ 10% maximum. Both maximum temperatures observed at the lower edge of the 15 ft. upper layer, $T_{c_{max}}$, and at the surface $T_{s_{max}}$, and corresponding dilutions are reported in the table. The thickness of the warm water layer was determined from vertical temperature profiles and taken as the depth where the temperature rise was half the surface temperature rise. In most runs quite a distinct interface existed (see Figure 2.9).

Discussion of Results for No Cross Current Conditions

To explain the variability of surface velocities with initial jet characteristics a semi-empirical two-dimensional analysis is developed.

Referring to Figure 2.10 the initial discharge per unit width is

$$q_o = \frac{Q_o}{L}$$

In rising to the surface turbulent entrainment will increase the mass flux along the jet. When the jet arrives at the surface the total mass flux q_s can be written as

$$q_s = k_1 S_{o_s} q_o \qquad (2\text{-}1)$$

Table 2.5 Summary of Run Parameters for Slotted Pipe Tests

Run No.	MODEL L (in)	B (in)	u_o (fps)	h (in)	α	T_a (°F)	T_o-T_a (°F)	PROTOTYPE L (ft)	B (ft)	u_o (fps)	h (ft)	α	REMARKS (ambient conditions)
22	30	.281	.42	5.5	90°	72.3	28.6	160	1.5	3.33	29.2	90°	LWS
23	30	.281	.42	5.5	45°	72.5	28.0	160	1.5	3.33	29.2	45°	LWS
24/26	30	.281	.42	5.5	0°	74.6	27.8	160	1.5	3.33	29.2	0°	LWS
25	37.5	.281	.33	5.5	0°	76.6	28.4	200	1.5	2.67	29.2	0°	LWS
27	37.5	.281	.33	5.5	90°	73.7	27.8	200	1.5	2.67	29.2	90°	LWS
28	22.5	.281	.56	5.5	90°	75.9	27.8	120	1.5	4.45	29.2	90°	LWS
29	30	.281	.42	6.4	90°	72.1	28.0	160	1.5	3.33	34.0	90°	HWS
30	30	.281	.42	6.4	90°	72.7	27.8	160	1.5	3.33	34.0	90°	Current Reversal at HWS; using Partition
31/32	30	.281	.42	6.4	90°	72.7	27.2	160	1.5	3.33	34.0	90°	Steady Current Ebb; 0.36 FPS
33	30	.375	.31	5.5	0°	72.4	27.6	160	2.0	2.50	29.2	0°	LWS
34	30	.281	.42	6.4	90°	72.5	27.5	160	1.5	3.33	34.0	90°	Current Reversal at HWS; No Partition
35	30	.281	.42	6.4	90°	73.4	27.0	160	1.5	3.33	34.0	90°	Steady Current, Flood, 1.12 FPS
36	30	.281	.42	6.4	90°	75.7	27.7	160	1.5	3.33	34.0	90°	Steady Current, Ebb; .72 fps
37	30	.281	.42	6.4	90°	74.5	26.7	160	1.5	3.33	32.0	90°	Steady Current, Flood, 2.2 fps
38	30	.281	.42	6.5	90°	76.4	28.0	160	1.5	3.33	34.5	90°	Steady Current, Ebb, 1.44 fps
40	30	.281	.42	6.4	90°	69.0	28.5	160	1.5	3.33	34.0	90°	Steady Current, Flood, 0.56 fps
41	30	.281	.42	6.4	90°	69.9	26.8	160	1.5	3.33	34.0	90°	Steady Current, Ebb, 0.36 fps, Full Surface Temperature Survey

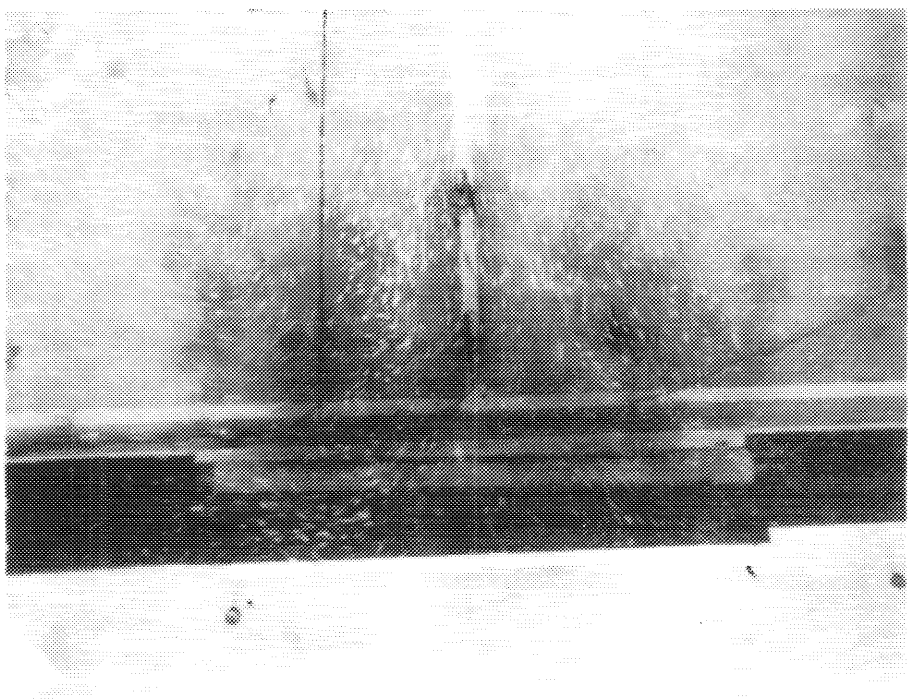


Fig. 2.8. Surface Velocity Pattern for Slotted Pipe Discharge
(Run 23, $\alpha = 45°$, L = 160 ft., B = 1.5 ft., u_o = 3.33 fps)

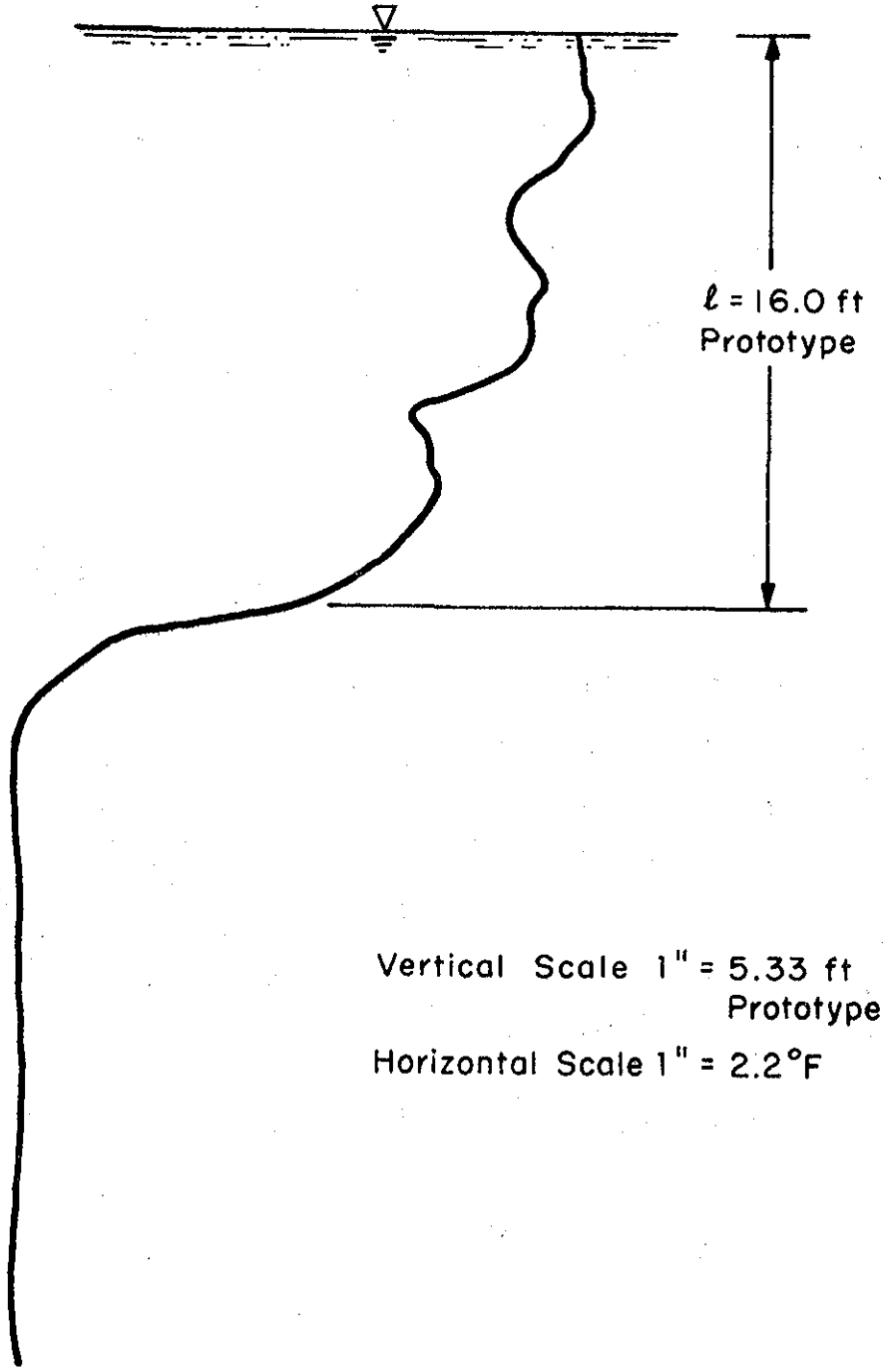


Fig. 2.9 Typical Warm Water Layer in the Flow Away Zone.

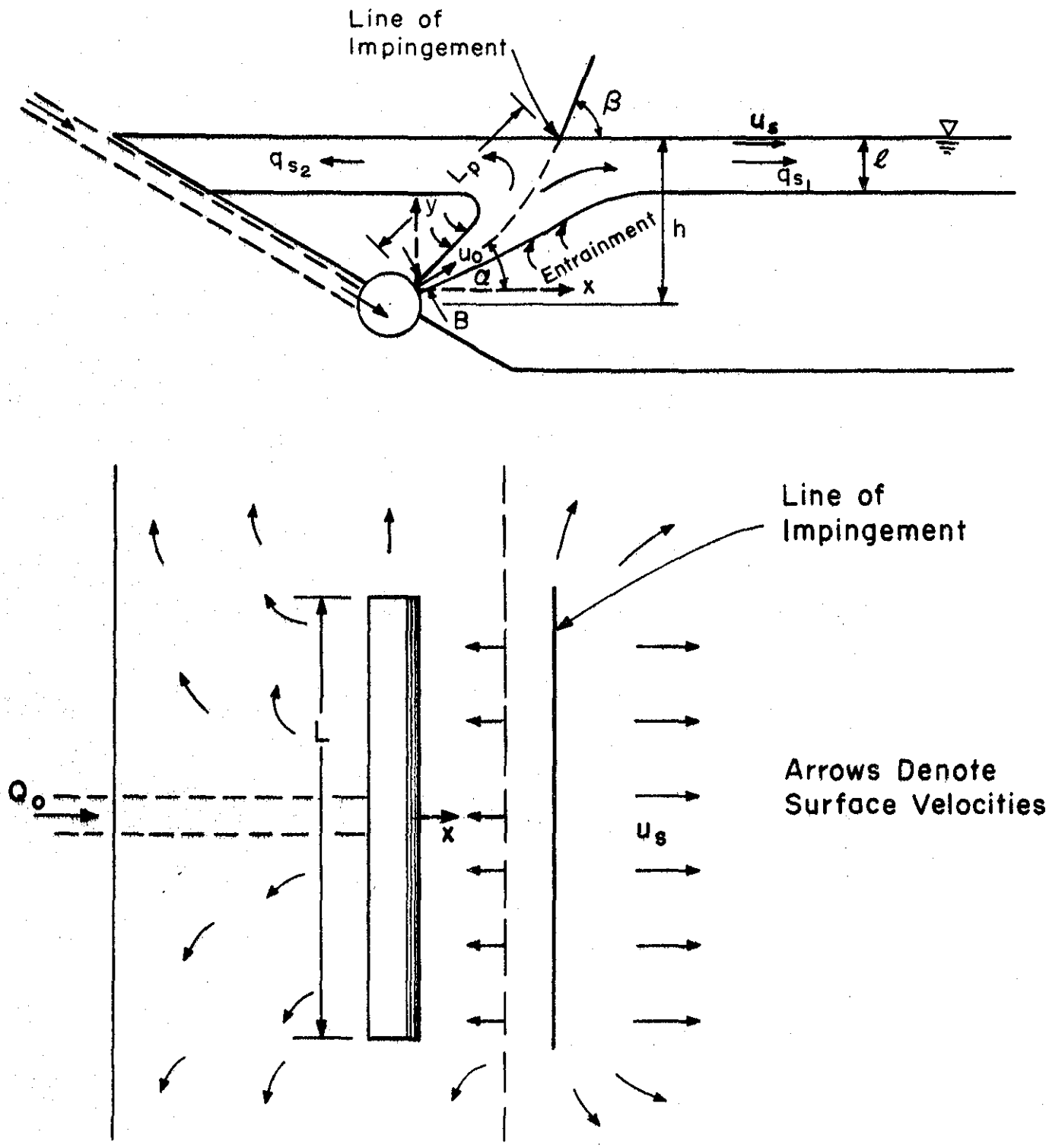


Fig. 2.10 Analysis of a Slotted Pipe Discharge.

where S_{o_s} is a theoretically predicted centerline dilution in an unconfined medium at the surface elevation, and k_1 is a factor which takes into account the boundary effect which will influence the theoretical predictions. In the following discussion, Reference 3 (Fan and Brooks) will be used for theoretical predictions of dilution.

Depending on the angle of impingement, β, the total mass flux, q_s, will in part move forward, q_{s_1}, and in part move backward, q_{s_2}. To determine these fractions the analogy of a free jet impinging on a flat surface with an angle β may be used. An analysis using a momentum and continuity equation yields

$$q_{s_1} = q_s \left(\frac{1 + \cos \beta}{2}\right) \tag{2-2}$$

The value β may be obtained as well from theoretical predictions of trajectories of slot buoyant jets (3).

Thus the mass flux moving forward in the warm water layer is

$$q_{s_1} = k_1 S_{o_s} q_o \left(\frac{1 + \cos \beta}{2}\right) \tag{2-3}$$

Final maximum velocities in the warm water layer will then depend on the thickness of the layer, ℓ , and on the velocity distribution. No theoretical information on the layer thickness is available, and it is certainly dependent on boundary conditions. Previous investigations (see Ref. 1) have shown that the layer thickness is correlated by a constant factor to the length of the path, L_p, of the rising jet. A similar dependence on the path length was observed in this study (see Table 2.7). Thus it can be written that

$$\ell = k_2 L_p \tag{2-4}$$

Dividing Equation 2-3 by Equation 2-4 would yield the average velocity $u_{s_{av}}$ in the warm water layer. In order to obtain the maximum velocity u_s an assumption of a certain velocity distribution would be necessary. Assuming

$$u_s = k_3 u_{s_{av}} \tag{2-5}$$

Table 2.6 Summary of Results for Slotted Pipe Tests (Stagnant)

Test No.	u_s (fps)	Lower Edge of 15 Ft. Layer $T_{c_{max}}$ (°F)	S_{o_c}	Surface $T_{s_{max}}$ (°F)	S_{o_s}	Depth of Warm Water Layer ℓ (ft)	IF_o
22	1.60	14.4	1.99	11.2	2.55	14.7	6.85
23	1.90	12.0	2.24	10.3	2.72	16.7	6.85
24/26	2.00	8.9	3.12	7.9	3.52	25.1	6.85
25	1.75	8.6	3.31	7.7	3.69	18.1	5.5
27	1.40	12.6	2.21	11.3	2.55	13.9	5.5
28	2.05	13.7	2.03	10.2	2.73	no data	9.15
29	1.60	12.6	2.22	8.5	3.30	15.5	6.85
33	1.75	12.3	2.25	10.3	2.68	16.0	4.45

Table 2.7 Survey of Observed and Predicted Values of Plume Characteristics

Run No.	Dilution S_{o_s} Observed (1)	Predicted (2)	Ratio $\frac{(1)}{(2)}$	β	L_p (ft)	ℓ (ft)	ℓ/L_p	Maximum Surface Velocity u_s Observed (3) (fps)	Predicted Eq. 2-7 (4) (fps)	Ratio $\frac{(3)}{(4)}$
22	2.55	3.7	.69	90°	29.2	14.7	.50	1.60	1.63	0.98
23	2.72	3.9	.70	66°	33.0	16.7	.51	1.90	2.01	0.95
24/26	3.52	4.8	.73	58°	46.5	25.1	.54	2.00	2.06	0.97
25	3.69	4.85	.76	60°	40.0	18.1	.45	1.75	1.74	1.01
27	2.55	4.0	.64	90°	29.2	13.9	.48	1.40	1.33	1.05
28	2.73	3.5	.78	90°	29.2	no data	--	2.05	1.96	1.05
29	3.30	4.1	.78	90°	34.0	15.5	.46	1.60	1.55	1.03
33	2.68	4.3	.63	68°	40.6	16.0	.40	1.75	1.90	0.92

where $k_3 > 1$ one finally obtains

$$u_s = \frac{k_1 k_3}{k_2} \frac{S_{o_s} q_o}{L_p} \left(\frac{1 + \cos \beta}{2} \right) \tag{2-6}$$

or simpler

$$u_s = k \frac{S_{o_s} q_o}{L_p} \left(\frac{1 + \cos \beta}{2} \right) \tag{2-7}$$

and k will be correlated from the experimental data, as no prediction of the values for k_1, k_2, k_3 is possible. A best-fit for Runs 22-29 and 33 resulted in k = 5.1.

The procedure for obtaining the values of S_{o_s}, β and L_p using Fan and Brooks (3) pp. 51 to 71, is explained below: An initial dimensionless momentum flux parameter m_o is related to the densimetric Froude number $\mathbb{F}_o$

$$m_o = 0.562 \, \mathbb{F}_o^{2/3}$$

Then a dimensionless vertical distance is defined as

$$\xi m_o = \frac{y/B}{4.41}$$

Using these values m_o and ξm_o the shape of the jet trajectory and the centerline dilutions can be determined from diagrams for various angles of discharge α. As an example see Figure 2.11 and 2.12 for the case of $\alpha = 90°$.

Table 2.7 provides a survey between observed and predicted values of dilution at the surface S_{o_s} (y = h), predicted values of β and L_p, observed values of ℓ, and gives a comparison between observed values for u_s and predicted values, using Equation 2-7, with k = 5.1.

Good correlations may be seen for both the observed surface dilution with respect to those theoretically predicted (boundary effects and the presence of the warm water layer cause this deviation) and for the layer depth as a function

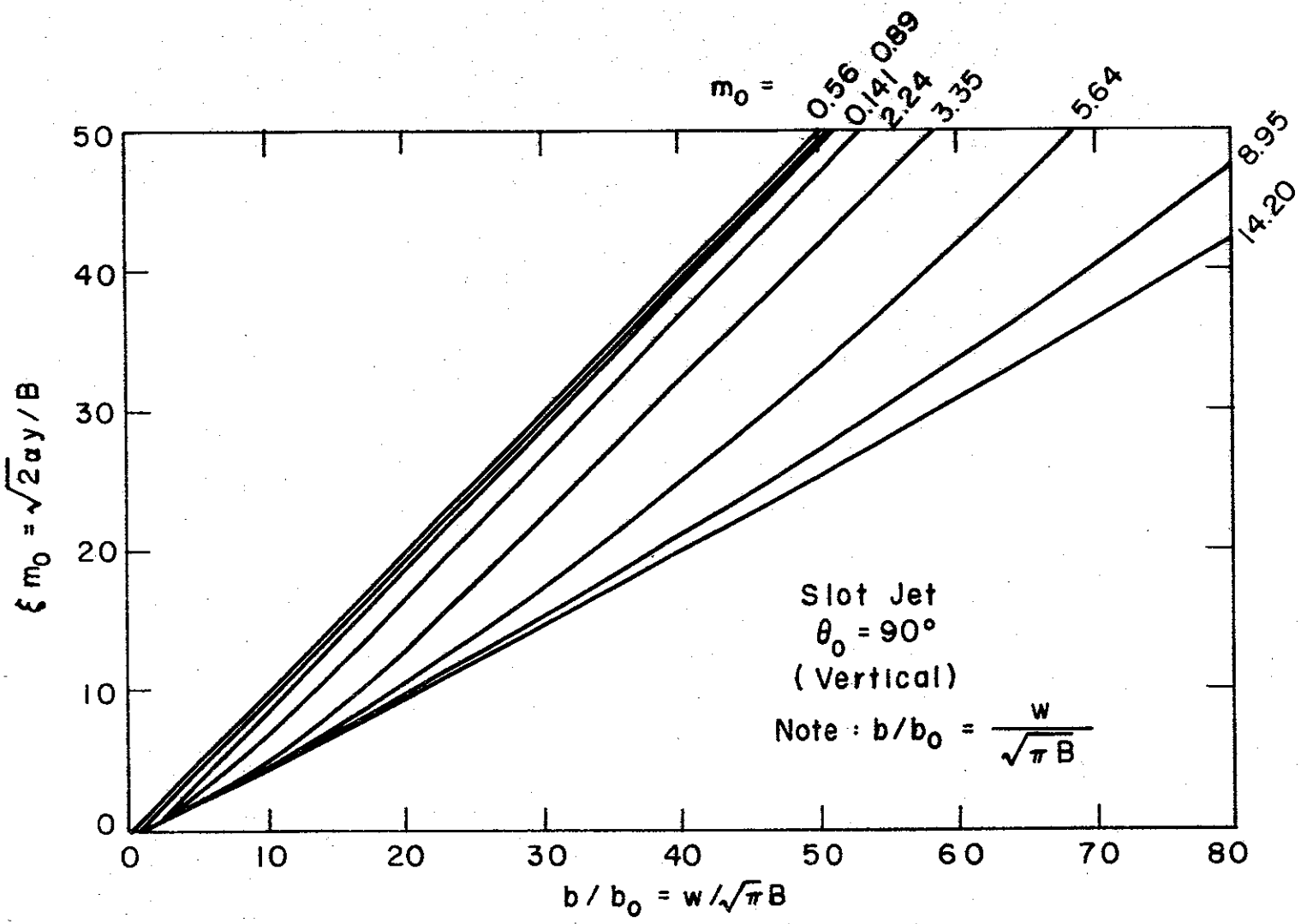


Fig. 2.11 Half-Widths, b/b_0, for Slot Buoyant Jets in Stagnant Uniform Environments: $\alpha = 90°$. Trajectories are all Vertical Lines. (Taken from Fan and Brooks (3))

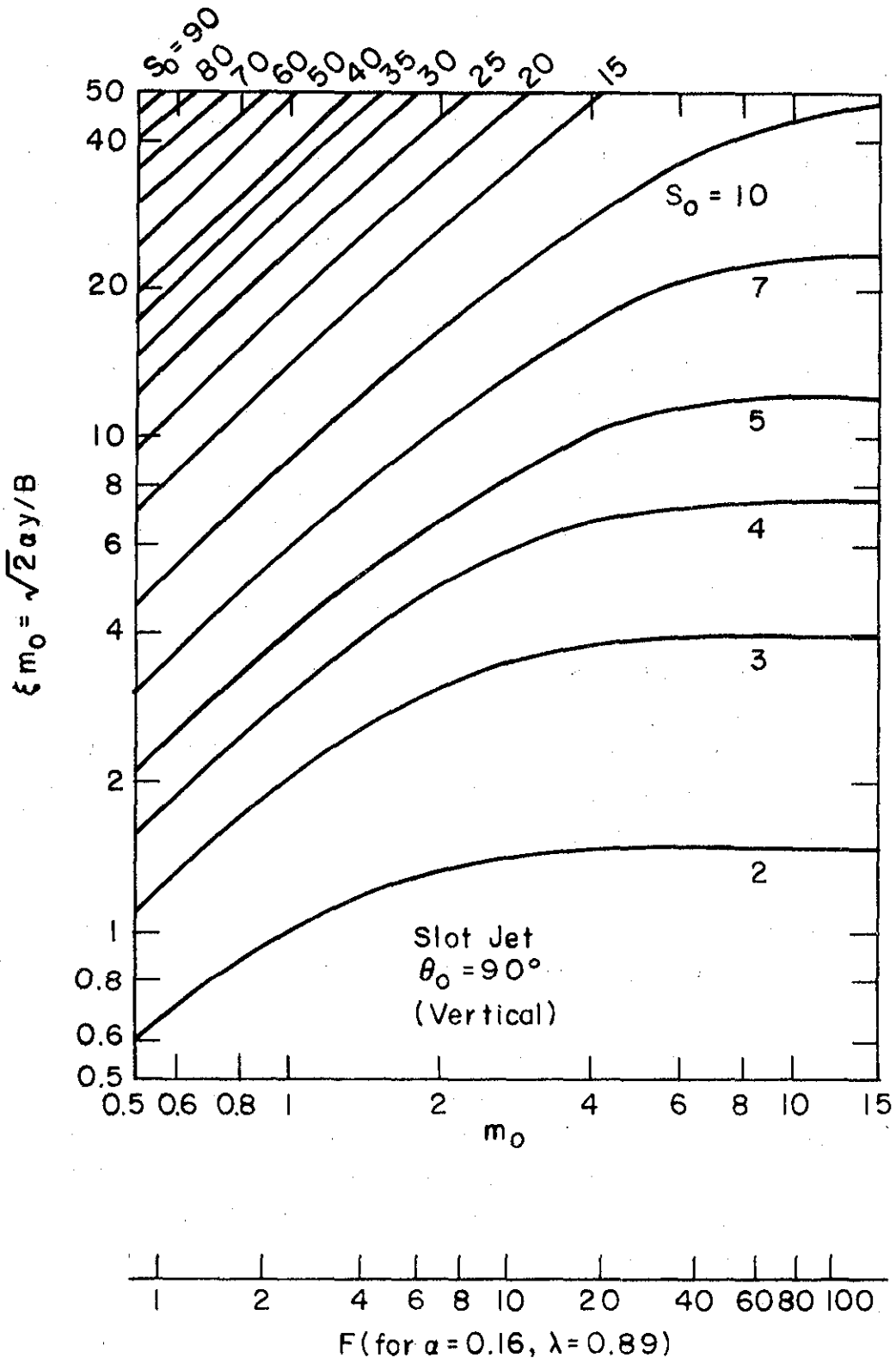


Fig. 2.12 Dilution of Slot Buoyant Jets in Stagnant Uniform Environments : $\alpha = 90°$ (Taken from Fan and Brooks (3))

of path length. In addition Equation 2-7 with k = 5.1 shows good agreement with experimental data and seems to be capable of predicting variabilities of surface velocities as a function of initial slot characteristics. Hence it may be used to evaluate the performance of different slot designs for the given geometry. While the form of the relationship is expected to hold for different geometries of the receiving environment, the value of the coefficient k may vary from case to case.

Parametric Changes of Surface Velocities

Using Equation 2-7 (in conjunction with Figures 2.11 and 2.12) the following dependencies may be derived with respect to surface velocities:

Effect of Slot Length, L:

Increasing L reduces u_s, as $q_o = \frac{Q_o}{L}$ decreases faster than the value S_{o_s} may increase due to decrease of u_o, and thus $\mathbb{F}_o$. (Compare runs 22, 27 and 28; 24/26 and 25.)

Effect of Slot Width, B:

Increasing B decreases the relative submergence y/B and the exit velocity u_o. The effect of the decreased y/B is stronger than the effect of decreased $\mathbb{F}_o$ and S_{o_s} and u_s will be decreased. (Compare runs 24/26 and 33.) Note, however, that a certain $S_{o_s} > 2$ has to be maintained in order to satisfy the temperature constraint.

Effect of Exit Velocity, u_o:

u_o is related to changes in L and B. A minimal u_o may be required from the point of view of internal manifold hydraulics and economics (pipe size).

Effect of Angle of Discharge, α:

Smaller values of α (near horizontal) give higher dilution S_{o_s} than large α (near vertical) as both entrainment paths are longer and the forward momentum of the jet is longer. The accompanying increase of the layer depth ℓ is not sufficient to offset these effects. Therefore, small values of α result in higher surface velocities than large α. (See Fig. 2.13)

Effect of Submergence, h

Increased h raises the value of S_{o_s}. This effect is balanced by the increase in ℓ. Thus changing h has in general little effect on surface

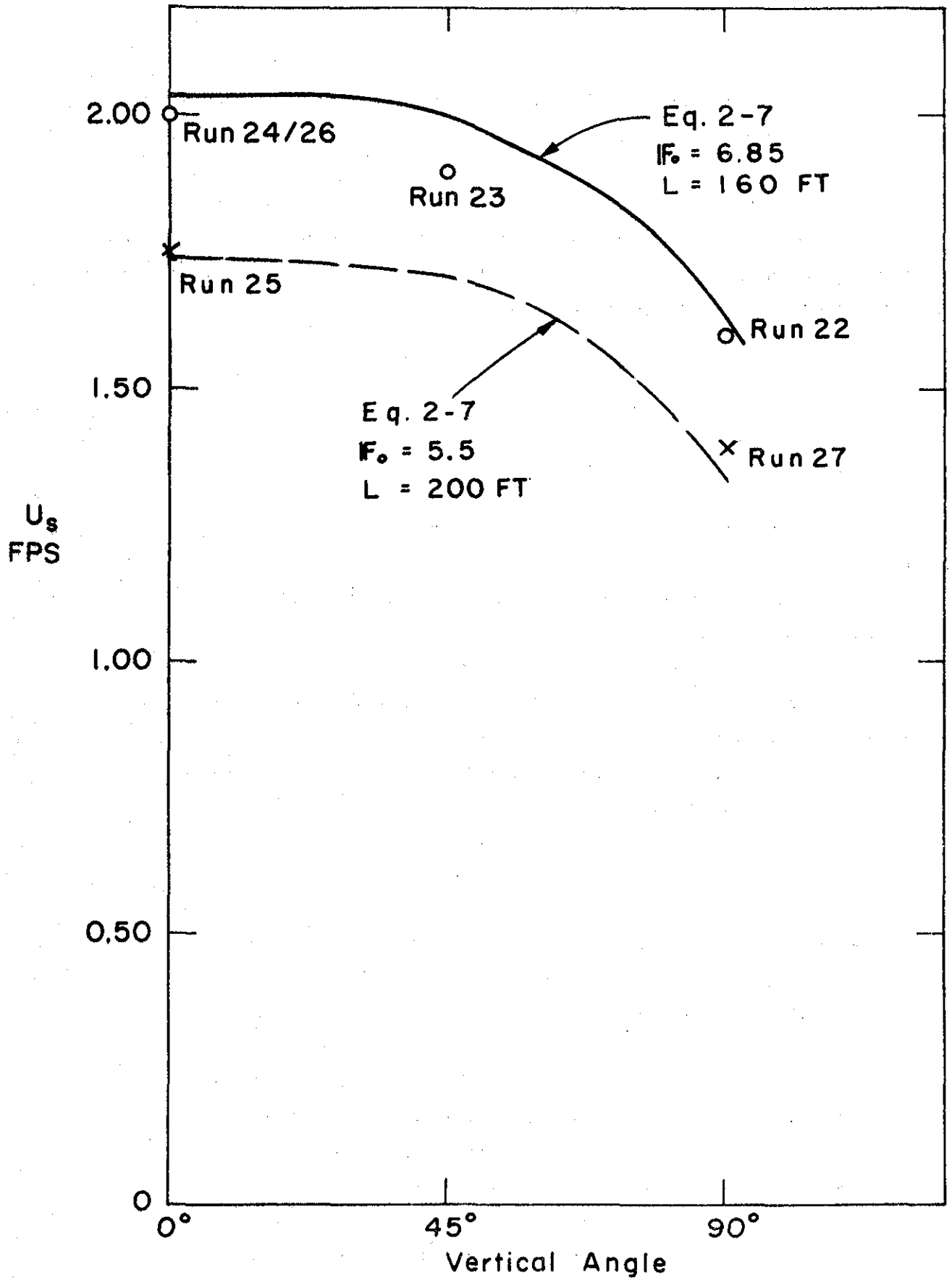


Fig. 2.13 Predicted and Observed Values for Surface Velocities Versus Slot Angle.

velocities, but yields improved dilutions. Yet the change of h is restricted by the limited depth of the canal. (Compare runs 22 and 29.)

2.3.3.2 Tests with Cross Currents

On the basis of the tests under stagnant conditions, the following design was selected as feasible with respect to low surface velocities and satisfactory dilutions while keeping the total length at a minimum and maintaining reasonable exit velocities:

$L = 160$ ft.

$B = 1.5$ ft.

$\alpha = 90°$

Elevation = -32 ft. below MSL

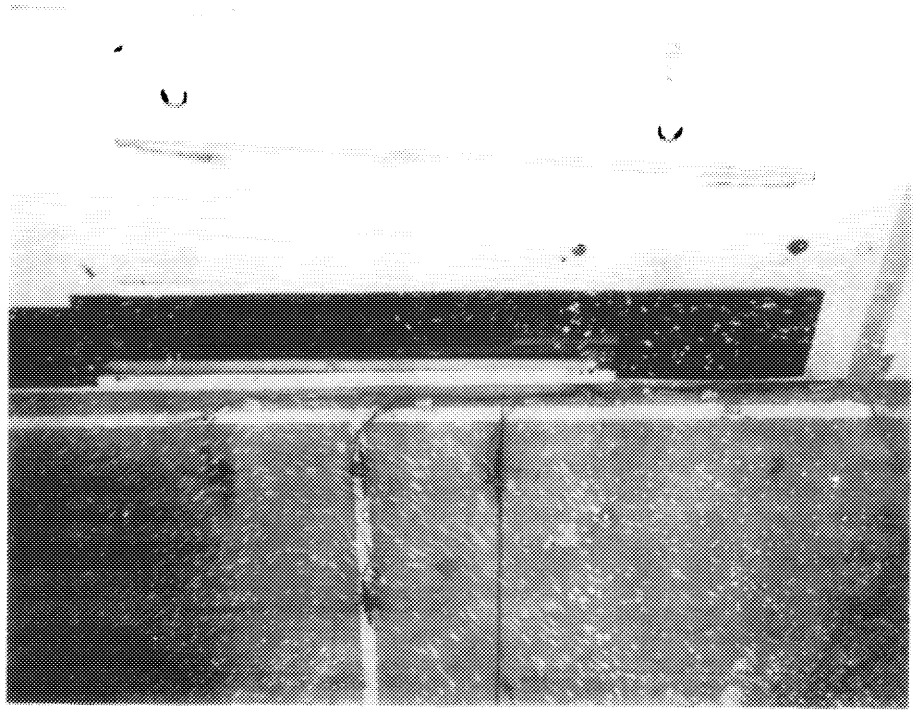
This design was subjected to further testing to determine the resultant surface velocities, dilutions at the 15 ft. layer and recirculation at the intakes under various cross flow conditions occurring during the tidal cycle.

Tests with Steady Cross Flows

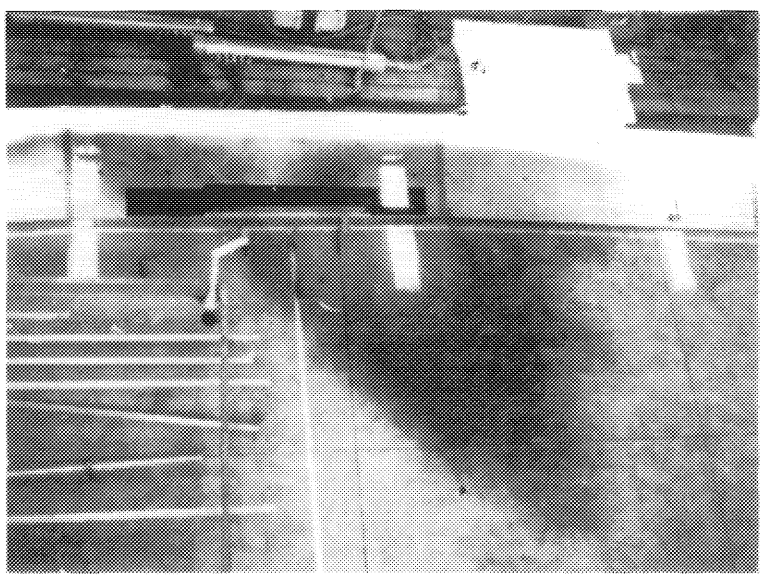
Under cross flow conditions the warm water layer is well deflected by the ambient current. This is illustrated in Figure 2.14 for a weak cross current of $u_a = 0.36$ fps eastward (Run 31).

a) Surface velocities perpendicular to the canal centerline are also strongly affected, as seen in Figure 2.15. The maximum surface velocity usually occurs within thirty feet of the prism line, and remains fairly constant with increased tidal velocity. (See Figure 2.15b) Outside of this region, however, the heated water is strongly deflected by tidal currents and hence the perpendicular velocity is reduced (Figure 2.15a).

b) Dilutions at the 15 ft. layer decreased for low cross flow velocities: Run 32, $u_a = .36$ fps, $S_{o_c} = 2.08$. Visual observation showed that for this magnitude of current some stagnation forms at the upstream end of the slotted pipe, i.e. the density current in the warm water layer which tends to spread in all directions under stagnant conditions is stagnated by the incoming cross flow. For stronger cross currents the increased cross flow momentum overcomes the spreading tendency

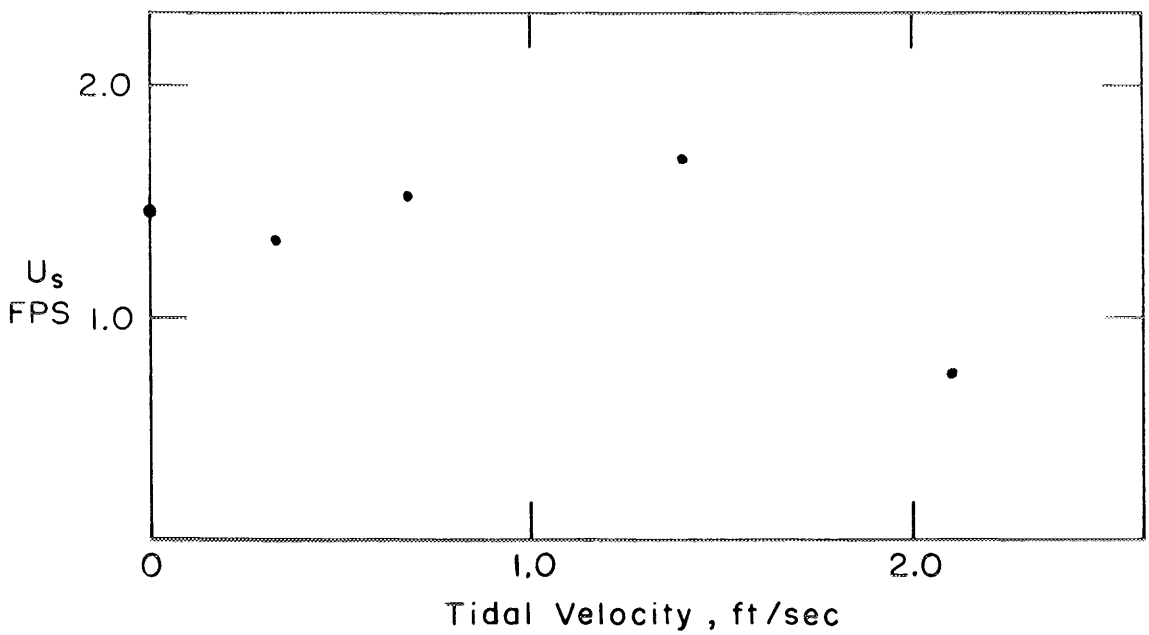


a) Surface Velocity Pattern in Vicinity of Discharge

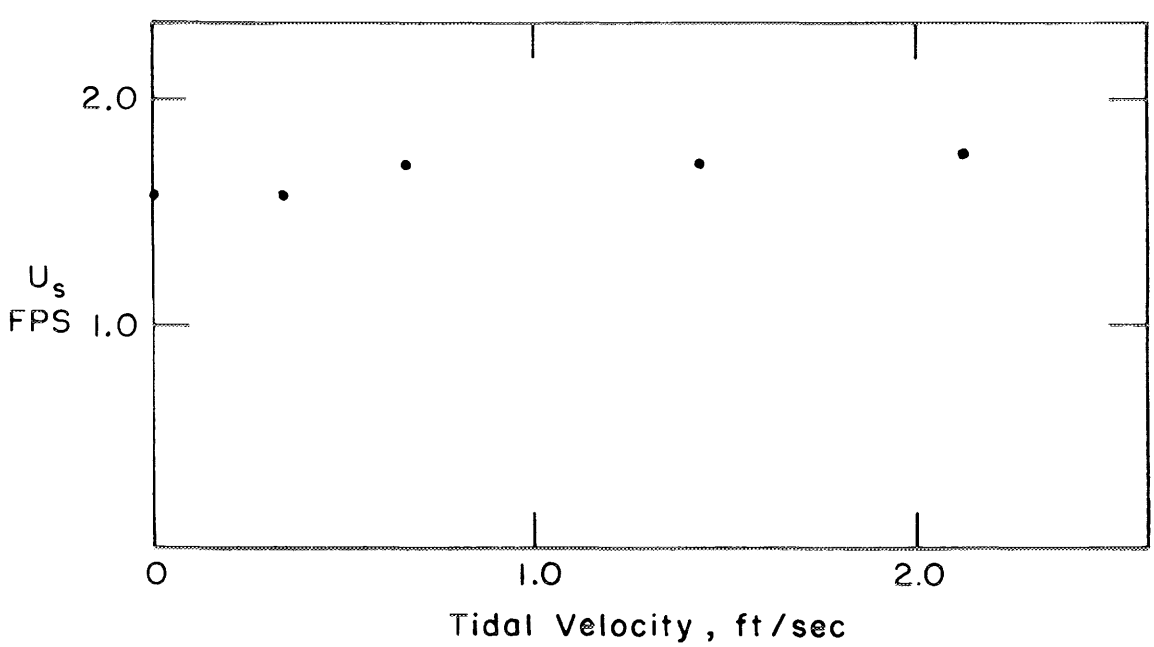


b) Dyed Water Shows Deflection of Warm Water Layer to the Right (east)

Fig. 2.14. Effect of Cross Current on Surface Current (Run 31, u_o = 0.35 fps)



a) 80 ft Off of Prismline



b) Local max.

Fig. 2.15 Maximum Surface Velocities for Vertical Slotted Discharge a) 80 ft from Prismline
b) Local max.

of the warm water layer and provides good flushing around the diffuser, resulting in high dilutions:

Run 35, u_a = 1.12 fps, S_{o_c} = 2.65

Run 38, u_a = 1.44 fps, S_{o_c} = 2.98

Run 37, u_a = 2.2 fps, S_{o_c} = 4.15

c) A full surface temperature survey was conducted in Run 41 for a weak cross-current of u_a = 0.36 fps eastward (same conditions as in Run 31). Temperatures were obtained over a wider area by moving the instrumentation frame. The surface isotherms are plotted in Figure 2.16 showing the deflection and spreading of the warm water layer.
As a consequence of the spreading of the surface layer its thickness decreases downstream from the discharge. Layer thickness along the prismline was measured in Run 31 and is plotted in Figure 2.17.
Surface temperatures at locations 1,000 ft. downstream from the diffuser were also determined. For a flood current of .56 fps (Run 40) and for an ebb current of .36 fps (Run 41) average temperatures (averaged over the canal width) of 5.4°F and 3.5°F, respectively, were found.

d) The design of the skimmer wall at the intakes was effective. Mixed temperature rises at the screenwells due to the passage of the warm water layer at the intake were low with about 0.9°F maximum.

Text with Reversing Cross Flow at HWS

In the final period of the flood tide warm water from Buzzard's Bay reaches the site area. This in conjunction with a warm water layer to the east of the discharge makes the period after HWS most critical for dilution requirements and recirculation.

Therefore a reversal test was done to evaluate the discharge performance. As a consequence of the capacity restrictions of the pumping system for the generation of the cross currents not the full tidal cycle, but only cross flow velocities of limited magnitude could be generated (Run 34). Therefore

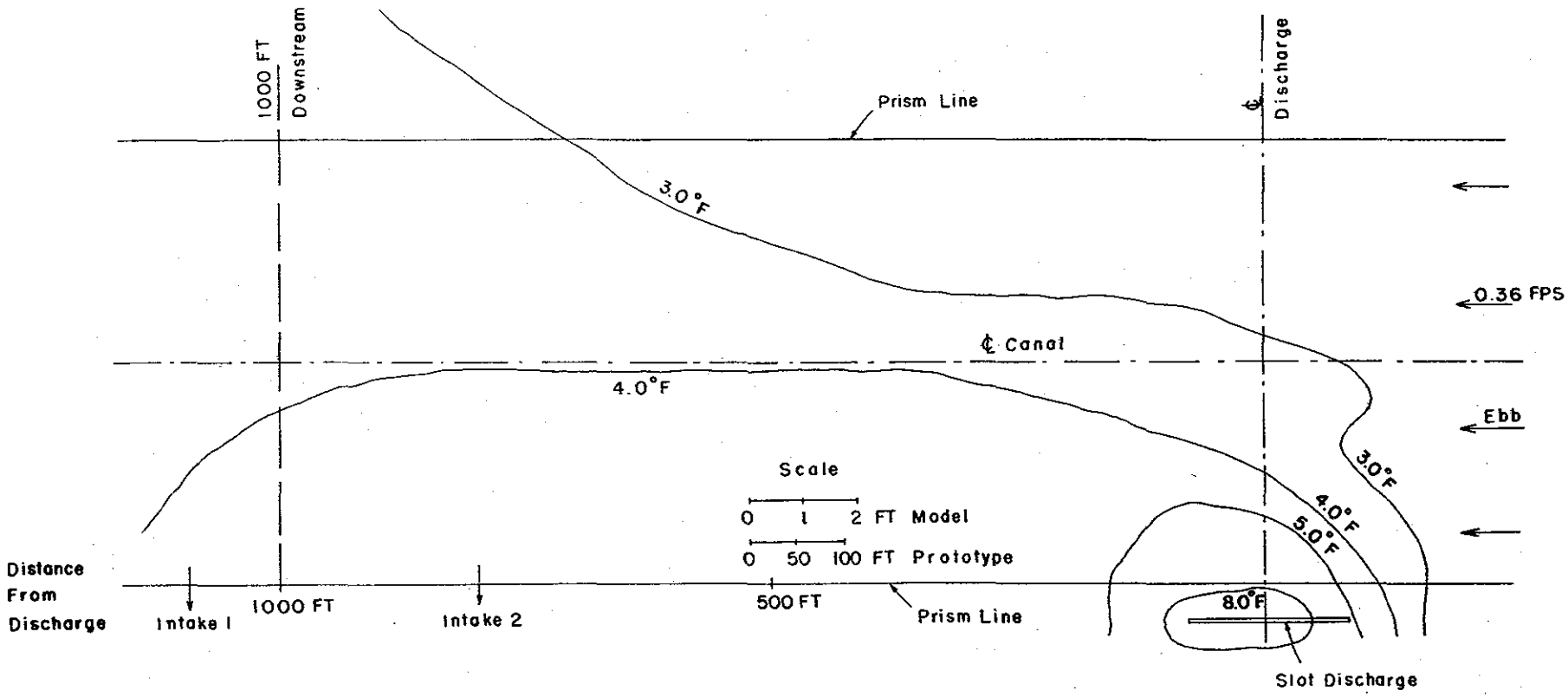


Fig. 2.16 Surface Isotherms in a Weak Cross-Current (Run 41, $U_a = 0.36$ FPS)

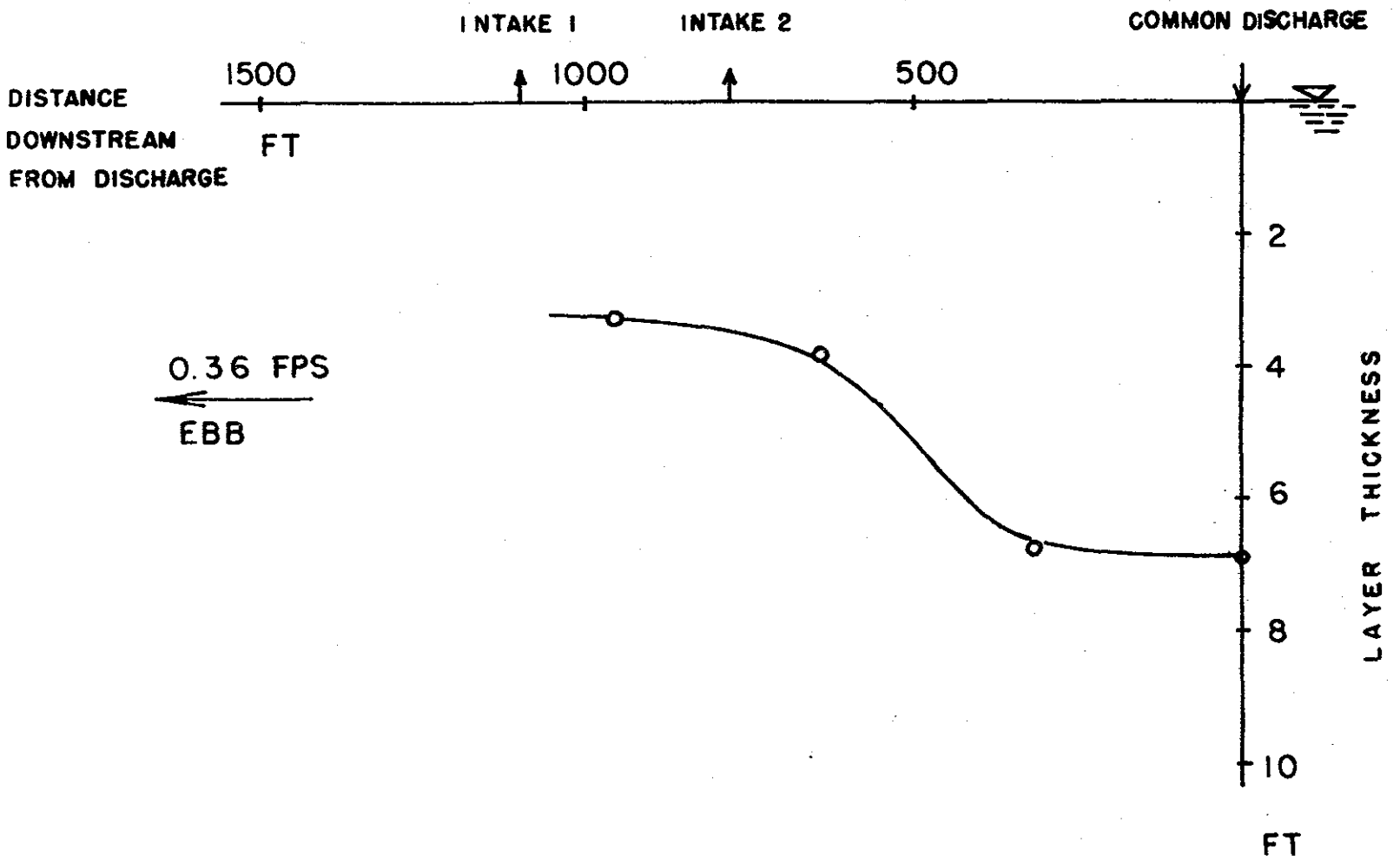


Fig. 2.17 Decrease of Warm Water Layer Thickness along Prismline

the test was started with a constant steady state velocity (0.56 fps for the flood) until the warm water layer was established from the discharge downstream to the model boundary. With this initial condition the continuous decrease and reversal of the velocity was performed at the proper model time scale. When the maximum velocity in the ebb direction (0.35 fps) had been reached, it was maintained until the initial warm water layer had been advected past the discharge.

The results of this test are presented in Figures 2.18 and 2.19. The dilution S_{o_c} exhibits some scatter due to turbulent fluctuations and experimental error, but is always better than 2.0. Recirculation at the intakes slowly increases to a steady value of 0.8°F.

From the point of view of being unable to establish the true initial conditions for this reversal test the values obtained are judged to be conservative as the warm water layer just before reversal is probably thicker due to the decreased advection away from the discharge point.

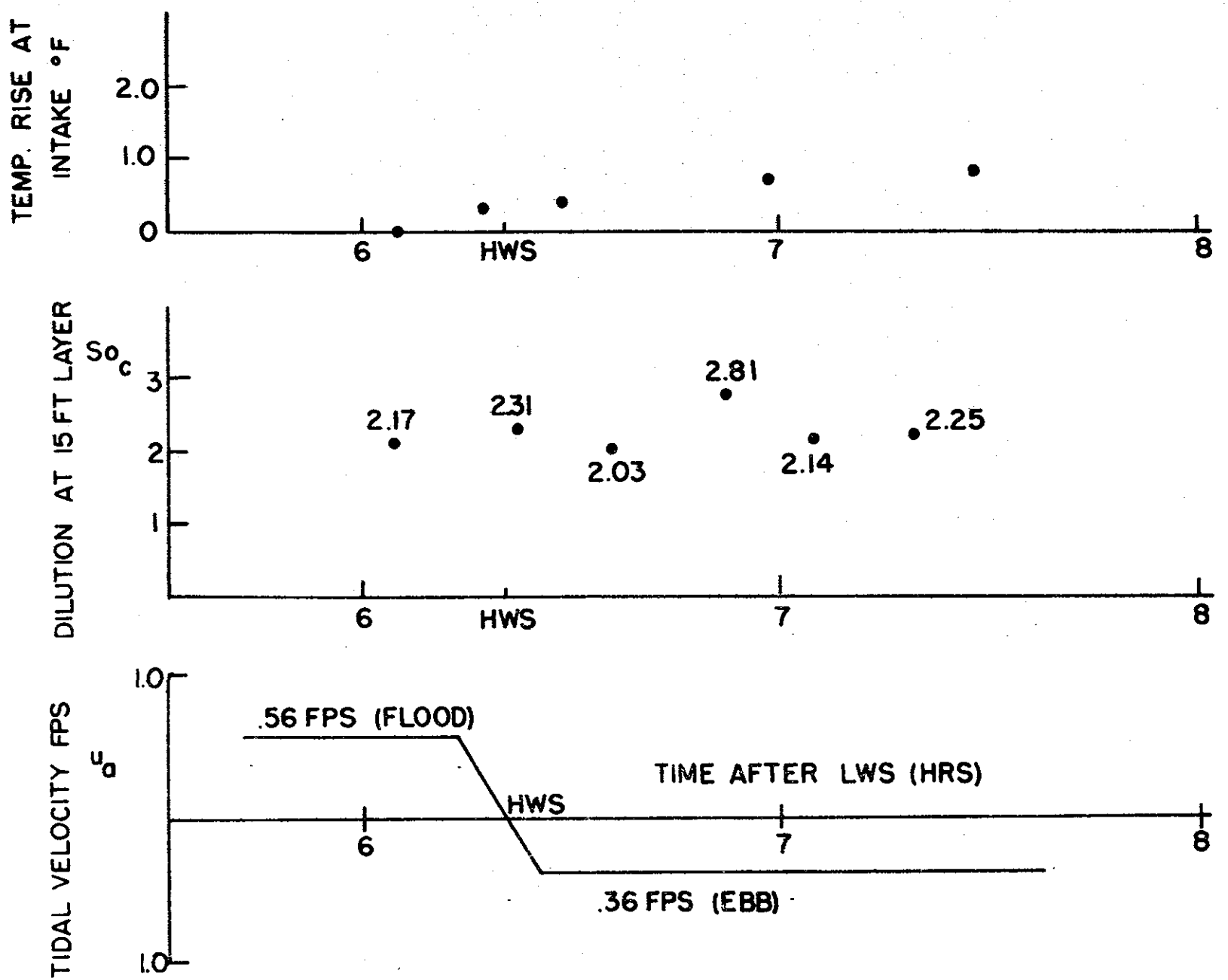


Fig. 2.18 Recirculation and Dilution During Tidal Reversal at HWS

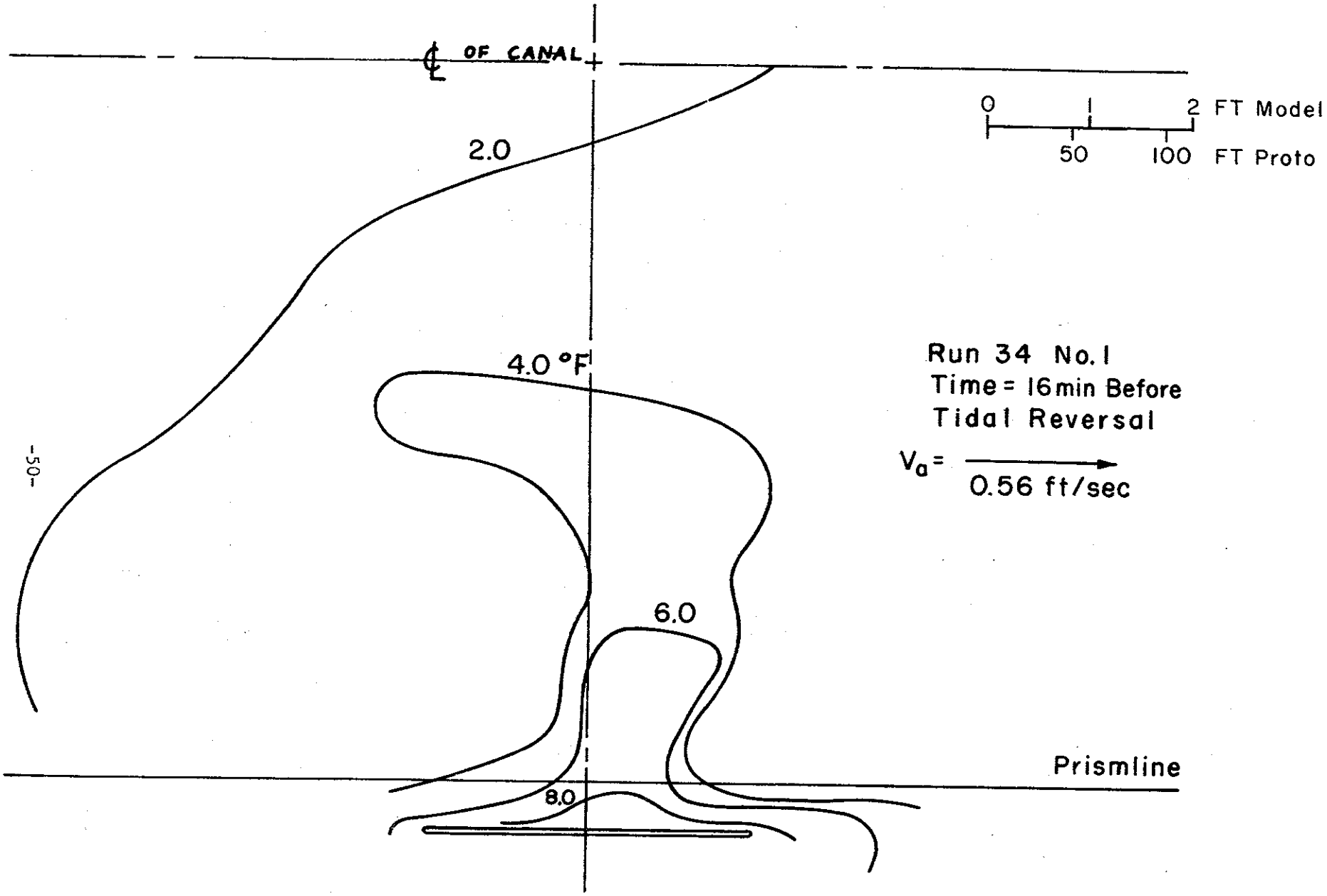


Fig. 2.19 (a) Isotherms for Reversal Test.

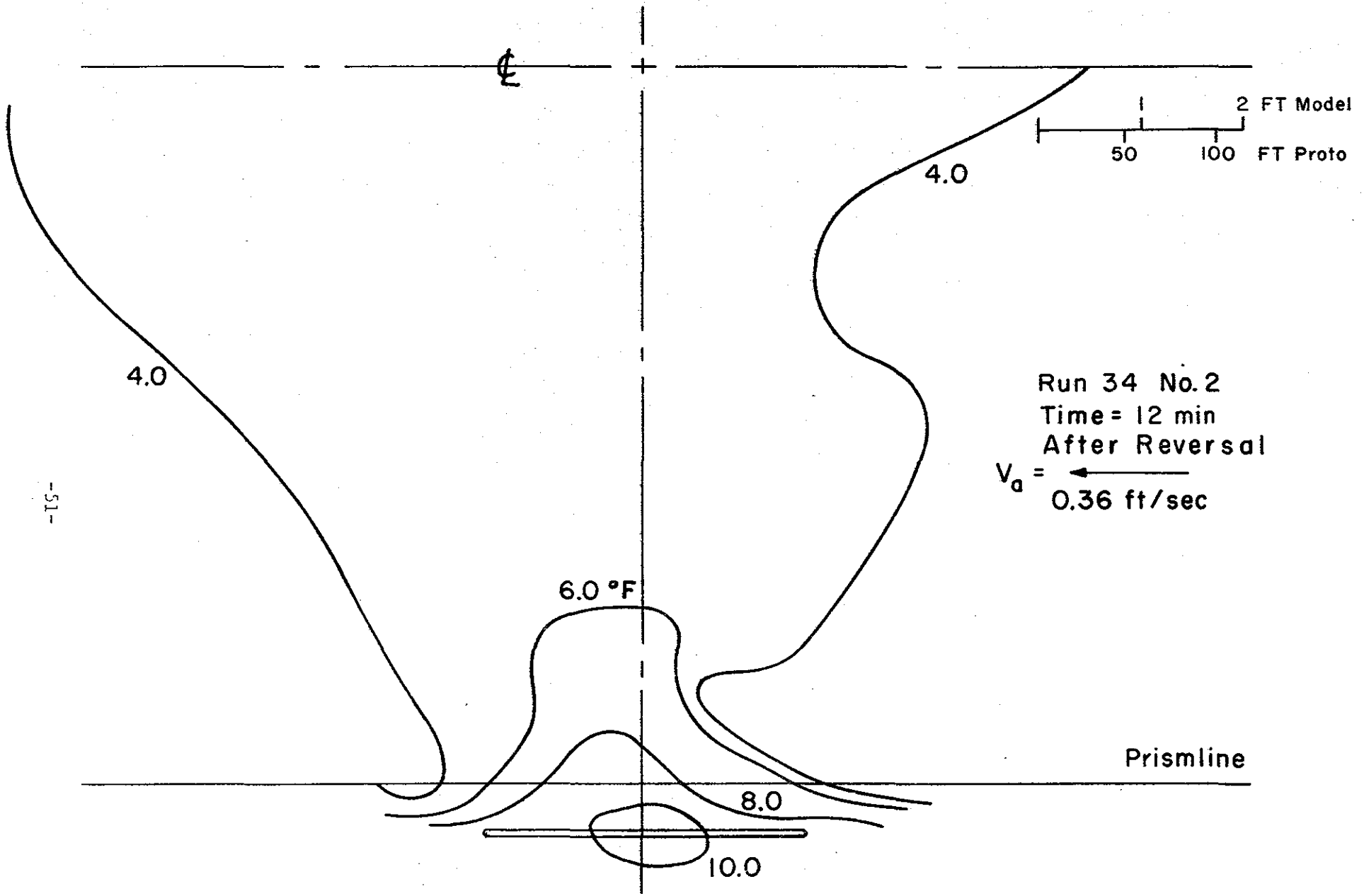

℄
1
2 FT Model
50
100 FT Proto
4.0
4.0
Run 34 No. 2
Time = 12 min
After Reversal
V_a =
0.36 ft/sec
6.0 °F
Prismline
8.0
10.0

Fig. 2.19 (b)

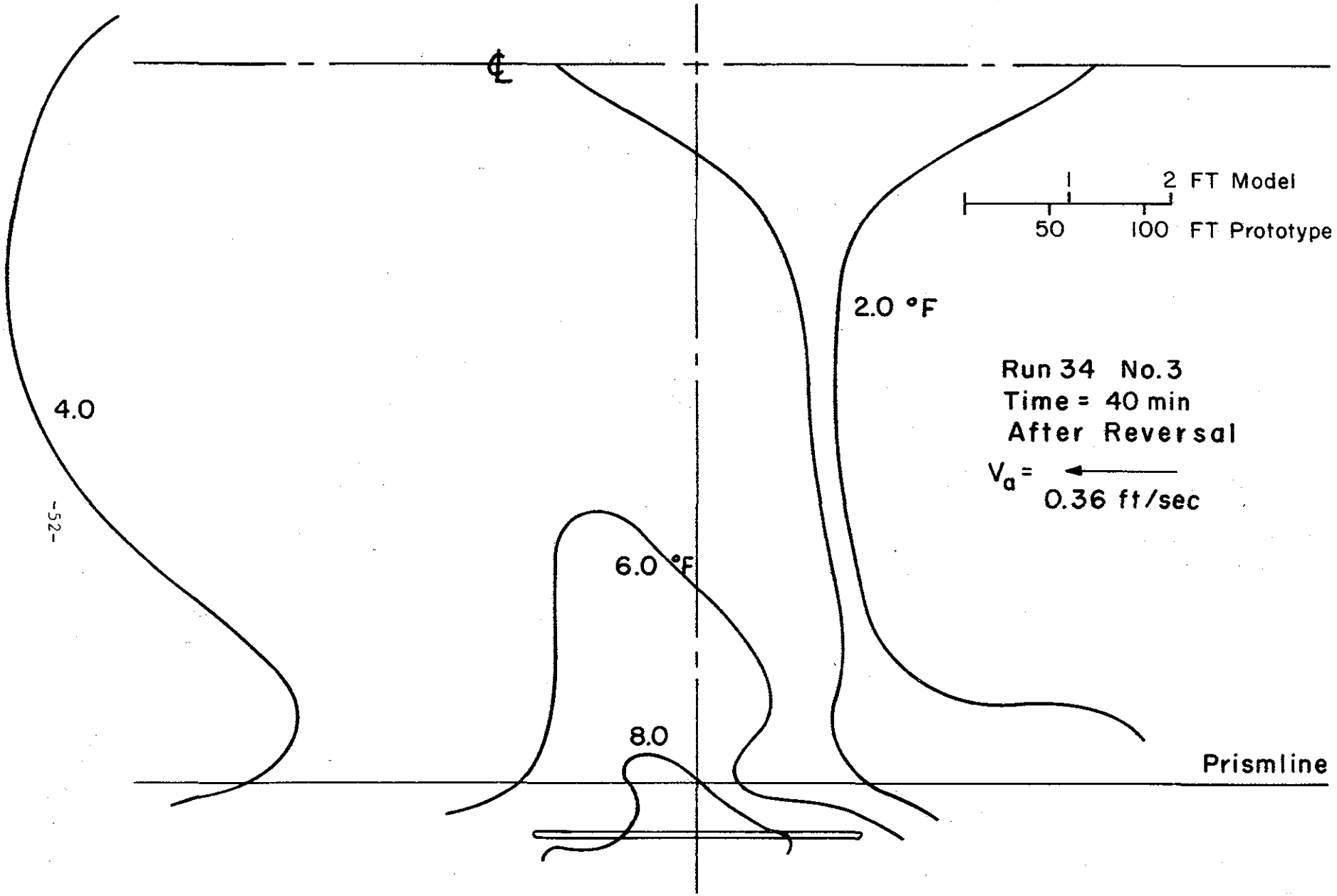

℄
2 FT Model
50
100 FT Prototype
2.0 °F
Run 34 No. 3
Time = 40 min
After Reversal
V_a =
0.36 ft/sec
4.0
6.0 °F
8.0
Prismline

Fig. 2.19 (c)

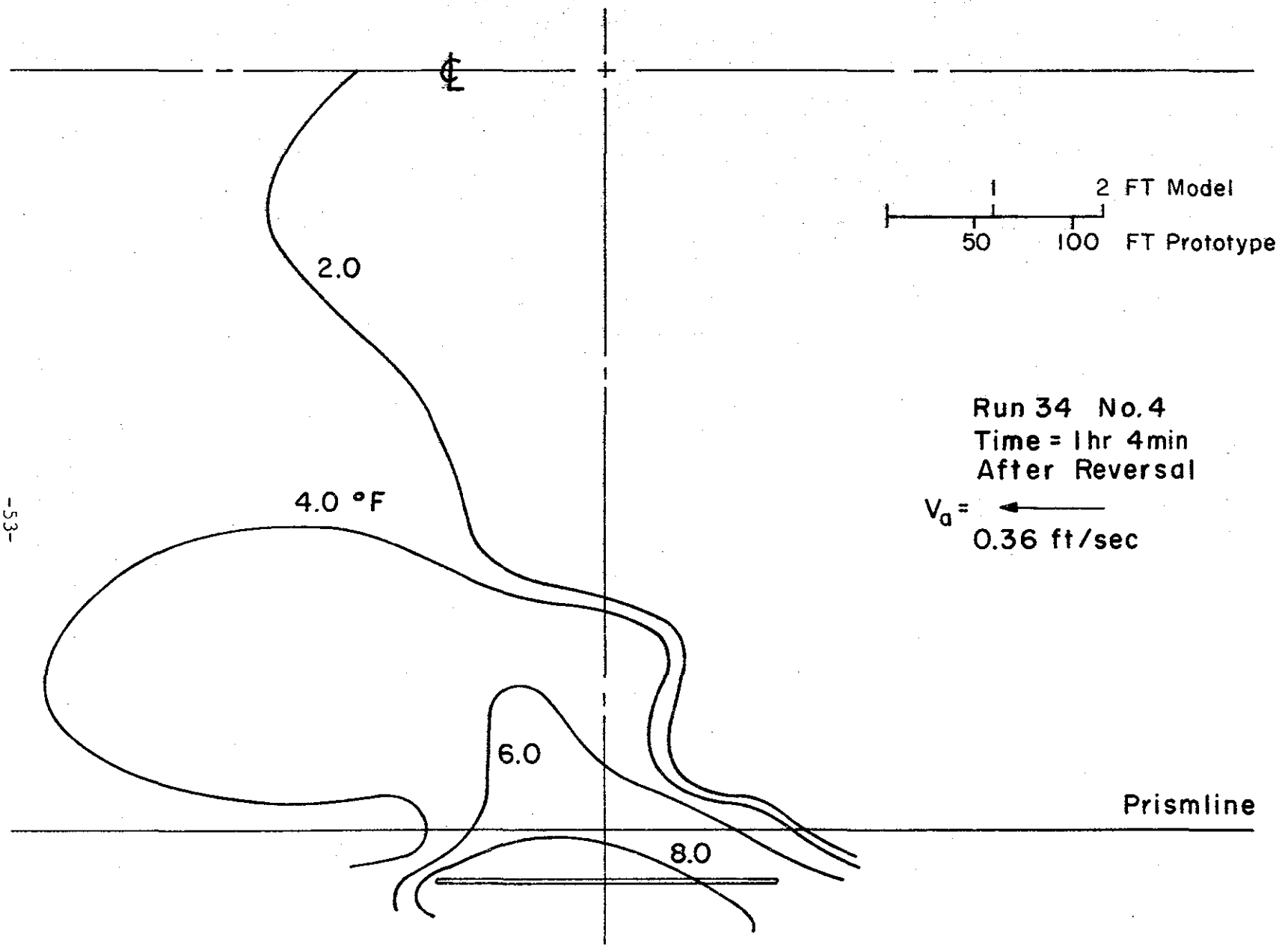

℄
2.0
4.0 °F
6.0
8.0
Prismline
1
2 FT Model
50
100 FT Prototype
Run 34 No. 4
Time = 1hr 4min
After Reversal
V_a =
0.36 ft/sec

Fig. 2.19 (d)

III. Conclusions

On the basis of the conducted test program, these conclusions on the performance of submerged outlets are given:

a) A locally concentrated high-velocity discharge, such as a round pipe or double-slot outfall arrangement, gives high dilutions but does not satisfy the requirement of low surface velocities throughout the tidal cycle.

b) A distributed discharge, such as a slotted pipe laid parallel to the prism line, will induce surface velocities which are a function of slot length, slot width, discharge angle and submergence. For the given canal geometry Eq. 2-7 in conjunction with theoretical predictions on slot buoyant jets given by Fan and Brooks (3), can be used to predict maximum surface velocities. Dilution can be varied by placing the pipe at a proper elevation.

c) The following slotted pipe arrangement satisfies both surface velocity and dilution requirements, while providing reasonable exit velocities and minimizing the slot length.

   $L = 160$ ft.

   $B = 1.5$ ft.

   $\alpha = 90°$

   Elevation = -32 ft. below MSL

d) The induced maximum surface velocities for this scheme are 1.60 fps under slack water conditions and are lower for cross flow conditions, except for a local area at the downstream end of the discharge.

e) Dilutions at the 15 ft. layer are 2.25 for HWS, lower for small cross flows (2.08) and improved for high cross flows (2.65) for tidal velocities greater than 1.1 ft/sec. Under conditions of tidal reversal at HWS the dilutions are better than 2.0 throughout.

f) Recirculation at the intakes is 0.9°F maximum.

As dual criteria both regarding surface temperatures and surface velocities had to be satisfied in the design of a submerged diffuser for the Canal Plant,

the final solution exhibits some unique features which deviate from conventional submerged diffusers. A tradeoff had to be found which keeps the dilution higher than a required minimum (temperature criterion), but low enough to minimize the flow-away in the warm water layer near the surface (velocity criterion). Given the constraining characteristics of the canal geometry the distributed low velocity slotted pipe discharge seems to satisfy these requirements in an optimal way.

IV. References

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