

NATURAL RESOURCE INSTITUTE  
UNIVERSITY OF MANITOBA

Practicum

THE BIOLOGIC, ECONOMIC AND LEGAL ASPECTS OF  
POLLUTION AND ASSOCIATED PROBLEMS FROM  
A MARINE THERMAL GENERATING STATION

Submitted by

C.A. Whalen

In partial fulfillment of requirements for the Degree Master of  
Natural Resource Management.

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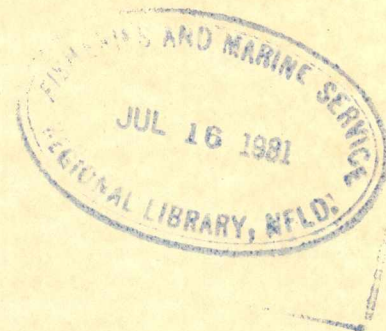
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## ABSTRACT

Concern was expressed by the Federal Department of the Environment that a heated discharge from a 300 megawatt steam electrical station located on a Newfoundland coastal bay would have detrimental effects on aquatic ecology. This report deals with the biological effects, including the extent of the thermal mixing zone and the influence on fish species within the zone; the maximum economic effect the discharge could have on the commercial fishery within the thermal mixing zone and the technical and economic feasibility of the various methods that could be used to cool the thermal discharge. A review was also made of the legal aspects respecting pollution and associated problems from the station.

Water temperature data, collected before the plant was operational, indicated naturally occurring minimum-maximum surface water temperatures. These base line data were compared to thermal mapping of the discharge zone after the plant was operational. Statistics on the number of fishermen and amount of fishing gear within the mixing zone were used to arrive at an estimate of the maximum economic impact the discharge could have if all fishing activity ceased within the required mixing zone. The costs of various cooling devices were reviewed to indicate the least-cost alternative to the present non-cooling of the thermal discharge.

Results indicated that the thermal discharge would be primarily a surface phenomenon, thus not significantly influencing

benthic communities or fish movement. Water temperatures in excess of experimentally determined lethal limits for fish frequenting the area can be expected at the end of the effluent pipe during periods of high ambient water temperatures. Thermal mapping of the mixing zone required to return water to ambient conditions indicated that the assimilative capacity of the bay would be sufficient to rapidly dissipate excess heat and that temperatures in excess of lethal limits for fish would occur only in the immediate outfall zone. If fish are attracted to this area, corrective action (eg. the use of barrier screening) should be taken to prevent fish entry. Outside of the immediate outfall zone it was recommended that surface temperature not exceed 19°C (the lowest tolerance limit for species frequenting the area) thus ensuring a cooler bottom layer for flora and fauna.

Present fishing activity within the thermal mixing zone (5,000-foot radius) results in an estimated gross income of \$2,932.00 annually. The review of alternative cooling methods indicated cooling ponds to be the least cost.

## CHAPTER I

### INTRODUCTION

Immense volumes of water are used in the cooling and condensing of steam to produce electrical energy. Each kilowatt hour of energy produced in a modern, highly efficient, coal-fired plant dissipates about 6,000 British Thermal Units (BTU's) or approximately two-thirds of the heat into the cooling water<sup>1</sup>. Passage of this cooling water into coastal and inland waterways can result in substantial water-temperature changes which affect fauna and flora. Terms such as thermal pollution, thermal effects, and thermal enrichment have been used to classify this new pollutant.

The Newfoundland and Labrador Power Commission (N.L.P.C.) has constructed a 300 megawatt steam electrical generating station on the south-eastern shore of Conception Bay, Newfoundland (Fig. 1). The station is of conventional design and burns bunker C fossil fuel. Cooling water for the condensing process is pumped from Indian Pond, a tidal pond with a volume of  $8 \times 10^4 \text{ m}^3$ , and is expelled into the sea (Fig. 1). During full electrical capacity (300 megawatts), 120,000 U.S. gallons per minute are discharged at an estimated  $13^\circ \text{C}$  above the ambient intake temperature thus producing a thermal load addition of

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<sup>1</sup>Krenkel and Parker, Biological Aspects of Thermal Pollution, Vanderbilt University Press, 1969.

1.45 x 10<sup>9</sup> BTU/hour to the coastal bay.<sup>2</sup>

Conception Bay is open to an inshore branch of the Labrador current that flows anticlockwise within the bay (Fig. 2). The mean tidal range in Conception Bay is 90 cm. and tides are semidiurnal.<sup>3</sup> Water within the bay exhibits a typical annual temperature cycle, warming from April through September and cooling during the rest of the year.

Study Objectives:

Primary objectives of the study included: (i) an assessment of the biological impact of the thermal discharge; (ii) a quantification of the maximum economic impact on the fishery, and a review of methods and relative costs of reducing or removing this impact; (iii) a review of the legal implications with respect to pollution and associated problems from the generating station.

In assessing the biological impact, a series of 24-hour surface-temperature records was collected in the effluent area. These data indicated the maximum surface water temperatures occurring under natural conditions before the plant was in operation. The records were taken in June and July when surface water temperatures are highest. Since fishes

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<sup>2</sup>N.L.P.C. data on Fisheries file 702-251-5.

<sup>3</sup>Canadian tide and current tables, 1969. Detailed hydrographic features are contained in Canadian Hydrographic chart #4565.

generally live closer to the upper lethal limit of their tolerance range, it was expected that the greatest danger would exist in the summer months when ambient water temperatures are at a maximum. Before the plant was in operation, several projections were made to determine the area that would be effected by an increase in temperature. These pre-operational projections were later compared to actual observations and mapping of the thermal mixing zone. A review was also made of fish species frequenting the discharge area and their thermal tolerances.

An important consideration was the impact the thermal discharge would have on the commercial fishery of the area. To what extent are fishermen likely to be effected and what alternatives are available for removing or reducing the potential pollutant? To determine this, an estimate was made of the maximum impact on the commercial fishery relative to the costs of installing cooling water facilities such as cooling towers or cooling ponds.

CHAPTER II

## BIOLOGICAL ASPECTS

A. Impact of increased water temperature on biological systems.

Water temperature, "a subtle, all pervading, complex environmental factor"<sup>4</sup>, influences every living process occurring in water and determines, to a large extent, the physio-chemical environment. Effects of artificially heated water on marine fishes in situ have been little studied, yet the literature contains much information on the direct and indirect effects of a temperature increase upon fishes and upon the varied aspects of their physiology and metabolism, as well as on the ecology of their environment. In general, high temperature affects a biological system by increasing the rate of biochemical reactions from one to six times for each 10°C increase.<sup>5</sup> Thus a temperature increase can affect a variety of metabolic functions, the results of which may not be immediately observable. For example, a temperature increase may not result in a fish kill, yet, may affect reproduction patterns such that over a period of time, the resident population is effectively destroyed. The effects of temperature changes are often long-term,

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<sup>4</sup>Brett, J.R. 1956, "Some Principals in the Thermal Requirements of Fishes". Q. Rev. Biol. 31(2):75-87.

<sup>5</sup>Gunter, G. 1957, "Temperature". In Treatise on Marine Ecology and Paleoecology, 159-184.

sublethal and interrelated with other environmental factors.

The direct effects of temperature on fishes have been examined by numerous authors. In general, the basic conclusion is that organisms are killed at temperatures only slightly above those at which they normally live. Various explanations have been suggested for heat death. These include asphyxiation due to insufficient oxygen to sustain increased metabolic activity<sup>6</sup>, central nervous system failure in killifishes<sup>7</sup>, decreased metabolic activity in the brain tissue of goldfish and largemouth bass<sup>8</sup>, and injury to living protoplasm with decreased oxygen consumption.<sup>9</sup> The failure of a number of biological systems at water temperatures above 30°C has been discussed by Drost-Hansen, who stressed that even though organisms may be alive at 33 or 34°C, many of their body mechanisms are irreversibly damaged.<sup>10</sup> It is probable that heat death results from the simultaneous failure of a large number of biological systems and not from any one particular system.

Young stages of fish are generally considered more

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<sup>6</sup> Mayer, A.G. 1914, "The Effects of Temperature upon Tropical Marine Animals", Pop. Tortugas Lab. 6(1):1-24.

<sup>7</sup> Orr, Paul R. 1955, "Heat Death. I. Time-Temperature Relationships in Marine Animals", Physiol. 2 vol. 28(4).

<sup>8</sup> Ibid., pp. 110-117.

<sup>9</sup> Timet, D. 1963. "Studies on Heat Resistance in Marine Fishes", Thalassia 2(3):5-21.

<sup>10</sup> Drost-Hansen, Walter, 1965, "The Effects of Biologic Systems of Higher-Order Phase Transitions in Water", Ann. N.Y. Acad. Sci. 125(2).

stenothermal<sup>11</sup> than the adults of the same species. In their natural environment, larval stages exposed to high temperatures of heated effluents would have little chance of acclimatization, ie. to adapt to changes slowly under natural conditions. Larval stages, if exposed to rapid temperature changes, would probably succumb to thermal shock more quickly than the more mobile adults. The literature indicates that any setting of maximum temperature guidelines would have to be selected to account for the more vulnerable larval stages.

In an even more immobile state than the young stages are the eggs of marine fishes. It has been suggested that high temperatures cause critical anomalies in the biophysical process occurring at the egg membrane.<sup>12</sup> A greater mortality of cod eggs at higher temperatures has also been noted.<sup>13</sup> A more rapid development of the eggs with increasing water temperature has been shown for the following marine species: herring<sup>14</sup>, plaice<sup>15</sup>, and cod.<sup>16</sup> Fish eggs, if exposed to excessive heat in

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<sup>11</sup> Having a narrow range of adaptability to temperature change.

<sup>12</sup> Ibid., 471-501.

<sup>13</sup> Bonnet, D.E. 1939, "Mortality of the Cod Egg in Relation to Temperature", Biol. Bull. Mar. Biol. Lab., Woods Hole 76:428-441.

<sup>14</sup> Blaxter, J.H.S. 1956, "Herring Rearing. II. The Effects of Temperature and Other Factors on Development", Mar. Res. No. 5:19.

<sup>15</sup> Johansen and Krogh, 1914, "The Influence of Temperature and Certain Other Factors upon the Rate of Development of the Eggs of Fishes", Publo. Circonst. Cons. Perm. Int. Explor. Mer. (68):1-44.

<sup>16</sup> Dannevig, H., 1894, "The Influence of Temperature on the Development of the Eggs of Fishes", Rep. Fishery Bd. Scotl. 13:147-153.

the effluent area would not only be subject to thermal shock, but also to rapid development and emergence with a resultant high mortality.

It can be concluded that fishes have a lower and an upper lethal-temperature limit or tolerance. This is specific for each species and the requirements vary for different stages in life history, such as spawning, development of eggs, and development of young. Setting of allowable temperature limits must consider not only species difference in temperature tolerance, but also the limits imposed at the various life stages.

Table I indicates the upper temperature tolerances reported in laboratory experiments for fish species found in the Conception Bay area. When original data indicated acclimation times for test animals this was reported in the table. The importance of acclimatization of fishes to survival times has been discussed by several authors.<sup>17,18,19</sup> In general, fish that are gradually exposed to increasing temperatures can withstand higher ranges than those immediately exposed to the same temperatures. Extrapolation of experimental temperature studies to marine fishes in situ requires caution.

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<sup>17</sup>Loeb and Wasteneys, 1912, "On the Adaptation of Fish to Higher Temperatures", J. Exp. Zool. 12:543-557.

<sup>18</sup>Brett, J.R. 1956, "Some Principals in the Thermal Requirements of Fishes", O. Rev. Biol. 31(2):75-87.

<sup>19</sup>Naylor, E. 1965, "Effects of Heated Effluents upon Marine and Estuarine Organisms", Adv. Mar. Biol. 3:63-103.

Laboratory experiments with marine species are notoriously difficult to conduct, reflecting the complex interrelations of factors that occur in the marine environment and the problems of duplicating these conditions in vivo. The majority of such experimental studies fail to indicate the criteria used to determine lethal limits; eg. if the limit indicated the first mortality occurring or the LD50 limit.<sup>20</sup> Studies also generally fail to state the length of time test animals were exposed to high temperatures, the rate of temperature change and the general condition of test animals. One must, however, out of necessity rely on such laboratory experiments as a general indication of the temperature range tolerated by fish species.

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<sup>20</sup>LD50 - when 50% of test organisms die.

TABLE I

Temperature tolerances reported in laboratory experiments for marine fishes.

Species	Acclimation Temp., °C.	Tolerance Limit, °C.	Duration Hours	Reference
<i>Alosa pseudoharengus</i>	15	23	90	*
<i>Clupea harengus</i> (adult)		20.8-24.7		Huntsman & Sparks, 1924
" " (adult)		19.5-21.2		Brawn, 1960
" " (larva)		22-24		Blaxter, 1960
" " (larva)	15.5	23	24	*
<i>Gadus morhua</i> (adult)		19.8-24.4		*
<i>Homarus americanus</i>	5	28.7		*
" "	10	28.4		*
<i>Microgradus tomcod</i> (adult)		29		*
" " 2cm.		19-20.9		*
" " 14-15cm.		23-26.1		*
" " 22-29cm.		25-26.1		*
<i>Myoxocephalus aeneus</i>		26.3-27		*
<i>Myoxocephalus actodecemopinosus</i>		28		*
<i>Osmerus mordax</i>		21.5-28.5		*
<i>Salmo salar</i>		28	1	*
<i>Tautoglabrus adspersus</i>		29		*
<i>Thunnus thynnus</i>		25		Williams, 1967

\*Source: Data based on Altman and Dittmer, 1966, and supplemental references. Environmental Biology, Bethesda, Md: Fed. Amer. Soc. Exper. Biol.

Huntsman and Sparks, 1924, "Limiting Factors for Marine Animals", Contr. Can. Biol. Fish., N.S. 2(6):97-114.

Brawn, 1960. "Temperature Tolerance of Unacclimated Herring". J. Fish. Res. Bd. Can. 17(5):721-723.

Blaxter, J. 1956. "Herring Rearing". Mar. Res. No.5, 19pp.

Williams, 1967. "The Biology of *Thunnus Thynnus*", M.S. Thesis, Memorial Univ. of Nfld.

For these species the upper lethal temperatures ranged from 19°C - 29°C. Actual temperature records in the effluent area before the plant was in operation (Fig. 5), indicated a maximum surface temperature of 58°F (14.4°C) and a mean maximum temperature of 47.4°F (8.6°C) and 54.6°F (12.6°C) during June and July. Surface temperature recordings, after the plant was in operation, indicated surface temperatures of +4°C above ambient (Fig. 3). During periods of high ambient surface water temperature, eg. 15°C, an increase of +4°C due to the effluent would result in temperatures approaching the lethal limits as indicated by experimental studies. Two factors, however, indicate that fish in the effluent area will not be directly exposed to these high temperatures. First, the species are not surface swimmers and second, the excessive temperature will occur only at the surface and in the immediate outfall zone. It is expected that the heated discharge will exhibit a gradient, with the highest temperature in the immediate discharge zone and a rapid reduction in temperature at distances further from the outfall.

A significant factor to the biota in the immediate effluent zone will be the rate of temperature fluctuation. Some American states have adopted a rate-of-change temperature criterion to protect aquatic life from a sudden sharp change in their environment. The value most frequently used is a limit of .5 - 1°C change per hour for marine receiving waters.<sup>21</sup>

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<sup>21</sup>Krenkel and Parker, Engineering Aspects of Thermal Pollution, Vanderbilt University Press, 1969. Pp. 75-76.

These criterion have been in response to the known extreme sensitivity of fish to rates of temperature change. Diurnal surface temperature variations before the Holyrood generating station was operational indicated a mean 24-hour change of  $2.2^{\circ}\text{C}$ , with a range of  $1^{\circ} - 6^{\circ}\text{C}$  (Fig. 5). To prevent fish from exposure to rapid rates of temperature change, eg. during periods of plant start-up, entry into the immediate outfall area should be prevented. Since the area where thermal shock is likely to be a factor should be small it may be feasible to section off the immediate outfall area by a barrier screen.

The effects of heated effluents on faunistic composition (excluding fish) has been reviewed by Naylor.<sup>22</sup> He noted that in the immediate outfall zones some change in species diversity did occur but was generally localized to the immediate outfall. At the Holyrood station this will not have a significant effect on the availability of fish food, due to the relatively small area where the discharge will extend to the ocean floor. Phytoplankton productivity could possibly be increased due to the effect of temperature on growth. This factor has been noted at other stations and probably accounts for fish being attracted to effluent outfalls.

#### B. Analysis of the thermal plume pattern.

The area required for thermal neutralization to ambient conditions was of concern to the Federal Department of the

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<sup>22</sup>Op. cit., pp. 63-103.

Environment (Fisheries Service) and the Newfoundland and Labrador Power Commission (N.L.P.C.). A rapid dissipation of excess temperature would reduce the influence on the aquatic ecology of the area. The N.L.P.C. was concerned with the dispersion pattern since any recirculation of warm water would decrease the efficiency of the condensing process.

A warm water discharge is a function of the thermal load (ie. the electrical output of the station), the receiving water temperature differential, meteorological conditions, the discharge velocity and current patterns of the receiving water. Heat budget calculations, which are summations of all sources of heat to a body of water minus sources of heat loss, have been determined for reservoirs and cooling ponds.<sup>23,24</sup> Such analyses become exceedingly complex; and useful solutions are essentially unobtainable when hydraulic problems such as turbulent mixing, stratified flow and density currents encountered in coastal regions must be considered.

Two estimates were made of the dispersion pattern before the electrical station was operative. The Federal Fisheries estimate was determined using surface temperature gradients observed in other marine areas receiving warm water

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<sup>23</sup>Morton, F.I. 1965, "Potential Evaporation and River Basin Evaporation", Jour. of Hydraulics Division, Proc. of A.S.C.E. 91:No. 4Y6.

<sup>24</sup>Harbeck, et al, 1959, "The Effect of the Addition of Heat from a power plant on the thermal structure and evaporation of Lake Colorado", Geo. Survey Prof. Paper 272-B, U.S. Government Printing Office, Washington.

discharges. Based on these observations, a gradient of  $2.8^{\circ}\text{C}$  per 1,000 feet from the effluent outfall was chosen. Using this gradient of  $2.8^{\circ}\text{C}$  surface temperature loss per 1,000 feet, implied that warm water would be contained with a 5,000-foot radius from outfall based on the maximum temperature differential of  $13^{\circ}\text{C}$  reported by the N.L.P.C. (Fig. 1, RDB estimate). The exact shape of the dispersion pattern would be dependant on the prevailing current structure and wind conditions, but would be contained within the maximum radius of 5,000 feet from outfall. A theoretical estimate of dispersion was made by the Bedford Oceanographic Institute using an idealized mathematical model. The result of this analysis was that the dispersion pattern would be contained within a 3,300-foot radius from outfall (Fig. 1, Bedford Estimate). These estimates were used in gathering statistics on fishing activity that was likely to be influenced.

Actual thermal plume dispersion pattern mappings were made in July, 1971, after the plant was operational (Fig. 3). The method used in detecting and measuring the plume was to set out a rectangular grid covering the receiving water. A boat was then used to traverse this grid as rapidly as possible, recording temperatures at one-foot depths. Temperatures were obtained using a Nansen reversing water bottle with an attached battery operated thermistor (Applied Research model FT3) and a reversing thermometer. The results of these mappings are given in Fig. 3. Map 2 shows conditions existing

under relatively high air temperature, negligible wind and wave action. Map 1 shows conditions under brisk wind conditions, lower air temperature and considerable wave action. A number of vertical depth recordings showed the water spread to be a surface phenomena, one to three feet deep. Actual mapping observations compared favourably with the predicted estimates made before the plant was operative.

CHAPTER III

## ECONOMIC ASPECTS

The economic consequences of thermal pollution are measured by the costs of alternative methods of heat reduction (eg. by cooling ponds or cooling towers) and the benefits to be realized from these pollution abatement installations. Benefits realized from these installations can be quantified by the economic loss imposed by the heated effluent (eg. on the commercial fishery) if cooling facilities are not installed. Pollution abatement requirements are not always justified on a purely economic efficiency basis, in the sense that benefits equal or exceed the costs of imposing such requirements, objectives other than efficiency may be of importance. A society has the prerogative to spend its resources on projects or programs that are not entirely justified on an economic basis. The Federal Fisheries Act, for example, states that anything deleterious to fish cannot be placed in waters. Justification of this act is not based on economic considerations, but recognizes social, historical priority, and equity questions. The courts, in interpreting legislation that is stated in absolute terms, such as the Federal Fisheries Act, cannot take cognizance of economic implications.

The decision to install cooling water facilities at the Holyrood generating station should consider the potential economic impact of the untreated effluent relative to the

cost of reducing this impact. Thus, based on the biological prediction of the extent of the warm water discharge, a projection was made of the economic impact if all fishing ceased within the mixing zone. This projection could then be compared with the alternative cooling methods available and their relative costs. It was considered necessary to determine the extent of the fishery in the effluent area, regardless of the low probability of significant damage. For example, if the fishery in the area adjacent to the plant effluent were considerable in terms of employment and revenue generated, then even with a low probability of damage, this risk factor could have a considerable bearing on the decision to install water cooling facilities.

A. Cooling Systems - Methods and Costs.

The cost of electrical power generation, cost at the busbar (ie. to the point of transmission) is expressed in mills<sup>25</sup> per kilowatt hour and is usually broken down into fixed and variable cost components. Fixed costs include those costs unaffected by plant output or load conditions; eg. interest rates, amortization of the plant capital cost, and insurance. In determining the fixed cost component of total busbar cost, the annual cost per year is calculated in dollars and then converted to mills per kilowatt hour annual capacity. Variable costs, operating or production costs, are determined by the

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<sup>25</sup>One mill is equivalent to 1/1000 of a dollar, 1/10 of a cent.

plant generating or electrical output and include fuel, payroll labour and other maintenance and operating expenses. The cooling system design will influence both the fixed and variable cost of electricity. In addition to cost, other factors indigenous to a particular plant such as the temperature differential to be cooled, meteorological conditions, geography and topography, type of coolant (eg. sea, brackish or fresh water) and environmental restrictions imposed by the receiving water mixing zone must be considered in the choice of cooling system method and design.

Cooling systems operate more efficiently the greater the temperature differential between the coolant and the surrounding air. This implies that water could be cooled more quickly by allowing it to leave the condenser at a higher temperature. Higher condenser water temperatures, however, result in reduced power generation. At higher water temperature, steam is not condensed as quickly and causes a higher condenser pressure (back-pressure). The higher back-pressure reduces the efficiency of the turbine and thus decreases electrical output. Thermal generating stations, to achieve economic optimization of the cooling system, must consider the two competing factors of higher condenser exit temperature and more efficient cooling versus a higher condenser temperature and reduced electrical efficiency.<sup>26</sup> Ideally, these factors should be considered prior to final in-plant

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<sup>26</sup>"Industrial Waste Guide on Thermal Pollution", Federal Water Pollution Control Administration, U.S. Dept of the Interior, Sept. 1968.

operating design conditions that are strictly specified for any station, such as condenser pressure and steam temperatures. If a cooling tower or pond must be designed around existing plant operating conditions, it is likely that added costs will be incurred in modifying the condenser pressure and temperatures.

#### 1. Cooling Ponds and Reservoirs.

##### Operating Parameters:

A cooling pond or reservoir is the simplest method of cooling thermal discharges, although it is the least efficient in terms of heat transfer. Heat is lost from the thermal discharge via evaporation, conduction and convection to the atmosphere and surrounding water. Cooling efficiency is dependant on surface water-to-air contact, wind velocity, water mixing and the air-to-water temperature differential. An increase in any of these parameters will increase the cooling efficiency.

##### Advantages of Cooling Ponds and Reservoirs:

- (a) Lower construction and operating costs relative to cooling towers.
- (b) The method offers considerable scope for improving the cooling efficiency, eg. by the use of supplementary spray ponds. Use of such systems allows for a reduction in the size of the pond surface area required or for an increase in the cooling capacity of an existing pond.

- (c) Cooling ponds and reservoirs may be beneficial for other purposes, eg. recreation, fish farming and aquaculture. Fish farming of exotic species in effluent waters has had considerable success in some areas. Sole and oysters have been cultivated in British coastal power stations.
- (d) Cooling ponds and reservoirs are also capable of being blended into the landscape to a greater extent than cooling towers.

Disadvantages of Cooling Ponds and Reservoirs:

- (a) The low heat transfer rate necessitates large land areas, generally, one acre surface area per thousand kilowatt capacity is required. Approximately a 300 acre (one-half square mile) pond would be required for the Holyrood station.
- (b) When salt water ponds are used, heat transfer by evaporation results in some water loss to the atmosphere, with a resultant increased salinity of pond water. Return of this hypersaline water to the sea could result in a changed composition of fauna, particularly sessile bottom invertebrates, in the immediate outfall area. The effect, however, should be localized due to rapid dilution with the sea water at outfall and by local runoff and precipitation into the cooling pond.

## 2. Cooling Towers.

### Operating Parameters:

Cooling towers are classified by basic differences in design or operation. A tower may be either "wet" or "dry", depending on whether water is exposed directly to the air. Heat transfer occurs by convection and evaporation in wet cooling towers. Water used in the condensing process passes into the top of the cooling tower where it falls slowly in fine droplets, thereby increasing the total water-to-air surface area. Heat is lost by evaporation of this water and by conduction-convection processes to the air. Dry towers transfer heat primarily by convection, since no direct exposure of water to air occurs. In both designs, the atmosphere is acting as the ultimate heat sink.

Towers are further categorized depending on the method of air movement within the tower. Natural draft towers, which can be wet or dry, depend on the air pressure differences within the tower and outside for air movement. Mechanical draft towers induce air movement by the use of fans. The basic requirement of both natural and mechanical draft towers is to increase air passage through the tower and thus facilitate heat transfer from the water to the air.

### Advantages of Cooling Towers:

- (a) The cooling water is contained on land; thus not necessitating usage of the ocean as an intermediate heat sink, with its potential impact on the aquatic environment.

- (b) Sophisticated design and optimization of both cooling towers and the condensing system allow for close control of the temperature differential to be cooled.

Disadvantages of Cooling Towers:

- (a) High capital costs tend to make towers unattractive for small generating units.
- (b) Since the basic heat transfer is dependent on the atmosphere, climatic variations present problems. Icing of intake air louvers, recirculation of heat exhaust and associated operation problems tend to cause relatively higher operation and maintenance cost than for cooling ponds or reservoirs in variable climates.
- (c) Possible side effects from fogging or ground level drizzle exists. A recent investigation of such problems encountered in the eastern United States showed the area affected was very small, fog extended a maximum of one-quarter mile from the towers with some minor icing up to three hundred feet.<sup>27</sup> Drift eliminators, which are baffles located above the water distribution system in the towers, can be used to reduce this problem. At the Holyrood station the nearest major highway is

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<sup>27</sup>Broehl, D.J., 1968, "Field Investigation of Environmental Effects of Cooling Towers for Large Electrical Plants", Portland General Electric Company (unpublished).

approximately one mile from the generating station.

- (d) Water is lost by evaporation from wet cooling towers, and non-evaporated substances are concentrated in the remaining cooling water. To prevent scale corrosion and general deterioration of the cooling structures, a portion of the cooling water is drained from the system for disposal. This water, called blowdown, contains concentrated solids, dissolved salts, minerals, and may also contain special chemicals used to prevent scale and corrosion of condenser tubes. Towers using sea water would require more frequent blowdown due to high salt concentrations. Water extracted for blowdown purposes represents another potential aquatic pollutant.

#### B. Comparative Costs for Cooling Tower Designs and Cooling Ponds.

Table II, presents the comparative costs for different cooling tower designs and cooling ponds. Cooling tower costs vary widely with location, fuel costs, load factors, and capitalization rates. Cost estimates should therefore be considered only as relative costs to indicate the lowest cost alternative.

Capital costs per kilowatt electrical output presented in Table II is based on a report presented to the U.S. Senate

Subcommittee on air and water pollution (1968 U.S. dollars)<sup>28</sup>.

The Holyrood station capital cost estimates are based on a 300 megawatt electrical capacity plus an estimated twenty-five per cent to account for increased costs incurred to prevent corrosion when using saline cooling water.<sup>29</sup> Expected increases in busbar costs of various cooling methods are based on a U.S. Department of the Interior study for thermal power plants near Lake Michigan.<sup>30</sup> The estimates are for freshwater cooling systems and include fixed and variable costs. Projected increases in busbar costs should be considered as minimal since the use of sea water cooling increases the initial capital cost, operating costs due to more frequent blowdown requirements, and maintenance costs due to excessive corrosion above similar systems using freshwater cooling.

TABLE II

Capital Costs and Busbar Cost Increases of Various Cooling Systems.

Design	Capital Cost \$ per Kw.	Holyrood Estimate \$ Millions	Per Cent Increase in Busbar Cost
Mechanical Draft (wet)	7	2.63	1.5
Natural Draft (wet)	11	4.13	3.0
Natural Draft (dry)	25	9.38	9.0
Mechanical Draft (dry)	27	10.13	10.0
Cooling Ponds	.54-1.49	.162-.447	<1.0

<sup>28</sup>U.S. Congress, Senate Committee on public works, 1968. Hearings before the Subcommittee on Air and Water Pollution: Thermal Pollution by Tor Kolflat. 90th Congress, 2nd Session, p.54.

<sup>29</sup>Woodson, R.C., "Cooling Towers for Large Steam-electrical Generating Stations", Electrical Power and Thermal Discharges, Gordon and Breach Science Publishers, 1969.

<sup>30</sup>"Feasibility of Alternative Means of Cooling for Thermal Power Plants Near Lake Michigan", U.S. Dept. of the Interior, Sept. 1970.

Auxiliary electrical power requirements for water pumping and fans constitute the major component of cooling tower operating costs. This cost is generally higher for mechanical draft towers than for natural draft. Annual operating costs for a mechanical dry or wet tower to service a typical fossil fueled (800 megawatt) station is estimated to be \$2,430,000 and \$860,000 respectively. A natural draft tower to service a similar size station would have an annual operating cost of \$700,000 and \$730,000 respectively for the wet and dry design.<sup>31</sup> Maintenance and repair costs for cooling towers are highly variable, but can be estimated to cost approximately 1% of the total cooling tower operating cost.

In general, wet tower designs have a lower initial capital cost relative to the dry tower variety. (\$7-\$11 versus \$25-\$27 per kilowatt capacity.) Manufacturers state that wet towers are practical for generating stations using sea water cooling, although such applications have not been placed in general operation.<sup>32</sup> Due to the generally untested technology of wet saline cooling towers, it is doubtful that such a cooling system offers a reasonable alternative for the Holyrood generating station. Dry cooling towers design, while technically feasible for saline cooling systems, cost three to four times more (capital costs) than their wet

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<sup>31</sup>Op. Cit., p. 372.

<sup>32</sup>No wet cooling systems using saline cooling are used in the U.S. Two saline water natural draft (wet) have been used for a 90 megawatt station in England.

counterparts.<sup>33</sup> The cost factor has tended to make dry towers impractical for small generating units.

Cooling ponds costing \$0.5 - \$1.5 per kilowatt capacity offer a considerable economic advantage relative to cooling tower capital costs of \$7 - \$27 per kilowatt. Based on an initial capital cost of \$0.5 to \$1.5 per kilowatt, a cooling pond to service the Holyrood station would cost between \$162,000 and \$447,000 as opposed to a cooling tower cost of \$2.6 to \$10.1 million. Operating, maintenance and repair costs are variable depending on location and construction design but would generally be lower than for cooling towers. In addition to being the lowest cost alternative, cooling ponds offer several other advantages. Low average mean air temperature and general meteorological conditions at the Holyrood site would be favourable for effective cooling by this method. Land availability and minimal environmental disadvantages also tend to favour the use of cooling ponds. Cooling ponds, both technically and economically, offer a practical alternative at the Holyrood plant to the present non-cooling of effluent waters.

### C. The Fishery Resource.

#### 1. Commercial fish landings and value:

Conception Bay, statistical area E, is divided into four sections (20-23 inclusive) for data collection by the

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<sup>33</sup>"Industrial Waste Guide on Thermal Pollution", Federal Water Pollution Control Administration, U.S. Dept. of the Interior, September 1968, p. 79.

Federal Department of Fisheries, Fig. 4. The generating station is located within section 22. Observations were made to determine the actual number of fishermen and the amount of fishing gear utilized within the warm water mixing zone. Using section 22, statistics for landed dollar value to fishermen per commercial species and the total amount of fishing gear utilized, an average dollar return per unit fishing gear was calculated. This value was then used, given the amount of fishing gear located within the warm water mixing zone, to estimate the annual value of fish taken from the area affected by the warm water discharge.

In 1969 and 1970, the total gross value of all commercial fish landings (inshore and offshore) for Conception Bay was \$1,511,876 and \$1,529,666 respectively. The inshore fishery accounted for \$1,345,135 and \$1,279,300 of this total value during 1969 and 1970. Section 22, the area receiving the generating station effluent, had an inshore fishery value of \$363,940 and \$350,564 in 1969 and 1970 respectively. The data indicates the major importance of the inshore fishery relative to offshore and the importance of section 22 as the second largest producer in Conception Bay, Table A-I.

## 2. Capital investment in the primary fisheries:

In 1969, the capital equipment employed in the primary fishery of Conception Bay was \$1,705,600. This investment in boats, fishing gear and shore installations was determined on a market value definition, ie. the amount of

money that would readily transfer title from a willing seller to a willing buyer. Fishery officers collecting this data sometimes place a standard value on boats and fishing gear of similar type and construction. Of the total Conception Bay equipment investment, section 22 employed equipment valued at \$372,402 (Table A-II). Fishing gear located within the warm water mixing zone was valued at \$13,460, based on 1969 statistics (Table III).

### 3. Employment in the primary fisheries:

The inshore fishing industry has historically represented an alternative source of employment in times of employment contraction in other sectors of the economy. Inshore fishing activity has also been a supplementary source of income. This factor would appear to be particularly pronounced in Section 22. During 1969, 790 men were employed in Section 22, 2 full-time, 140 part-time and 648 casual fishermen.<sup>34</sup> Thus approximately 80% of those engaged in the inshore fishery fished for less than five months. During 1969, twelve fishermen had fishing gear placed within the warm water mixing zone. This included two part-time and ten casual fishermen.

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<sup>34</sup> Full-time fishermen - fishing for 10 months or more per year.  
 Part-time fishermen - fishing from 5-10 months per year.  
 Casual fishermen - fishing for less than 5 months.

TABLE III

Commercial fish landed value, capital investment and employment.

	Area E	Section 22	5000' Radius Mixing Zone
Landed fish value \$/year	\$1,364,424	\$359,465	\$2,932 <sup>b</sup>
Capital investment in gear and shore installations	\$1,705,600	\$372,402	\$13,460
Employment <sup>a</sup>	1,576	790	12

a. - Total number of fishermen; full-time, part-time and casual.

b. - Based on an average catch per unit fishing gear.

#### 4. Fishing activity within the effluent mixing zone:

During 1969, the following fishing gear was employed within the effluent mixing zone:

5 salmon nets

7 cod traps (2 traps and 5 gill nets)

100 lobster traps

Fishing gear is placed in areas suited to proper water depths and ease of mooring. Such fishing stations or berths are used annually.

Based on Section 22, total landed value of fish (Table A-I) and total units of fishing gear used (Table III) an average expected return per unit of fishing gear was calculated.

Return Per Unit of Salmon Gear:

Total landed value, salmon <sup>a</sup>	- \$24,450
Total units of salmon gear <sup>b</sup>	- 423
Return per unit gear	- 24,450÷423
	- \$58.00
No. of units within the mixing zone	- 5
Expected return	- 5 x \$58.00
	- \$290.00.....\$290.00

Return Per Unit of Cod Gear:

Total landed value, cod <sup>a</sup>	- \$308,899
Total units of cod gear <sup>b</sup>	- 1,010
Return per unit gear	- 308,899÷1,010
	- \$306.00
No. of units within the mixing zone	- 7
Expected return	- 7 x \$306.00
	- \$2,142.00.....\$2,142.00

Return Per Unit of Lobster Gear:

Total landed value, lobster <sup>a</sup>	- \$17,416
Total units of lobster gear <sup>b</sup>	- 3,475
Return per unit gear	- \$17,416÷3,475
	- \$5.00
No. of units within the mixing zone	- 100
Expected return	- 100 x \$5.00
	- \$500.00.....\$500.00

Total Expected Return from Gear Within the Mixing Zone      \$2,932.00

a - For Section 22, averaged over 1969 and 1970.

b - For Section 22, averaged over 1969 and 1970.

As indicated from actual measurement of the warm water mixing zone, the heated water spreads primarily on the surface. At a distance of two hundred and fifty feet from the effluent outfall, the depth of heated water did not exceed three feet from the surface. Since fishing gear is set well below this depth, the impact on gear located within the mixing zone should be minimal.

The maximum effect, in terms of present values of commercial fish caught, would result in an annual loss of approximately \$2,932.00 if fishing activity ceased completely within the mixing zone.

CHAPTER IV

## LEGAL ASPECTS

A. Federal Fisheries Philosophy re: Pollution.

Legal action has never been a key instrument in the solution of fisheries-pollution problems. Recognition that legal action is, in itself, a negative approach to pollution abatement has resulted in exhaustive efforts to negotiate an economic rather than a legal solution. Dangers inherent in such an approach are obvious, the reasons are not. In some situations, it is not possible to achieve desired economic development and, at the same time, totally preserve the fisheries' environment. A choice must be made that cannot be based strictly on technical availability of abatement techniques, but must also recognize social, economic and political considerations. To state the technical abatement techniques required and to legally enforce their use would be to disregard these other considerations. In the vast majority of situations, legal action can only be taken after the fact. In such cases, compensation or granting of injunctions by the courts does little to restore the environment. There can, therefore, be considerable justification for the "legal action last resort" philosophy. However, it must be made very clear that legal action will be used against recalcitrant offenders.

B. Statutory Law.

The relevant acts and pertinent sections which are applicable to potential pollution from the generating station are:

1. The Federal Fisheries Act.

Section 33(2); "No person shall deposit or permit the deposit of a deleterious substance of any type in water frequented by fish, or in any place under any conditions where such deleterious substances or any other deleterious substance may enter any such water."<sup>35</sup>

Deleterious substance is defined by the act as any substance that, if added to any water, would degrade or alter or form part of a process of degradation so as to alter the quality of water and render it deleterious to fish. Fish as interpreted by the act refers to shellfish, crustaceans and marine animals.<sup>36</sup>

Violation of Section 33 can result in a fine not to exceed five thousand dollars for each offence.<sup>37</sup> The courts, in addition to any punishment they impose, may order that person to refrain from committing any further such offence.<sup>38</sup>

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<sup>35</sup>Section 33 (11), a. Deleterious substance includes any water that contains a substance in such quantity or concentration, or that has been so treated, processed or changed, by heat or other means. RSC. 1970, The Canada Statute Citator.

<sup>36</sup>Section 2, C.

<sup>37</sup>Section 33 (5).

<sup>38</sup>Section 33 (7).

## 2. The Federal Clean Air Act.

This act administered by the Minister of the Environment is intended to control ambient air quality and air pollution. It is binding on Her Majesty in right of Canada and provinces and any agent thereof.<sup>39</sup> Power is granted to the Governor in Council to make regulations prescribing the "quantities and concentrations of substances and classes of substances in air."<sup>40</sup> Any person found liable on summary conviction is subject to a fine not exceeding two hundred thousand dollars for each offence.

Combustion of bunker C fuel emits a variety of gaseous wastes including dioxides and trioxides of sulfur, nitrous oxides and particulate material. Sulphur oxides are of particular concern since in combination with atmospheric water corrosive sulphuric acid mist is formed. The generating station has installed gas scrubbers which should remove the majority of these gaseous wastes.

## 3. The Canada Water Act.

This act provides for management of Canada's water resources including research, planning and implementation of programs relating to conservation, development and utilization of water resources. The act, primarily intended for inland water development, empowers Ottawa and one or more provinces to set up water management authorities which set

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<sup>39</sup>Section 2(3).

<sup>40</sup>Published in the Canada Gazette.

standards for multi-purpose use within the water management area. Conception Bay would have to be designated as a water management area before any action could be taken under this act and an authority to supervise its development would have to be appointed. This water management authority would then be required to set standards of purity to be recommended to the federal and the provincial governments for ratification.

Given the intent of the legislation as a long-term planning and multiple-purpose development plan, it is doubtful if the act could be used effectively to curtail any immediate pollution hazard within Conception Bay.

#### 4. The Clean Air, Water and Soil Authority Act.

This act established the Newfoundland and Labrador Clean Air, Water and Soil Authority. The authority is vested with "prohibiting, restricting and regulating the use of water from any specified body or bodies of water generally for household, industrial, commercial or irrigation purposes."<sup>41</sup>

The act can prescribe standards of emission for any gaseous or particulate substance emitted to the air from any public, industrial, or commercial works.<sup>42</sup> The minister has responsibility for prescribing penalties for offences against the act.<sup>43</sup> A literal interpretation of the act appears to exclude sea water; however, a more liberal interpretation

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<sup>41</sup>Section 16(1) b.

<sup>42</sup>Section 16(1) O.

<sup>43</sup>Section 16(4).

consistent with the intent of the act may allow for the inclusion of a coastal bay. The fact that sea water is not specifically included in the act may reflect the constitutional question concerning responsibility for seacoast areas.

Section 109 of the British North America Act indicates that the natural resources of lands and minerals are the property of the province. Other resources such as water and fish are not mentioned. The reason being that the law has never recognized ownership of such resources while they remain in the natural state. Ownership is legally recognized only after the resource has been reduced to possession. This, however, should not imply that there can be no legal rights over water or fish in the natural state. Certain rights do accrue to those who "own" the land underlying the water, eq. rights of use or usufructory rights. If ownership of the seacoast bed was clearly established as provincial, these proprietary rights could form the basis of some legislative jurisdiction. Federal legislation can, however, affect the proprietary rights of the provinces and can overrule provincial legislation on subject matters that are within federal jurisdiction, eq. the fisheries as envisaged by Section 91 of the British North America Act.

The invoking of statutory law by federal agencies or departments against a provincial public utility raises complex constitutional questions of legislative jurisdictions

as defined by the British North America Act, 1867. A key question with respect to potential pollution from the generating station is the extent of immunity of this particular project, as a provincially created instrumentality, from federal laws.

Section 91(12) of the B.N.A. Act grants the Federal Crown jurisdiction over "seacoast and inland fisheries". Considerable litigation has resulted from interpretation of this power. In general, provincial legislatures have jurisdiction over all proprietary and marketing aspects of fishing<sup>44</sup>, while the federal government controls the regulatory aspects of fishing including pollution measures.<sup>45</sup> To what extent is the provincial crown liable should there arise a conflict regarding pollution and its effects on fish? Both the federal and provincial governments have powers to legislate respecting water usage; the federal crown to protect the seacoast fishery and the provincial government in producing electrical energy. There is then an overlapping of jurisdictions respecting water usage. In general, it can be stated that in cases of overlapping or concurrent jurisdictions, federal legislation takes priority over incompatible provincial

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<sup>44</sup>A-G for British Columbia v. A-G for Canada; Fish Cannery Reference (1930) A.C. III.

<sup>45</sup>Gibson, D., "The Constitutional Context of Canadian Water Planning", Alberta Law Review, Vol. 7, No. 1, 1967.

legislation.<sup>46,47</sup> The extent to which the provincial government is immune from federal legislation and vice versa is a legal complexity that is largely unresolved.

The problem of provincial immunity from federal statutory law, with respect to this particular project, is largely hypothetical. If the N.L.P.C. were in violation of any federal pollution statute, it is highly unlikely, if for none other than political reasons, that the conflict would be resolved by court action.

C. Common Law.

The body of law that has been extracted from previous judicial decisions and custom constitutes the common law. The public, as lawful residents of a province or country, have certain rights that have not been embodied in any specific statute. An individual or the public at large has the basis for a legal action if activities of others interfere with the exercise of these accepted public rights. For example, the public right of navigation in water designated as navigable watercourses, the public right of fishing in tidal waters, and the right to full enjoyment of one's land free from nuisance or damage imposed by other parties.

The N.L.P.C. will be transporting bunker fuel by tanker to the generating station and fishing gear located in

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<sup>46</sup>Reference re: Troops in Cape Breton (1930) S.C.R. 554.

<sup>47</sup>Gibson, D., "Interjurisdictional Immunity in Canadian Federalism", Canadian Bar Review, March, 1969.

the area will be subject to damage. In general, the right of navigation takes precedence over the right of fishery in tidal waters.<sup>48</sup> The rule, however, is subject to qualification, since the right of navigation must be exercised reasonably.<sup>49</sup> The key question to be considered in adjudication by the courts will be: "Could the navigation have been conducted in a reasonable manner so as to have prevented damage to fishing gear?" The burden of proof will be on the fishermen to show that the navigation was unreasonable. Fishing gear located within the area should be marked, for example by radar reflectors, to strengthen any claim for damages.

A public right of fishing exists in tidal waters, and an infringement of this right is cause for a legal action.<sup>50</sup> Increasing the temperature of waters has been recognized by the courts as a pollutant.<sup>51</sup> If fish mortality results from pollution, specimens of dying or dead fish should be dispatched immediately for pathological examination. In cases where temperature is the prime element of pollution, eg. a discharge

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<sup>48</sup>Wisdom, A.S., The Law on the Pollution of Waters, 1966, Shaw and Sons Ltd.

<sup>49</sup>"The reasonable man of ordinary prudence" is the central figure in negligence issues." Fleming, J.H., The Law of Torts, The Law Book Company Ltd., Australasia, 1971.

<sup>50</sup>Wisdom, A.S., The Law of Rivers and Watercourses, 1966, Shaw and Sons Ltd., p. 53. B.C. Fisheries, 15 D.L.R. 308 at 318 (J.C.P.C.).

<sup>51</sup>Tipping v. Eckersley (1855), 2K. and J. 264; Pride of Derby Angling Assocn. Ltd. v. British Celanese Ltd., (1953) 1 All E.R. 179; Goldmid v. Tunbridge Wells (1866), 14 L.T. 318.

of heated condenser water, a series of temperature readings should be given in proof, supported by technical evidence on the fatal or ill effects of heated water on aquatic life.<sup>52</sup>

Gaseous emissions from the generating station may form the basis for a nuisance action, if such emissions cause damage to surrounding land or the plaintiffs' enjoyment of his land. Action against pollution amounting to a public nuisance can be instituted by the Attorney-General representing the public. In such cases, it is not necessary to prove actual damage to the public. A private person who sustains special injury from a public nuisance can bring an action without the Attorney-General as a party to the claim. This person must show that he has sustained particular damage or injury beyond the general injury to the public and that such damage is direct and substantial.<sup>53</sup> A plaintiff must prove his case against the defendant for material damage liability based on the civil action standard, ie. a plaintiff must show that on the "balance of probabilities" he sustained damages, as opposed to proving beyond a shadow of doubt that the damage flowed from the defendant's plant. Nuisance liability would be subject to the defence that the provincial statute, in establishing the generating station, implicitly authorized whatever degree of air pollution that is inevitable.

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<sup>52</sup>Op. Cit., p. 29.

<sup>53</sup>Hickey et al. v. Electric Reduction Co. of Canada, Ltd. (1971) 21, D.L.R. (3rd) 368.

CHAPTER V

## CONCLUSIONS

1. The thermal plume should not extend beyond a 3,000 - 5,000 foot radius from the effluent outfall. The exact shape and dispersion pattern within the area prescribed by these radii will depend on prevailing wind and current directions.
2. Dispersion of the heated effluent is primarily a surface phenomenon, and no effects on fish movement patterns should occur.
3. Experimentally determined thermal tolerance limits for species found in the Conception Bay area should not be exceeded within the mixing zone, except in the immediate area of thermal discharge.
4. Estimates of capital costs for cooling towers to service a 300 megawatt marine station range from \$2.63 - \$10.13 million, depending on design. The capital cost of a cooling pond to service a similar size station would be \$162,000 - \$447,000. In addition to being the least cost cooling alternative, cooling ponds would appear to be technically feasible given the availability of land in the area and general meteorological conditions.
5. Commercial fishing for salmon, cod, and lobster exists within the effluent mixing zone. Based on the number of fishermen (12) and the amount of fishing gear used within the

mixing zone, if all commercial fishing ceased within the mixing zone, an annual loss of \$2,932.00 can be expected.

6. Statutes that could be invoked to deal with pollution from the generating station include the Federal Fisheries Act, the Federal Clean Air Act, the Canada Water Act, and the provincial Clean Air, Water and Soil Authority Act. All acts raise certain questions respecting applicability to the Holyrood situation.

7. Any legal action by the Federal Government based on statutory law would raise several questions: (i) the extent of provincial government immunity from federal legislation and (ii) the constitutional question of whether a province can pass a law limiting liability for damage to a fishery.

The provincial statute establishing the N.L.P.C. has authorized in a practical sense whatever degree of pollution that is inevitable. If the courts viewed this as being inconsistent with a federal statute, eg. the Fisheries Act, it is probable that the provincial government would not be immune from the federal legislation.

8. The possibility of legal action based on the common law also exists. Interference with fishing rights and nuisance claims are potential causes for legal actions.

Private legal actions based on interference with fishing rights and/or nuisance would have to establish that

the plaintiff suffered greater injury than the public in general and that the injury was direct and substantial.

Recent evidence indicates that private actions for interference with the private right to a fishery are not likely to succeed.

Legal actions by the Attorney-General of Canada can be instituted in the common interest of the public. In such cases the plaintiff would have to show an interference with established public rights (eg. to a fishery) and full enjoyment of one's land.

## RECOMMENDATIONS

1. That surface temperature not exceed  $19^{\circ}\text{C}$ , the lowest tolerance limit for species frequenting the area, to ensure a cooler bottom layer for fauna. If temperature exceeds this limit in the immediate outfall zone an appropriate sized area should be sectioned off to prevent fish entry. A permanent 24-hour thermograph should be installed at the effluent outfall.
2. A regular monitoring program be initiated to gather data on various in-plant operations, such as chlorination condenser cleaning, the steam-boiler water treatment process, and the magnesium treatment process used in the gas scrubbers. All these treatment processes involve chemical additions to water, some of which may prove toxic if discharged with the normal effluent.
3. Fishing gear located in the area be adequately marked, eg. by radar reflectors. This will minimize the possibility of damages from tankers and strengthen any subsequent claims for damages.
4. Commercial fishery catch statistics be collected on an individual basis from fishermen within the thermal discharge area for a number of years. These data can provide an accurate assessment of any changes in fishing success that may be attributable to the thermal discharge.

A P P E N D I X    A

## Commercial inshore fish landings and value by species and section.

Section	Species	Landings (inshore) 1000's lbs.		Value (\$)	
		1969	1970	1969	1970
20	Cod	15,809	14,281	526,800	563,262
	Salmon	12	19	6,311	11,066
	Caplin	202	98	1,939	1,087
	Squid	11	5	286	155
	Lobster	9	4	4,974	2,961
	Cod tongues	5	4	686	628
	Cod Oil	1,022	259	108,372	4,399
	Herring	14	27	313	725
	Tomcod		21		427
			<u>17,084</u>	<u>14,718</u>	<u>649,681</u>
21	Cod	7,894	6,670	246,507	241,451
	Salmon	9	25	5,154	13,363
	Caplin	250	463	2,455	4,965
	Squid	1	-	7	
	Lobster	4	5	2,382	3,125
	Cod tongues	1	1	86	128
	Cod Oil	196	1	2,033	1,557
	Herring	3	133	68	2,623
		<u>8,358</u>	<u>7,298</u>	<u>258,692</u>	<u>267,212</u>
22	Cod	10,789	8,478	323,742	294,056
	Salmon	20	52	16,568	32,331
	Caplin	482	272	4,884	4,383
	Squid			27	
	Lobster	19	18	16,708	18,123
	Cod tongues			48	
	Cod Oil	81	13	812	352
	Herring	39	47	1,151	1,319
		<u>11,430</u>	<u>8,800</u>	<u>363,940</u>	<u>350,564</u>
23	Cod	662	934	23,661	31,452
	Salmon	57	52	39,359	32,722
	Squid	1		15	
	Lobster	9	14	8,142	11,780
	Cod Oil	12		123	
	Herring	51	23	1,522	860
		<u>792</u>	<u>1,023</u>	<u>72,822</u>	<u>76,814</u>
Grand Total All Sections		37,664	31,919	1,345,135	1,279,300

TABLE A-II

Enumeration of fishermen, boats and fishing equipment for  
Section 22.<sup>1</sup>

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No. of Inshore Fishermen:

Full-time	2
Part-time	140
Casual	<u>648</u>
	<u>790</u>

Boats (<10 tons):

Total selling value	\$153,265
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Fishermen's Shore Installations:

Total Selling Value	44,445
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Inshore Fishing Gear:

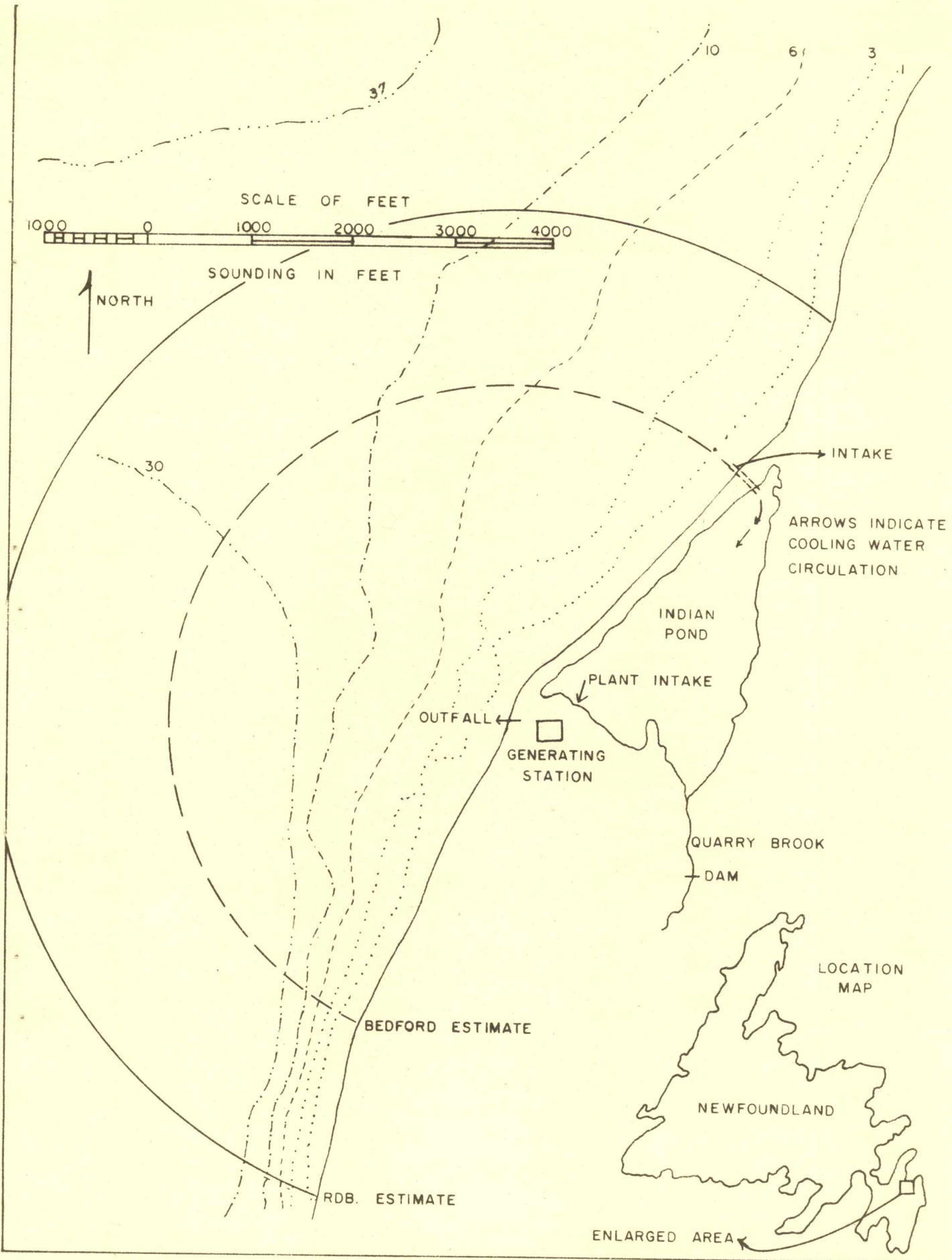
Total Selling Value	<u>174,692</u>
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Total	<u><u>\$372,402</u></u>
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<sup>1</sup>Federal Fisheries Statistics, 1969.

A P P E N D I X    B



HYDROGRAPHY OF CONCEPTION BAY AND ESTIMATED

FIG 1 RADII OF AREA TO REACH AMBIENT CONDITIONS.

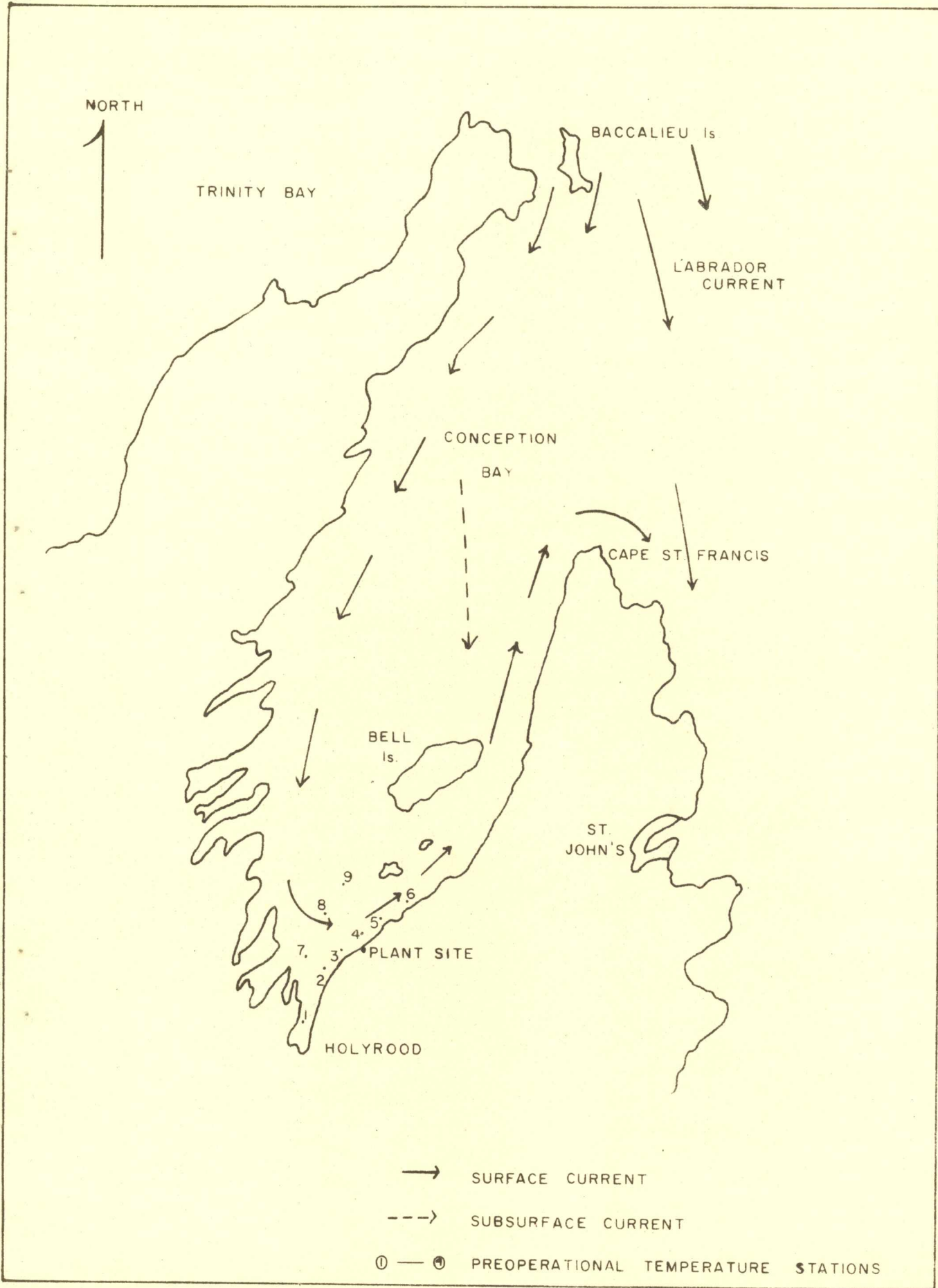


FIG. 2 CURRENT DIRECTION AND PREOPERATIONAL TEMPERATURE

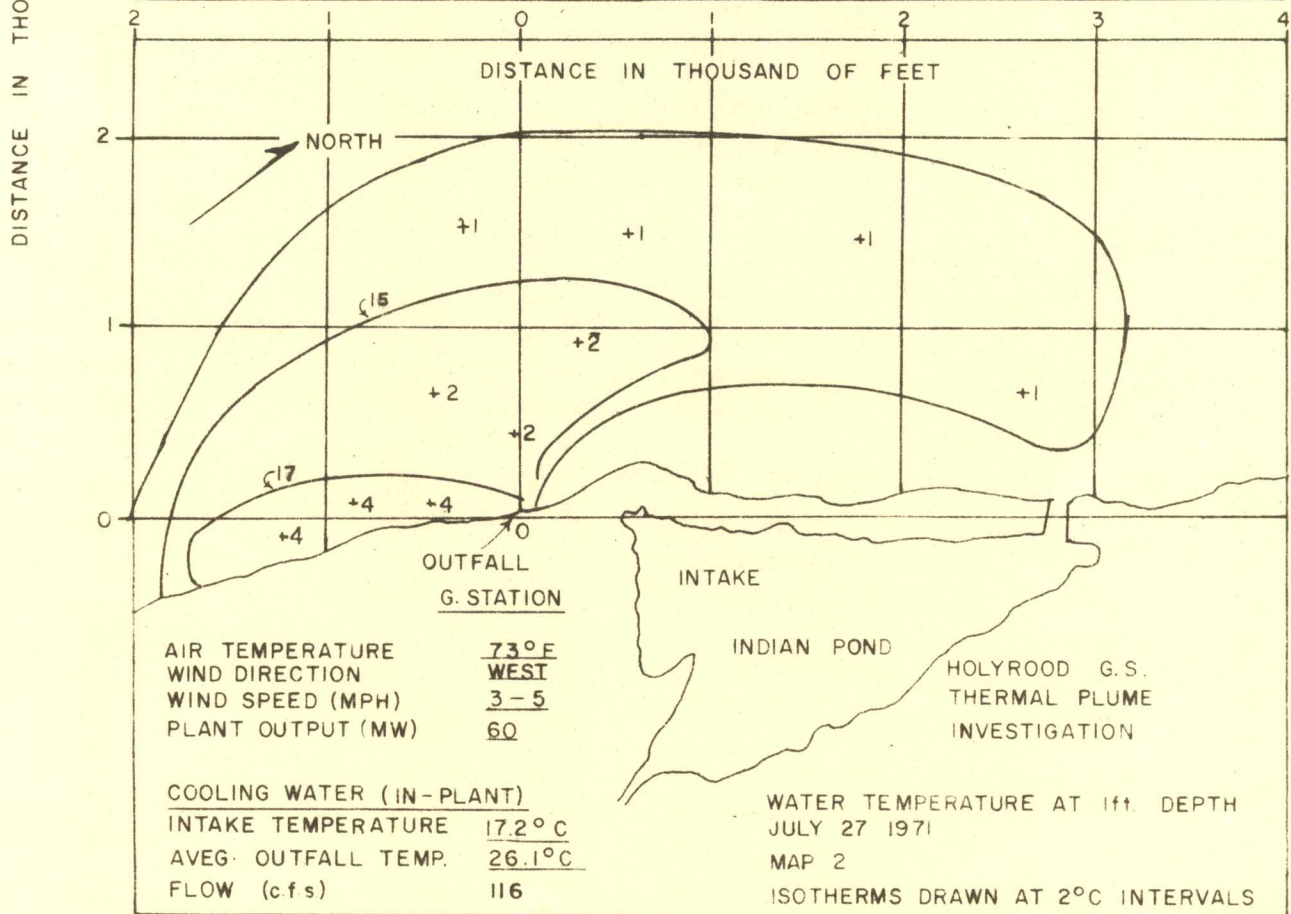
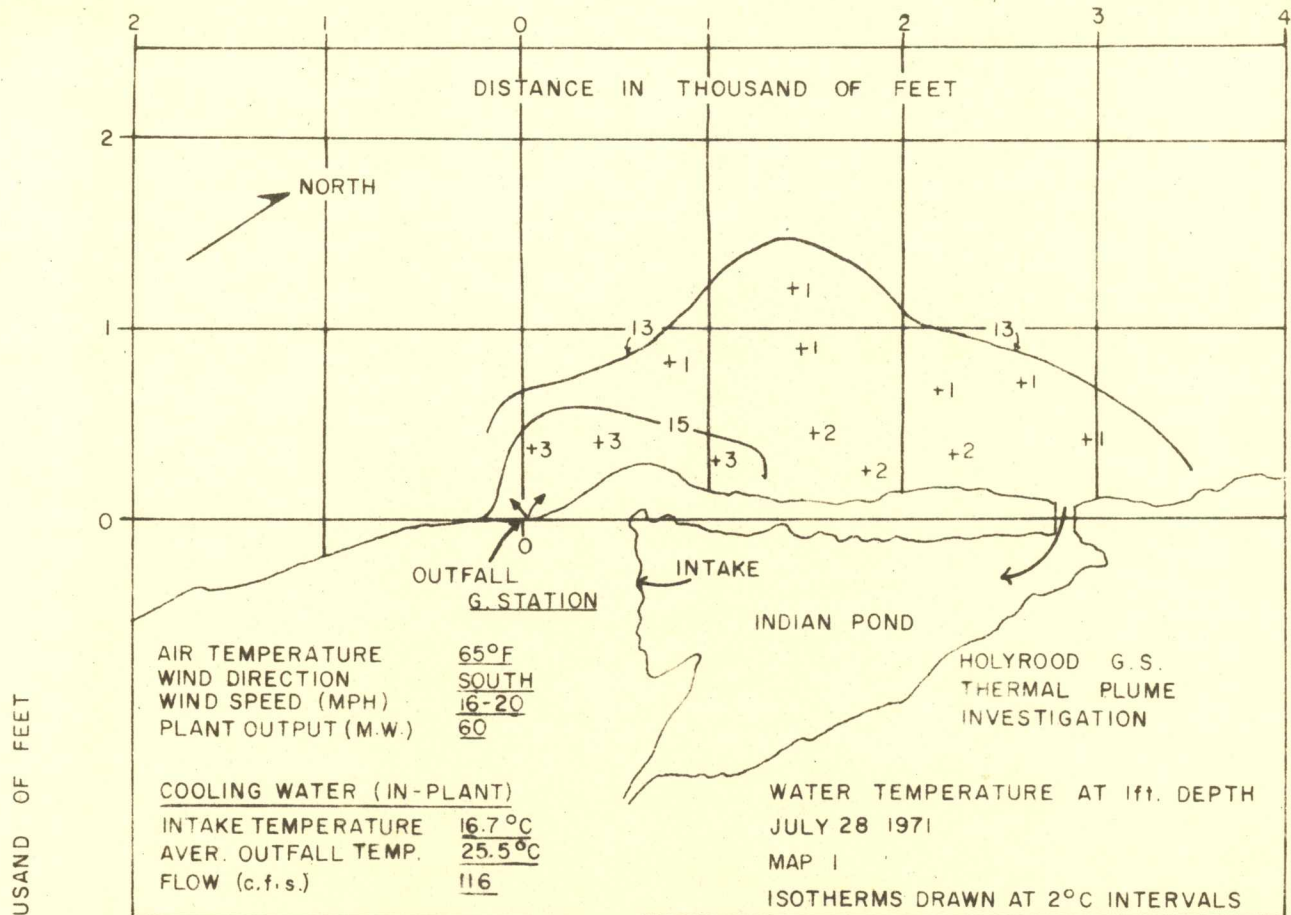


FIG. 3 ISOTHERMS WITHIN THERMAL PLUME

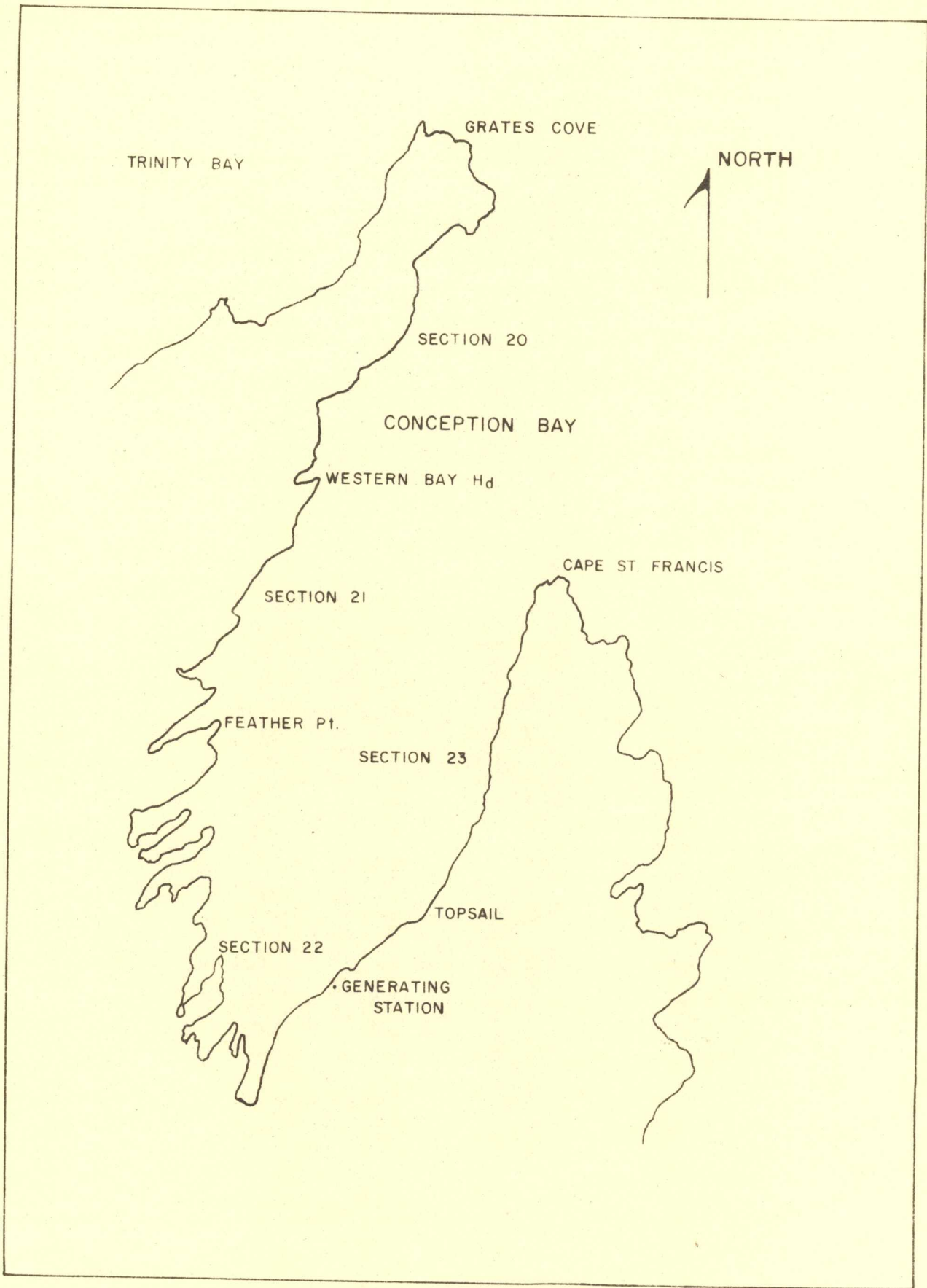
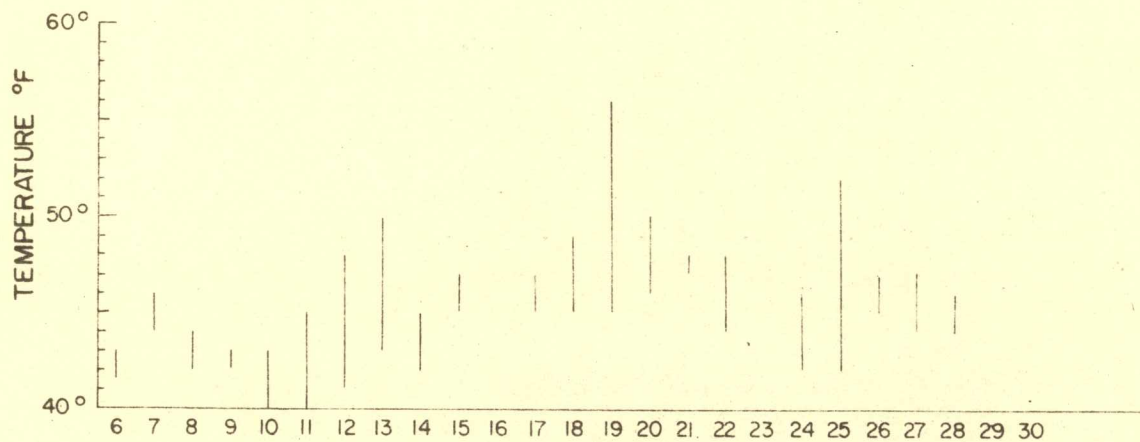


FIG. 4 CONCEPTION BAY, STATISTICAL AREA "E",  
WITH SUBSECTIONS



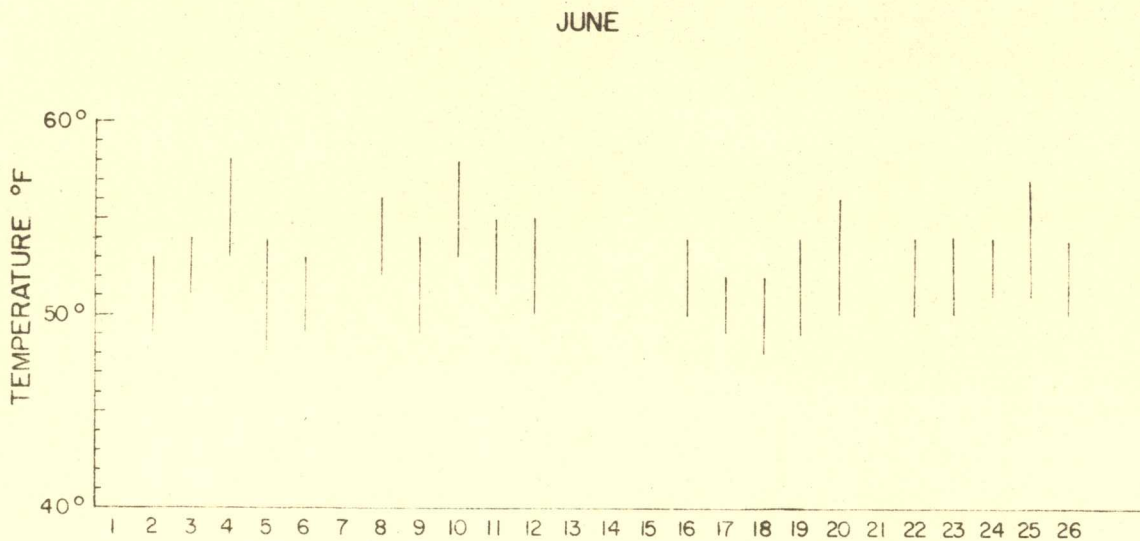
JUNE

N = 21

$\bar{X}$  24 HR. TEMP  $\Delta$  = 4.07 °F

$\bar{X}$  MAXIMUM TEMP = 47.38 °F

$\bar{X}$  MINIMUM TEMP = 43.03 °F



JULY

N = 20

$\bar{X}$  24 HR. TEMP  $\Delta$  = 4.00 °F

$\bar{X}$  MAXIMUM TEMP = 54.55 °F

$\bar{X}$  MINIMUM TEMP = 50.15 °F

FIG. 5 24 HR. MINIMUM & MAXIMUM SURFACE WATER TEMPERATURES OF CONCEPTION BAY

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