UNIVERSITY OF MANITOBA

THE EFFECTS OF THERMAL DISCHARGES FROM THE BRANDON GENERATING STATION ENTERING THE ASSINIBOINE RIVER

by

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A Thesis
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ABSTRACT

Heated discharges from thermal generating plants in Canada which employ once-through cooling will increase dramatically during the remainder of this century. The impact of these discharges on natural waters is difficult to determine because such effluents typically consist of large volumes of moderately heated water, the effects of which are not easily measured. The method of estimating the effects of heated discharges upon an aquatic ecosystem is to monitor several physical, chemical and biological parameters for the purpose of developing converging lines of evidence to indicate what may be happening.

The Manitoba Hydro Brandon Generating Station is a 237 MW, fossil-fuel, peaking facility with a cooling water pumping capacity of 200 cfs. Various amounts of cooling water are removed from the adjacent Assiniboine River, warmed, and then returned. The data recorded in this study includes mean monthly flow rates in the Assiniboine River at Brandon; upstream, downstream and discharge temperatures from the point of thermal discharge into the Assiniboine River; diversity indices for benthic macroinvertebrate communities at designated sampling stations upstream and downstream from the thermal effluent outfall.

Mean monthly flow rate data for the Assiniboine River at Brandon between 1953 and 1969, prior to flow control regulation by the Shellmouth Reservoir control installation, indicated that the flow rates were often less than the 200 cfs pumping capacity of the Brandon Generating Station cooling water pumps. There has been only one monthly mean below 200 cfs at Brandon since flow regulation commenced. Some of

the spring and summer flow increases are attributable to meteorological conditions, but flow augmentation has been most significant during autumn and winter months, the period when flows are lowest.

Temperature data available for most of the period between November 11, 1974 and May 22, 1975 demonstrated that mean daily downstream temperatures could rise between one and 3.5 degrees C above upstream temperatures. Greater differences in maximum temperatures were observed for shorter durations and this was estimated conservatively. The rates of downstream temperature fluctuations were greater than upstream temperature fluctuations during periods of high discharge temperatures.

The diversity index values representing benthic macroinvertebrate communities did not uncover evidence of degredation to the ecosystem attributable to the thermal effluent. More knowledge of the mixing patterns of the thermal effluent in the receiving waters is required, however, so that biological samplers can be installed in and out of those waters influenced by thermal discharge temperatures.

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CHAPTER I

SUMMARY

It has been unquestionably established that the demand for electricity in North America will grow appreciably during the remainder of this century and that thermal generation will be the predominant means of production. In Canada it appears that once-through cooling will continue to be permitted where water supplies are adequate. This study first reviews the anticipated growth in demand for cooling water and examines many of the physical, chemical and biological implications of discharging heated effluents into natural waters.

Flow rate data for the Assiniboine River at Brandon demonstrates that the mean monthly flows have increased since 1969, the year the Shellmouth Reservoir control system was commissioned. This has been the result of increased precipitation but the major significance of this control is the fact spring and summer flows may be held back to augment winter flows. It is during autumn and winter when river flows are lowest and the Brandon Generating Station typically has its greater generating demands.

Water temperature data was available for the period between November 11, 1974 and May 22, 1975. Tables of daily mean temperatures, and temperature fluctuations, for upstream and downstream locations permitted a comparison of the temperature effects of the discharge. The plant was not generating peak loads during most of this period, judging from the infrequent incidence of high discharge temperatures. The temperature fluctuation rate was more pronounced downstream.

There is concern that Manitoba Hydro's Brandon Generating Station may be discharging sufficient quantities of heated water into the Assiniboine River at Brandon to cause damage to the biota of the recieving waters. No deleterious effects were registered by the benthic macroinvertebrates monitored in this study. There were no measurable lethal or sublethal effects registered by the diversity indices developed. There was evidence that if any upset did occur that recovery took place approximately 2.2 miles downstream from the thermal outfall.

This study does not conclusively indicate negligible thermal degradation of the Assiniboine River due to the operation of the Brandon Generating Station. This is due in part to lack of information from Manitoba Hydro on:

(a) electricity production schedules;

(b) cooling water flow rates;

(c) accurate cooling water and river temperatures.

CHAPTER II

CONCLUSIONS

1. A study of the biological data, represented as diversity indices, indicates that the thermal effluent discharged from the Brandon Generating Station into the Assiniboine River did not cause any measurable damage to the benthic macroinvertebrate communities during those periods when the samples were collected.

2. The impact of the Brandon Generating Station thermal discharges during the study period March, 1974 to May, 1975 was minimized because monthly flow rates were consistently above corresponding monthly means, and electricity generation, as evidenced directly on site and from available discharge temperature data, was low and sporadic.

3. The maximum temperature data collected in November and December, 1974, and January, February, March and April, 1975, when normal water temperatures for the Assiniboine River were low and stable, demonstrated several examples of downstream temperatures exceeding upstream temperatures by more than two degrees C leaving no margin of protection for the aquatic ecosystem.

4. The increased rate of temperature fluctuations of downstream waters compared with upstream waters, attributable to thermal discharges, represents a stress-causing influence upon organisms in that aquatic ecosystem.

5. There are no discernible benefits to the aquatic ecosystem of the Assiniboine River receiving waters resulting from the

thermal discharges of the Brandon Generating Station.

6. Some hazards caused by thinning ice conditions in the waters receiving thermal discharges from the Brandon Generating Station include inconvenience and danger to people and cattle crossing the Assiniboine River, and for some winter activities such as snowshoeing and cross-country skiing.

CHAPTER III

RECOMMENDATIONS

1. Install monitoring equipment to continuously record the volumes of condenser cooling water utilized.

2. Conduct model studies of the thermal effluent dispersion at different flow rates in the Assiniboine River and different levels of electricity generation.

3. Maintain temperature monitoring equipment in the Cooling Water Pumphouse adequately to provide accurate upstream, downstream and discharge temperature data; calibrate equipment regularly; know exact locations of thermocouples.

4. Re-establish a temperature monitoring station in the vicinity of the one previously destroyed at the Lost Island Farm; maintain this equipment adequately; know exact locations of thermocouples.

5. Provide daily electricity production schedules to correlate with other data; insure that advance notice of start-up or shut-down of the generating facility is provided to future investigators.

6. Study alternative modes of discharge to determine the most environmentally acceptable method of conducting the thermal effluent into the receiving waters with a view to minimizing the impact on that ecosystem.

7. Implement a continuous monitoring program under the direction of an independent body or government agency to regularly

determine any effects of thermal effluents discharged by the Brandon Generating Station and report their results to an appropriate regulatory authority.

8. Determine the effects of the weir, constructed by Manitoba Hydro immediately downstream from the Cooling Water Pumphouse, upon population distributions and migration of aquatic organisms.

CHAPTER IV

INTRODUCTION

4.1 The Problem of Thermal Discharges

This study deals with the effects of discharged condenser cooling water upon an natural aquatic environment. The Manitoba Hydro Brandon Generating Station is a steam-generating plant which burns fossil fuels. Cooling water is obtained from the Assiniboine River adjacent to the Brandon Generating Station and discharged one hundred yards downstream from the intake. The Brandon Generating Station is a peaking electrical unit which typically operates on a discontinuous basis and at varying levels of capacity which implies parallel variations for the amounts of spent condenser waters discharged. The flow of the Assiniboine River is important when the receiving capacity for a particular period is considered. In an aquatic environment the rates of temperature change, as well the magnitude and the duration of any change, can be significant.

In this report the term "thermal pollution" typically refers to a temperature increase in a natural water body resulting from a discharge of heated water by industries using such waters for cooling purposes. Clark *et al.* (1) defined "thermal pollution" as "the addition of heat to natural waters to such an extent that it creates adverse conditions for survival and preservation of aquatic life." This implies that only when a thermal effluent is sufficient to create a limiting pressure on some aspect of the aquatic ecosystem does it constitute thermal pollution. It also implies that a natural water body may accept some quantity of thermal effluent which is within the adjustment capacity of a particular aquatic ecosystem and which does not constitute an adverse condition for any measurable component of that community. One author, Merriman (2), objected to the term "thermal pollution" because it implied any warming was harmful. He preferred the word "calefaction" which simply means the state of being warmed, although he admitted there is clearly an upper limit to the amount of heat that could be discharged without harmful results.

Rainwater *et al*. (3) considered heat a pollutant of equal danger to a nation's waters as the more tangible forms of wastes. They explicitly stated; "The waters of the nation* cannot accept heated waste-waters without quality degradation and human sacrifice of beneficial uses." A definition of thermal pollution these authors included was simply; "man-caused deleterious changes in the normal temperature of water."

It is projected that by the year 2000 heat additions to Canadian freshwaters could reach 98.6×10^{10} BTU/hr which represents a considerable increase from the 4.8×10^{10} BTU/hr discharge for 1970 (Table 3). Cook and Biswas (4) stated that the main question which requires investigation is what effects such volumes of heat will have on aquatic ecosystems.

Parker and Krenkel (5) stated that any large scale modification in the thermal regime of a natural water body or reservoir will change

*U.S.A.

the ecology and usually for the worse. The most obvious deleterious change is the heat killing of fish. A less obvious, but equally deleterious impact, could be the sublethal effects which can include changes in reproduction and migration patterns. They also pointed out that thermal discharges reduce the assimilative capacity of a water body.

Usinger (6) and Gaufin (7) described pollution as essentially a biological problem because its primary effect is on living organisms. Many studies of water pollution have been directed toward gathering data for such physical and chemical parameters as suspended solids, dissolved oxygen, biochemical oxygen demand, and others. These indicate the condition of a water only at the time of sampling, which may, or may not, be most critical. Gaufin (7) stated; "The qualitative and quantitative composition of an aquatic population is determined by recurring critical conditions, even though of short duration, as well as the more stable or long-term environmental factors." The structure of this population is, therefore, a function of conditions which have existed during its development.

4.2 Purposes of the Study

Manitoba Hydro has two large steam-electric generation units in Manitoba outside the metropolitan area of Winnipeg; one at Selkirk adjacent the Red River, and one at Brandon adjacent the Assiniboine River. Three previous studies of the Assiniboine River waters in the region of the Brandon station were completed by graduate students of Dr. A. B. Sparling of the Department of Civil Engineering, University of Manitoba. Each study dealt with some aspect of evaluating changes in water quality of the Assiniboine River downstream from the Brandon Generating Station outfall which may have resulted from the thermal discharge.

Two distinct purposes were recognized at the initiation of this study. First it was necessary to collect and process data which would reflect upon the condition of the aquatic environment. The second purpose was to develop a consensus from this information together with some related information reported in three previous studies conducted separately by Mr. L. W. Pommen (1972-1973), Mr. W. R. Donald (1973-1974) and Mr. A. C. Jorgensen (1974-1975). The major thrust of the study was an attempt to evaluate the effects of the Brandon Generating Station thermal discgarges upon the aquatic environment and to designate a point or region downstream at which recovery was complete.

Most Canadian hydro-electric sites will soon be developed and future electricity demands will mainly be met by large fossil-fuel and nuclear plants. The environmental impacts of these generating stations will be multitudinous. The literature pertaining to Canadian development indicates that once-through cooling will be the mode of waste heat dissipation used most often. It is necessary to develop an ecological knowledge and understanding of the thermal effects of this heat in order to determine its impact upon an aquatic ecosystem. Gibbons et al. (8) stated: "Basic research in this field must be approached with an attitude that thermal alteration will occur to the aquatic environment but that whether this change is a stress or an enrichment to the biological systems may be unresolved." Many publications cited experiences with thermal discharges from once-through cooling in the United States. There is no doubt Canada's vast water resources have considerable capacity to receive waste heat but limits must be respected and alternative closed-cycle systems encouraged for adoption.

CHAPTER V

LITERATURE REVIEW

5.1 The Generation of Electrical Energy

5.1.1 Introduction

Electricity is produced by one of two basic methods; by falling water (hydraulic), or by steam (thermal) (9). These media are both used to drive turbines each connected to a generator. In hydraulic production the potential energy of a water head is utilized by directing it to plunge down a considerable drop and over the blades of a turbine. The thermal means of generating electricity requires either fossil fuel, or nuclear fuel to produce a hot steam under high pressure which is directed at the blades of a turbine. There is no major conceptual difference between power plants consuming fossil fuels and those using nuclear fuel (9,10). In both plant types the fuels are used to produce steam.

The spent steam is recondensed after it passes the turbine blades. This is accomplished by cooling the steam in a condenser using water from a natural water body or recirculating water cooled by an artificial cooling device (9,10). The subject of this investigation concerns the disposal of heated condenser waters into a natural water body. While this study does not deal with the actual steam generation process it became evident that ultimately the subject could not be avoided. Two reasons are apparent for minimizing wasted heat:

1. reducing the amount of expensive and valuable energy-yielding materials used; 2. reducing the amount of wasted heat for disposal. As a result of refinements in fossil-fueled plants during the past 35 years the rate of waste heat discharge has been reduced by one-half (3).

Rainwater et al. (3) presented some interesting statistics concerning the operational temperatures and pressures involved in the thermal generation of electricity. In fossil-fuel plants steam may enter the turbines at temperatures over 538 degrees C and leave at temperatures below 38 degrees C. In the most modern plants steam may be produced at temperatures near 566 degrees C with pressures over 3000 psi. In comparison nuclear power plants produce a steam at temperatures near 315 degrees C, and at pressures between 1000 psi and 2000 psi depending upon the type of process modification.

In the United States and elsewhere there are increasing restrictions for discharging wasted heat into natural waters. This has been exacerbated by the fact many stringent controls and restrictions have been placed on new plant siting. The demand for all forms of energy has continued to grow, however, and many new generating plants are now locating along coasts or estuaries using saline or brackish waters for cooling (11, 12). When saline waters are used in cooling towers it raises the costs by at least 25 percent above those of a freshwater tower, mainly for more expensive, corrosion-resistant materials (12).

The anticipated electricity generation in the United States until the year 2000 is shown in Table 1. This demonstrates that the major source of this electricity will be steam generation. Parker and