Thermal Pollution

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EFFLUENTS from THERMO-NUCLEAR ELECTRIC POWER STATIONS: HOW AND WHY it could AFFECT LAKE ONTARIO

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People in North America have enjoyed a high standard of living for some time now, but it has been only recently that the true costs of our lifestyle have become apparent. What I mean when I say this, is the effect upon the environment caused by economic growth, population growth and urbanization, etc. all factors inherent in a growing industrialized economy. Southern Ontario is an area where this type of technological living is concentrated, an important part of which is the need for large quantities of energy. A very important and unique form of energy that is required is electricity. In this essay, I hope to show how the growing demand for electrical energy in this area could possibly put a strain on Lake Ontario, making us pay a price for our development, which the majority of people are not willing to pay. The Lake is not the only concern, of course, but I wish to use it as an example so that interest in other areas of environmental modification might possibly be stimulated.

When Southern Ontario was in its early stages of development, electrical power was produced by harnessing water-power (i.e., Niagara Falls) so much so that it became referred to as 'hydro'. Because of our location, other such natural sources of power are severely limited, and even though we are connected to other regions which are better endowed, by a power grid, it has still become necessary to supply electricity by other means in the immediate area. This is done by burning fossil fuels to make steam which, in turn, drives turbines that produce the power; two such stations are the Lakeview and Hearn generating stations located in the western and eastern edges of Toronto. These plants are located on the Lake because water is needed to cool the steam back to its liquid state. The process of burning fuel to produce electricity is not completely

efficient with some of the heat being wasted and disposed of in the Lake waters. This has been a well accepted state of affairs up until the last decade. Within the last ten years, numerous problems have begun to pile up causing changes to take place.

These generating stations not only produce waste heat but also discharge pollutants into the air, such as sulphur dioxide and fly-ash. This problem is especially important because most of the plants are in high density urban areas where the problem is particularly noticeable. Attempts have been made to reduce this problem by switching from fuels such as coal to natural gas and oil, but here we find another complication, the "energy crisis". Whether this phenomenon has been contrived or it is real, there is still the problems of future availability of fossil fuels of any type especially gas and oil. Since so many of our modern industries depend on petroleum products, and many important materials are produced from oil, there is some concern that these fuels should be saved for the petro-chemical industry and not burned up to produce energy. The problem is complicated even further by the fact that the need for electric power is growing at a fantastic rate. "Ontario Hydro's electric load is expected to double by 1983 and may redouble by 1993".[1] In order for Ontario Hydro to maintain the supply of electricity, they will have to switch from fossil-fuel burning to the use of nuclear powered generating stations. Ontario Hydro says that by 1990 at least 50 per cent of this province's electrical energy will be powered by nuclear power.[2] This move to nuclear power appears to solve our immediate problems because 1) they do not produce air pollutants such as sulphur dioxide and fly-ash, 2) we have large supplies of uranium to fuel our present and

future needs right within our own country. There are, however, other factors which are perhaps more important. Nuclear power plants are less efficient than their fossil fuel counterparts, and dispose of their waste heat mainly through the cooling water,[3] and, therefore, into whatever body of water they are located on. This body of water will be Lake Ontario in most cases as we will see later on. Secondly, there is the concern about radioactivity escaping to the environment; from the point of view of this paper I will only be concerned with what escapes into the Lake water. Nuclear power has been around a relatively short time and using this technology to generate electricity is an even more recent phenomenon.[4] The generating stations that will be needed ten years from now are being planned into a plan of action that must be adhered to if we wish to make sure that there will be no shortages.

> We estimate that the total lead time between start of public participation to acquire a new site and the in-service of the first generating unit is 11 years for a fossil-fuelled station and 12 years for a nuclear station.[5]

One nuclear station, Pickering, has been operational for several years now on the north shore of Lake Ontario just east of Toronto. Depending on the plan of action Ontario Hydro takes there could possibly be up to a total of five nuclear stations all on the north shore of Lake Ontario.[6] One possibility is the creation of energy centres where the equivalent of three Pickering stations are on 1 site in order to save on the capital costs. By viewing the future situation from this point in time, it appears to me that nuclear stations will become far more popular from Ontario Hydro's viewpoint than fossil-fuelled stations. This is due to the uncertain availability and rising costs of all fossil fuels, not to

mention the air pollution factors involved with coal, oil and natural gas.

If these stations do become as popular as it seems they might, a serious problem for Lake Ontario could develop. This is because of the stress this would impose upon the ecosystem of the Lake. Electric generating stations are by no means the only source of environmental stress to be found along the lakeshore. However, I have chosen to look at them for some specific reasons. Electric power stations lead to further economic development which then puts even further pressures on the environment. Electricity has been billed as the clean energy, which is a somewhat misleading statement. The literature released to the public by Ontario Hydro is often with scenes of children playing, parkland, etc. reinforcing the idea that there are no harmful effects from hydro. Finally, the electric power industry is responsible for a large portion of the use of water for cooling purposes; in fact, over 44 per cent of all water withdrawn in Canada is for one end use, condenser cooling in thermal steam electric plants with 99 per cent of it being returned.[7] Now that nuclear plants are becoming dominant, the thermal effluent situation is going to be aggravated plus the addition of the problem of radioactive elements being released to the environment.

Thermal Effluents

Tremendous quantities of cooling water are required in the operating of a nuclear plant, about 50 per cent more than a conventional thermal generating station of comparable size.[8] This water is taken into the cooling system just off shore near the Lake bottom, run through the system and returned to the surface of the Lake. (See page 6 for diagram

relating the position of the cooling system in relation to the reactor.) Approximately 1.25 million gallons of water per minute is required for a station the size of the one at Pickering, with the water being returned about 18 degrees Farenheit warmer than the average intake temperature of 52 degrees.[9] Ontario Hydro states in several of its publications that the amounts of waste heat put into the Lake are small in comparison to solar inputs. They state that by 1990, the heat put in Lake Ontario due to all the generating stations is equal to 0.3 per cent of the average annual solar input.[10] This type of comparison doesn't really tell you anything about the possible effects; it, in fact, gives the impression that there is no way that it could become a problem. By discharging these large amounts of warmed water, the real consequences occur on the local scale. This means that the balance of life in the area surrounding the plant is where the effects take place.

> In local areas, however, the ecological consequences of discharging heated water into the Lake could be serious. It is apparent from a review of the growing literature on thermal pollution, that the oxygen level of the Lake waters, rates of chemical reactions and precipitation, algae growth and water quality could be affected by heated water trapped in certain areas of the Lake.[11]

If the generating stations that Ontario Hydro plans for the north shore of Lake Ontario are developed as energy centres, this will have a very serious effect on the local conditions. This is due to the fact that three stations will be concentrated in one local area, so that the impact will be definite in the small area around the plant and perhaps extend out farther along the shoreline. This could be caused by effects

from the Lake currents (see page 17) along the shore. The shallower waters near the shore are very important because this is the area where aquatic life is concentrated especially in terms of plants and animals at various stages in their life cycles.

There are many direct and indirect effects that the addition of heated effluents can have on the lake life. It has been found that temperature affects many physical properties of water, all very important, including density, viscosity, vapour pressure, surface tension, gas solubility and gas diffusion.[12] An important effect is stratification, this is when the heated water coming from the power station forms a definite surface layer called the epilimnian. Then there is a layer called the thermocline which separates the surface layer from the bottom layer or the hypolimnian. This layering is due mainly to the fact that the warmer the water the less dense it is, and this phenomenon is a confusing known fact for stations such as Pickering (see page 19). There is a rapid drop in temperature as you travel downward through the thermocline. The main affect this has is reduced mixing of the waters so that the oxygen content of the hypolimnian is lowered. The fish and other organisms found in the lower, colder water then may suffer due to this lack of oxygen. The organisms that can move about freely enough to choose their outside habitat can pick the area they prefer but this is also a problem.

It has been shown that some species found in the Lake (i.e., splake and alewives) are attracted to the warm water up to near lethal temperatures in the winter time.[13] Even though the organisms may not be

killed there are still changes which take place, which range from effects in behaviour down to differences created in the individual cell. Many authors have noted that patterns of behaviour such as breeding can be modified by warmer temperature waters. Fish embryos can develop too early in the warmer effluents only to be there before their food supply has ~~gotten~~ become established. Rates of growth are also influenced, for every 18 degree Fahrenheit rise in temperature, the metabolism of a fish doubles since it is cold blooded and depends on the surrounding environment to establish its own bodily temperature. This means that its oxygen, food, etc. intake must also double if it is to survive. Unfortunately, the rise in temperature which causes a need for more oxygen also causes it to be less available, since oxygen solubility decreases as temperature increases. This doesn't take into account the problem of stratification which also means less oxygen is available. The amount of oxygen available is really very important since this is one of the primary factors which determines what type of fish can live in that area, the most desirable fish (according to human preference) usually are the ones requiring more oxygen. As I mentioned earlier, there are even more ~~elusive~~ subtle affects:

> Subtle modifications of the cellular contents such as cytoplasm, nucleous mitochondria, robosomes, etc., are also of significance. These cellular components assimilate nutrients providing energy and generally controlling the maintenance, growth, reproduction of the cell itself.[14]

This author goes on to describe how elevated temperatures can cause disruptions in these cellular parts and their functions especially the effect upon the various membranes (alteration of the proteins and lipids).

Even if these fish were only attracted to the warmer water, this would still pose a problem. Since they would tend to concentrate into one area this would make them susceptible to any toxic discharges that would enter that region regardless of source, wiping out a larger percentage of the population than would normally be the case. There also exists the possibility that the fish could be killed if once accustomed to the warmer waters were exposed to colder waters suddenly due to shut-down of the plant.

Plant life such as algae are also greatly affected, given adequate nutrients and sunshine, the warmer temperature causes excessive growth; conditions for this are most prevalent near shore where the power plants intake and outfall are situated.

Bottom fauna are perhaps the most sensitive of all organisms found in Lake Ontario (upper tolerance of many is 90 degrees Fahrenheit, which is also upper limit of Hydro's discharges) and because of their relative immobility are particularly easy to disrupt[illegible].[15] They are in the middle of the food web and so are of particular importance in the stability of the entire system of aquatic life.

The real crux of the matter of thermal discharges is that we are dealing with the exceedingly complex phenomena of life systems. There are vast amounts of literature on the subject, yet no one can give concrete answers as to how this additional heat will affect Lake Ontario. Only one change can eventually lead to the upset of the whole community. Heat also can contribute to other problems of pollution.

> Synergistic actions of pollutants are more severe at higher water temperatures. Given

> amounts of domestic sewage, refinery wastes, oils, tars, insecticides, detergents and fertilizers more rapidly deplete oxygen at higher temperatures, and the respective toxicities are likewise increased.[16]

It is possible that combinations of effects could indeed have very serious consequences. Tampering with such complex and interrelated ecosystems and chemical combinations is risky at best, Ontario Hydro cannot be sure that what it is planning to do will not have harmful results. It is best summed up by this statement by Dean E. Arnold, a research limnologist with the University of Michigan Great Lakes Research Institute, "In general, we can conclude that no desirable effects of heated discharges are likely, that undesirable effects may be produced directly; and that even if this does not happen, undesirable processes already underway may be accelerated."[17]

There is also another related factor in thermal effluents, that is the effect of the water intake itself. The current created is strong enough to draw through the cooling system small fish and other small animal and plant organisms. The organisms are not always killed but many suffer physical damage due to the mechanical action of being drawn through the system, not to mention the effect of concentrated heat. Small fish such as alewife have become a problem at Pickering prompting them to have a special system to automatically clear the intake grating. Also constructed were "groins" providing a channel where the cooling water could be withdrawn without causing excessive build-up of silt and other light bottom material. This again has influence upon the aquatic life, by killing and damaging fish (which will die prematurely) this provides

more dead organic material which will further deplete the oxygen supply as decomposition takes place. This additional material also provides food for further growth again, increasing oxygen demand. Silt movement towards the intake also modifies the conditions for the benthic organisms found there, near the bottom of the Lake.

Radioactive Effluents

This is an area where much discussion has taken place within recent years. As a part of normal operations, wastes from decontamination operations, laundry, laboratories and bleeding of the heavy water system are disposed of into the Lake. This is done by diluting the radioactive material in the cooling water to so-called acceptable levels so that they are put into the Lake at very weak concentrations. Some of the radionuclides released are H-3, I-131, Cs-137, Cs-134, Sr-90, Sr-89, Co-60 and of lesser importance Ba-140, La-140, Ru-106, Zr-95, Nb-95, Ce-144, Fe-59, Zn-65.[18] The half-lives of these radionuclides range from a few hours to several years and even though the concentrations discharged fall within international limits established (see page 20), there still seems to be a concern among many within the scientific community.

> Although considerable amounts of radioactivity is involved in these processes, the magnitude of the problem is mitigated because of the dilution effect of the pollutants in the air and water which brings their levels to below permissible concentrations. With the increase in the number of nuclear reactors, however, the problem could become much more serious...[19]

There is a controversy as to what constitutes a safe limit for

radioactivity. Right now, Ontario Hydro is operating on the premise that there are limits below which there are no harmful effects. Many other authorities claim that any amounts of radioactivity have some degree of harmful effect. The problem with radioactivity is that it builds up within organisms including man and is not removed from the environment or organisms except by natural decay, which can take considerable time. Two men, Tamplin and Gofman, who have written many articles and books on the subject of radioactivity from nuclear power plants are so concerned over the subject they have proposed a stoppage of construction of nuclear power plants till more information about possible effects is known. There are many ways radioactivity can reach man (see page 21) and the effects of certain levels of exposure are uncertain but when these effluents are released into the Lake it is known that a concentration factor is present.

> ...the dietary needs of all vegetable and animal life dictate the intake of specific elements. Those elements whether radioactive or not, will concentrate even in the lowest and most basic forms of life. They are passed up food chains... the concentrations increase sometimes by hundreds of thousands of times.[20]

This means that even if the levels of radionuclides are harmless as they are released into the Lake, it is possible for them to be concentrated by living organisms till it does become harmful. This concentration also takes place within certain organs of many animals including man. (i.e., I-131 build-up in the thyroid) This build-up in the various organisms within the aquatic environment also is expected to bring about changes within the metabolism of the animals exposed, but exactly what will happen

is impossible to say.

In concluding this paper, I would like to point out that this is but a brief introduction to the problems that are involved with the addition of more power plants on Lake Ontario especially ones that are nuclear fuelled. There is no real problem with the current thermal stations, but I am afraid as are many others that the additional load put on the Lake and other environmental systems may just prove to be the last straw. Ontario Hydro admits to a limited extent that certain changes will take place, an increase in fish population will result supposedly for our benefit. But is any change good or bad in our eyes, really the right way to approach the environmental modification situation. Many biologists consider any change which affects diversity more than 20 per cent either way is detrimental in the long run.[21] And in the long run, it is predicted that further moves will be made towards electricity. Donald K. McIvor, director of Imperial Oil, has said:

> Ultimately, however, I believe that in the very long term - by which I mean the first decades of the 21st century - we'll become an electrical society. That is, we'll have switched to predominantly electrical usage to keep warm, move around and run machinery. This transition will be made through nuclear fission to generate electricity...[22]

The problems that will stretch into the 21st century have their roots in the decisions made within the next few years. What is needed now is more public awareness about the present situation. The first major steps towards nuclear power are being made here in Canada and in the United States and the majority of the public is unaware of the consequences these actions could have. What I have mentioned in this

paper is but a fraction of the problems associated with nuclear plants and when you take into consideration that not only plants on the north shore of Lake Ontario but also on the south shore, indeed these plants will be all over North America. If the public is informed about the consequence of a move to nuclear powered electrical generating stations and are prepared to accept what might happen, then the go-ahead option should be made. I feel that the only proper way to make a choice in a matter of this kind is to let an informed public decide. It is the entire populace which must put up with the consequences and so small special interest groups can aid the public but I don't think they should take over their responsibility. In my research of this paper, I myself have come to feel that more time is needed to see what the possible effects could be; our past record where we have intervened in eco-systems is very poor. I would like to end this paper with a quotation, that applies particularly to the aspect of the situation that I have looked at:

> Most people are aware that a pollution problem exists, but they tend to ignore it unless it affects them directly. If we have pollution, it is because of public indifference not because of a lack of technical "know-how" of ability to pay. Somehow this indifference must be broken down, and a sense of urgency created equal to the seriousness of the situation.[23]

FOOTNOTES

1. Ontario Hydro (1974) Long-Range Planning of the Electric Power System, p. 1.

2. Ontario Hydro, Energy Concerns of the Seventies, p. 7.

3. See chart page 14 , from Thermal Effects on Lakes and Rivers by Dr. W.R. Effer.

4. See chart page 15 , from Fuelling Canada's Future by Rowland, W. (1974)
p. 144 - it can be seen from this chart that nuclear generated electric power is a recent phenomenon.

5. Ontario Hydro (1974), Long-Range Planning of the Electric Power System.

6. Ibid. p. 17.

7. Statistics Canada, 1973, Canada Yearbook, p. 4.

8. Biswas, A.K. (1974), Energy and the Environment, p. 24.

9. Ontario Hydro, 1971, Pickering Generating Station, p. 3.

10. Effer, W., 1972, Thermal Effects on Lakes and Rivers

11. H.G. Acres Limited, Effects of Thermal Inputs to Lake Ontario, 1968 - 2000.

12. Parker, F.L. and Krenkel, P.A. (1969), Thermal Pollution, Status of the Art, Report No. 3, see also page 15

13. Everest, G., 1973, Some Effects of Heated Effluent on Fish Populations at Three Thermal Generating Stations, p. 139.

14. Jensen, L.D., Spectrum of Biological Concerns from Power Plant Thermal Discharges, p. 4.

15. Ontario Hydro (1972), Environmental Design Manual.

16. MacKenthom, K.M., (1969), The Practice of Water Pollution Biology, p. 24.

17. Quoted in Fuelling Canada's Future, by Rowland, W., (1974) p. 107.

18. Wong, K.Y., Basis for the Derived Limits For the Release of Radionuclides in Gaseous and Liquid Effluents from Ontario Hydro's Nuclear Stations, p. 31.

19. Biswas, A.K., (1974), Energy and the Environment, p. 28.

20. Curtis, R. (1969), The Perils of the Peaceful Atom, p. 53.

21. Cairns, J. (1969), quoted in Biological Aspects of Thermal Pollution, Parker and Krenkel, (eds.).

22. McIvor, (1974), quoted in the Financial Post.

23. Conservation Council of Ontario, Water Pollution in Ontario.

This is a competently prepared essay - Reasonably well written and researched. At times ~~a~~ a bit more elaboration could be expected as the reason your meaning is obscure because an interesting point should be pursued. I enjoyed reading it.

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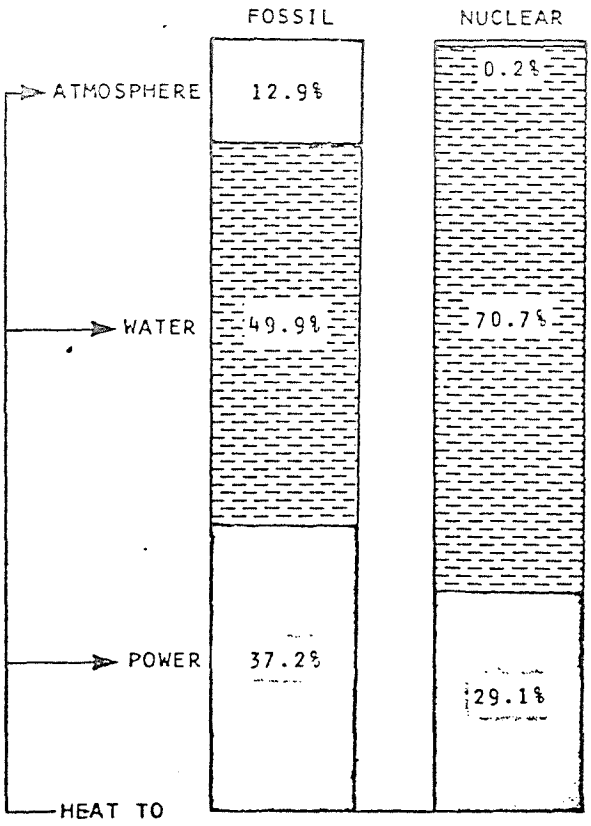
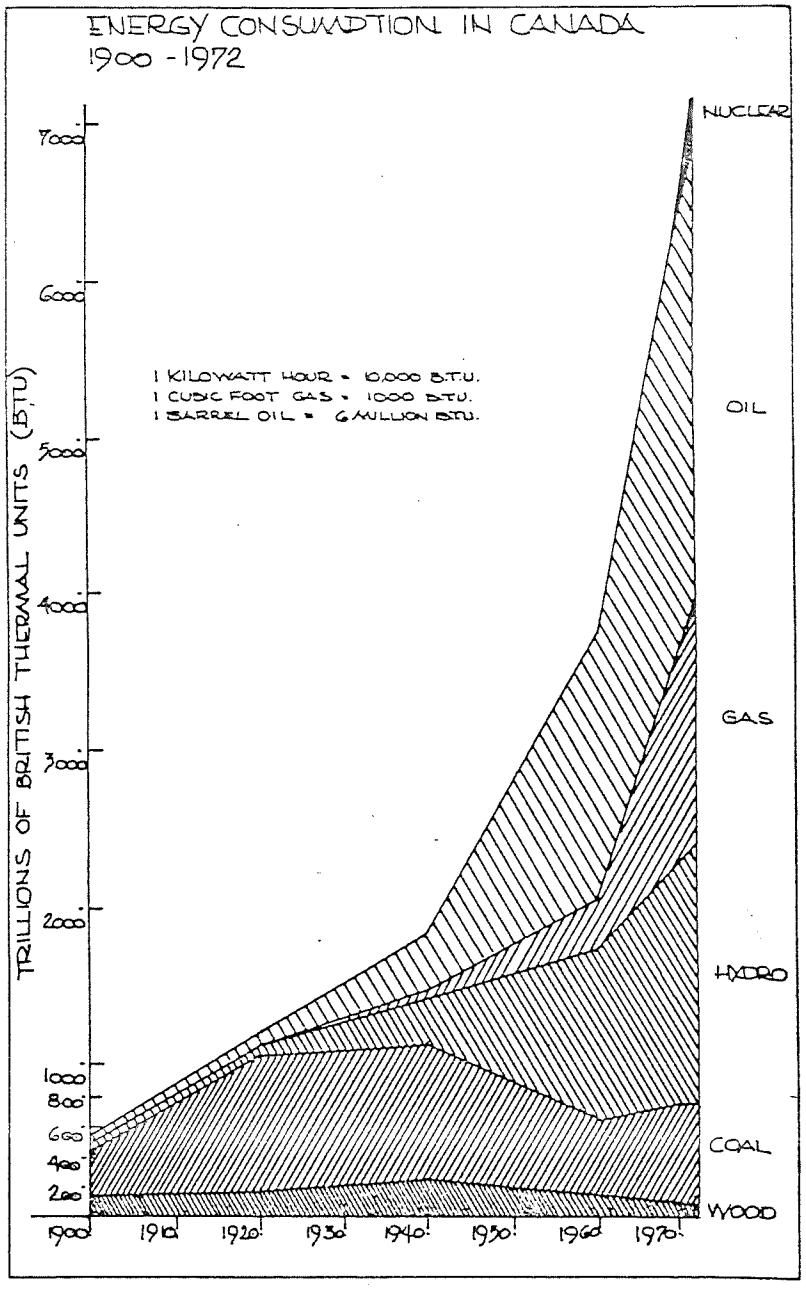
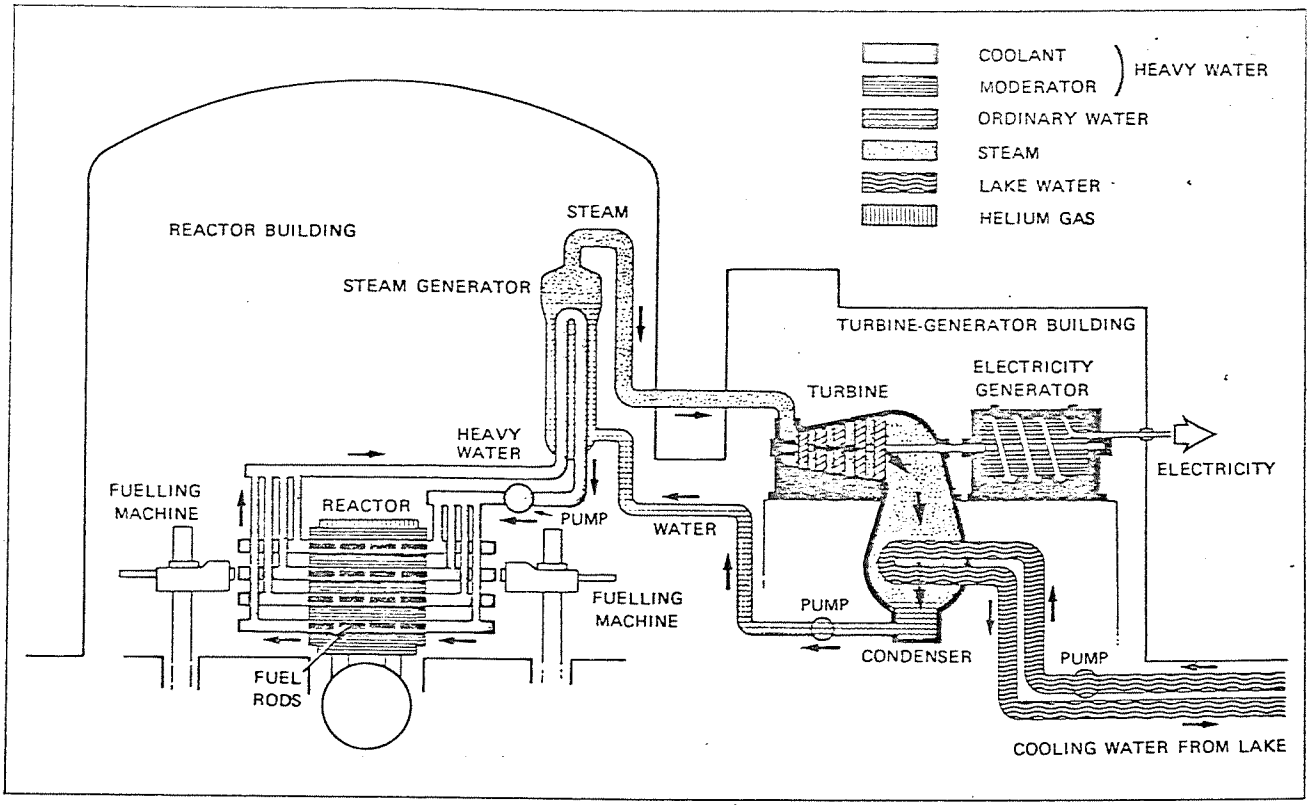


Figure 2.5.3 Fossil and Nuclear Percentage Heat Distribution.

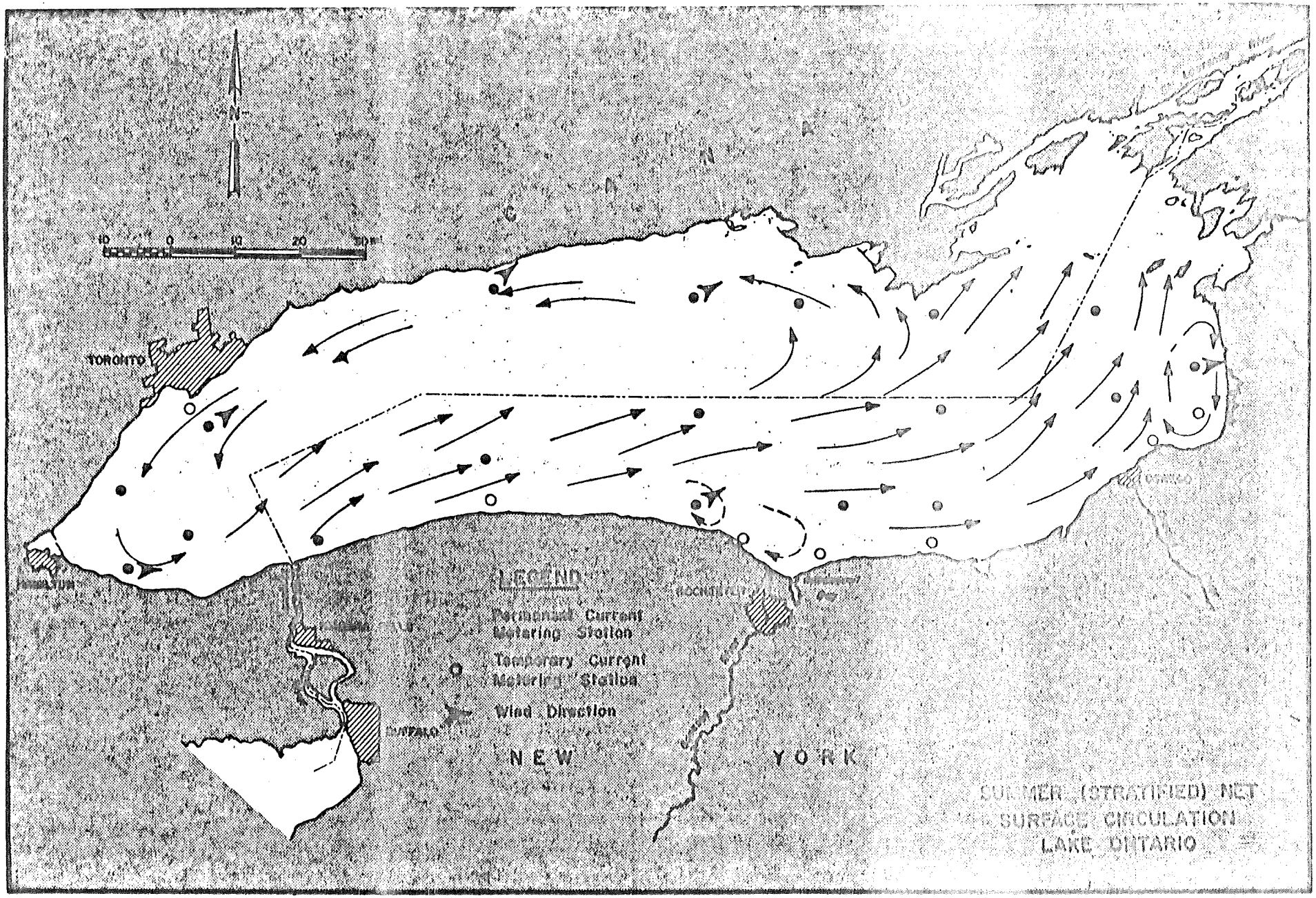
EFFER W.R (1972) Thermal Effects on Inland and Rivers.



Redekind, W. (1974) Finding Canada's Future p144.



Rowland. W. (1974). Fuelling Canada's Future p. 92

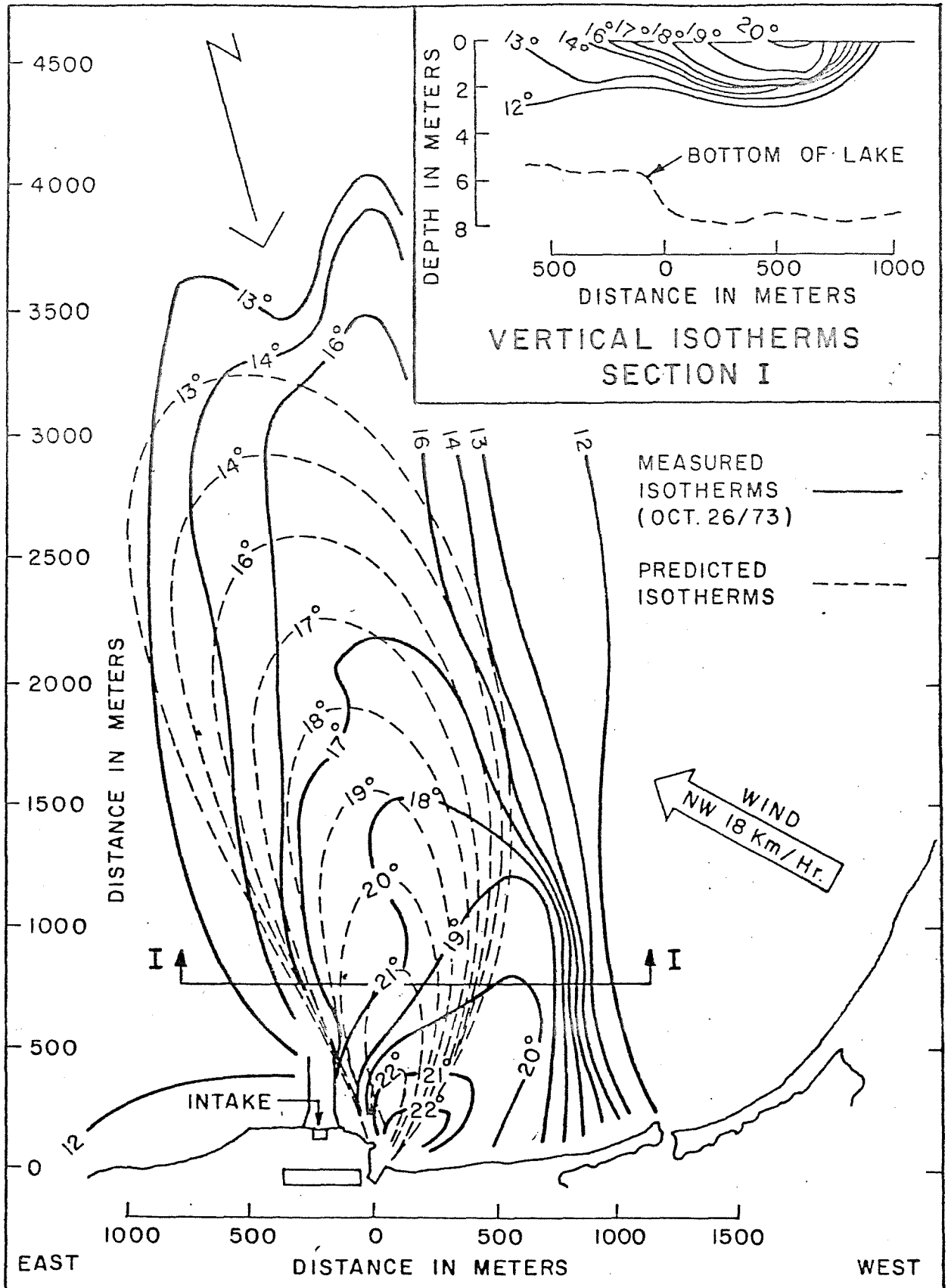


Amon (1980) Water Pollution Problems and Impacts ... Area p.56

WATER PROPERTIES AS A FUNCTION OF TEMPERATURE

Temperature °C	Vapor Pressure mm.Hg	Viscosity Centipoise	Density gm/ml	Surface Tension Dynes/cm.	Oxygen Solubility mg/l	Oxygen Diffusivity cm^2/sec
0	4.579	1.787	0.99984	75.6	14.6	
5	6.543	1.519	0.99997	74.9	12.8	
10	9.209	1.307	0.99970	74.2	11.3	15.7
15	12.788	1.139	0.99910	73.5	10.2	18.3
20	17.535	1.002	0.99820	72.8	9.2	20.9
25	23.756	0.890	0.99704	72.0	8.4	23.7
30	31.824	0.798	0.99565	71.2	7.6	27.4
35	42.175	0.719	0.99406		7.1	
40	55.324	0.653	0.99224	69.6	6.6	

PARKER, F. L. and KRENKEL P. A. (1969) Thermal Pollution
Status of the art



PICKERING NUCLEAR G.S.

MEASURED AND PREDICTED SURFACE TEMPERATURES DUE TO THERMAL DISCHARGE FIGURE 5

EFFER, W. R. & BRYCE JB (1974) Thermal Discharge Studies on the Great Lakes p11

AVERAGE RADIOACTIVE RELEASES 1973

Airborne Releases

Station	Tritium		Noble Gases		I-131		Particulates	
	Ci/d	% DRL	Ci-mev/d	% DRL	Ci/d	% DRL	Ci/d	% DRL
NPD	3.6×10^{1}	7.7×10^{-2}	3.3×10^{2}	3 *	1×10^{-4}	1.2×10^{-2}	3×10^{-5}*	1.3×10^{-3}
Douglas Point	5.5×10^{1}	5×10^{-2}	3.7×10^{2}	1.5*	5.3×10^{-5}	1.3×10^{-2}	1.8×10^{-6}	2×10^{-4}
Pickering	1×10^{2}	3.3×10^{-1}	1.1×10^{2}	1.8	1.5×10^{-5}	2.5×10^{-2}	3×10^{-5}	2×10^{-2}

Liquid Releases

Station	Tritium		Gross β Activity	
	Ci/d	% DRL	Ci/d	% DRL
NPD	13	0.2	2.7×10^{-4}	0.07
Douglas Point	21	0.8	5.5×10^{-3}	3.7
Pickering	11.5	.04	5×10^{-3}	0.3

DRL = Derived Release Limits (International Standard)

* Argon 41

Ontario Hydro (1973) Release of Radioactive Materials in Effluents of Nuclear Power Stations. pp.

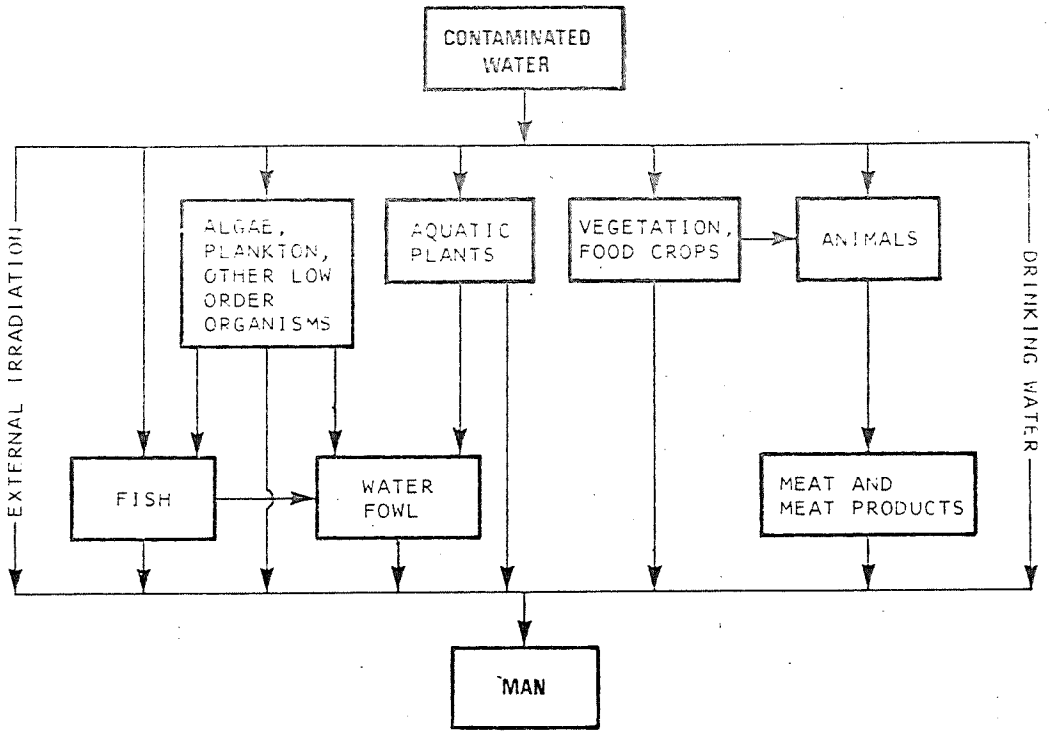


Figure 3-4-1

Exposure Pathways to Man from Liquid Releases

ONTARIO HYDRO (1972) Environmental Design Manual
P 2-5-4

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3. Biswas, A.K. (1974) Energy and the Environment, Ottawa, Environment Canada.

4. Brown, T.L. 1972 Energy and the Environment, Columbus, Ohio, Charles E. Merrill Publishing Company.

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9. Effer, W.R. (1972) Thermal Effects on Lakes and Rivers, paper presented at the Canadian Nuclear Association Symposium May 16-17, 1972.

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