An IJC Report to the Governments of Canada and the United States

REGULATION OF THE RICHELIEU RIVER AND LAKE CHAMPLAIN

INTERNATIONAL JOINT COMMISSION

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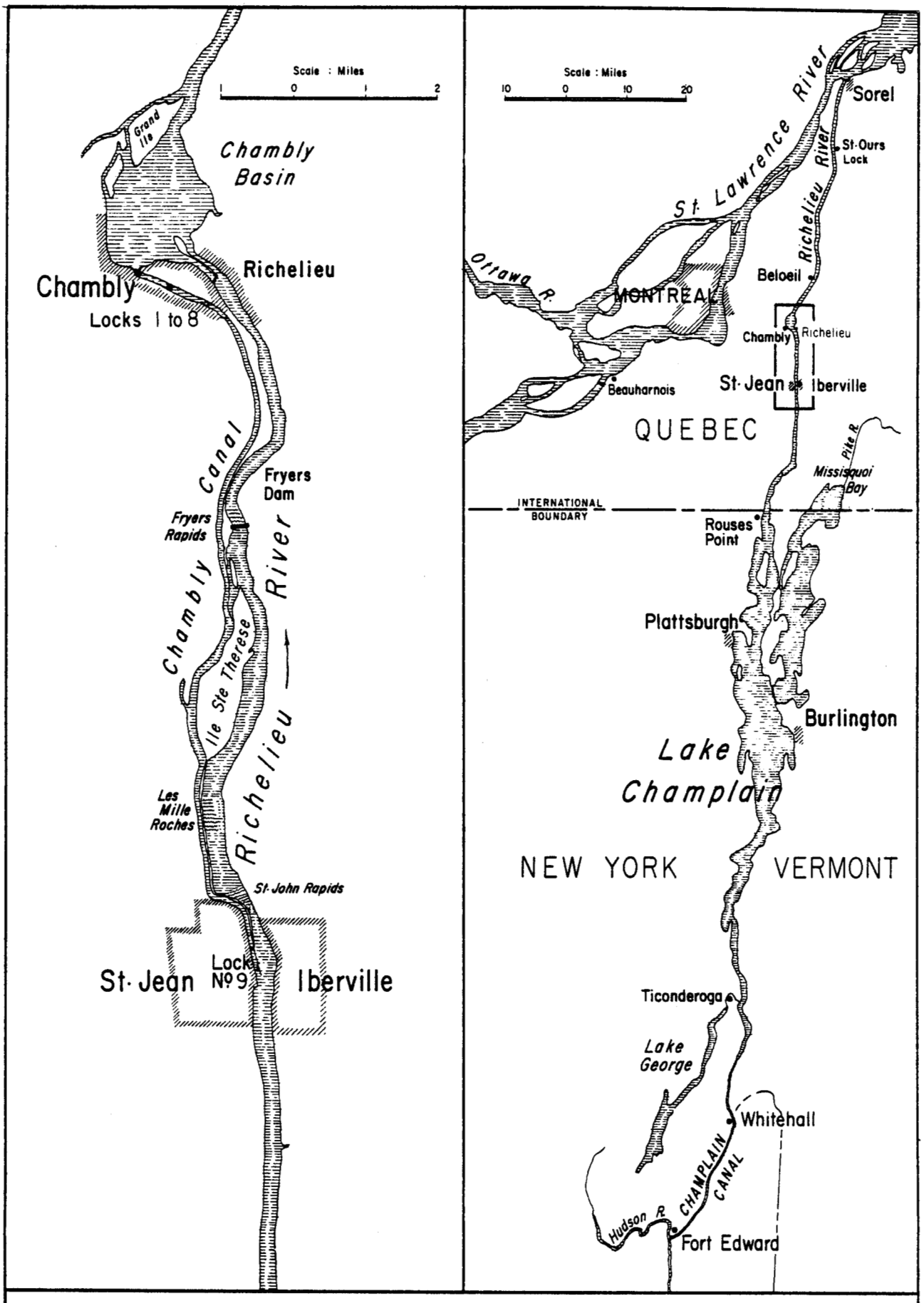
JANUARY 1981



RICHELIEU RIVER - LAKE CHAMPLAIN

DRN. A.J.M. 1972

CAN-SECTION I-J-C

TEXT OF LETTER OF TRANSMITTAL

The following letter was sent to the Secretary of State, Washington, D.C. and the Secretary of State for External Affairs, Ottawa, Canada:

"With this letter, the International Joint Commission transmits its report on the regulation of Lake Champlain and Richelieu River in response to the Governments' request in 1973 that the Commission investigate and report upon the feasibility and desirability of regulating the Richelieu River for the purpose of alleviating extreme water conditions in the Richelieu River and Lake Champlain.

Throughout this inquiry the bewildering complexity of the interactions between the environmental, physical and economic aspects placed an onerous task upon the participants in their endeavours. Following the Commission's interim report of March 1975, the emphasis was shifted from alleviating extreme water conditions to an investigation of environmental consequences. Furthermore, since the Reference was received eight Commissioners have been replaced. In addition, at the present time, one Canadian vacancy exists and the Canadian Chairman has announced his intention to resign on February 1. Moreover, because of the election of a new President in the United States there is a possibility of United States vacancies. Because of the complexity of the investigation, new Commissioners will require a significant time period for review of the record before it would be possible for them to make an informed judgment on the issues.

For these reasons the Commission believes it is important that the Governments have the considerations, conclusions, and recommendations which derive from the extensive study which it has made. Such information is contained in the attached report. The Commission, however, is not including the background information which is customarily included in its reports which summarizes the description of the area involved, the nature of the inquiry, the Board's investigation and the history of

public participation. The Commission believes that it is necessary to forego such a summary, in order to assure that further delay does not result.

The report of the International Champlain-Richelieu Board, combined with technical reports of its Environmental Impact, Physical Aspects and Net Benefits Committees as well as the two supplemental reports comprise a comprehensive review on the regulation of Lake Champlain and the Richelieu River. These reports, the three thousand pages of transcript recording the public hearings and subsequent submissions are all an integral part of the Commission's examination and the subject of numerous deliberations. Therefore, the Commission believes that the basis for its considerations, conclusions and recommendations is contained within the information already provided to Governments and in the public record."

FOREWORD

The International Joint Commission wishes to acknowledge with gratitude the valuable contribution of the members of the International Champlain-Richelieu Engineering Board and the International Champlain-Richelieu Board, of the members of their three Committees and the ad hoc groups which assisted the Boards. The Commission wishes to recognize the contribution of private individuals and public organizations of both countries in this inquiry. The cooperation and support of the federal, state and provincial agencies is acknowledged with appreciation.

INTERNATIONAL JOINT COMMISSION

REPORT ON REGULATION OF THE RICHELIEU RIVER AND LAKE CHAMPLAIN

Lake Champlain and the Richelieu River are both components of the waterway linking the Hudson and St. Lawrence Rivers. Regulating the levels of Lake Champlain by means of increasing the capacity of Richelieu River to pass flood waters and limiting the outflow by control works at all other times, has been periodically considered for nearly a century.

Introduction

The Governments of the United States and Canada, as a result of the grave concern in both countries caused by substantial flood damage in the early 1970's, requested the International Joint Commission in March 1973 to investigate and report upon the feasibility and desirability of regulating the Richelieu River for the purpose of alleviating extreme water conditions in the Richelieu River and Lake Champlain. A copy of the Reference is appended.

The Commission's brief response on the issues concerning the regulation of Lake Champlain and the Richelieu River is based on an intensive and extensive feasibility investigation conducted by its International Champlain-Richelieu Board, the testimony received at ten public hearings, written submissions received by the end of 1978 and a series of lengthy deliberations on a large number of topics.

The background information is found in the report and appendices of the International Champlain-Richelieu Board, their two supplemental reports and the transcript of public hearings, all of which have been transmitted to the two Governments and are available to the public.

Socio-Economic Considerations

The Board's findings on economic feasibility were based on the conventional procedures for establishing the economic benefits and costs of a major investment project. The costs of dredging and all structures are based on 1977 Canadian price levels, while the benefits and non-structural measures are based on 1976 dollars in the country in which they occurred. The interest or discount rate used was 7.5 percent over the 50-year project life. The benefits consisted of the damages to various economic sectors during spring flooding that would be prevented by undertaking various options. The assessed damages included physical damages to structures, contents, grounds, roads, public utilities and crops, and "non-physical" damages stemming from restrictions on access, flood fighting costs, clean-up costs, lost income, substitution of planned crops by lower value crops and the devaluation of facilities or increased maintenance costs. Diminished impacts of flooding in these areas were the benefits of the option, while the costs were those of building and/or operating, as relevant, the option under consideration.

These options included a number of structural and non-structural measures. The option favoured by the Board, the gated structure at St. Jean with regulation plan FCE-1 was estimated by the Net Benefits Committee to have a benefit/cost ratio of 1.8, and 2.0 in conjunction with the non-structural program. Therefore, on the basis of the conventional procedure as employed by the Board, this demonstrates that, within the limitations of the analysis, regulation is economically feasible, that is, damage reduction outweighs the costs.

A number of concerns have been expressed, however, concerning both the validity of the Board's analysis in its own right, and as to whether the benefit/cost analysis reflects all of the social gains and losses that might be expected from regulation. Commissioners have varying opinions as to whether these concerns individually or collectively will have a significant impact on feasibility and desirability.

With respect to the Board's analysis itself, there has been expressed some concern that the analysis of agricultural damages is

inadequate and thus overestimates the benefits to be expected. The majority of Commissioners, while noting that greater precision is possible, believe that the basic parameters affecting agricultural damage were adequately taken into account and further that, even if such damages were modified substantially in either direction, they would not significantly affect the overall benefit/cost analysis.

In this regard, the Commission notes that Quebec agricultural damages are not the dominant component of flood damages and that, if they were the sole justification for remedial measures, none of the structures analyzed would be cost-effective. On the other hand, it is clear that if a significant reduction to agricultural damages is to be realized, of the solutions that have been examined, a structure in the Richelieu River will be required, the cost of which would be largely balanced by benefits to be gained in other sectors and, indeed, largely in the United States. Partial alleviation may also be feasible using diking and pumping as currently under study by the Province of Quebec.

Other concerns relate to the range of benefits and costs incorporated into the analysis. The Board did not incorporate costs that could result from losses in wetland areas, including diminished expenditures by sports fishermen, largely because it believed that the recommended environmental criteria would prevent such potential costs. These "environmental" values are an important aspect of the decision-making criteria and if value losses were significant they should be taken into account. At least one Commissioner believes that losses in this category would be significant. It may not be possible to determine definitively whether such losses will occur or their extent.

Intangible social-environmental values should also be part of any overall decision making process. These can only be assessed, at least in this case, qualitatively. These social aspects sometimes tend to be neglected when the measurable effects are compared. They deserve separate consideration. Such values include:

(a) the <u>option value</u> which persons place on maintaining Lake Champlain in its present state for their possible future use;

(b) the social preservation value to society as a whole including the value to many people who have no intention of using Lake Champlain of knowing that it is preserved in an essentially unregulated state.

The Commission has made no conclusions on the effect of these social values in this study. To some people, and perhaps to Governments, however, they may be crucial to the entire balance, but they lie outside the technical analysis of the Commission.

On the other hand, a number of benefits were not incorporated into the analysis. While the Board's estimates included direct losses to shore property from spring flooding, they did not include the value of losses to real property caused by erosion which is most severe at high water levels. Such losses can be extensive but were not incorporated into the benefit/cost analysis since substantial further studies were required for a quantitative estimate of dollar losses and consequent benefits from water level regulation. Other damages during high or extended spring levels would include the values associated with diminished recreational opportunities during the early summer and even less tangible damages such as concern over the uncertainty of flood damage to property, health problems due to degraded water quality during and after floods, and aesthetic problems.

Damages from extreme water level conditions can also occur at low summer levels, generally when the summer Lake levels fall below 94.5 feet. Most significant is restricted access for recreational boating to marinas, ramps and docks, and exposed beaches, leading to economic losses to the recreational industry and supporting services as well as intrinsic value losses to recreationists themselves. Other impacts resulting from low water, including those on water intakes and other structures, water quality, fisheries and wildlife, were generally not considered to be significant by the Board.

All these and similar values should be assessed as part of the overall decision making process at such time as a definitive structural proposal and operating plan are under consideration. Also, the matter of at what elevation damages should be considered

"legitimate" in the sense that they should be counted in the benefit/cost assessment (e.g. the one-, two-, ten-year or some other flood) is a policy matter for the Governments, that lies outside the analysis of what damages do, in fact, occur or could be prevented.

Existing Conditions

Flood damages occur to some extent virtually every year in the Richelieu Valley and around Lake Champlain. They will continue to occur, although at a reduced extent and less frequently, with whatever preventative or remedial measures are put in place. Unnecessary damage occurs when such measures can be undertaken at costs lower than the benefits that can be achieved, taking due regard for environmental considerations.

The flooding problem in this Basin has been particularly pronounced in three periods in this century: 1900-1903, 1933-1937 and 1969-1978. In 1976, one of the highest floods in recent years occurred, Lake Champlain reaching the level of 101.5 feet. Since this was also the year in which field surveys were carried out in connection with the Reference, the Commission obtained a substantial amount of data on the flood damages which resulted.

The Board estimated that $7.45 million of spring flood damages occurred in 1976: $4.03 million in the United States and $3.42 million in Canada. Two thirds of the U.S. damages were to residences, permanent or seasonal, while 43 percent of Canadian damages occurred in this sector. In Canada the agricultural damages, largely losses to crops, were about equal to residential damages whereas in the United States agricultural damages accounted for only about 7 percent of the U.S. total.

Since 1976 was an unusually severe flood, it cannot be considered as typical even when considered within the context the very high spring levels occurred during the 1969-78 period. Estimates derived from the Board's data for a more typical or "average" year, yield average annual damages of about $3.6 million for economic conditions prevailing in 1976 of which $2.1 million would be in the United States and $1.5 million in Canada. The Board developed these damages on the basis of response to a questionnaire received from a representative sample of affected

property owners. The survey developed information on the nature and types of flooding at all levels in 1976 up to an elevation one foot above the 1976 peak along with an assessment of damages sustained in past years of high levels. On the basis of the Board's analysis, it can be estimated that, typically, 58 percent of damages in Canada and 10 percent of U.S. damages would occur in the agricultural sector.

The timing of the flood peak and the period over which waters recede are important factors affecting agricultural crop damages. Late spring peaks or slow drawdowns, which extend high levels well into the month of May, either result in delays in planting crops and hence in lower productivity or the substitution of faster growing, lesser value crops. Any regulation scheme developed to accommodate environmental criteria should take into account the effects of reducing the rate of drawdown on planting time. In this regard, the Commission notes that economic studies of the Board reflect an expected average impact of both unregulated and regulated water levels on planting times. While the 1976 flood, which the Board used as a reference flood, had an earlier peak and longer duration at levels between 98 and 100 feet than similar magnitude floods in earlier years, this was not believed to affect significantly the value of physical damages to structures, etc. Non-physical damages such as restricted access to non-agricultural sectors would have been affected by the extended duration at lower flood levels, but not above 100 feet. The Board compensated for this difference in the analysis by applying adjustment factors. On the other hand, non-physical damages to agriculture were not considered to be atypical in 1976 since the unusually high spring peak and the long duration of flooding was assumed to be offset by the early date of the spring peak and the early recedence to below flood levels. The flood levels ended at approximately the same date in earlier years even though the maximum high water levels were less than in 1976.

Environmental Assessment

The Commission believes that any scheme for regulation of the Lake must adhere to specific environmental regulation criteria which protect existing wetlands as follows:

(a) maintenance of the heterogeneity and diversity of habitat types and distributions of the wetlands;

(b) preservation of required acreages needed to support birds, fur-bearing mammals, and fisheries resources, the ecosystems dependent on these vertebrates, and to prevent deterioration or endangerment of these species;

(c) and, assuring sufficient acreage for the maintenance of environmental aesthetic values of the region as part of a general "quality of life" concept.

Having stated the guiding principles, a consideration of associated issues and questions follows:

1. What are the specific ecological values of wetlands important to the Champlain-Richelieu system?

Wetlands ecosystems in the United States have a special status within Federal policy for the environment. Between 1950 and 1977, the Council on Environmental Quality estimated that the United States lost 40 percent of its available wetlands zones through development activities. This loss amounted to nearly 48 million acres along coastal, estuarine and inland waterways and has led to declines in populations of birds, reptiles, fur-bearing mammals, and precious fisheries resources. The decline in acreage has been accompanied by increasing damages attributable to flood plains development, dumping of toxic solid and liquid wastes, and what many people believe is a general decline in "quality of life".

While the Commission is an international body and therefore not legally bound by the domestic legislation and policy in either country, the Commission is guided by the general principles of law common to both countries to assure that its considerations are consistent, to the extent possible, with these laws and policies. The following U.S. policy has recently emerged with the perspective

of rigorous protection of wetlands. The Commission is sensitive to this policy as an indicator of values.

Presidential Executive Order, 11990 -- Protection of Wetlands -- issued in 1977 delineated Federal (United States) policy approaches to the management and utilization of those wetlands under Federal jurisdiction. The Order recognized the wetlands as important to erosion control and sediment control, as transition zones between aquatic and terrestrial habitats necessary to the propagation of aquatic species and their supportive aquatic-terrestrial ecosystems, and as potential nutrient sinks in the prevention of reverine, estuarine and coastal eutrophication. The Order specified no construction activities in Federally managed wetlands (e.g. draining, dredging, diking, channelizing, impounding, and use of structure or facilities in such systems) unless the head of an Agency found no alternative. Exceptional conditions included protection of life and property. Many states, including New York and Vermont, have adopted similar policies.

The motivation behind Executive Order 11990 was the conclusion that the 40 percent loss of wetlands during the period of the 1950's to 1970's was a "result mainly from unwise land use practices". Despite any debate about what constitutes "wise land use practice", there are no debates of the undesirability of wetland losses of the magnitude documented.

Because of the ecological uniqueness of wetlands, most of the properties acquired by various nature conservancy groups have been of the wetlands types: beach and dune areas, marshlands, coastal marshes, barrier islands, and similar ecotypes. There is also a strong motivation to increase the size of available wetlands through removing wetlands properties from development potential and perhaps adding to them adjacent areas acquired through public or private funds. Against this scenario many environmental and Government groups perceived a loss of wetlands in the Champlain-Richelieu system.

The Champlain-Richelieu wetlands are inland river-lake freshwater marshes unique in the eastern United States with most of the comparable systems being estuarine or connected to estuaries

through the inland waterways system in the southern States. Furthermore, that part of the Champlain-Richelieu System which lies within the United States remains one of the few unregulated waterways.

2. Which types of wetlands are vulnerable to flow management in the Champlain-Richelieu System?

Vulnerability of wetlands depends on whether one is increasing or decreasing water levels through flow management. There are five types of wetlands specified by the Board. Three types of wetlands in Lake Champlain are described in this section and are of primary concern for their ecological relationships to known species of fish and wildlife. Two other types of wetlands present have unknown ecological significance and have not been considered in most of "damage" or vulnerability assessments.

(a) Trees and downed terrestrial vegetation. This wetland type is created by the activities of animals such as beavers, or the natural flooding of forest floor. Inundation would destroy this habitat. Beavers, if important to this habitat, could go elsewhere if a non-urbanized, wooded and riverine corridor were available. Lack of such a corridor would be detrimental to other animals as well which depend on this habitat for food and nesting grounds.

(b) Reeds and tall grasses. This wetland type has species such as cattails and papyrus. Inundation could destroy this habitat, but because these species regenerate from roots in the sediments, destruction is not necessarily permanent. Periods of inundation usually exist to allow access of fishes and invertebrates to breeding substrate. Desiccation periods usually coincide with arrival of birds for nesting areas. The issue here is to assure that inundation-desiccation cycles do not disrupt the access to the area required of the desired species in the desired progression through an appropriate seasonal interval.

(c) Macrophytes and submerged aquatic vegetation. These habitats are sensitive to low flow and only sensitive to high flows if the water becomes turbid and restricts the access of light to the plants.

3. What is the relationship between ecological diversity and flow management?

An ecological hypothesis which guides a lot of environmental and theoretical biological studies deals with relationships between the number of different types of species in a place and the population distributions within those different types of species. This relationship is known as diversity. Indices of diversity measure or quantify the patterns of species numbers and populations distributions.

Many biologists believe that systems with "high diversity" are often ecologically "better" than systems with "low diversity" all other things being equal. However, it is very difficult to relate values of diversity to values of ecological desirability because diversity is a comparative measurement dealing only with population structure. Some ecologists have attempted to "prove" theoretically that highly diverse systems are ecologically desirable. The primary evidence in favour of the hypothesis is that polluted systems, which have reduced species numbers because of toxic conditions, or population distributions dominated by nuisance or undesirable species, have lower values of diversity indices than nonpolluted systems. The comparison is not without exception, and ecologists have documented many systems of very low diversity that were ecologically desirable because they support rare and endangered life forms.

A factor which biologists have established as critical to diversity is heterogeneity, or the structural differences among habitats. Put simply, the more different kinds of habitats present, the more different kinds of species can be supported. Destruction of habitat types removes the potential for certain types of species and reduces the upper limit of achievable diversity.

It is feared that management of flows in the Champlain-Richelieu system may result in a lowering of diversity through habitat destruction. On the other hand, management of flows does not necessarily result in loss of habitat and lowering of diversity.

4. Are wetlands manageable through flow control?

The answer is "Yes", providing one has decided what is to be managed. The Champlain-Richelieu study groups and Boards have examined a variety of flow regimes and their environmental impacts. The primary thrusts of these evaluations were the mitigation of flood damages, the preservation of cold water fisheries using the northern pike (Esox lucius) as an indicator species, and preservation of wetlands areas. As a first basis for flow regulation, several structural alternatives and flow regulation plans were evaluated. A gated structure at St. Jean, operated in accordance with Plan FCE-1, was found to satisfy the environmental criteria developed from studies of the fisheries and wetlands research and assessment projects more closely than the other concepts.

If to this basic flow regulation scheme maintenance of species diversity through prevention of habitat simplification is added, flow management can achieve the desired flood protection and maintain the wetlands ecology.

To manage for diversity, one assesses the current distribution of habitat types, their current productivity levels, and species distributions and, on the basis of regulatory criteria to meet these factors, devises a plan which

(a) maintains the habitat distribution, and

(b) maintains sufficient habitats to assure productivity levels.

With the habitat distribution assured, the biotic potential for species distributions is assured. With habitat size maintained, population structures are maintained.

It is the belief of the Commission that flow management schemes derivable and refinable from Plan FCE-1 are capable of accommodating the environmental criteria. Thus, the Commission believes:

(a) Regulation of flows in the Richelieu River and thus control on levels in Lake Champlain are possible which will:

(i) protect habitat heterogeneity and diversity;

(ii) assure acreage for the support of fisheries and wildlife which are desirable in the region;

(iii) mitigate flood damages to agricultural and other property.

(b) That such regulation is achievable using a system based on the gated structure with a regulation plan such as FCE-1.

5. What environmental factors make regulation either desirable or undesirable?

The Commission believes that regulation is feasible, but points to an approach which allows for the undoing of regulation if later on management is shown to be problematic. The approach built into FCE-1 permits a return to an unregulated state at a future time should this be necessary because a gated structure does not create a permanent impoundment, and thus does not have accompanying it any of the environmental problems associated with permanent impoundments. Furthermore, during periods of low water supply the gates can be operated to enhance the environment.

In the environmental studies performed, the northern pike was chosen as an indicator. The northern pike requires substrate during its spawning cycle, and it was believed that the submerged macrophytes and freshwater meadows were the prime habitat for spawning. Many studies of the northern pike have demonstrated the adaptability of the pike to a wide variety of substrate situations.

A second issue is "accessibility" depth. The current plan is based on the need for 0.5 foot depth of water above the vegetation level for an extended period of time during the spawning season to allow egg hatching and development of fry. Also, adult fishes need a minimum depth above the vegetation level to reach the spawning substrate. Using sedges and freshwater meadows as the vegetative substrate, a level of 98.5 feet for the spawning season was considered to be a desirable

level to be achieved as often as possible. Later discussions of the uncertainties in the accessibility depth requirement focused on the possible need for an elevation of 99.5 feet as being more nearly the goal. This additional one foot is critical in flood damage assessments.

Another aspect pertains to a 39-year hydrological record subject to intensive modelling efforts. It was found that in 13 of those years, randomly distributed, the 98.5 foot level was achieved for a period of 40 days. This would suggest on a long-term average basis, that one out of three years at elevation 98.5 assured a successful year class for the pike. The 13 out of 39 statistic has led to some confusion, and the point has been raised before the Commission that what is needed is not a long-term average of one out of three years but a requirement of one year in any three consecutive year period at elevation 98.5.*

The Commission accepts the 13 out of 39 concept rather than the one out of three concept because of the period from 1941 to 1952, a run of 12 years, the one out of three requirement was not met, and the northern pike fisheries remained viable. Also, if the period from 1971 to 1976 is indicative of trends in natural water levels in the area, there will be no problem in meeting the 98.5 level or greater and having to contend with a one out of three year requirement. That is, the run of data in recent years suggests again that pike are strong in the Champlain-Richelieu and control will not lower the levels to their detriment. If one considers the historical record as cyclic and anticipates that early years in the hydrological record will repeat themselves regardless of recent high levels, then operation of the gated structure to meet environmental criteria may not be necessary during low supply years.

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* The one out of three year consecutive data means that one year in every three must meet the flow requirement. If this situation is invoked, it is not possible with any flow plan currently under Commission review or conditions that would occur in nature to achieve the required flow and accessibility depth.

The Commission believes it is possible to manage to protect habitat heterogeneity and species diversity with a gated structure. One is not locked into a fixed level in the Lake with this kind of control. Among the options proposed were those which would have fixed a target level in the Lake, and the structure used or management plan followed, as appropriate, to manage all flows above the target level without differentiation among levels and times for special circumstances. A gated structure allows special circumstances to be incorporated into the flow management plan so that the target regulatory levels can be changed. Different levels might also be managed at different times.

The biotic communities which have evolved in Lake Champlain have attuned themselves to certain cycles in Lake levels and environmental conditions. Many of these cycles have strong random components. It is usually found that the organisms which are capable of withstanding random environmental fluctuations are often hardier than those which must exist within narrow limits. At certain times of the year, when conditions in the Lake are quiescent and environmental conditions relatively unchanging, for example in mid-summer, the organisms which dominate the community may include some with narrow tolerances. The same is true for a period of time in the early spring or autumn when conditions are again fixed. This assures a succession of resident species during a seasonal cycle, and again heightens diversity. Since it is possible to regulate flows many ways with a gated structure, it is possible to manage flows so that species with wide tolerances only or species with restricted tolerances only, do not dominate the system. Thus by assuring succession of species in a seasonal cycle, one manages for diversity also.

Finally, because the organisms have evolved to accommodate random fluctuations of water levels in their cycles, the loss of the wetlands through flow management, especially the fresh-water meadows, should not occur. It is possible and indeed

feasible to manage these meadows for no net loss of habitat over a decade cycle. However, the Commission must point out that managing flows for diversity is not totally compatible with added development of the flood plains area. The reason for this is that at least once in ten years, the management plan has the built-in probability of a damaging flood for any new development.

Effect of Chambly Canal and Weed Growth

At least two influences on water levels deserve attention. A great deal of comment was received by the Commission on the water level effects of the widening of the Chambly Canal between 1970 and 1974. It has been generally concluded that this project had some effect on Lake Champlain levels, and the Commission wrote to the Government of Canada in July 1979 bringing this matter formally to its attention. The question of the extent to which the Chambly Canal widening has affected Lake Champlain levels has been debated considerably. The best estimate, based on mathematical models and tests carried out by Parks Canada in the spring of 1979, appears to be from 0.25 to 0.33 foot when flows are over 30,000 cfs.

Another impact on water levels is that caused by excessive weed growth in Lake Champlain and the Richelieu River. Aquatic weeds increase friction in the River channel causing retardation in flow, thereby increasing Lake levels and they also decrease the effective cross-sectional area of the River. The influence of so many variables including nutrients entering the system, temperature, magnitude, duration and timing of peak flow, and the subsequent runoff distribution, result in the weed growth having varying effects on Lake levels from year to year and also from month to month in the same year. The impact is maximum in the month of August and minimum between November and April, based on available data presented by the Board. Since most weed growth occurs in the summer months, there is an impact of slowing summer and fall water discharges from

the Lake which can result in slightly higher pre-flood Lake levels during the next spring. During the last 25 years, the Board concluded that the average Lake levels during summer have increased by 0.57 foot due to weed growth. No estimates of average damages attributable to excessive weed growth are available. In addition, during some years, the Board found that the effect of weeds was to raise the late spring and summer levels extending the peak flow season, and thereby making it difficult to assess accurately the effect of canal widening separately from other physical changes taking place in the River system. Appropriate agencies in each country should take corrective action to compensate for these effects.

Evaluation of Structural Solutions

The object of structural solutions is to reduce the frequency of extreme high and low water levels and at the same time maintain the integrity of Lake Champlain and the Richelieu River. Thus, it is necessary to excavate through the St. Jean shoal, the natural hydraulic control of the outflows from Lake Champlain, to increase the discharge capacity of the Richelieu River. This would allow the passage of flood waters at a lower Lake elevation. In order to prevent a permanent lowering of Lake Champlain an artificial control to limit the outflow at lower Lake elevations is necessary. This can be accomplished with the existing Fryers Island Dam after completion of such works as diking, a gated structure near St.Jean, or a fixed crest weir.

Common to all structural solutions is the excavation of a channel in the Richelieu River through the St. Jean shoal, 700 feet wide, 8000 feet long and a bottom elevation of 85.0 GSC (Geodetic Survey of Canada) datum. This would require removal of approximately 320,000 cubic yards at a cost of $3.3 million. The dredging would have minor impacts on some of the existing works. The eel fishery would be relocated downstream from Fryers Island.

As noted earlier, the costs of dredging and all structures are based on 1977 Canadian price levels, while the benefits and

non-structural measures are based on 1976 dollars in the country in which they occurred. The interest or discount rate used was 7.5 percent over the 50-year project life.

Fryers Island Dam, located about five miles downstream from St. Jean, has 31 control gates each 30 feet wide and 12.5 feet high and with a sill elevation of 83.2 feet GSC. The gates can be operated so as to maintain a fixed pool elevation as high as 95.5. When the flow in the Richelieu River is 40,000 cfs or greater the level of Lake Champlain can be drawn down by as much as 1.8 feet. Under natural conditions the discharge from Lake Champlain is 30,000 cfs when the Lake is at elevation 99.1. The same discharge can be achieved by operating Fryers Island Dam with a pool elevation of 95.5 and a Lake elevation of 98.5 or 0.6 foot lower; or with a pool elevation of 94.0 and a Lake elevation of 97.8 or 1.3 feet lower. For discharges of 20,000 cfs or less Lake Champlain can be maintained higher than would occur under natural conditions.

Diking and drainage works are required between St. Jean and Fryers Island to protect property as a result of maintaining a pool level of either 94.0 or 95.5 at the dam. The improvements planned for the Chambly Canal, such as replacing Lock #9 would not be necessary, since the Canal would terminate at Fryers Island instead of St. Jean. The capital cost savings would amount to $1.5 million.

In addition to channel dredging improvement to Fryers Island Dam would cost $250,000. Diking and drainage works would cost $9,643,000. The estimated annual cost would be $1,344,000. The Fryers Island project would reduce the average annual damages by 74 percent. This represents an average annual reduction of $1.40 million in Canada and $1.70 million in the United States and an overall benefit/cost ratio of 2.3. If the gates at Fryers Island are operated to a maximum environmental benefit the average annual flood damage prevented in Canada would be $1.32 million and in the United States $1.55 with an overall benefit/cost ratio of 2.1.

Fryers Island Dam can be operated to maintain an elevation of 97.5 on Lake Champlain for 40 days when the flow is greater than

20,000 cfs. With a flow of 10,000 cfs the Lake would be at elevation 96.4. This is due to the height of the control gates and the backwater effect. All of the environmental criteria cannot be met.

The gated structure at St. Jean, which was recommended by the Board, is another structural alternative. The six sector gates are hinged on the downstream side. When fully open the crest of the gates is at the same elevation as the channel bottom; when fully closed the crest elevation is 95.0 GSC. Thus the gates act as a set of moveable weirs which provide the maximum flexibility possible. The outflow can be operated to enhance natural spawning conditions, to decrease flood damage or to lengthen the duration of selected water levels. The Commission is of the opinion that the gated structure can be operated to meet all the environmental criteria.

The structure is capable of discharging a flood flow of 40,000 cfs when the elevation of Lake Champlain is at elevation 99.1 or 1.9 feet lower than the elevation required under natural conditions for the same discharge. The average annual peak level of Lake Champlain, 99.8 feet, would be reduced by 1.2 feet. The crest of the gates can be raised to maintain a Lake elevation 98.5 or higher whenever required. The deviation from natural Lake levels, be it higher or lower, would depend upon the criteria adopted, the regulation plan selected and improved flood forecasting. Those used by the Board in their feasibility study are preliminary and subject to refinement.

The estimated cost of new gated structure at St. Jean with 10 foot sector gates would be $16.07 million including channel dredging. The annual costs would be $1.41 million. Using the trial plan of regulation, FCE-1, the Board estimated that the gated structure at St. Jean would reduce the average annual damages by 62 percent. This represents an average annual reduction of $1.14 million in Canada and $1.46 million in the United States and an overall benefit/cost ratio of 1.8.

A fixed crest weir at St.Jean is another structural option. It would have a crest elevation of 92.85 GSC, nearly eight feet above the dredged channel. Dredging permits the structure to

operate as a free flowing weir and eliminates the possibility of the St.Jean shoal raising the water levels higher than those dictated by the weir. The maximum discharge of the weir is equal to the maximum capacity of the Richelieu River between Lake Champlain and St. Jean.

The discharge capacity depends solely upon the level of Lake Champlain. It has the capability to discharge a greater volume of water than natural conditions, particularly during the spring peak. For example, when Lake Champlain is at elevation 99.1 the discharge under natural conditions is 30,000 cfs whereas the discharge with a weir would be 40,000 cfs with the same Lake elevation. Similarly, natural conditions would require a Lake elevation of 100.0 to discharge 40,000 cfs. Furthermore the lower the rate of discharge, the smaller the difference between the Lake level required under natural conditions and the fixed crest weir. The difference for 20,000 cfs is 0.8 foot and for 10,000 cfs, 0.3 foot. The same level is required for an outflow of 5,000 cfs.

Thus, the weir duplicates the natural rhythm of water levels. It reduces extreme levels between 1.0 and 1.9 feet, maintains average levels and slightly raises extreme low levels. A fixed crest weir reflects natural conditions in that the Lake levels would be low during periods of low runoff. Such a situation existed during the 1940's and 1960's and will occur again. The duration of high or low levels would be duplicated because peak levels only last a few days.

The fixed crest weir cannot regulate the levels of Lake Champlain since there are no controls. The fixed crest weir could not meet the criteria developed by the Environmental Impact Committee.

The estimated cost of the fixed crest weir including channel dredging would be $7.87 million with an annual cost of $0.67 million. It would reduce the average annual damages by 52 percent. This represents an average annual reduction of $0.95 million in Canada and $1.23 million in the United States and an overall benefit/cost ratio of 3.3. This alternative has the lowest cost and the highest benefit/cost ratio.

Economic Evaluation of Regulation Plans

The Board investigated in detail three regulation plans for the gated structure in the St. Jean Rapids. Plan FCE-1 had a spring target elevation of 98.5 feet, Plan FCE-2 had a spring target level of 98.0 feet and Plan FCE-3 had a spring target level of 97.0 feet. Although the estimated benefit/cost ratios for the three plans were similar, FCE-1 best satisfied the environmental criteria developed by the Board. If the target elevation is changed, then the balance of benefits would be changed.

The Board, as a result of its analysis of regulation plan FCE-1, concluded that the plan could serve as the basis for developing a more definitive plan of regulation. The flood forecasting procedures used by the Board provide better regulated levels and flows than would be possible without a forecast. Forecasts are in an early stage of development. As experience is gained, operational techniques are improved and more data are acquired, the forecasts can be utilized to improve regulation. At present they are used only to indicate whether the forecast volume would be greater or less than the historical mean inflow volume. With continuing improvement of the forecast, the regulation plan can be modified so as to better meet the criteria for regulation.

The benefits from regulation represent reduced damage to residences, agricultural production, recreational facilities (marinas, campsites, beaches), public utilities and commercial and industrial development. The Board estimated that the gated structure, operated in accordance with Plan FCE-1,would reduce these damages in total by about 60 percent.

The Commission also notes that regulation used with the gated structure and dredging would provide the outflow flexibility required to cope with the upward trend of Lake levels caused by weed growth in the Richelieu River and the widening of the Chambly Canal.

Lastly, regulation permits the raising of the minimum flows in the Richelieu River during drought periods with the attendant environmental, aesthetic and public health benefits.

In its consideration of the benefits from regulation, the Commission took note of a number of points raised in statements at the public hearings.

Some witnesses argued that the zero flood damage level used by the Board, 97.0 feet, was too low, thus overstating the benefit of regulation. They suggested that damages considered in the benefit determination should be those occurring above the average annual peak elevation of Lake Champlain which they stated to be 99.5 feet rather than those above the one-year event of 97.0 feet as developed by the Board. The Board considered that the minor damages below 97.0 feet were not flood damages but represent the normal cost of using the shoreline of the Lake. While the Commission appreciates the argument by witnesses, it recognizes that standard procedure in the United States is to assess the benefits of flood protection works to include the full range that damage is reduced. This is public policy as practised by U.S. federal agencies having national water control functions and is the basis for cost/benefit determination on federal projects, with the consequent effect on national project priority. The Board's methodology is also consistent with current practices in Canada. The Commission has utilized a similar policy in its assessment of benefits in its 1976 report to Canada and the United States on further regulation of the Great Lakes.

Testimony at the public hearings suggested that the agricultural damages in Canada reported by the Board may be, on one hand, too high and, on the other hand, too low. With respect to agricultural damages in Quebec, which the Commission understands is one of the primary concerns in providing flood control, the Commission wishes to note some concern over the precision of the damage estimation methodology. The stage damage curves for agriculture were based on a sample survey of agricultural properties in the flood region in 1976, but without precise delineation of flooded areas on detailed topographical maps. Nevertheless, the estimation of damages is adequate to show significant impacts on the Quebec agricultural community and crop productivity from extreme high water levels which can be alleviated by water level regulation.

Evaluation of Non-Structural Measures

As part of its assessment, the Board considered various non-structural measures for preventing flood damages. These were

evaluated both as independent remedial measures and, for those found to be cost-effective, in conjunction with structural alternatives. They recommended flood forecasting and flood plain regulation, with average annual benefits of $76,000. Flood-proofing would increase benefits to just over $1 million. The Commission notes, however, that these measures alone despite their high benefit/cost ratios, would do little to alleviate damages occurring from extreme water levels and hence would not adequately address the problem posed by the Reference. The damages prevented would represent only about 8 percent of average annual flood damages occurring in the United States and 32 percent in Canada, or 18 percent of the combined total.

These measures would be desirable as ancillary measures to a structural solution to flood damage. The Board estimated that incremental annual benefits of $349 thousand from forecasting and flood plain regulation would increase the benefits expected from FCE-1 to $2.94 million, with net benefits after costs of $1.48 million or a benefit/cost of 2.0. Total benefits would increase slightly by adding flood-proofing, to $2.99 million but with a slightly lower benefit/cost ratio. Similar incremental benefits would be expected with other structures, including a fixed-crest weir, and hence should be implemented in conjunction with any structural measures.

The Commission fully supports the implementation of the three programs identified by the Board as being cost-effective: a system of flood forecasting and warning, flood plain regulation to prevent development in flood-prone areas, and flood-proofing where feasible. In addition, the Commission believes that certain other measures, such as relocation, evacuation and compensation, may be beneficial on certain specific properties, even though they must be rejected (as they were by the Board) as general measures due to their high cost in relation to benefits throughout the entire flood plain.

Conclusions

On the basis of the foregoing considerations, the Commission has arrived at the following positions:

1. The Commission concludes that a flood forecasting and warning system in conjunction with flood plain regulation which would reduce the average annual flood damage by up to 20 percent is both feasible and desirable.

2. The Commission concludes that a gated control structure at St. Jean in conjunction with dredging through the St. Jean shoal to increase channel capacity is feasible, in a technical sense, and could be operated so as to alleviate extreme water conditions in the Richelieu River and in Lake Champlain while at the same time maintaining or enhancing other beneficial purposes, including such beneficial environmental purposes as the protection of habitat heterogeneity, species diversity and biological productivity. Of the structural alternatives, only the gated structure at St. Jean accommodates all the proposed environmental criteria. It should be noted that under the existing natural regime these criteria cannot be accommodated. In addition, the gated structure can be adapted to future changes in environmental criteria. The Commission also concludes that managing this system in accordance with the proposed criteria would not be consistent with further flood plain development because damaging floods will still occur.

3. The Commission concludes that it is now more appropriate for the two Governments to determine the desirability of control works to alleviate extreme water conditions than for the Commission to make that determination. A number of factors in addition to flood control will need to be considered in resolving this issue including the weights Governments may wish to assign socio-economic values,

environmental and other criteria. Many of these factors are addressed in the considerations summarized in this report. Others may be found in the reports of the Board and of the public hearings. It may be that Governments may wish to investigate some of the remaining uncertainties further or it may be that sufficient research has already been done.

The Commission believes that further assessment and recommendations covering requests 3, 4 and 5 of the Reference should await the determination of the Governments of the desirability of regulation. In addition, the Commission believes that it should await advice from the Governments before acting on the pending application of the Government of Canada, dated 5 January 1976.

Recommendations

Although the Commission has concluded that it is technically feasible to operate a gated structure at St. Jean that accommodates the proposed environmental criteria, the Commission was unable to determine the desirability of the gated structure and therefore is unable to make recommendations regarding the regulation of Lake Champlain and the Richelieu River. However, the Commission does recommend that a flood forecasting and warning system be instituted as soon as practicable and that flood plain regulation be implemented by the appropriate jurisdictions as a matter of urgency.

Signed this 20th day of January 1981 as the International Joint Commission's report to the Governments of the United States and Canada on the regulation of Lake Champlain and the Upper Richelieu River.

Robert J. Sugarman

S.M. Hodgson

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APPENDIX

TEXT OF REFERENCE

On March 29, 1973, the Assistant-Secretary of State of the United States of America and the Under-Secretary of State for External Affairs of Canada sent the following Reference to the International Joint Commission through identical letters addressed respectively to the Canadian and United States Sections of the Commission:

> "The governments of Canada and the United States of America have agreed, pursuant to Article IX of the Boundary Waters Treaty of 1909, to request the International Joint Commission to investigate and report upon the feasibility and desirability of regulation of the Richelieu River in the Province of Quebec for the purpose of alleviating extreme water conditions in the Richelieu River and in Lake Champlain, and for other beneficial purposes.
>
> On June 10, 1937, the International Joint Commission approved construction and operation by Canada of remedial works in the Richelieu River in Quebec for reclamation and protection from flooding of low lands located in Quebec.
>
> The Commission's Order of Approval would have also provided some protection for levels of Lake Champlain. Pursuant to the Commission's Order, a dam was completed at Fryers Island about 1939. However, other works required to expand the channel of the Richelieu River were not undertaken. Because the channel works were never completed, effective regulation of the Richelieu River for flood control and other purposes has not been achieved. This has caused grave concern in both the United States and Canada, as high water conditions in recent years have caused substantial flooding damage. Because of these recent high water conditions, hydraulic and regulation studies of the area between the Chambly Basin and Lake Champlain have been conducted by the Government of Canada jointly with the Province of Quebec, to examine other means of regulation, primarily for flood control purposes.
>
> In light of this situation, the Commission is requested to make:
>
> 1. recommendations regarding the desirability of operating the Fryers Island project or alternative works in the Richelieu River to alleviate extreme water conditions in the lake and the river, bearing in mind (a) water supplies and sanitations,

(b) recreation, (c) navigation, (d) environmental factors including fish and wildlife, (e) reclamation of wetlands, and (f) such other beneficial purposes as may warrant consideration in the judgement of the Commission.

2. recommendations regarding the most practicable and economically feasible system of regulatory works and method of regulation of the Richelieu River to alleviate such extreme water conditions, bearing in mind the uses specified in point 1 (a) through (f) above.

3. an estimate of the capital and operating costs of works necessary to implement the plan of regulation recommended by the Commission.

4. an estimate of the benefits to and adverse effects on each country of implementation of the plan of regulation recommended by the Commission. It is requested that the Commission include in its report the bases upon which such estimates of benefits and adverse effects are made.

5. recommendations concerning how the cost of implementing the plan of regulation recommended by the Commission might be apportioned between the United States and Canada. It is again requested that the Commission include in its report the bases upon which such recommendations are made.

In view of the urgency created by the existing high water conditions, the Commission is requested to submit, as soon as possible to the Governments of Canada and the United States, an interim report and recommendations on the desirability of regulating outflows from Lake Champlain and on interim measures which might be instituted to alleviate flooding together with a preliminary appraisal of benefits in each country. The Commission is also requested to submit its final report and recommendations to the two governments if possible within one year of receipt of this reference.

In the conduct of its investigation and otherwise in the performance of its duties under this reference the Commission shall utilize the services of engineers and other specially qualified persons and other resources made available by the concerned agencies of Canada and the Province of Quebec and the United States and will make use of information and technical data heretofore acquired or which may become available in either country during the course of the investigation."

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